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Design of a releasable snowboard binding system to prevent upper body injury

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1. Snowboard
2. Binding
3. Injury Prevention

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Abstract

The objective of this project was to design, build, and test a snowboard binding system that prevents upper body injury to snowboarders due to the “flyswatter effect”. This effect occurs when the user catches the longitudinal edge of the snowboard during turns, swinging the user’s upper body towards the terrain. The system was designed to release under shear stress caused by the effect, and a moment lock mechanism activated by normal riding forces was integrated to prevent inadvertent release.

Acknowledgements

We'd like to thank several people that made the progress on this project possible. First and foremost, we'd like to thank Professor Christopher Brown for his insights and guidance throughout the project. Secondly, we'd like to acknowledge all of the work that the Manufacturing Laboratories at WPI has put into this MQP. Mike O'Donnell, Chris Stefaniak, and Dave Willens worked hard to manufacture all of the parts. Toby Bergstrom helped the group and provided organization in the shop as well as allowed the group to use his personal winch for testing purposes.

We would also like to thank Brendan Powers for allowing us to modify and use a ski binding test rig for our bench tests. His assistance was vital in compiling our results. Lastly, we would like to thank Bellevue Springs of the UK for providing us with free disc spring samples, allowing us to build the moment lock mechanism.

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1. Introduction

Snowboarding is a winter sport that has steadily gained popularity in the past two decades (Idzikowski et al. 2000). Given its increased popularity, the number of recorded snowboarding injuries has also escalated dramatically with the wrist being the most commonly injured area of the body. There is currently an ongoing debate over methods besides protective equipment that can be used to prevent snowboarding injuries. One mechanism which has the potential for preventing injuries through modifications is the snowboard binding, which connects the rider's boot to the snowboard. The concept of injury-preventing bindings has existed for some time, and many impact-release bindings have already been developed. However, critics of these bindings suggest that impact-release bindings pose an added risk to the rider (Shealy 2006). Inadvertent release and the fact that both feet are attached to one snowboard are cited as risks added by impact-release bindings.

This project aims to modify bindings to prevent injury to snowboarders. The objectives of this project are:

- To establish from the literature candidate injury types that can be addressed by snowboard bindings
- To design and develop a binding that can reduce specific snowboard related injuries while providing all support, functionality, and comfort of current commercial bindings
- To develop a means to test the design and a means to analyze and evaluate the results.

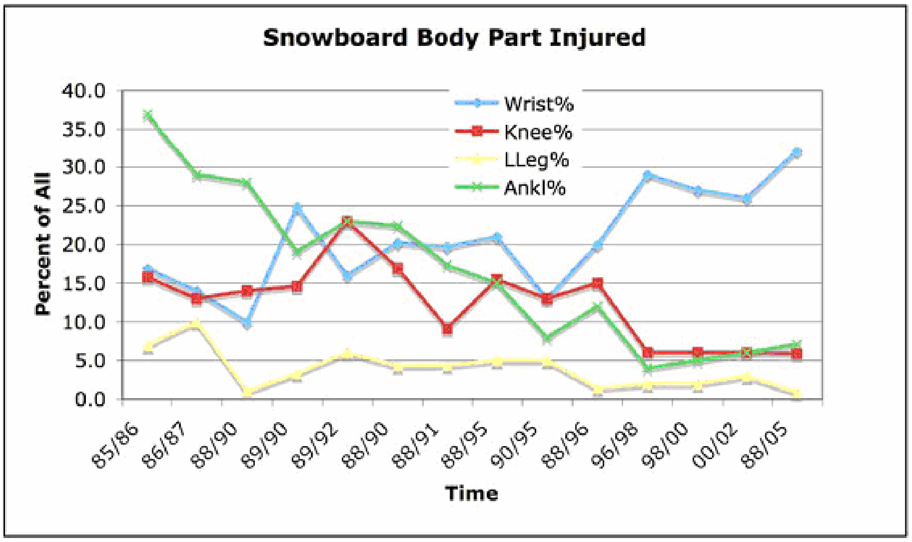
2. Background

In order to better understand snowboarding injuries and injury prevention methods, it was necessary to research snowboarding injury statistics and develop an understanding snowboarding dynamics and current safety systems.

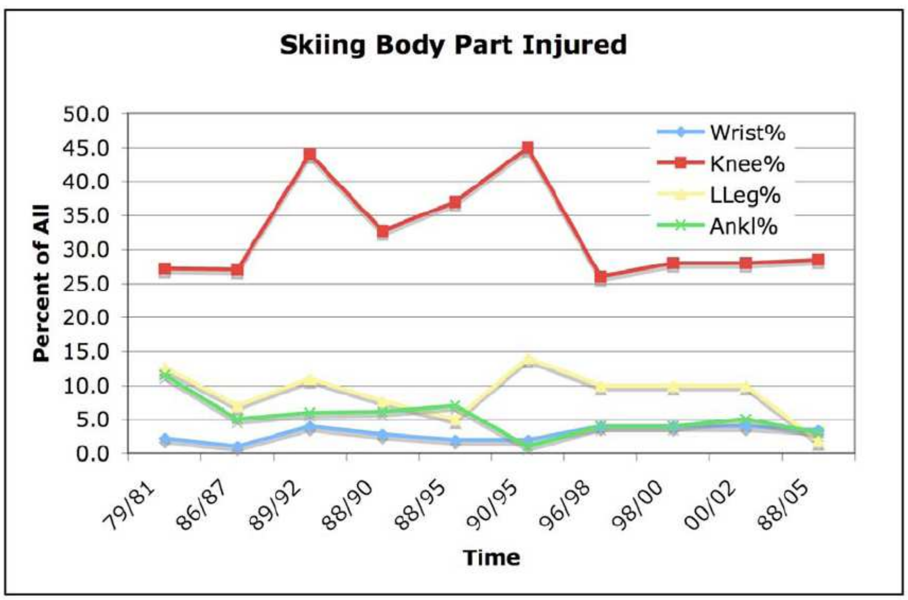
2.1 Rationale

The Colorado Snowboard Injury Survey reported data on snowboarding injuries from 1988 to 1998. A total of 7430 injuries were reported from 47 medical institutions, 3645 (49.06%) being upper body injuries. Of the reported upper body injuries, those to the wrist were the most common, accounting for 21.6% of all snowboard injuries (Idzikowski et al. 2000). These injuries were most common with beginners; experts tended to receive injuries to the shoulder, elbow, and hand. The majority of snowboarders fall within the beginner to intermediate demographic. The study further determined that ninety-two percent of upper extremity injuries are caused by falling (Idzikowski et al. 2000). Other studies demonstrate the same trend in injury rates for snowboarders, and most note that the lower extremity injury rate in snowboarders is lower than that of skiers due to the variations in riding mechanics. (Shealy 2006). A comparison of these compiled injuries can be observed in Figures 1 and 2. For a more detailed table of each data point see Appendix E.

Based on these studies, the project focused on designing a snowboard system which would aim specifically at reducing wrist injuries. Since the greatest percentage of injuries involved the wrist and were incurred by the largest amount of snowboarders, it was determined that if our design limited its focus to strictly preventing wrist damage, it would reduce the greatest amount of injuries. It was further decided that since nearly all wrist injuries were a result of a fall, the design would center on lowering upper body injury rates by altering the fall dynamics, in one type of fall specifically.



1 - Snowboarding Injuries by Body Part (Shealy 2006)



2 - Skiing Injuries by Body Part (Shealy 2006)

Occasionally when riding, the user's longitudinal edge will catch in the terrain, creating a "flyswatter" or hinge effect where the upper body of the rider is pulled to the ground at a higher velocity than the riding speed before the fall (Appendix D). This is what causes a large amount of wrist and arm injuries from snowboarders trying to catch themselves as they fall. By eliminating this hinge effect, the force of the fall is not directed distinctly downward and the impact would be spread out over a longer time and distance. One means of removing the “flyswatter” effect that has already been developed is a system of releasable snowboard bindings.

2.2 State of the Art

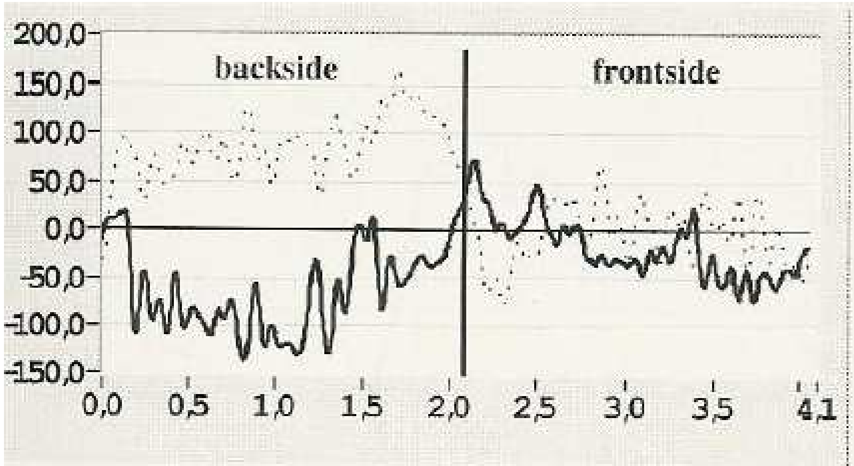
There has recently been controversy surrounding the use of releasable snowboard bindings. In a report to ASTM F27.85, Jasper Shealy concluded that there exists no evidence that a releasable binding on a snowboard would reduce the occurrence of any injuries and instead may bring about more safety issues than non-releasable bindings (Shealy 2006). The opposition claims that after any catch/collision/falling test performed at 20 mph on both release and non-releasable snowboard designs will clearly demonstrate that non-release bindings will come out less safe than release bindings (Miller 2007).

Currently, several different models of releasable snowboard bindings can be found with varying design considerations. In fact, there are releasable snowboard bindings available commercially from Miller Snowboard Corporation, who has led the way in bringing releasable bindings into better acceptance in the snowboard community. The Miller Snowboard Corp. boasts that since the design’s conception in 1988, there have been no injuries due to the releasable binding (as of 2004) and that studies by various medical groups have found injury rates on snowboards without releasable bindings to be 250% higher than bindings that do. Their available release bindings can be retrofitted to any binding and board (Davis 2004).

Through patent research, it was found that most binding release systems were based around a force peg/recession combination with compression springs providing the locking force. These designs came in both riser-like assemblies that were placed between the boot and board or in designs that did not change the height of the boot relative to the board. Those without riser-like designs dealt primarily with torque and lift-out release; meaning that if too much of a moment is placed around the axis of the shin, the boot would come free (the same with lift out forces above threshold). Most of those with the riser design dealt with all impact and torque forces; recess CAM surfaces and compression strength of the spring involved set the threshold forces for the varying directions of impact and twist. However, none targeted one specific force. Also, no patents researched had a mechanism specifically built in to avoid inadvertent release. A detailed description of the patents analyzed can be found in Appendix B.

2.3 Snowboarding Dynamics

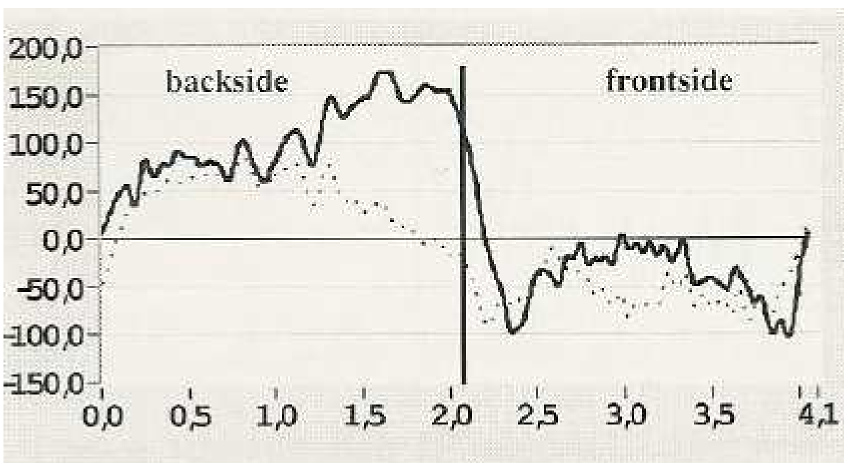
There is very little previous research on snowboarding dynamics or the forces on the snowboard and boot during normal riding conditions. However, one study attempted to measure the moments and forces relative to every axis of the boot during normal riding and turning conditions. The forces relevant to the "flyswatter effect" are those that go in the direction of the longitudinal axis of the boot, while the relevant moments are about the lateral axis of the boot. Figure 3 displays the shear force in the longitudinal direction with respect to the boot vs. time during a normal snowboarding S-turn (Knunz et al).



. Fy at the back (—) and the front (.....) boot during a carved snowboard turn.

3 - Forces during carved snowboard turn (Knunz et al.)

Figure 4 plots the moment about the lateral axis of the foot vs. time during a carved snowboard turn.



. Mx at the back (—) and the front (.....) boot during a carved snowboard turn.

4 - Moments about foot during carved turn (Knunz et al.)

Although limited, the knowledge of the forces during normal riding conditions is vital to the ability to design a successful releasable binding and set the system's threshold forces.

3. Project Approach

Due to the limited amount of literature available on forces on the boot during riding, it was necessary to make a variety of assumptions and hypotheses about the dynamics of the fall being studied. A basic conceptual understanding of the dynamics of the fall was necessary to try to reduce injury rate. It was also necessary to establish specific aims for the binding system in order to focus the design initiative.

3.1 Riding Dynamics Assumptions

In order to better understand the problem, the group attempted to analyze the dynamics of a fall due to the "flyswatter effect". The group also attempted to develop an understanding how a shear release system would affect the fall dynamics. Ideally, a normal caught edge situation can be modeled:

$$\frac{1}{2} m v_1^2 = \frac{1}{2} I \omega^2$$

In this model, m is the mass of the rider, v_1 is the initial translational velocity, I is the moment of inertia of the rider, and ω is the rotational velocity of the rider. This situation assumes that upon catching the edge, the rider's board does not continue to travel, and energy is conserved from translational to rotational.

With a shear release system, the rider's motion can be modeled:

$$\frac{1}{2} m v_1^2 = \frac{1}{2} I \omega^2 + \frac{1}{2} m v_2^2 + E$$

In this model, m is the mass of the rider, v_1 is the initial translational velocity, I is the moment of inertia of the rider, ω is the rotational velocity, v_2 is the rider's final translational velocity, and E is the energy required to cause release. However, although threshold shear force, or V, is a measurable number, calculation of the energy associated with release is far more complicated. Conceptually, if V decreases, v_2 increases, ω will decrease. This is a desirable result; lower rotational velocity will lower the impact force of the rider. ω and v_2 can be related through functions of V, and their corresponding energy terms, $\frac{1}{2} I\omega^2$ and $\frac{1}{2} mv_2^2$, can be related through functions of E. However, neither E nor the distribution of V between rotational and translational velocity is easily obtainable.

Another major assumption revolved around the moments during riding. Because of the limited available research on forces on the boot during riding, it was assumed that when catching the edge of a snowboard while riding, there is no moment placed on the board about the lateral axis of the foot, but there is at all other times. The design of the binding was based on this theory. The moment lock was created in this design to make sure that during a moment, the board would not be able to release, so there would be no inadvertent release while snowboarding down a hill. However, when catching the edge, if there was no moment, the binding would be able to release and prevent injury to the rider.

3.2 Specific Aims

The team's main goal, the foundation of the entire project, was also an original idea in the design of releasable snowboard binding. This goal was to create a binding that will release under a shear force significantly smaller than the forces encountered during snowboarding. This would allow the rider's binding to release when the edge of the board contacted and caught in the snow, causing the "flyswatter effect".

The success of the moment lock mechanism was another goal the team aimed to achieve, and also another unique idea for releasable bindings. The moment lock, if designed correctly, would still allow a binding release in the event of a shear force occurring due to the catching of an edge. However, based on the team's assumptions, the moments that occur while normal riding on a snowboard should activate the moment lock and prevent inadvertent release.

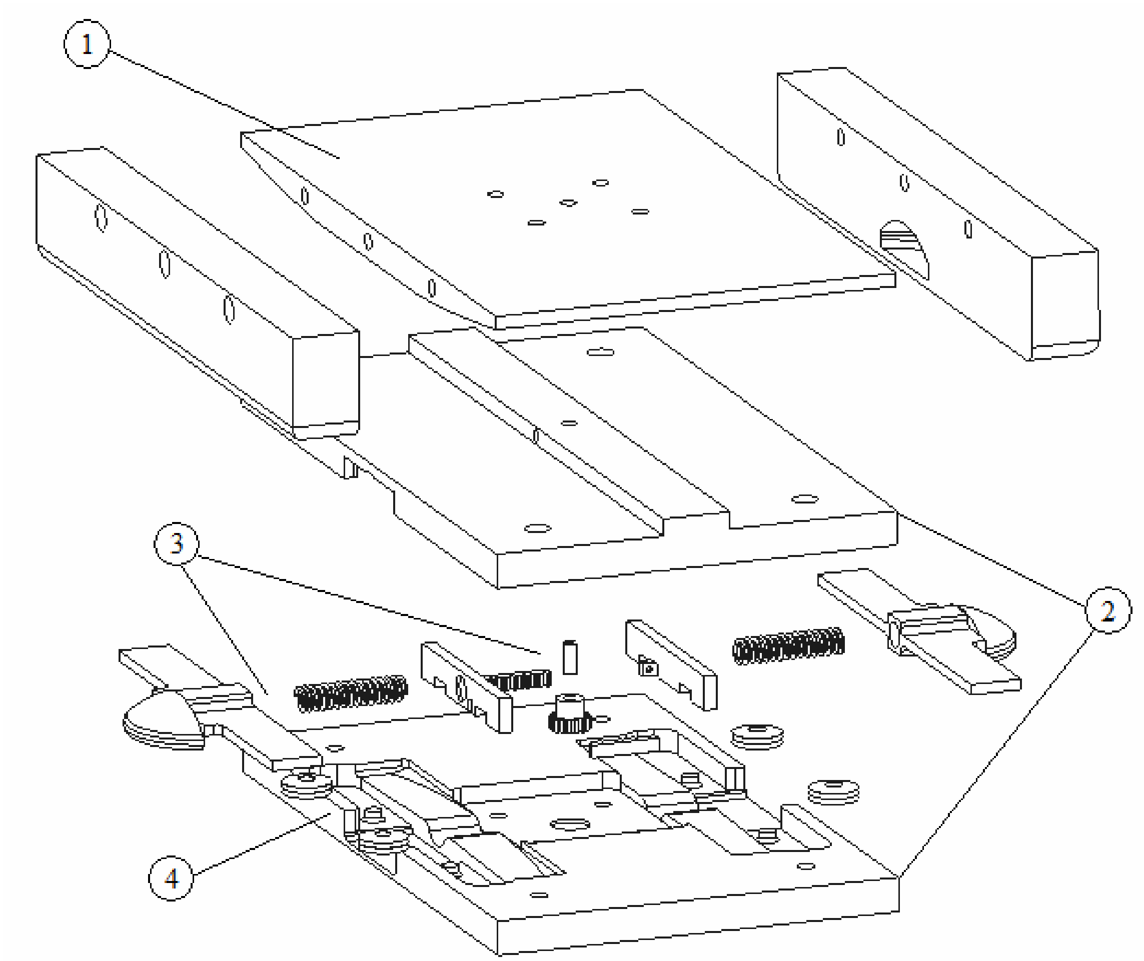
A third major goal in the completion of this project was to design and create an adjustable preloading system for the binding. The preloading system allowed the springs in the design to be compressed to any desired amount, which would in turn raise the shear force needed to release the board higher and higher. However, if adjustments needed to be made on the fly in order to preload the system to the right amount, a quick and easily accessible system would be needed. The team felt that a preload system that could be adjusted at anytime, anywhere, would allow riders to correctly preload their system and further prevent injury.

4. Design

The design for this project was guided by the principles of Axiomatic Design, a methodology that is guided by simple rules and results in documented design decisions and fewer design iterations. One of the chief processes in this methodology is the creation of a design decomposition (Appendix A), which matches functional requirements and design parameters. Each functional requirement or design parameter can have only one counterpart or it is considered coupled. Coupling increases the iterations necessary before the desired outcome is reached.

4.1 Design of Part

Although the principals behind this release binding are relatively simple, the design went through several iterations before reaching the final model. This section will give a summary of each primary element of the design. These components can be categorized into the four major sections of the design, which will be described below. This section is a summary intended for easier reading for an enhanced understanding of the design of the project; it is not an exhaustive description. Please refer to Appendix A for a comprehensive detailed description and complete decomposition of each design parameter and the functional requirements each meet. For a complete exploded assembly and the subdivisions that will be described in this summary see Figure 5 below with the corresponding Table 1 containing the description of the sections.



5 - Exploded Assembly

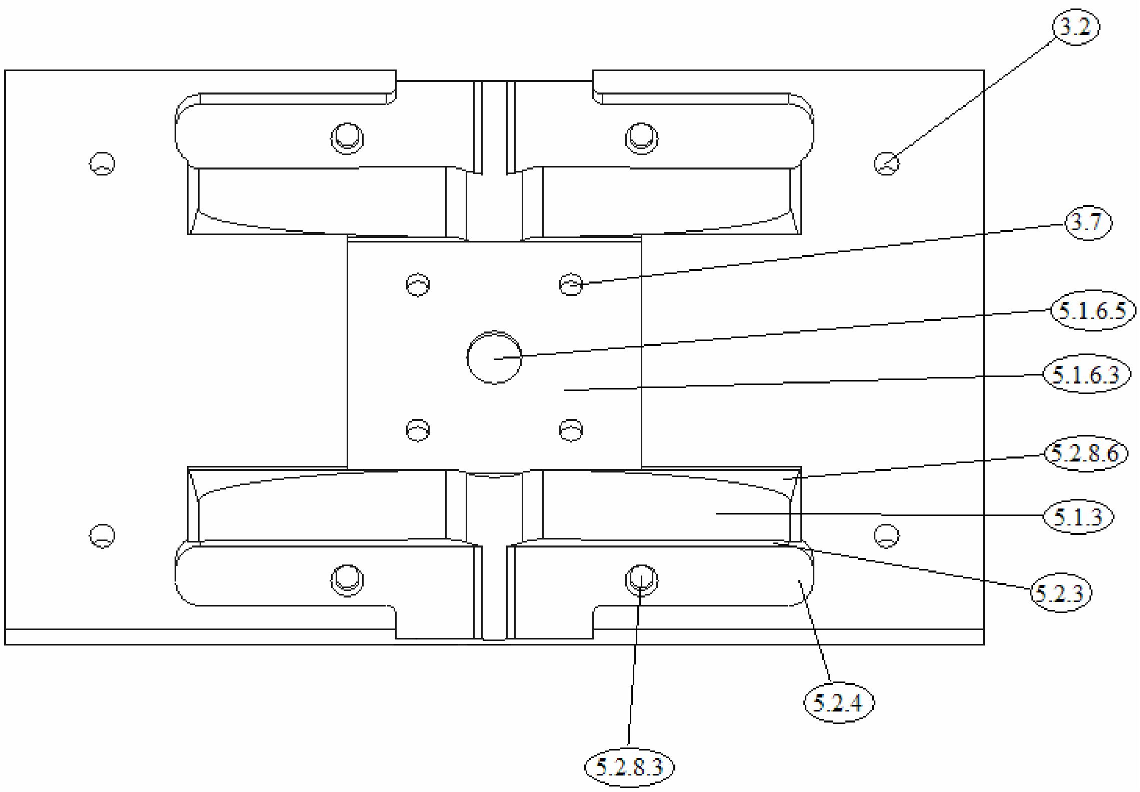
Number	Element
1	Boot Plate Assembly
2	Fastening Plate Assembly
3	Shear Release Mechanism
4	Moment Lock System

Table 1 - Exploded Assembly Elements

4.1.1 Fastening Plate

The fastening plate is the element which connects the primary snowboard binding and the release binding to the board. It is divided into two sections, which is necessary to situate and continually access the internal components, the shear release pre-load system and moment lock system, in the internal recesses. Without dividing the fastening plate into two parts, it would be impossible to machine or to set these necessary components into the interior. These two sections are held together by screws located on each corner.

The bottom half of the fastening plate is connected to the board with screws that are the same size used to connect conventional bindings to the board, allowing this innovation to be readily placed on commercially available boards. The geometry of this model can be viewed in Figure 6 below with the corresponding Table 2 containing the description of the part.

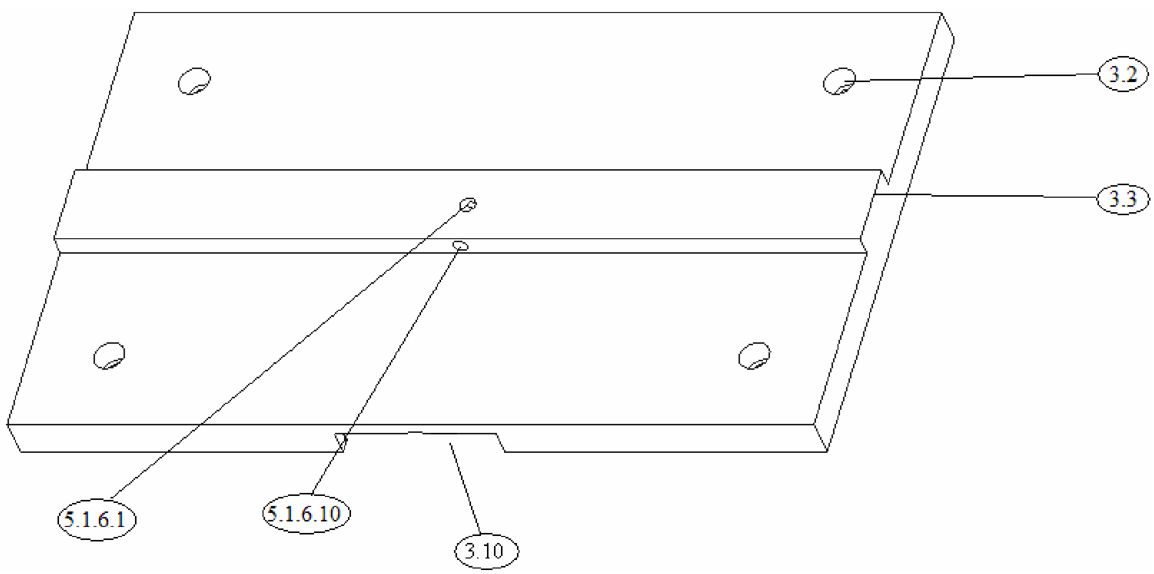


6 - Fastening Plate Bottom

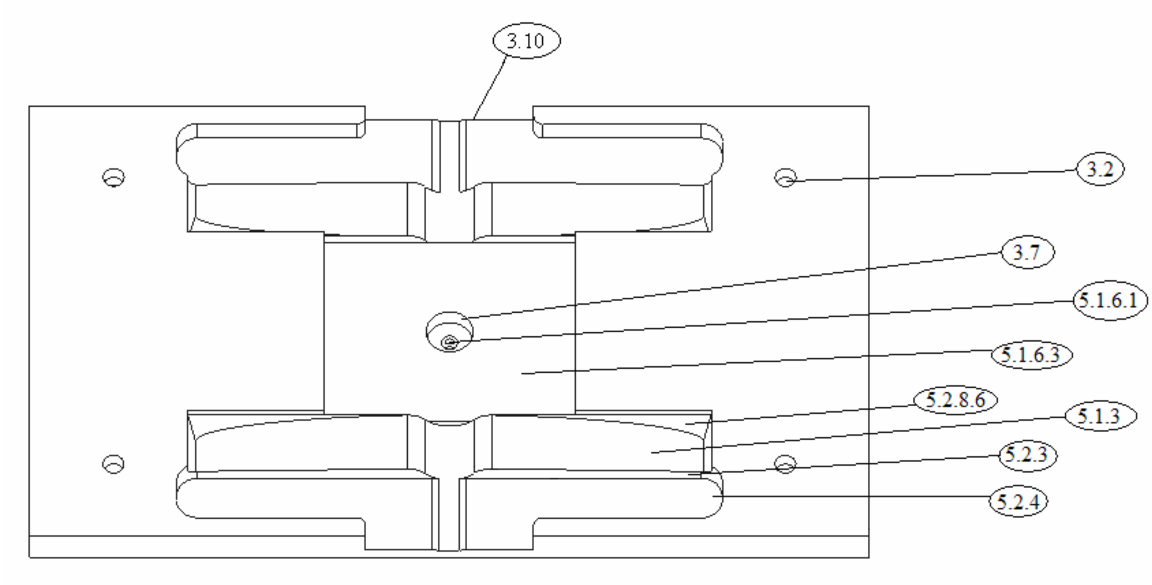
Description	Design Parameter
#1/4-20 Cap Screw (FP)	3.2
Fastening Plate Mounting Screws (6mm)	3.7
Depression Groove	5.1.3
Gear Recess	5.1.6.3
Spur Gear Recess	5.1.6.5
Side Wall of Moment Lock Recess	5.2.3
Cylindrical Protrusions	5.2.8.3
Correctional Groove	5.2.8.6

Table 2 - Fastening Plate Bottom Design Parameters

The top surface of the upper half of the fastening plate has a track rail, a rectangular protrusion along the length of the plate. The specific purpose of the track rail is controlling the direction of release to prevent movement detrimental to the design purpose. The holes about the track rail on the top surface of the fastening plate pertain to the pre-loading system for the shear release which will be explained in the Shear Release description. The fastening plate top can be observed in Figure 7 and Figure 8 with the corresponding Table 3 containing the description of the part.



7 - Fastening Plate Top



8 - Fastening Plate Top (Bottom View)

Description	Design Parameter
#1/4-20 Cap Screw (FP)	3.2
Track Rail	3.3
Fastening Plate Mounting Screws (6mm)	3.7
Depression Groove	5.1.3
Preload Manual Adjustment Cap Screw (#6-32)	5.1.6.1
Gear Recess	5.1.6.3
Spur Gear Recess	5.1.6.5
Stopper Cap Screws (#4-40)	5.1.6.10
Side Wall of Moment Lock Recess	5.2.3
Correctional Groove	5.2.8.6
Peg Hole	3.10

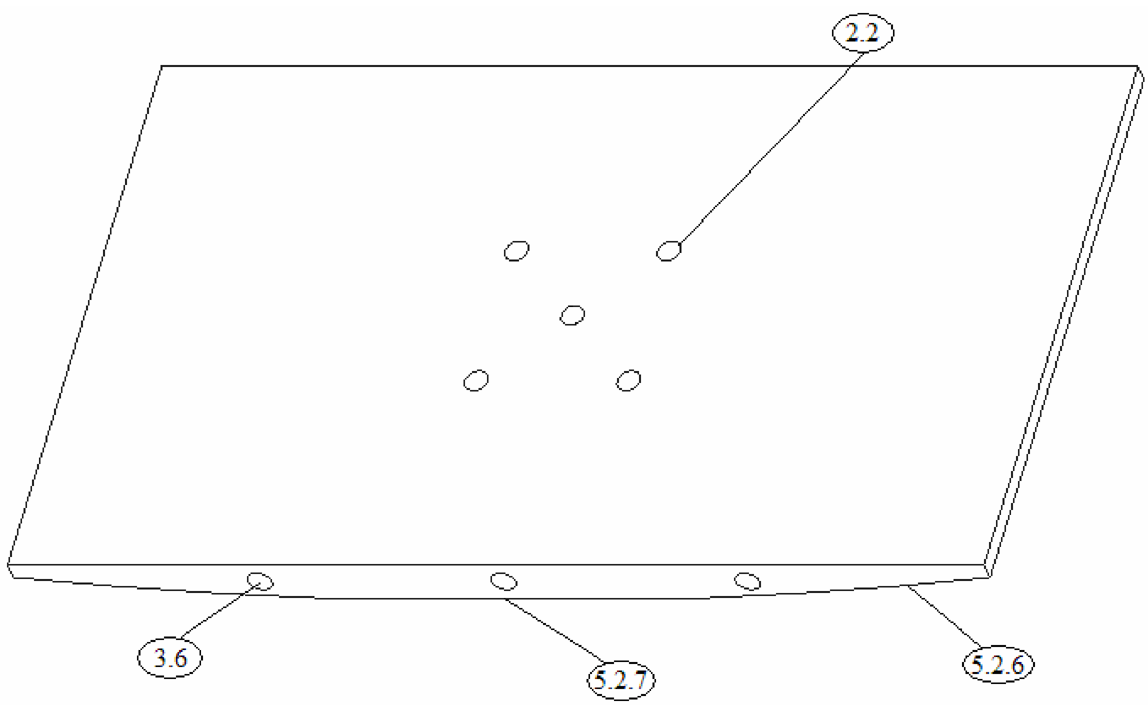
Table 3 - Fastening Plate Top Design Parameters

4.1.3 Boot Plate

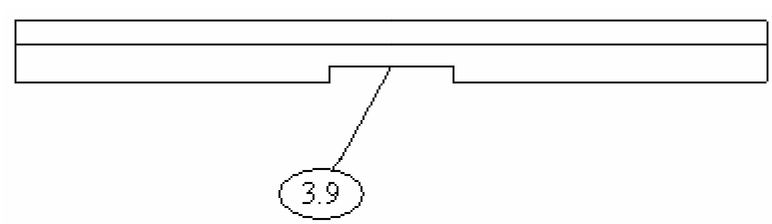
The boot plate is the element designed to release from the mechanism in the presence of threshold shear stresses (without significant moments applied to it). The geometry of the boot plate is split into two separate sections, the boot plate top and side pieces. This geometry is separated due to manufacturability.

The boot plate top is perforated with holes in a pattern equivalent to those in the bottom of the fastening plate. This allows the connection of commercially available bindings to the top of the boot plate. These two parameters allow the design to be implemented immediately using any combination of bindings and boards.

Located on the bottom of the boot plate is a guide slot which matches the track rail on the top of the fastening plate and the two are integrated together. This design allows for support of the vertical surfaces and prevents twisting motions, as well as directs the motion of release in the shear direction. The cam surfaces located on either side of the of the bottom surface are crucial in allowing the moment lock to function, as will be explained in the section pertaining to the system. The boot plate top can be seen below in Figure 9 with the corresponding Table 4 containing the description of the part.



9 - Boot Plate Top

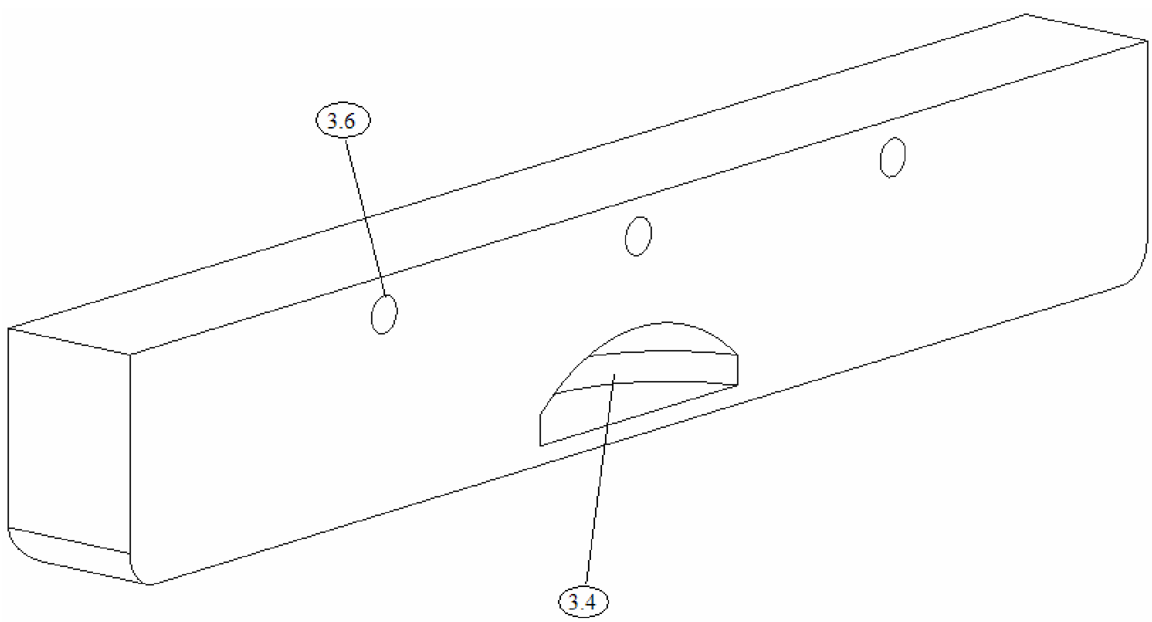


10 - Boot Plate Top (Front View)

Description	Design Parameter
Mounting Plate Screws (6mm)	2.2
Boot Plate Assembly Cap Screw (#1/4-20)	3.6
Guide Slot	3.9
Boot Plate CAM Surface	5.2.6
Boot Plate Flat Surface	5.2.7

Table 4 - Boot Plate Top Design Parameters

The boot plate sides are connected to the boot plate top by screws set towards the top of its geometry. The primary feature of the sides is the CAM recesses located halfway down the length of the inner side along the bottom edge, and are a vital shear release mechanism. This can be observed in Figure 11 with the corresponding Table 5 containing the description of the part.

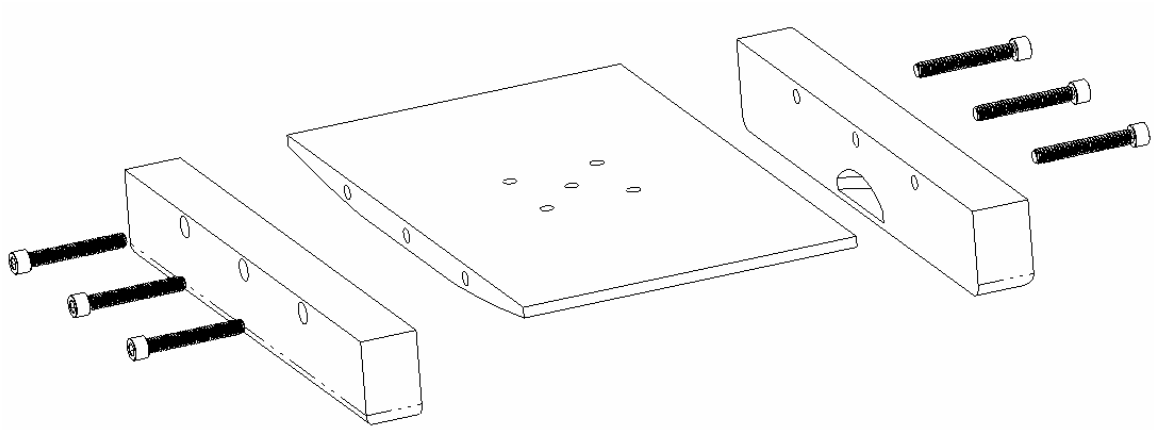


11- Boot Plate Side

Description	Design Parameter
Boot Plate Recess	3.4
Boot Plate Assembly Cap Screw (#1/4-20)	3.6

Table 5 - Boot Plate Side Design Parameters

An exploded assembly of the boot plate can be seen below in Figure 12.

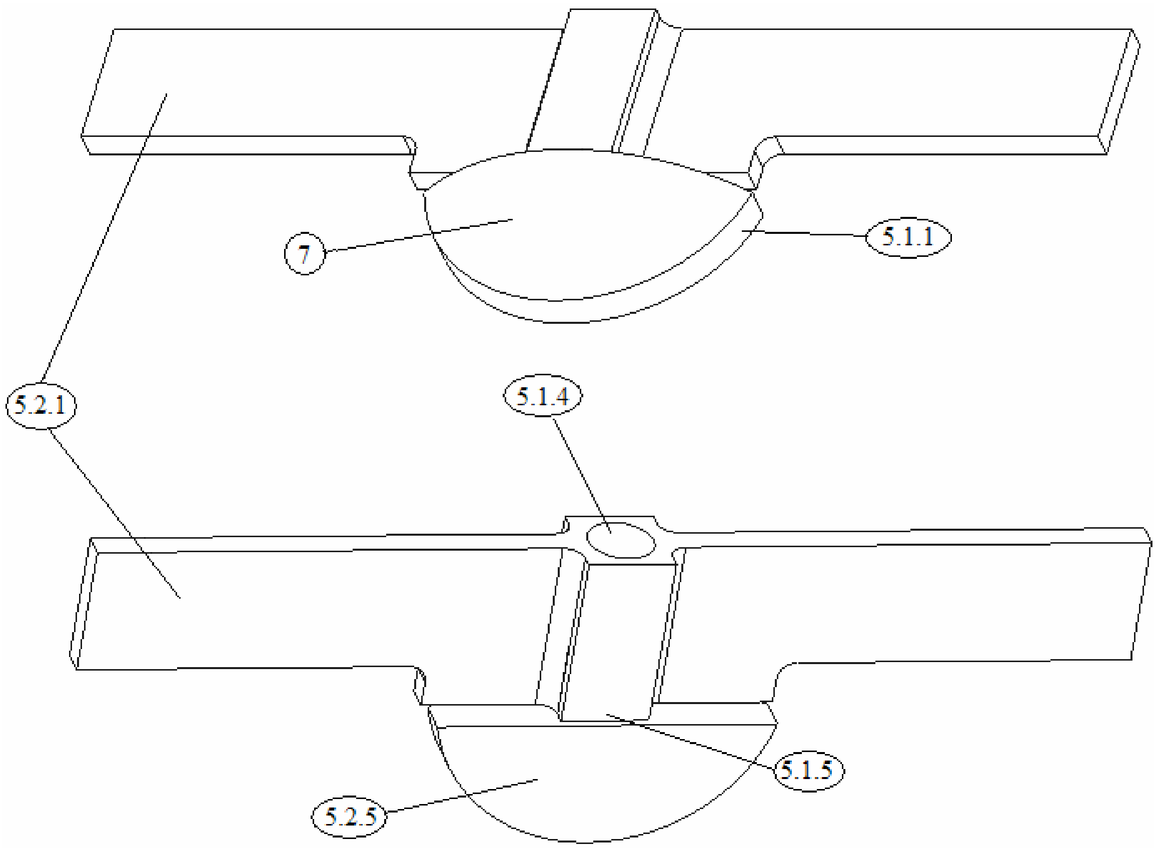


12- Boot Plate Exploded Assembly

4.1.4 Shear Release Mechanism

The shear release mechanism, one of the primary innovations in this design, is the principal system of injury reduction. Once a threshold shear stress is reached, particularly in the instance of a "flyswatter" effect with instantaneous forces, the boot plate is released to reduce the force of impact and to modify fall dynamics to reduce upper body injury.

The shear release mechanism is based off of a compression spring-peg assembly common to other releasable binding designs. The compression springs allow the pegs to depress under force. The spring fits into a hollow cylindrical portion in the rear of the peg and presses against the pack of this hollow protrusion. The peg, referred to as a force peg, is designed with a specially designed CAM surface head. This CAM surface portion of the force peg fits into the recesses found on the boot plate sides, which can be seen in Figure 11. The side CAM surface is vital to the shear release since it is fitted with the CAM surface of the recess and allows the surfaces to slide against one another in the presence of appropriate shear forces which depress the force peg against the force of the compression spring, sliding the force peg into the depression groove in the fastening plate. The geometry of the force peg can be viewed in Figure 13 with the corresponding Table 6 containing the description of the part.



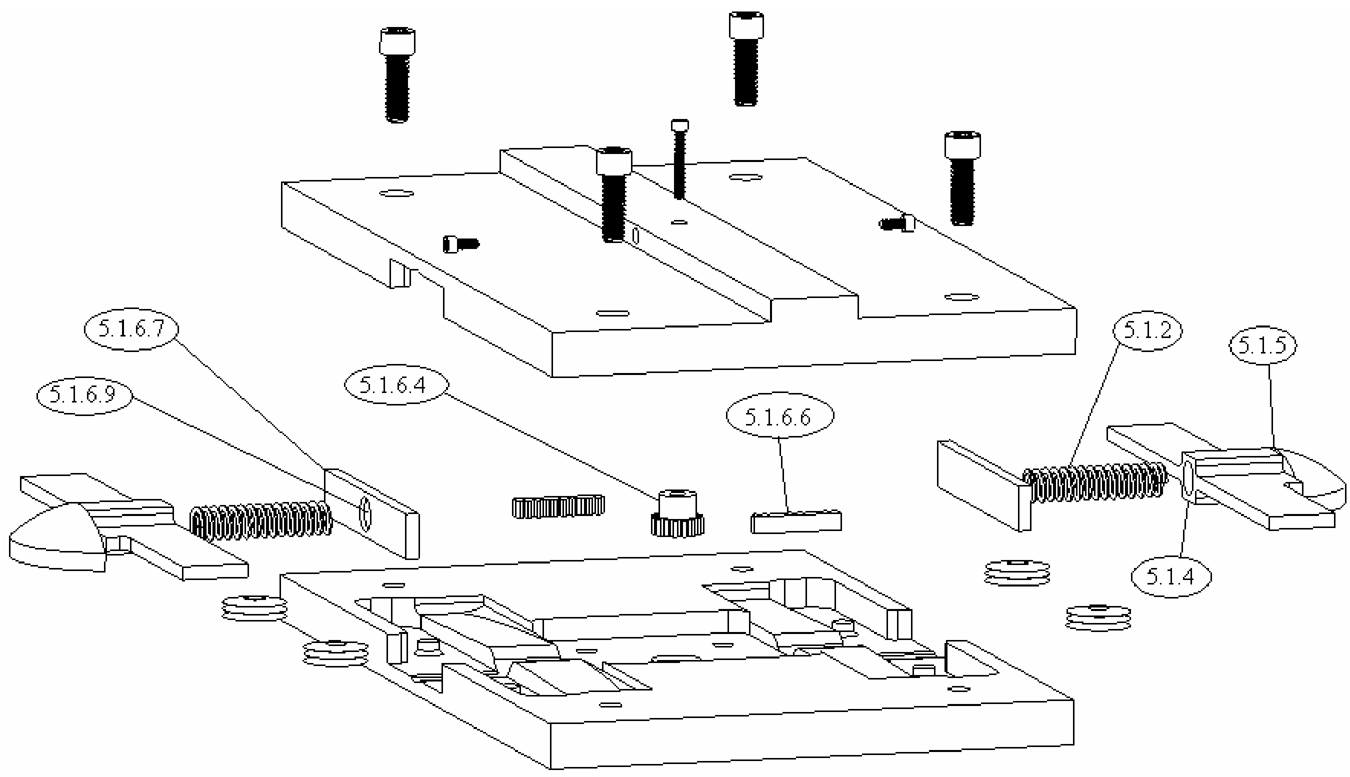
13 - Force Peg

Description	Design Parameter
Side CAM Surface of Force Peg	5.1.1
Hollow Protrusion	5.1.4
Back of Hollow Protrusion	5.1.5
Locking Pegs	5.2.1
Flat Bottom of Force Peg	5.2.5

Table 6 - Force Peg Design Parameters

The other end of the compression springs interface with an end plate which has a circular indent to fix the spring in place. The position of these end plates can be adjusted by turning the spur gear set in the fastening plate bottom via a cap screw accessible through the top of the plate.

This spur gear acts on gear racks attached to the end plate, moving them inward and outward. This method pre-loads both compression springs equally. A labeled exploded assembly in Figure 14 with the corresponding Table 7 containing the description of the part demonstrates the placement of the pre-loading mechanism in the fastening plate.



14 - Pre-loading System in Fastening Assembly

Description	Design Parameter
Compression Spring	5.1.2
Hollow Protrusion	5.1.4
Back of Hollow Protrusion	5.1.5
Spur Gear	5.1.6.4
Gear Rack	5.1.6.6
Spring End Plate	5.1.6.7
Circular Indentation	5.1.6.9

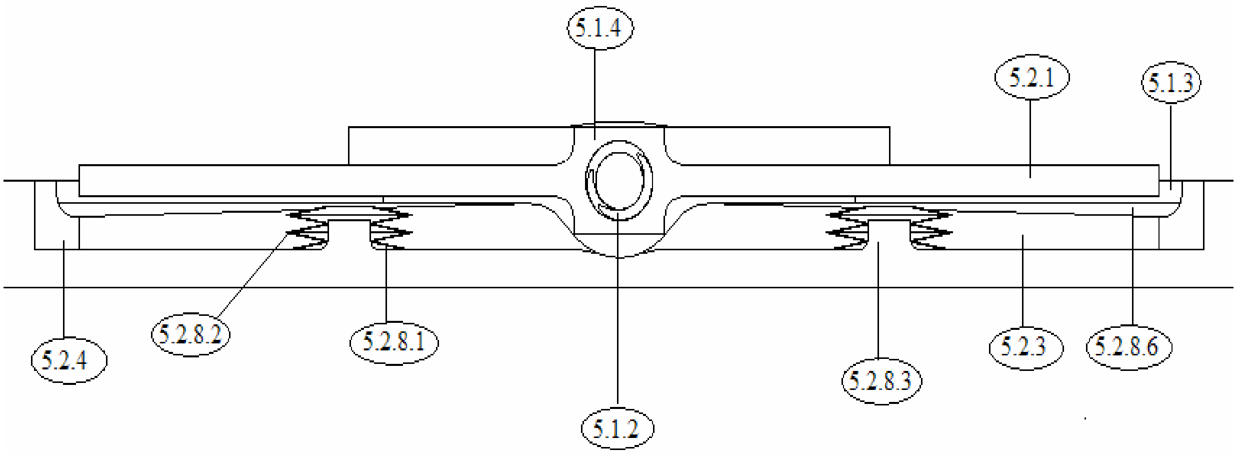
Table 7 - Pre-Load System Design Parameters

NOTE: This view labels the Pre-Loading System and describes how it will fit together in the interior of the fastening plate. This view also demonstrates how the fastening plate fits together and shows the positioning of the moment lock mechanism .

4.1.5 Moment Lock Mechanism

The other primary innovation in this design is the moment lock mechanism. As previously mentioned, it is expected that in the occurrence of the “flyswatter” effect there are no moments placed on the board by the rider. In this effect, inadvertent release can be prevented by keeping the binding from releasing whenever there is a moment placed on the board by the user. It is this prevention of unintentional release that the moment lock was designed.

The primary moments placed on a snowboard during riding are about the lateral axis of the foot. The moment lock was therefore designed with these moments in mind. When a substantial moment is placed about this axis, the user presses down on one of the ends of the boot plate. The CAM bottom surfaces of the boot plate allow a small degree of rotational motion. This motion is translated from the boot plate to the force peg via the flat bottom of the force peg head. The twisting motion of the force peg is allowed by a CAM surface placed below the head of the peg. Rotating the force peg head causes rotation of the locking pegs or “wings”. The wings press against disc springs placed underneath. If sufficient moment is present, the wings depress the disc springs enough to lock against the vertical surface of the moment lock recess instead of allowing depression. This effectively locks the force peg in place and disallows release. A model of the placement of the wings and disc springs can be seen in Figure 15 with the corresponding Table 8 containing the description of the part.



15 - Moment Lock System

Description	Design Parameter
Compression Spring	5.1.2
Depression Groove	5.1.3
Hollow Protrusion	5.1.4
Locking Pegs	5.2.1
Wall of Moment Lock Recess	5.2.3
Recess Round	5.2.4
Disc Spring	5.2.8.1
Disc Springs Stacked in Serial	5.2.8.2
Cylindrical Protrusion	5.2.8.3
Correctional Groove	5.2.8.6

Table 8 - Moment Lock System Design Parameters

NOTE: This view is shown as a side view of the inside of the moment lock recess. The central figure is the force peg, only the front protruding CAM surfaces are not shown as they are in "front" of this view.

4.1.6 Second Generation Changes

For the second generation design, several changes were made to various components in our binding assembly. These changes were made to rectify certain issues that arose during the assembly and testing of the previous design. Through these changes our group intended to create a design that would successfully release under shear stresses multiple times without error.

One of the major changes to our design was completely redesigning the preloading system. Originally the system was designed so that it could be adjusted at any time in the event that tuning needed to be made while snowboarding on a mountain. However, this created a complex preloading system with many parts that had the possibility of displacing, corroding, and jamming. Additionally, the design required set screw holes drilled in the sides of the track rail on the fastening plate top to lock the preloading system and no drill bits for that size screw long enough to machine those holes were available.

So to redesign the preloading system, a block was developed, machined out of Delrin®, which was placed in the same area that the original system was set. This preloading block had holes drilled into the sides where the preloading springs were to be placed, and Delrin® pegs that were shaped to slide within these holes. With this design, based on the amount of compression one desired, pegs could be placed in the spring holes followed by the insertion of the springs, allowing a variety of preloading systems.

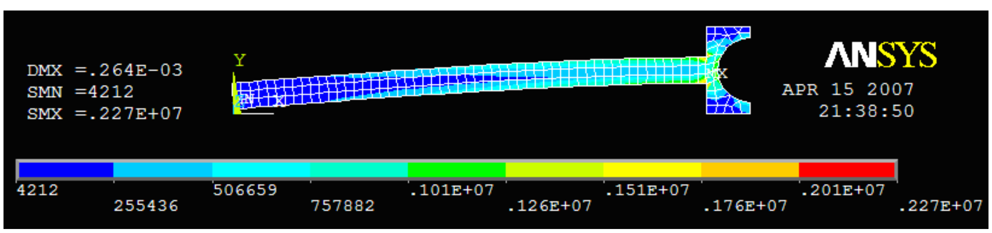
Several alterations were also made to the top and bottom of the fastening plates. First, new CAM surfaces were created in the areas where the force pegs were set in order to better guide the pegs when depressed and prevent them from shifting upwards or downwards, which could allow the pegs to contact surfaces potentially locking the system up. Also, chamfered surfaces were created on the corners of the opening holes in the side plates. These were created to improve the guidance of the force pegs when transferring out of the depressed state. Finally, rounded surfaces were created on the corners of the depressed area to better guide the force pegs when entering their depressed state.

The remaining changes were minor ones but developed to help create an easier testing environment. First, the peg indents located on the boot plate were widened to allow an easier release from the binding. Second, the squared edges on the back portion of the force pegs were rounded to better prevent the component from catching on a surface and jamming. Finally, the holes machined for the original preloading system were removed, not to aid with the testing methods, but to help reduce the manufacturing time and coding.

4.2 Material selection

As with any design project, material selection is a critical aspect. Choosing materials that can not withstand maximum expected stresses and strains can cause failure in the design and possible dangers to human safety. Considerable consideration was required when deciding the materials to use in our releasable snowboarding design.

The foremost material selection concern in the assembly was that of the force pegs. Since the 'wings' of the force pegs are only 0.150 inches thick and would be subjected to large moments and shear forces, a material was needed that would not bend or deform under great amounts of stress. A stress analysis using the maximum moment found in literature was performed using ANSYS 9.0, the results of which can be seen in Figure 16 below.



16 - ANSYS Stress Analysis of Stainless Steal in kPa

With a maximum calculated stress of approximately 230 MPa, 303 type stainless steel with a yield strength of 240 MPa was chosen as the material for the force pegs. For the second iteration of the design, the part was manufactured from brass in order to test the actual magnitude of the forces on the peg, and determine the feasibility of using materials that are easier to manufacture.

For the parts of the assembly that compose the boot and fastening plates, the group chose to manufacture the parts out of Delrin®, an crystalline acetyl homopolymer resin material. For these parts, a strong, stiff material that would not easily bend or deform under big loads was needed. However, as these parts accounted for a majority of the assembly, a material that was too dense would add unneeded weight to the snowboard, which could cause problems if used commercially. The material would also need to articulate well between itself and the force pegs, allowing diminutive friction and minimal wear. Finally, since this material would have significant exposure to snow and ice conditions, the material needed low moisture absorption and would not crack under frigid climates. Based on these restrictions, Delrin® was determined to be an excellent choice, due to its high strength, stiffness and fatigue endurance properties, superior impact and wear resistance and low moisture absorption as compared to other possibilities (Ensigner-Hyde).

The remaining materials were chosen based on time, budget, and manufacturing constraints. For example, brass spur gears and gear racks were used not because of their material properties, but simply because the brass parts could be ordered in smaller sizes than their steel counterparts. This made it far easier to fit them into the assembly. Also, the spring endplates used in the preloading system were made out of aluminum due to the fact that scrap aluminum was readily available in the manufacturing labs. Although it is generally considered unwise to combine metals due to the increased potential of corrosion, materials selection was based on a mix of benefits and convenience for the prototype.

When choosing a disc spring several factors had to be considered. The most important of all was the deflection due to certain loads, as a certain amount of deflection was needed under certain moment conditions. It was decided that a low activation moment would be desirable, as moments and shear forces escalate quickly during a carved turn. After reviewing the literature, it was decided that the moment lock should activate at approximately 15 Nm to prevent inadvertent release during a turn (Knunz et al. 2000).

The disc spring stacks are located 1.5 in (0.0381 m from the center of the force peg. With the selected disc springs, the height of five stacked springs is 0.22 in. The height at which the moment lock engages is 0.2 inches; therefore a depression of 0.02 inches (0.5mm) is necessary. By examining Table 9, it can be observed that the amount of deflection will occur at approximately 419 N. With this disc spring set up, the moment lock will activate at: 419*0.0381=15.96 Nm or approximately 16 Nm.

Disc Springs to DIN 2093								15% Defl.		30% Defl.		45% Defl.		60% Defl.		75% Defl.		90% Defl.	
Code No.	Outer Dia. (De) mm	Inner Dia. (Di) mm	Thick. (t) mm	Cone Ht. (ho) mm	Overall Ht. (lo) mm	Cone Ht. / Thick. Ratio	Weight per 1000 pcs.	Defl. mm	Force N	Defl. mm	Force N	Defl. mm	Force N	Defl. mm	Force N	Defl. mm	Force N	Defl. mm	Force N
								Stress δII N/mm^2	Stress δIII N/mm^2	Stress δII N/mm^2	Stress δIII N/mm^2	Stress δII N/mm^2	Stress δIII N/mm^2	Stress δII N/mm^2	Stress δIII N/mm^2	Stress δII N/mm^2	Stress δIII N/mm^2	Stress δII N/mm^2	Stress δIII N/mm^2
D186206	18.0	6.2	.60	.60	1.20	1.00	1.06	.09	124	.18	221	.27	296	.36	355	.45	400	.54	438
								78	236	196	452	354	647	554	823	794	980	1,074	1,116

Table 9 - Disc Spring Selection

http://www.bellevillesprings.com/19-28.pdf

3. Methods

5.1 Manufacturing Methods

The components of the assembly that needed to be manufactured were produced by the staff of WPI's Manufacturing Laboratory, located in Washburn Laboratories. The Delrin® and stainless steel/brass force peg components were machined using the Haas VF-2 and VF-4 Computer Numerically Controlled mills, while the spring endplates were cut from scrap aluminum. David Willens cut the endplates, Mike O'Donnell machined the stainless steel force pegs, and Christopher Stefaniak was responsible for machining the Delrin® components for the assembly, as well as the entire second design iteration. Although unable to manufacture the parts independently, the team monitored the machining of the parts in order to document any problems that may have arisen during the procedure.

5.2 Product Assembly

Once the components were machined, assembly of the design was required for bench testing. However, several problems arose during the assembling that needed to be rectified before the design could be successfully tested. Therefore, several adjustments were made to the original design in order to get the binding assembly in working order.

One of the biggest issues that arose was the dimensions of the components made out of Delrin®. Although the tolerances specified on the model drawings should have prevented any assembly issues, several components did not fit together. Some dimensions, although off by as little as 0.001 inches caused assembly problems. However, any tolerance issues with the Delrin® parts were easily filed until the parts were able to successfully fit together.

Another necessary adjustment was associated with the assembly of the preloading system. In the original design, the brass gear racks, which were used to adjust the spring endplates, had no constraints to keep them moving in a singe direction. Therefore any reaction force that the springs applied to the endplates shifted the gear racks off of the spur gear component, which caused the endplates to shift at a slant, potentially jeopardizing the preloading system. Also, when machining the top of the fastening plate, a drill long enough to make the holes for the set screw was not available which made locking the preloading system in place impossible. Without this function, the design could only be tested at the lightest preloading level.

To address this problem, the group drilled and threaded two holes, one on either side of the system, and inserted cap screws which were placed to prevent the gear racks from slipping. Also, since the binding was to be tested with the preloading system as loose as possible, rectangular visco-elastic polyurethane foam pieces were placed all around the system to hold the components in place and help prevent any unwanted movement.

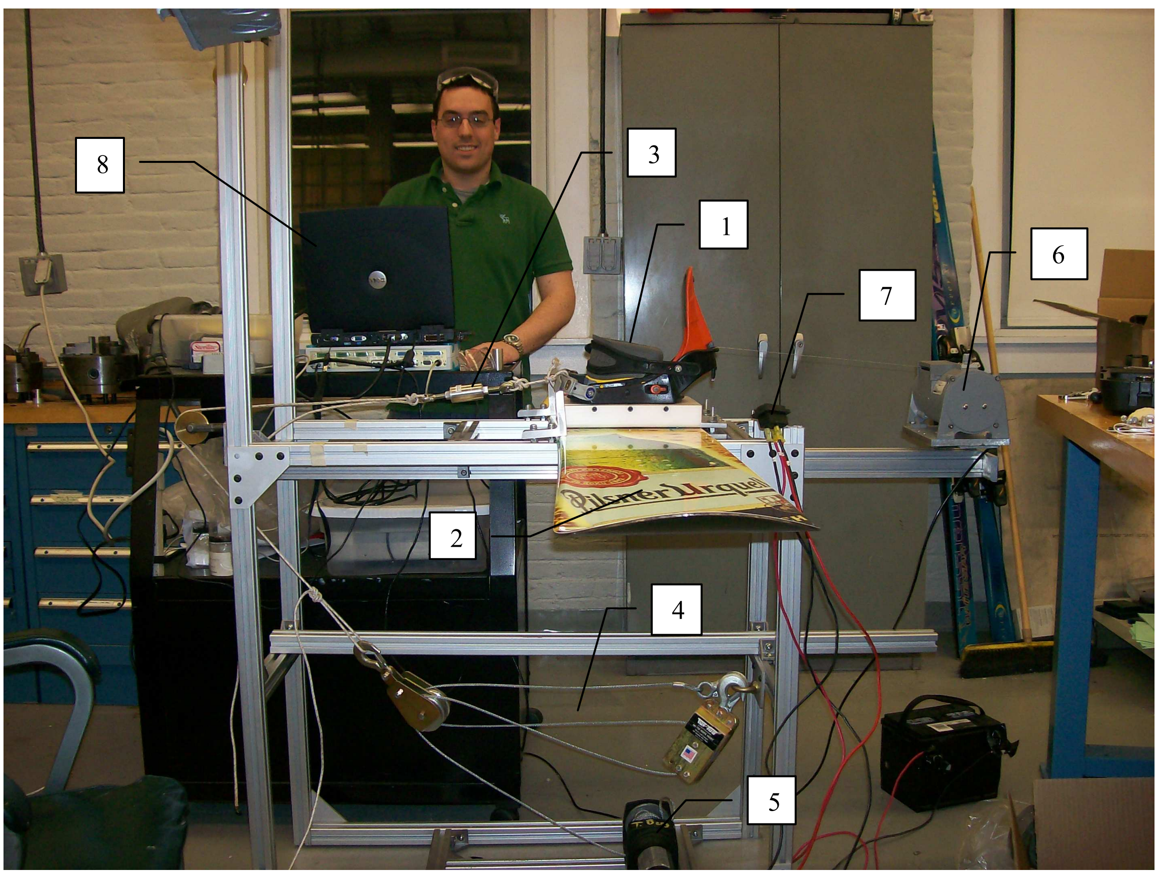
The last major adjustment of the device involved the insertion of the force pegs into their boot plate indents. In the original design, the pegs and indents had perfectly corresponding shapes. However, when the pegs fit the indents flawlessly they had no opportunity to move. Because of this, it was very difficult, if not potentially impossible, for any shear force on the boot plate to initiate the depression of the force pegs.

To rectify this problem, the group placed blocks of visco-elastic polyurethane foam inside the fastening plate, between the 'wings' of the force pegs and the inner walls they come into contact with when preloaded. The placement of these blocks kept the pegs slightly depressed at all times, allowing for some space between the pegs and their indents. This permitted the force pegs to successfully depress, releasing the binding from the assembly.

5.3 Testing

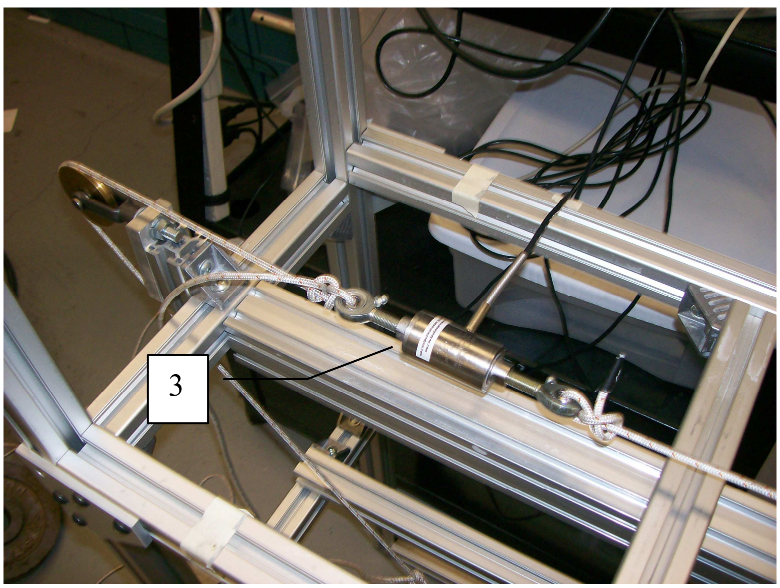
When determining the feasibility of a new product or assembly it is important to test the design both in the lab and in the field. The team developed a static bench test as a means to analyze and determine 1) whether the boot plate would release from the fastening plate under a shear force; 2) the amount of shear force needed to release the boot plate; and 3) that a moment applied to boot plate would prevent a shear release. It was decided that if the bench tests were successful, a second test, a field experiment involving an actual snowboarder catching his edge, would be needed to demonstrate releasabilty in an accurate scenario. Unfortunately this test was later discarded due to the inability to produce two binding systems that released consistently and the possible harm that could be incurred by the rider due to a failed release.

The device was lab tested on a modified bench originally designed and built by Brendan Powers, current Lab Manager of the Surface Metrology Laboratory of WPI to analyze releasable ski bindings. Several alterations of the bench were completed to accommodate the size and shape of the snowboard, allow for functional shear force testing to be conducted and the ability of acceptable data to be collected. The bench was constructed from a frame of aluminum beams designed to restrain a snowboard in place with space for the releasable riser and binding attached to successfully shear off. The aluminum frame was needed to handle the high forces that would be applied to the binding to achieve release. Figure 17 shows the entire bench test with appropriate sections numbered.



17 - Bench Test Device

A snowboard binding was screwed into the releasable riser design (1) which was screwed onto the snowboard (2) that was clamped down firmly to the bench to prevent any mobility. A rope was attached to the binding, rotated about single pulley and was pulled by a cable and winch. A tension tensor (3) was used to measure the forces needed to attain release of the boot plate from the fastening plate. In Figure 18 a closer view of the tension sensor placed between the binding and the pulley can be observed. The pulley was moved upwards during testing to be level with the location of where the rope was attached to the binding so that the recorded force was accurate to the actual force which was applied.



18 - Tension Sensor

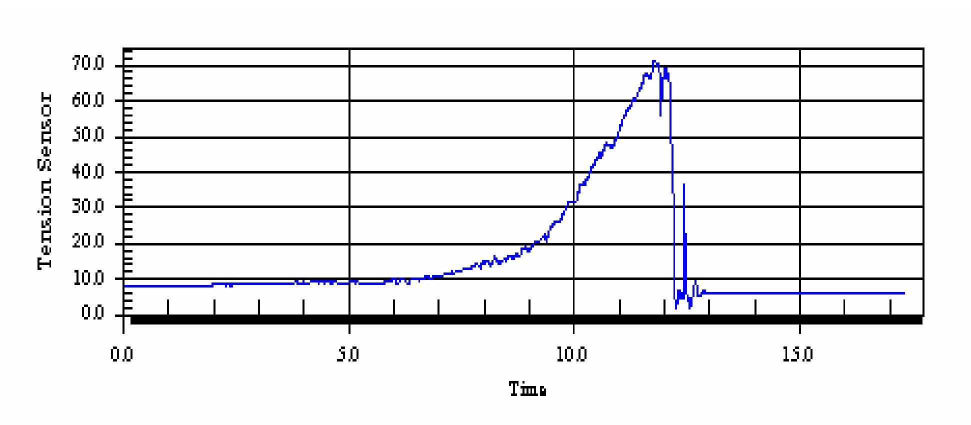
The block and tackle assembly (4) was used to reduce the amount of output force that was generated by the winch (5). In order to power the winch a 12 volt car battery was attached to a switch (7) as a means to easily control the winding of the steel cable and the attached rope to apply a force to the binding. The basis of the test was to continue winding the steel cable, which would put greater and greater amounts of force on the binding, until it reached the point at which the force pegs would depress, and the binding would separate. A displacement sensor, located behind the snowboard, was attached to the binding to record the distance the boot plate moved during a static test.

The data collection assembly (8) consisted of a Spider 8 amplifier system and a laptop running Catman 4.0 software. The signals from the tension sensor and the displacement sensor were amplified by the Spider 8 amplifier system and the data were collected and displayed graphically over time.

The bench was also originally designed to apply a moment to the system and apply a shear force simultaneously to demonstrate that the moment lock system would work as predicted. Unfortunately the force pegs did not initially releasing as expected and it was therefore decided to abandon tests on the ability of the moment lock and demonstrate merely releaseability of the boot plate and binding under shear force.

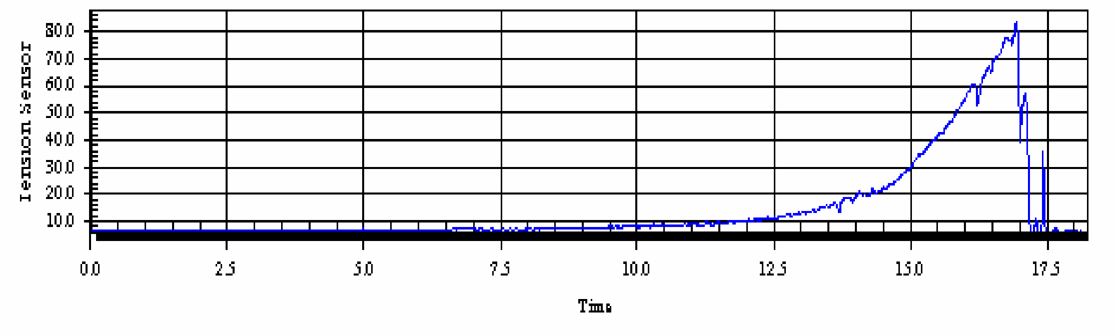
4. Results

The initial bench test was the most successful. The binding continued to resist the increasing tension until around 70 pounds of force, at which point the force pegs fully depressed, and the boot plate was able to shear away from the rest of the assembly. This result was similar to the predicted value based on the original calculations involving the spring constant of the included springs and the assumption of friction. The recorded tension force versus time data can be seen below in Figure 19.



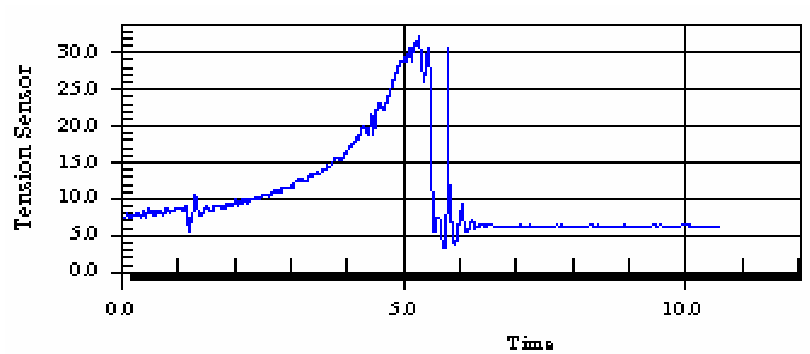
19 - Test 1 Results

Our second test generated slightly different results. During this test the boot plate resisted until the tension force reached around 80 pounds at which point it released. It is believed that this increase in tension was the result of a single force peg catching on an edge within the fastening plate. The extra force was needed to depress it the remaining way. This test data can be seen below in Figure 20.



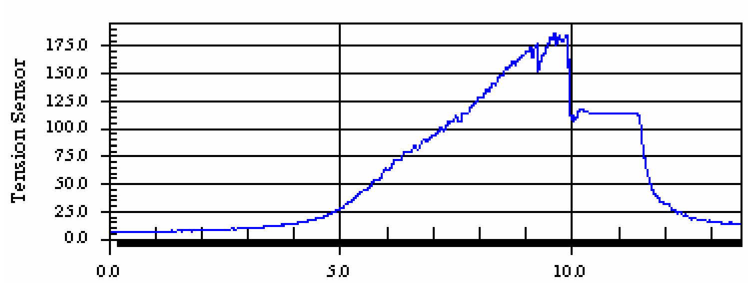
20 - Test 2 Results

For the final recorded test using the original design iteration, the results differed again. For this test, as the boot plate was attached to fastening plate, one of the force pegs was stuck inside the assembly, and as a result, the boot plate was held in place by a single peg. As a result, when the static test was performed, the boot plate released from the assembly at approximately 35 pounds of force, roughly half of the threshold force of the first binding. Though this test was unsuccessful, it confirmed the assumption of the amount of force required to cause a fully functional prototype to release. This data can be observed below in Figure 21.



21 - Test 3 Results

Once the second iteration of the design was completed and assembled, static bench tests were performed on it using the identical methods as before. However, due to a machining error on one part, as well as a design flaw on another part, we were unable to successfully test the binding. As the tension force continued to tighten on the binding, the force pegs, as they began to depress, locked within the fastening plate and became immovable. The consequence led to the continual increase the tension force until a maximum of around 180 lbs. was reached and the experiment was immediately halted to prevent the destruction of the test bench. The resulting data can be seen below in Figure 22.



22 - Second Iteration Test Results

5. Discussion

The results of the bench tests confirm the prototype's ability to release under shear stresses. However, the inconsistent success of bench tests also suggests many areas for improvement in the design. For instance, the problems with the catching of the force peg suggest that a guidance system for moving parts would make the binding system more consistently successful. Also, because the force peg had to be partially depressed in order to complete the bench tests, the moment lock system was disabled and could not be tested. Another limitation of the testing was that, due to the failure of the second design iteration, the prototype could not be field tested. A field test would have verified the usability of the design in real snowboarding situations, and would have confirmed the group's hypotheses that shear release would decrease upper body impact force. It also would have helped in testing the theory behind the moment lock system. Some design alterations are necessary to make the prototype consistently successful and reproducible.

6. Conclusions

- The first binding was unable to work successfully as designed, but when assessed and adjusted, could successfully work in limited capacities
- With some adjustment, the prototype will release under shear forces greater than the threshold force
- The second binding had better features and a simpler setup, but failed due to force pegs locking the system when in the process of being depressed
- The econd design also had a manufacturing flaw in the fastening plate top, and a design flaw in the boot plate side, which added to the failure of the design
- The first preloading system was successful, but limited in its design
- The second preloading system worked better due to increased stability but is limited in its adjustments

7. Recommendations

After designing and testing the two iterations of the binding assembly, the team determined a set of recommendations that should help improve further generations of this MQP project. All recommendations should be taken into consideration for the continuation this project.

First, an in-depth study of moments and forces on the binding during riding would greatly aid the design process. The study would help to develop the moment lock and shear release systems and also provide accurate data to determine threshold forces for the design.

Improved interfacing of parts to avoid undesirable interaction would greatly assist the functionality of the design. For example, a better means of guidance surfaces for the force pegs would have kept them from continuously contacting parts on the fastening plate which would result in them locking up. If a more careful analysis into the different interaction possibilities between moving parts were to occur, the potential for successful releasability would greatly improve.

A minor recommendation would be to have an increased selection of springs and preloading systems to vary threshold forces for bench and field testing. The team's options when designing the binding were limited, but a more careful study may lead to new ideas when preloading the design.

Finally, a design directed towards a commercialized product would help with field testing. In this scenario, the product would have to be designed to weigh significantly less and possess increased compatibility with snowboards, as well as be further weather proofed for cold and wet environments. In following these recommendations, the successfulness of the binding on a bench test can also be duplicated in the field.

Appendix A – Detailed Decomposition

A.1 Boot Attachment

1	FR	Attach Boot to Binding System	DP	Preexisting Binding

In order to attach the boot to the binding system, we will be using a preexisting binding model. This will be attached to the system by attaching the binding mounting plate to the boot plate, which will be described in the following sections.

A.2 Binding Restraint

2	FR	Restrain Binding to Boot Plate	DP	Preexisting Binding Mounting Plate
2.1	FR	Allow Adjustment of Boot Angle	DP	Preexisting Binding Angle Adjustment Mechanism
2.2	FR	Fix Mounting Plate to Fastening Plate	DP	Screws

The mounting plate of the preexisting binding will be used to mount the binding to the boot plate. This is necessary to connect the boot to the safety binding system.
As this is the prototype, a system to allow angle adjustment is not provided in the binding. Rather, the user will adjust the angle by through the mechanisms available in the pre-existing binding.

A.3 Boot Plate to Board Interface

3	FR	Attach Boot Plate to Board	DP	Fastening Plate
3.1	FR	Allow Manufacturing of Fastening Plate	DP	Geometry Split in Half
3.2	FR	Attach Two Halves of Fastening Plate	DP	Screws
3.3	FR	Fix Boot Plate in Direction of Shear Release	DP	Track Rail
3.4	FR	Fix Boot Plate to Fastening Plate Below Threshold Shear Stress	DP	Boot Plate Recesses and Fastening Plate Pegs
3.5	FR	Allow Manufacture of Boot Plate Recesses	DP	Split Geometry
3.6	FR	Assemble Boot Plate Components	DP	Screws
3.7	FR	Attach Fastening Plate to Board	DP	Screws through Bottom Half of Fastening Plate
3.8	FR	Allow Adjustment of Boot Plate Position on Board	DP	Fastening Plate to Board Interface
3.9	FR	Allow Interface between Track Rail and Boot Plate	DP	Guide Slot
3.10	FR	Allow Force Pegs to Extend Outside Fastening Plate	DP	Peg Hole

This branch details how the boot plate (which the binding holding the boot is affixed to) is attached to the snowboard itself. The boot plate is connected to the fastening plate as described below, using the force pegs that are used in the safety mechanism (that will be described further in this section).

Branch 3 Children Descriptions

3.1	FR	Allow Manufacturing of Fastening Plate	DP	Geometry Split in Half
3.2	FR	Attach Two Halves of Fastening Plate	DP	Screws

Due to the complex inner recesses of the fastening plate that allow the safety release, moment lock, and pre-loading systems (as described later in this section) to function, the fastening plate cannot be constructed out of one piece of material. This is solved by splitting the fastening plate at half of its height, allowing the material to be removed for the inner recesses. The two halves will then be fitted together by screws.

3.3	FR	Fix Boot Plate Angle in Direction of Shear Release	DP	Track Rail & Vertical Surfaces of the Binding System

To ensure that the boot plate is fixed in the shear direction perpendicular to the board length, a track rail down the middle of the fastening plate (in the direction of shear) was added to support the interaction between the vertical surfaces of the boot and fastening plate. This helps ensure that the release will happen in the shear direction as well.

3.4	FR	Fix Boot Plate to Fastening Plate Below Threshold Shear Stress
DP	Boot Plate Recesses & Fastening Plate Pegs	

Physically attaching the boot plate to the fastening plate is done through the insertion of the force pegs located on the sides (facing the longitudinal direction of the board) of the fastening plate into matching recesses on the sides of the boot plate. The force pegs are designed to fix the boot plate to the fastening plate unless under stresses described in the safety mechanism branch.

3.5	FR	Allow Manufacture of Boot Plate Recesses	DP	Split Geometry
3.6	FR	Connect Boot Plat Components	DP	Screws

Due to the locations of the recesses that hold the force pegs, the boot plate cannot be machined from one block of material. Therefore, the two vertical surfaces on which the recesses are located will be manufactured separately from the piece that interacts with the top of the fastening plate. These vertical pieces will then be screwed onto the horizontal middle section.

3.7	FR	Attach Fastening Plate to Board	DP	Screws Through Bottom Half of Fastening Plate
3.8	FR	Allow Adjustment of Boot Plate Position on Board	DP	Fastening Plate to Board Interface

The fastening plate is attached to the board by screws set through the fastening plate's bottom half into the board. The board will have multiple hole patterns to allow for different positions to be set.

3.9	FR	Allow Interface between Track Rail and Boot Plate	DP	Guide Slot

In order for the Boot Plate to be guided in shear release by the track rail successfully, the track rail must have an interface with the Boot Plate. A Guide Slot is cut from the bottom of the Boot Plate to allow a location for the Track Rail to fit into.

3.10	FR	Allow Force Pegs to Extend Outside Fastening Plate	DP	Peg Hole

The peg hole exists between the Moment Lock Recess and the outside of the Fastening Plate to allow the CAM surfaces of the Force Peg to extend outside the fastening plate. This allows the peg to lock into the Boot Plate recesses.

A.4 Transference of Forces

4	FR	Transmit moments about the longitudinal and lateral axis
	DP	Horizontal Surfaces Interfacing between Components

In order to effectively ride the snowboard, the moments, and therefore forces as well, need to be transmitted from the boot to the board. These forces are transmitted through the horizontal surfaces interfacing with each other of the main bodies of the boot plate and binding plate, but also through the force peg and locking pegs of the safety mechanism.

A.5 Safety Release Mechanism

5	FR	Prevent "Flyswatter" Effect	DP	Releasable Binding
5.1	FR	Enable Binding To Release At Threshold Force	DP	Shear Release Mechanism
5.2	FR	Prevent Release Over Threshold Moment	DP	Lateral Moment Lock System

Branch 5 details the more complex details of the design of the safety snowboard binding, the safety mechanism for which it was chiefly created. The main goal of this binding design was to eliminate what is commonly called the "Flyswatter Effect". This effect can be observed when the longitudinal side of the board "catches" in the snow during riding. This caught side acts as a hinges, swinging the rider's upper body towards the ground. This incurs greater injury upon the rider than if he/she had fell without this hinge motion, as the rider hits the ground with greater speed with this effect, therefore amplifying the force of impact.

There are two major branches which will be described in detail below.

A.5.1 Shear Release Mechanism

5.1	FR	Enable Binding To Release At Threshold Force	DP	Shear Release Mechanism
5.1.1	FR	Provide Peg-Recess Interface that Allows Depression	DP	Peg/Recess Side CAM Surfaces
5.1.2	FR	Provide Threshold Force	DP	Compression Spring
5.1.3	FR	Allow Force Peg to Depress	DP	Depression Grooves
5.1.4	FR	Align Compression Spring Along Axis of Depression	DP	Hollow Protrusion at Back of Force Peg
5.1.5	FR	Provide Interface Between Force Peg and Compression Spring	DP	Back of Hollow Protrusion
5.1.6	FR	Allow Adjustment of Threshold Force	DP	Shear Release Preload System

Branch 5.1. Children Descriptions

5.1.1	FR	Provide Peg-Recess Interface that Allows Depression	DP	Peg/Recess Side CAM Surfaces

To provide a sliding interface that will allow them to depress, the force pegs have a base that serves as a cam surface. Under a level of shear stress that is greater than the force provided by the compression spring (see below), the binding plate surfaces on either side of the recession will slide along the cam surface of the force peg, depressing it.

5.1.2	FR	Provide Threshold Force	DP	Compression Spring

In order to allow the force peg to depress under force, a compression spring is used. This is inserted into the hollow cylinder located behind the head of the force peg and attached to the end plate connected to the pre-loading system.

5.1.3	FR	Allow Force Peg to Depress	DP	Depression Grooves

In order to allow the locking pegs to depress, a groove is cut allowing the locking pegs to depress into said recess over the threshold shear stress.

5.1.4	FR	Align Compression Spring Along Axis of Depression	DP	Hollow Protrusion at Back of Force Peg

The hollow protrusion located behind the force peg houses the compression spring and aligns the compression spring along the axis of depression. The inner diameter of this hollow cylinder matches the outer diameter of the spring to allow the spring to be inserted securely.

5.1.5	FR	Provide Interface Between Force Peg and Compression Spring	DP	Back of Hollow Protrusion

The compression spring presses against the back of the force peg (while housed in the hollow protrusion) to provide the threshold force necessary for release.

5.1.6	FR	Allow Adjustment of Threshold Force	DP	Shear Release Preload System

As shear forces impacted upon the binding both during normal riding conditions and that of an occurrence of the Flyswatter Effect are currently unknown, a system to adjust the amount of force required to depress the spring is necessary. This is achieved with the use of a gear system located inside the fastening plate allowing the spring to be pre-loaded. This system has its own branch, and the children are described below.

A.5.2 Shear Release Preload System

5.1.6	FR	Allow Adjustment of Threshold Force	DP	Shear Release Preload System
5.1.6.1	FR	Allow Manual Adjustment	DP	Cap Screw
5.1.6.2	FR	Prevent Cap Screw from Interfering with Release	DP	Indent in Track Rail
5.1.6.3	FR	Provide Space for Preload System	DP	Gear Recess
5.1.6.4	FR	Provide Interface for Cap Screw Rotation to Gear System	DP	Spur Gear
5.1.6.5	FR	Prevent Movement of Spur Gear	DP	Circular Recess in Gear Recess
5.1.6.6	FR	Provide Interface Between Spur Gear Rotation and Spring System	DP	Gear Racks
5.1.6.7	FR	Allow Position of Gear Racks to Influence Compression Spring	DP	Spring End Plate
5.1.6.8	FR	Allow Simultaneous Pre-Loading of Both Compression Springs	DP	Symmetrical Placement of Gear Racks
5.1.6.9	FR	Prevent Slippage of Spring on Spring End Plate	DP	Circular Indent
5.1.6.10	FR	Prevent Reverse Rotation of Spur Gear due to Spring Force	DP	Stopper Cap Screws

<u>Branch 5.1.6 Children Descriptions</u>

5.1.6.1	FR	Allow Manual Adjustment	DP	Cap Screw

An interface is necessary to allow the user to preload the compression springs manually. This is done through a cap screw accessible through the top of the track rail.

5.1.6.2	FR	Prevent Cap Screw from Interfering with Release	DP	Indent in Track Rail

To prevent the manual adjustment cap screw from interfering with the shear release, an indent is cut into the track rail. The cap screw head is located in this indent, barring interaction between the cap screw and the bottom of the boot plate.

5.1.6.3	FR	Provide Space for Preload System	DP	Gear Recess

A recess is located in the center of the fastening plate to allow placement of the shear release preload system.

5.1.6.4	FR	Provide Interface for Cap Screw Rotation to Gear System	DP	Spur Gear

Once the cap screw is rotated, it requires a means to interact with the preloading system located inside the fastening plate. This is done by attaching a spur gear to the bottom of the cap screw. Turning the cap screw causes rotation of the spur gear.

5.1.6.5	FR	Prevent Movement of Spur Gear	DP	Circular Recess in Gear Recess

To prevent the spur gear from changing position, a cylindrical recess is cut in addition to the Gear Recess. The spur gear sits in this cylindrical recess, preventing it from moving inside the Gear Recess.

5.1.6.6	FR	Provide Interface Between Spur Gear Rotation and Spring System	DP	Gear Racks

Once the spur gear begins rotating, it necessitates an interface with the compression spring system. This is done by connecting two gear racks on either side of the spur gear, whose locations changes depending on adjustment of the cap screw and therefore rotation of the spur gear.

5.1.6.7	FR	Allow Position of Gear Racks to Influence Compression Spring	DP	Spring End Plate

In order to interact with the compression spring itself, the gear rack requires a surface that interfaces with the compression spring. Thus, an end plate is attached to the end of the gear rack.

5.1.6.8	FR	Allow Simultaneous Pre-Loading of Both Compression Springs	DP	Symmetrical Placement of Gear Racks

One concern with the shear release pre-loading system is pre-loading the two compression springs to different degrees. To prevent this, the gear racks that determine the level of loading on the compression springs are placed symmetrically on either side of one spur gear.

With the gear racks placed in this fashion, the amount they are displaced with a turn of the cap screw are equal. Therefore the amount of loading that is placed on the springs is also equal.

5.1.6.9	FR	Prevent Slippage of Spring on Spring End Plate	DP	Circular Indent

In order to secure the compression spring to the end plate, the end plate's surface is notched to allow a circular indent, the diameter of which is equal to that of the outer diameter of the spring. The internal end of the spring is then fitted inside this depression.

5.1.6.10	FR	Prevent Reverse Rotation of Spur Gear due to Spring Force	DP	Stopper Cap Screws

In order to prevent the spur gear from rotating backwards due to the preloaded spring force, cap screws are located to either side of the manual adjustment cap screw. When the manual adjustment of the desired preload is complete, the stopper cap screws are tightened against the manual cap screw, preventing rotation.

A.5.3 Lateral Moment Lock System

5.2	FR	Prevent Release Over Threshold Moment	DP	Lateral Moment Lock System
5.2.1	FR	Provide Locking Surfaces	DP	Locking Pegs
5.2.2	FR	Allow Locking Pegs to Rotate When Not Depressed	DP	Moment Lock Recess
5.2.3	FR	Provide Surface for Locking Pegs to Lock Against	DP	Wall of Moment Lock Recess
5.2.4	FR	Prevent Scraping Between Ends of Locking Pegs and Moment	DP	Recess Round
5.2.5	FR	Provide Interface for Transferring Lateral Moment	DP	Flat Bottom of Force Peg
5.2.6	FR	Allow Moments to be Applied to Force Peg	DP	Bottom CAM Surfaces of Boot Plate
5.2.7	FR	Allow User to Place no Moment on Board	DP	Bottom Middle Flat Surface of Boot Plate
5.2.8	FR	Provide Preload System	DP	Moment Lock Preload System

One of the major grievances with current releasable binding is the possibility of inadvertent release during normal riding conditions. In this binding, this is prevented by the moment lock system. The theory which this binding has been designed around is that in the event of a "Flyswatter Effect" occurrence, there is no moment being applied to the board. Rather, instantaneous shear force due to the sudden stop of the caught board is predominant. Thus, a system was devised to prevent release while moment is applied to the snowboard; release is only allowed when shear force is the major force present and only if it overrides the force provided by the compression spring. We will look at the children of 5.1.2 below.

<u>Branch 5.2. Children Descriptions</u>

5.2.1	FR	Provide Locking Surfaces	DP	Locking Pegs

In order for the lock to function, surfaces that interact with the fastening plate are necessary to prevent depression of the force peg. The locking pegs that serve this purpose are located on the left and right quadrants of the hollow cylinder behind the force peg that houses the compression spring. When lateral moment is present, these locking pegs press up against the walls of the inner recess of the fastening plate and do not allow force peg depression.

5.2.2	FR	Allow Locking Pegs to Rotate When Not Depressed	DP	Moment Lock Recess

A recess is located on either side of the fastening plate to allow the locking pegs to depress and to make room for the moment lock preload system, as described below.

5.2.3	FR	Provide Surface for Locking Pegs to Lock Against	DP	Wall of Moment Lock Recess

The locking pegs need something to press against in order to fulfill their primary function, to prevent force peg depression. If moments above the threshold are present, the locking pegs rotate beyond the depression groove and lock against the wall of the Moment Lock Recess.

5.2.4	FR	Prevent Scraping Between Ends of Locking Pegs and Moment	DP	Recess Round

To prevent the locking pegs from scraping the sides of the Moment Lock Recess, the recess is extended on either side by a small radius.

5.2.5	FR	Provide Interface for Transferring Lateral Moment	DP	Flat Bottom of Force Peg

An interface is necessary to transfer whatever moment is applied by the user to the moment lock. The flat bottom of the force peg serves this end; as the rider rotates his/her foot laterally the rotation from the boot plate acts on the force peg through the flat surface.

5.2.6	FR	Allow Moments to be Applied to Force Peg	DP	Bottom CAM Surfaces of Boot Plate

In to allow the rotation which enables the Lateral Moment Lock to perform its function, a degree of freedom had to be introduced to the binding system. This must be placed about the lateral axis to in specific. Due to the structural and stress constraints on the fastening plate, this was located on the bottom of the boot plate. CAM surfaces were cut into the front and back three inches of the boot plate bottom to serve this purpose. Thus, when the rider puts force on the toe or heel of the boot to steer the snowboard, the moment created by this is transferred to the moment lock to prevent release.

5.2.7	FR	Allow User to Place no Moment on Board	DP	Bottom Middle Flat Surface of Boot Plate

If the bottom of the Boot Plate were a single curved CAM surface, the user would always be putting a moment on the board and there would be no neutral position. In order to allow the user to place no moment on the binding (when riding straight down the slope, for example), the middle four inches of the boot plate (where the flat of the foot is approximately located) bottom is flat.

5.2.8	FR	Provide Preload System	DP	Moment Lock Preload System

In order for the binding to neglect minimal moments and to give feedback to the user (in effect reducing the amount of rotation noticeable by the rider), a system is used to pre-load the Moment Lock, requiring a certain amount of moment for varying degrees of locking peg rotation. This system has its own branch, and the children are described below.

A.5.4 Moment Lock Preload System

5.2.7	FR	Provide Preload System	DP	Moment Lock Preload System
5.2.7.1	FR	Provid Threshold Moment	DP	Disk Springs
5.2.7.2	FR	Maximize Deflection of Disk Springs	DP	Disk Springs Stacked in Serial
5.2.7.3	FR	Fix Disk Stack in Location	DP	Cylindrical Protrusions
5.2.7.4	FR	Support Disk Stack Along Height	DP	Sponge Shell
5.2.7.5	FR	Maintain Contact of Disk Spring Surface Areas	DP	Epoxy
5.2.7.6	FR	Prevent Force Peg from Hitting Disk Stack when Resetting	DP	Correctional Groove

<u>Branch 5.2.7 Children Descriptions</u>

5.2.7.1	FR	Provid Threshold Moment	DP	Disk Springs

The lateral moment lock pre-loading system is driven by the disc springs placed underneath the both sides of the locking pegs. The disc springs deflect enough under the threshold moment to allow the locking pegs to rotate enough as to not be able to depress into the groove provided. With moments present below the threshold, the locking pegs do not depress the disc springs enough to lock against the interior surface of the fastening plate recess.

5.2.7.2	FR	Maximize Deflection of Disk Springs	DP	Disk Springs Stacked in Serial

Due to the small size of the disc springs available to fit the fastening plate recess and match the deflection and force requirements, multiple disc springs must be stacked upon one another. In order for the disc springs to provide the necessary deflection that will allow the moment lock to work, the disc springs had to be stacked in serial. Stacking disc springs in this fashion multiplies the deflection per spring by the number of springs, while the force required for this deflection remains unchanged. See Appendix F for more information.

5.2.7.3	FR	Fix Disk Stack in Location	DP	Cylindrical Protrusions

In order to fix the disc stack base in the desired location, cylindrical protrusions are located on either side of the force peg. The bottom of the Disc Spring Stack then slides onto this. The protrusion rises to the height at which the maximum deflection of the disc springs/locking pegs are expected

5.2.7.4	FR	Support Disk Stack Along Height	DP	Sponge Shell

The protrusions themselves only rise to the height at which maximum deflection of the locking pegs is expected. In order to keep the disc springs in place above that point, a cork/sponge rod/shell is used. The cork/sponge depresses with minimal force and does not expand due to compression, keeping the disc springs in their required location without affecting the forces involved in the moment lock.

5.2.7.5	FR	Maintain Contact of Disk Spring Surface Areas	DP	Epoxy

To maintain contact between the surface areas of the disc springs and prevent slippage, epoxy is used to secure the faces of the disc springs that interface with each other.

5.2.7.6	FR	Prevent Force Peg from Hitting Disk Stack when Resetting	DP	Correctional Groove

As the moment lock system will allow the force peg to depress under negligible moments, the locking pegs can depress at a slight angle. To prevent the locking pegs from coming back out at an angle, a curved surface was introduced to the back of the depression groove that brings the locking pegs back to the horizontal position when depressed. This prevents damage to the moment lock preload system, which would be hit by the locking pegs with the force of the compression spring if indeed the locking pegs came out at an angle.

A.6 Lift Force Release Prevention

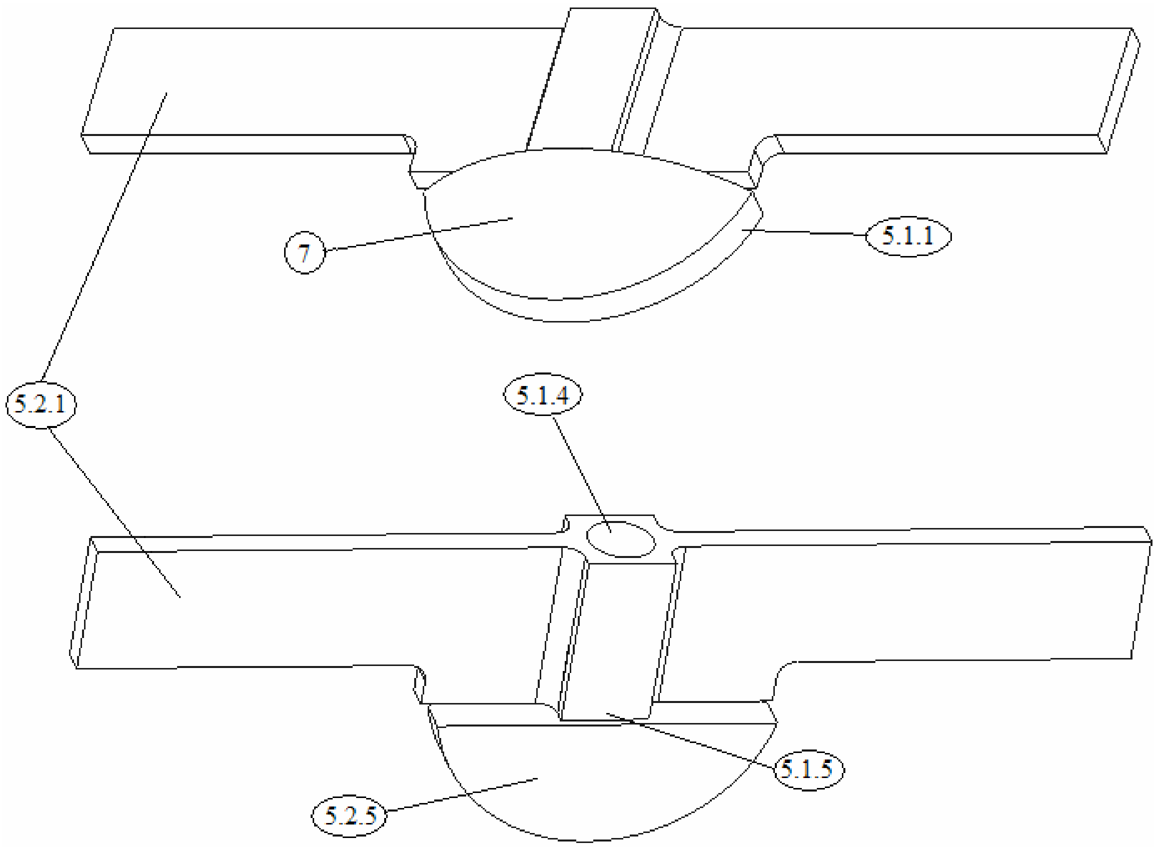
6	FR	Prevent Release From Lift Forces	DP	Flat Bottom of Force Peg

Release due to lift forces is prevented by the interface between the flat bottom of the force peg and the boot plate. Since there are no CAM surfaces, they merely press up against each other with no chance of release.

A.7 Boot Plate Reattachment

7	FR	Allow Simplistic Reattachment of Boot Plate	DP	Upper CAM surface of Force Peg

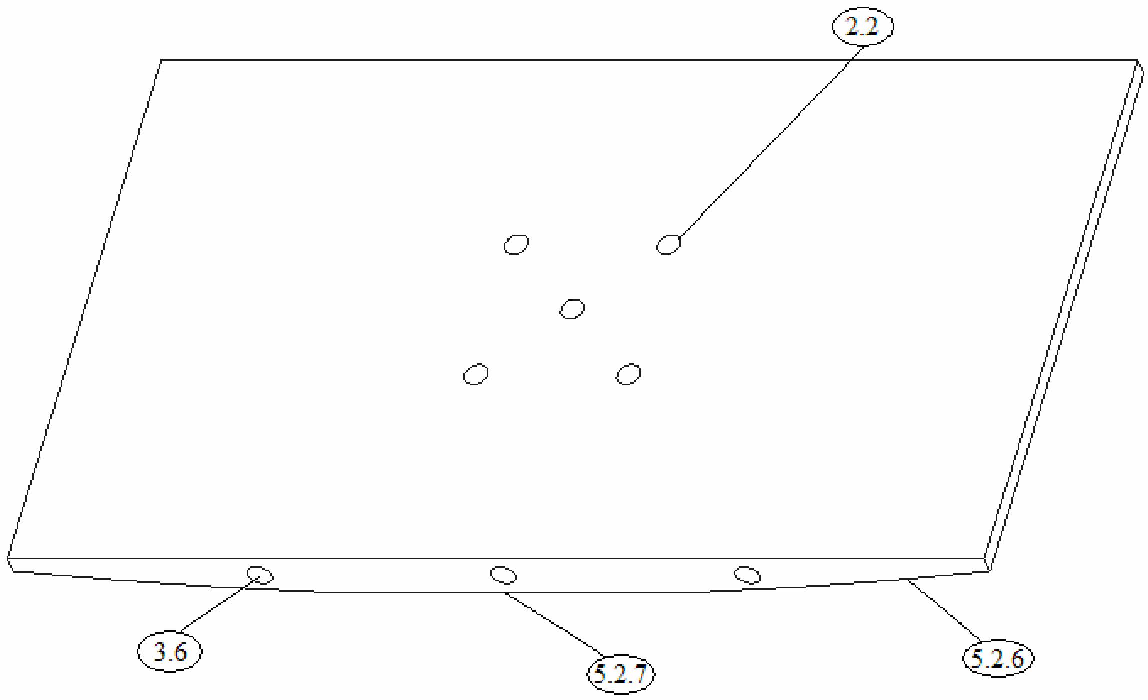
In the event of a release, it is necessary to allow the user to reattach the binding plate to the fastening plate with minimal effort in order to be feasible for use. To facilitate this, the upper portion of the force peg is a dome-like cam surface. This allows the user to step into the fastening plate. The surface below the recess on the boot plate slides along the cam surface, depressing the plate. The peg then pops back into place due to the force of the compression spring when aligned with the corresponding recession on the boot plate.



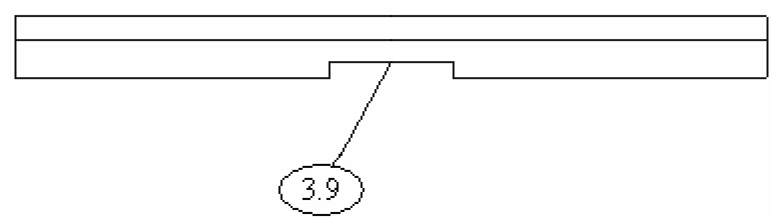
Force Peg

Description	Design Parameter
Side CAM Surface of Force Peg	5.1.1
Hollow Protrusion	5.1.4
Back of Hollow Protrusion	5.1.5
Locking Pegs	5.2.1
Flat Bottom of Force Peg	5.2.5

Force Peg Design Parameters



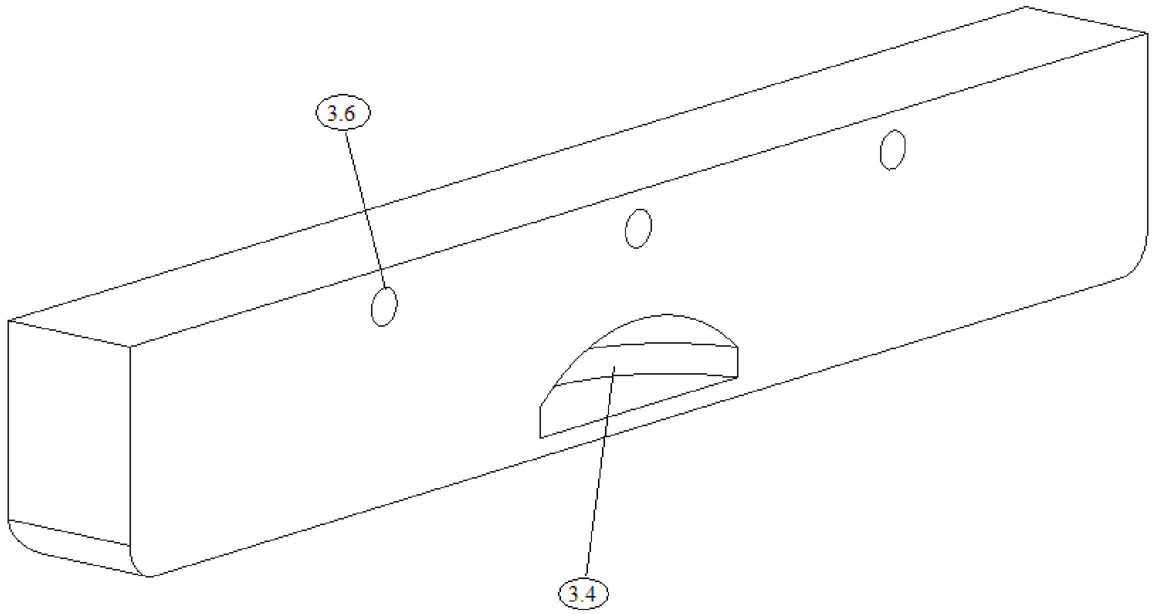
Boot Plate Top



Boot Plate Top Front View

Description	Design Parameter
Mounting Plate Screws (6mm)	2.2
Boot Plate Assembly Cap Screw (#1/4-20)	3.6
Guide Slot	3.9
Boot Plate CAM Surface	5.2.6
Boot Plate Flat Surface	5.2.7

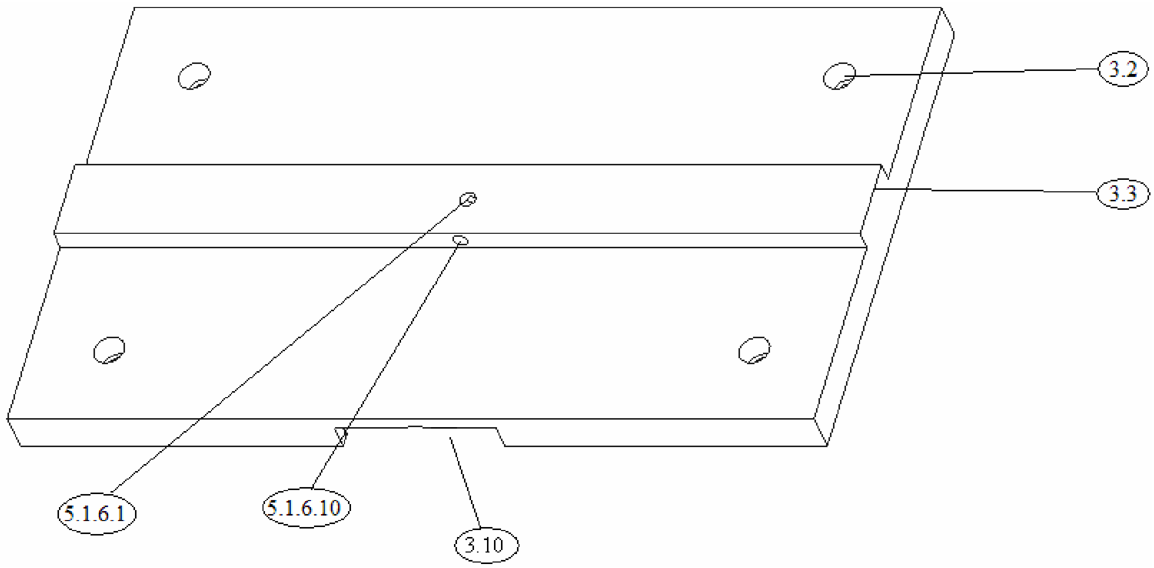
Boot Plate Top Design Parameters



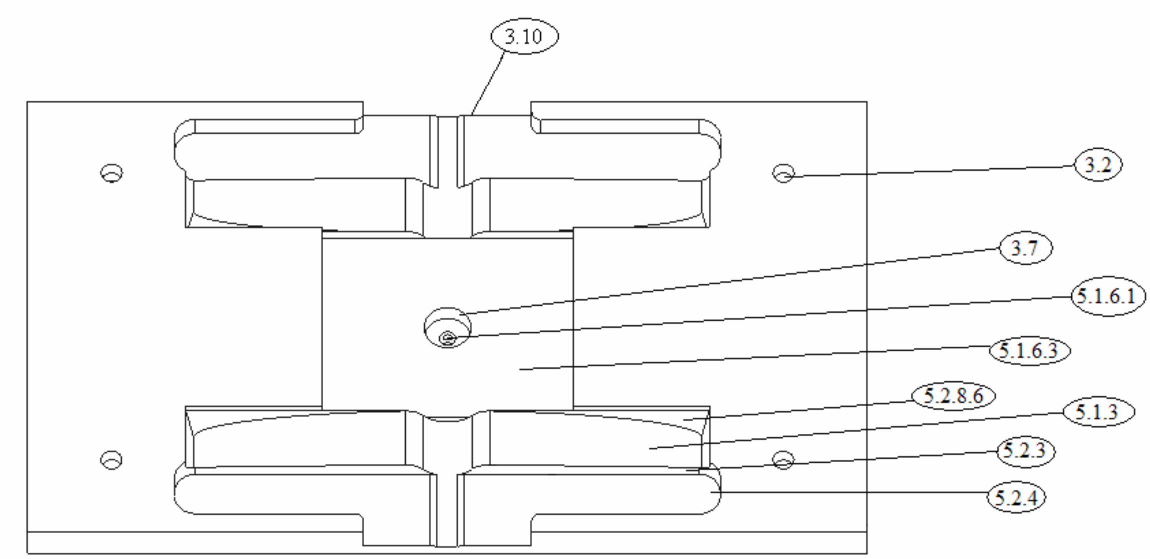
Boot Plate Side

Description	Design Parameter
Boot Plate Recess	3.4
Boot Plate Assembly Cap Screw (#1/4-20)	3.6

Boot Plate Side Design Parameters



Fastening Plate Top

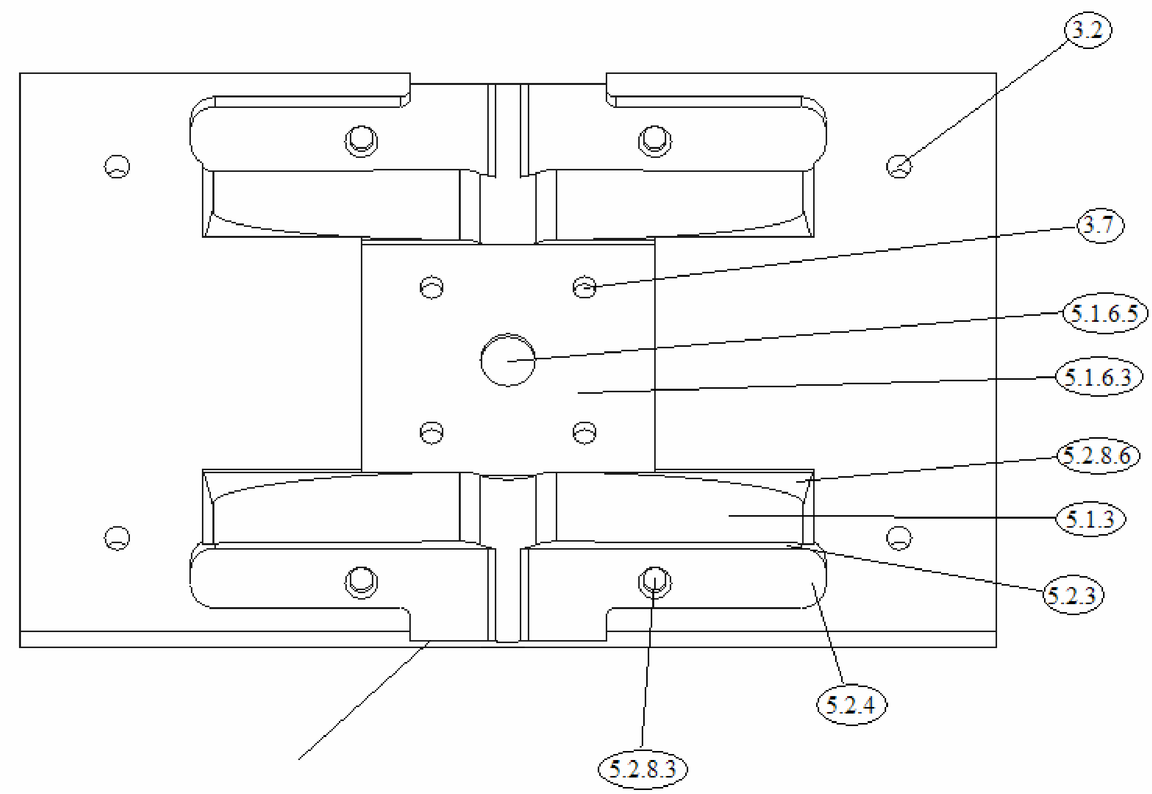


Fastening Plate Top Bottom View

Description	Design Parameter
#1/4-20 Cap Screw (FP)	3.2
Track Rail	3.3
Fastening Plate Mounting Screws (6mm)	3.7
Depression Groove	5.1.3
Preload Manual Adjustment Cap Screw (#6-32)	5.1.6.1
Gear Recess	5.1.6.3
Spur Gear Recess	5.1.6.5
Stopper Cap Screws (#4-40)	5.1.6.10
Side Wall of Moment Lock Recess	5.2.3

Correctional Groove	5.2.8.6
Peg Hole	3.10

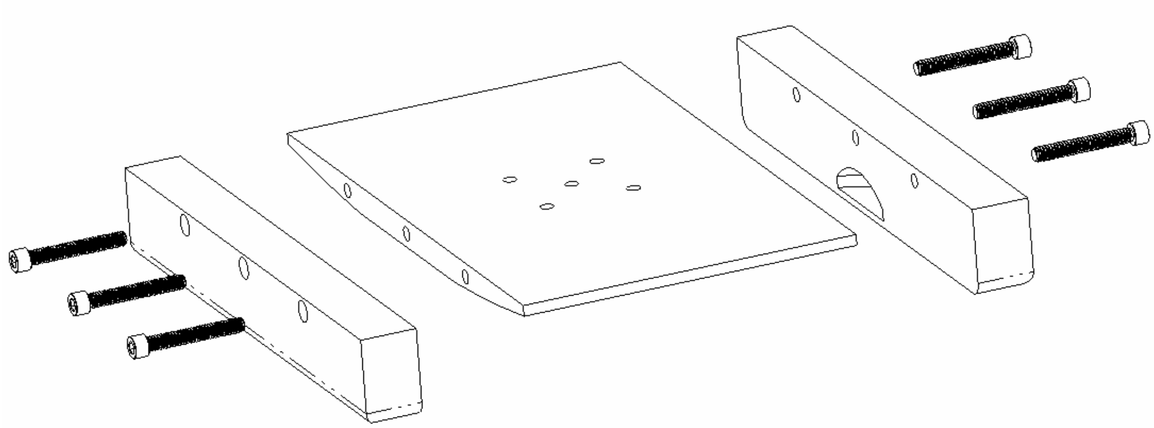
Fastening Plate Top Design Parameters



Fastening Plate Bottom

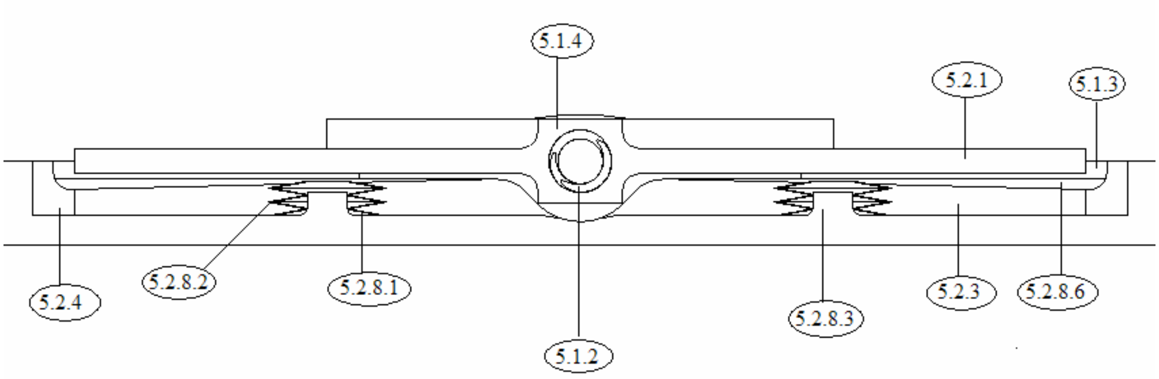
Description	Design Parameter
#1/4-20 Cap Screw (FP)	3.2
Fastening Plate Mounting Screws (6mm)	3.7
Depression Groove	5.1.3
Gear Recess	5.1.6.3
Spur Gear Recess	5.1.6.5
Side Wall of Moment Lock Recess	5.2.3
Cylindrical Protrusions	5.2.8.3
Correctional Groove	5.2.8.6

Fastening Plate Bottom Design Parameters



Boot Plate Exploded Assembly

Note: This view shows how the boot plate is assembled.



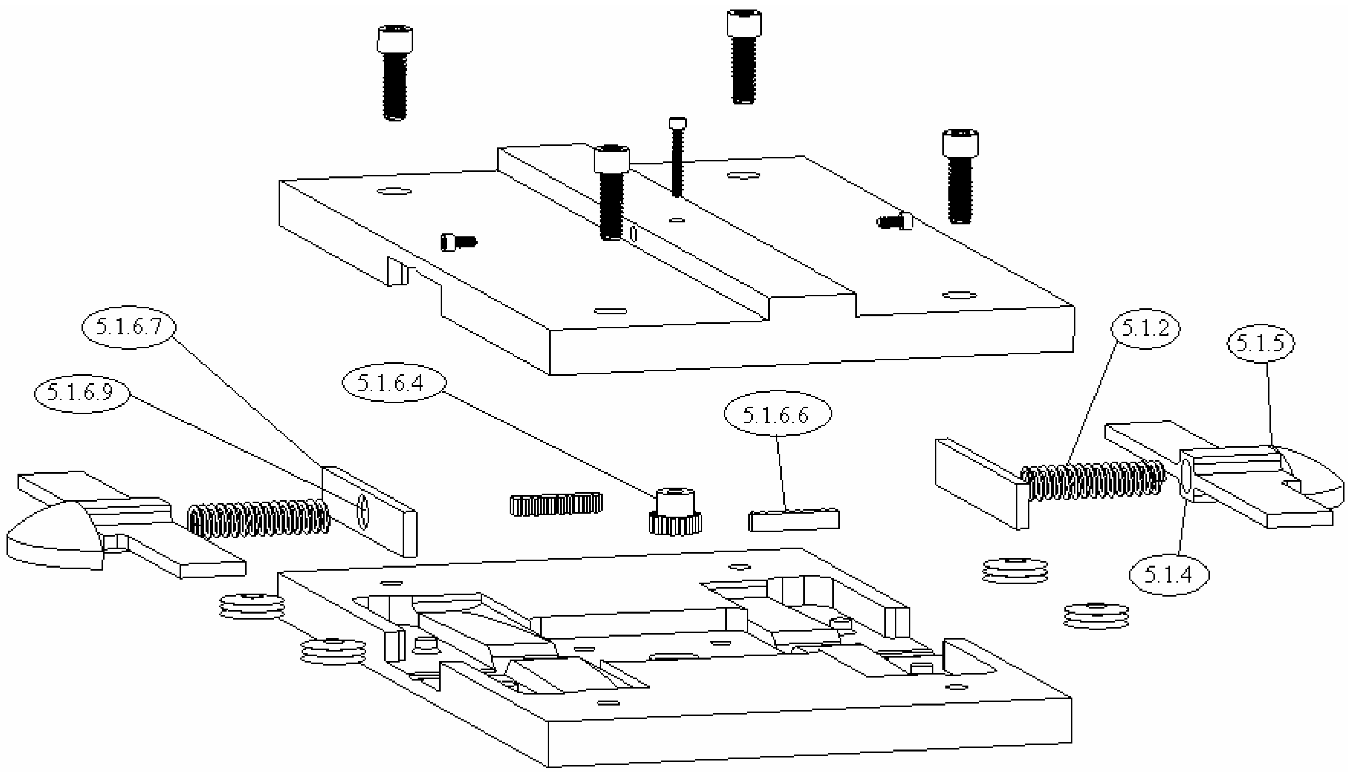
Moment Lock System

Description	Design Parameter
Compression Spring	5.1.2
Depression Groove	5.1.3
Hollow Protrusion	5.1.4
Locking Pegs	5.2.1
Wall of Moment Lock Recess	5.2.3
Recess Round	5.2.4
Disc Spring	5.2.8.1
Disc Springs Stacked in Serial	5.2.8.2
Cylindrical Protrusion	5.2.8.3
Correctional Groove	5.2.8.6

Table X: Moment Lock System Design Parameters

Note: This view is shown as a side view of the inside of the moment lock recess. The central figure is the force peg, only the front protruding CAM surfaces are not shown as they are in "front" of this view.

Also not shown (for a better view of the disc spring stack) are the 5.2.8.4 and 5.2.8.5 the sponge shell and epoxy, which support the disc spring stack.



Pre-Loading System in Fastening Assembly

Description	Design Parameter
Compression Spring	5.1.2
Hollow Protrusion	5.1.4
Back of Hollow Protrusion	5.1.5
Spur Gear	5.1.6.4
Gear Rack	5.1.6.6
Spring End Plate	5.1.6.7
Circular Indentation	5.1.6.9

Pre-Load System Design Parameters

Note: This view labels the Pre-Loading System and describes how it will fit together in the interior of the fastening plate. This view also shows how the fastening plate fits together and how the Moment Lock mechanism is positioned.

Appendix B – Patent Research

A patent search was necessary to find what current innovations exist that attempt to address the same problems as this project. To complete this patent search, www.uspto.gov was utilized, with TIFF file viewing software, to search for and examine patents. This website only has electronic files of patents backlogged to 1975. This is not a problem, as snowboarding as a sport has evolved fairly recently, with corresponding specialized safety bindings have come about even more recently, as our patent search could not locate any safety release bindings designed before the 1990's.

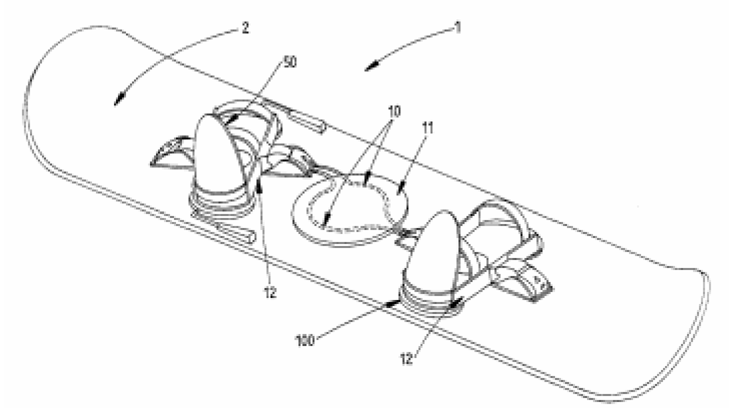
In the advanced search section of the website, the search was conducted by patent title by using Boolean operators as such:

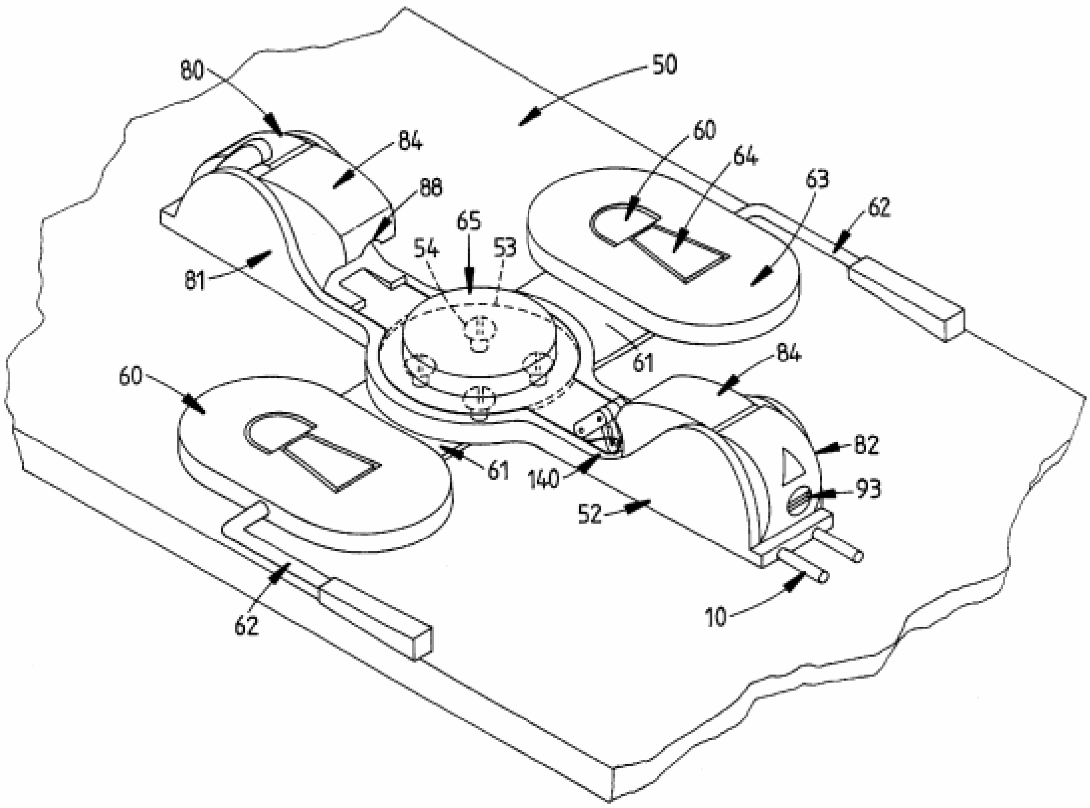
(snowboard AND binding AND (safe OR safety OR release OR releasable OR rotate OR rotation OR treewell OR avalanche OR torque OR force OR moment OR friction))

This was identified as an all-inclusive list of the types of mechanisms that we would like to research. The words "snowboard" and "binding" were regarded as basic necessities, along with one other word associated with our safety efforts. This resulted in 18 patents, several of which were closely related to our projects and some peripherally. The list of referenced patents for each of the relevant patents on the list was also investigated, which expanded our search and resulted in at least one of the patents analyzed.

Patent # 6,279,924 USA: Snowboard Safety Release Binding

This patent is characterized by release mechanisms located on each side of the boot (and "binding plate"), and not necessitating a built-in riser to house the mechanism. The binding has a step-in fastening mechanism (with a "binding plate" secured to the bottom of the boot) with several safety mechanisms built into the release apparatus to help prevent injury.



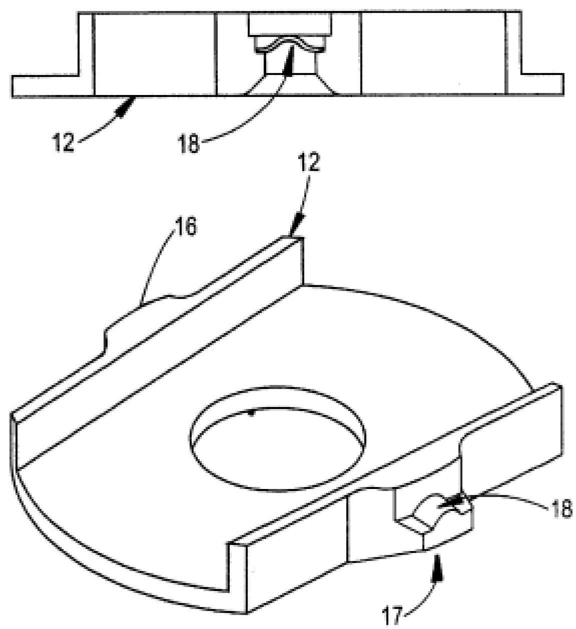


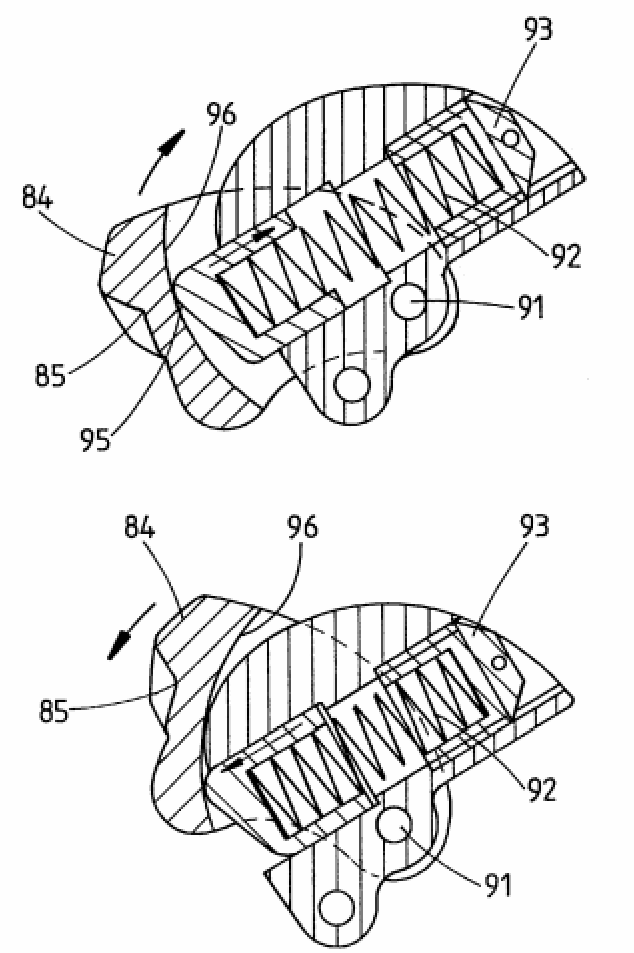
Release Mechanism

The first safety mechanism releases the binding under lift-out forces and torque about the shin-bone axis that are over preset thresholds. When the mechanism is stepped in and the binding plate is locked into the binding, protrusions with cam surfaces on the side of the binding plate fit into recessed cam mechanisms in the release block. The release block is biased into the lower position by a compression spring. The spring provides compression force between a fixed end (at the back of the mechanism) and a slide-able cam. The end of this slide-able cam is pressed against a curved internal surface of the release block (in contact with the binding plate). Lifting the release block results in compression of the spring, hence the bias towards the lowered position. The compression force provided can be adjusted by a screw on the end plate which can preload the spring. A significant amount of lift-out force on the binding plate would allow the release block to pivot upward against the spring force and allow the release of the binding plate.

In this design the binding also releases under a threshold force about the vertical axis. The torque release system uses the same compression spring force as the lift-out release system; the release force is delivered in an alternate fashion and direction. Due to the matched cam surfaces on the binding plate protrusions and the release block, as the torque applied reaches the threshold force the release block is forced upward, the binding plate protrusions slip out sideways from the release block's recesses, and the binding plate is released. As the same spring is used for this system, the amount of torque needed can also be adjusted by the pre-loading screw on the end plate of the spring.

The geometry of the cam surfaces on the binding plate protrusions and release block recesses affects the ratio of the threshold forces necessary for a lift-out and rotational release force. A shallower cam shape reduces rotational release forced compared to necessary lift-out forces, while steeper cam surfaces increase it.

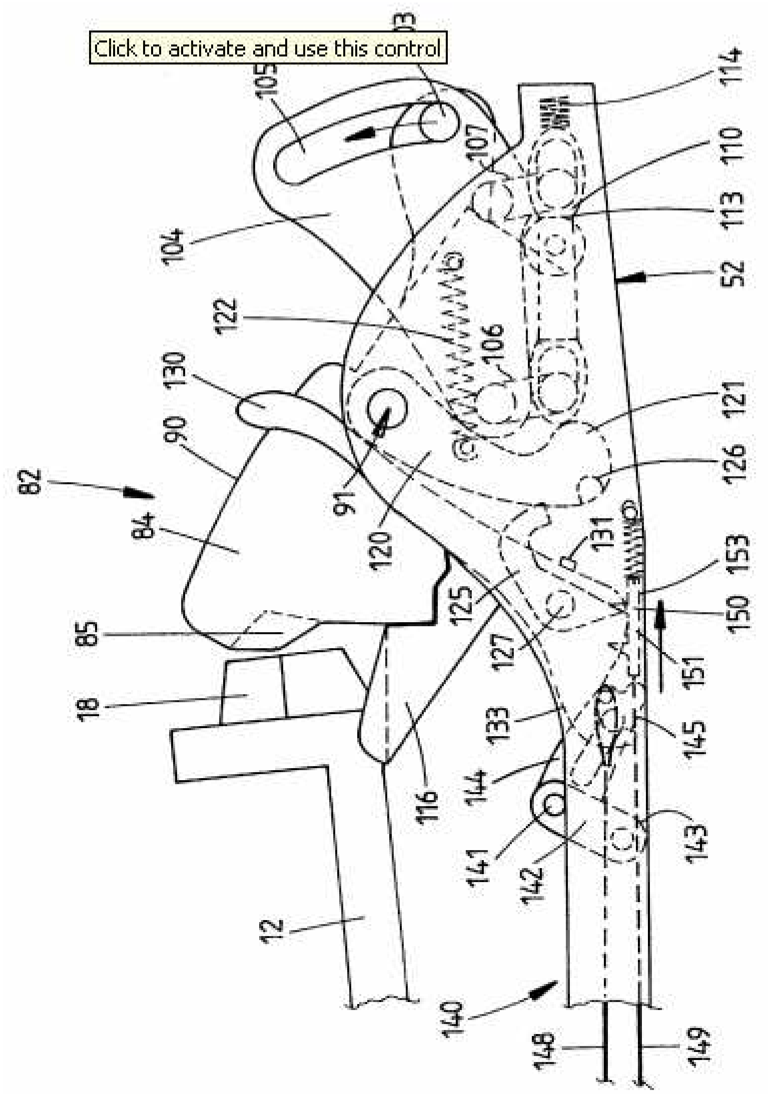


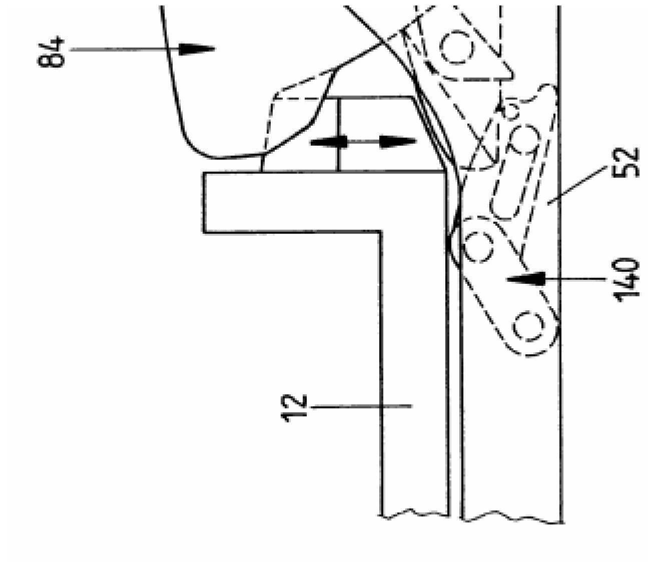


The design violates both axioms. The torque release and lift-out release mechanisms are coupled, as the both use the same compression spring and both are affected when the spring pre-load is adjusted. Adjustment of the ratio of the release forces by geometry of the cam surface is clumsy, as it will create unnecessary iterations for each user, and is currently non-adjustable. This would also cause the necessity of a high variety of cam surfaces to appease all individuals. An adjustable cam surface would be complicated, and provides more room for error with user adjustment, and thus violates axiom two.

Cable Coupling Dual Release

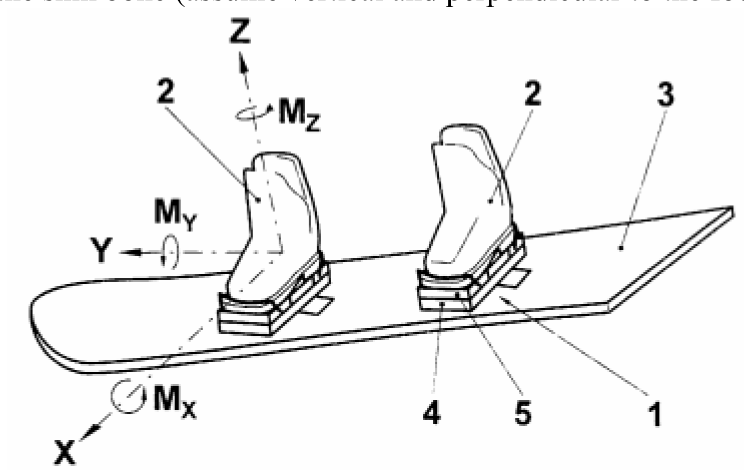
Release mechanisms for both bindings are connected with flexible cables, which may pass under the guiding plate and over the mounting plate (secured to the snowboard) to reach the release mechanisms on both sides of the binding. The cables are connected to the release mechanism by a “sensor plate”, which is constructed by a linkage, catch, and tension spring. The sensor mechanism is made of two bars hinged together, with one end fixed to the binding and the other end slide-able (the cable is connected to the slide-able end). The tension spring in the other binding acting on the cable pulls the slide-able end back and biases the sensor mechanism to this retracted position. When the binding plate is stepped into the binding, the sensor mechanism hinges is pushed down and extended, creating tension on the cable. There is a duel release mechanism (a catch) in line with the tension spring and connected to the release latch. IN the event of a forced release, the boot is no longer pushing down the sensor mechanism hinge and the slide-able end is pulled back by the tension force. Moving in this manner, the catch moves the release latch in a counter-clockwise manner and releases the binding.



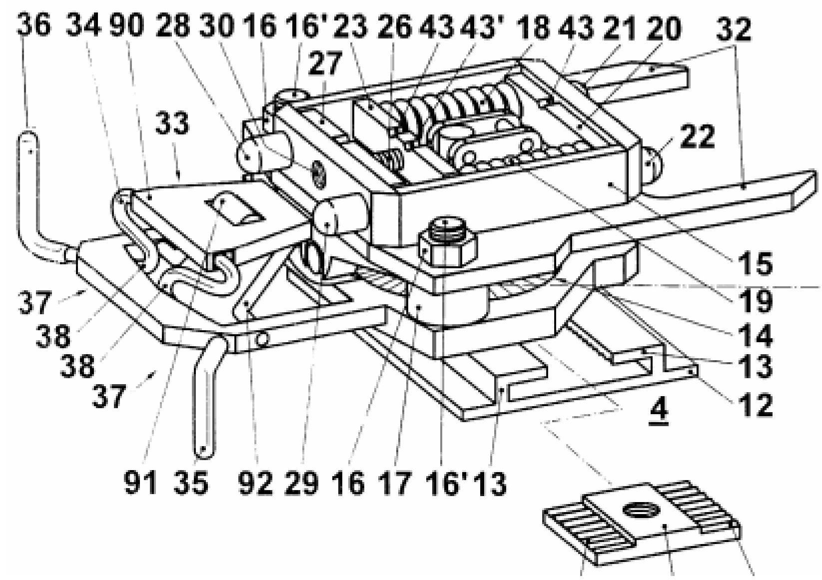


Patent # 6,428,032 USA: Safety Binding for a Snowboard

This particular design is located beneath the boot in two parts (a "boot plate" and "fastening plate"), which also acts as a riser as the mechanism elevates the boot off of the snowboard. The boot is secured to the boot plate by a pair of clamping stirrups. The safety binding is designed to release due to rotational forces about the longitudinal and lateral axis of the foot and about the shin bone (assume vertical and perpendicular to the foot axis).



The boot plate snaps into the fastening plate in a step-in mechanism. Two springs housed in the fastening plate put compression force on four rounded bolts (located axially on each end of each spring protruding from the frame that houses the springs). These rounded bolts snap into troughs in the corresponding surfaces on the heel and toe of the boot plate. The troughs (cylinders designed to fit the rounded bolts) are located in a radial groove on the surface of the boot plate opposite the bolts. This allows an amount of movement that can be adjusted via a screw set in the groove.



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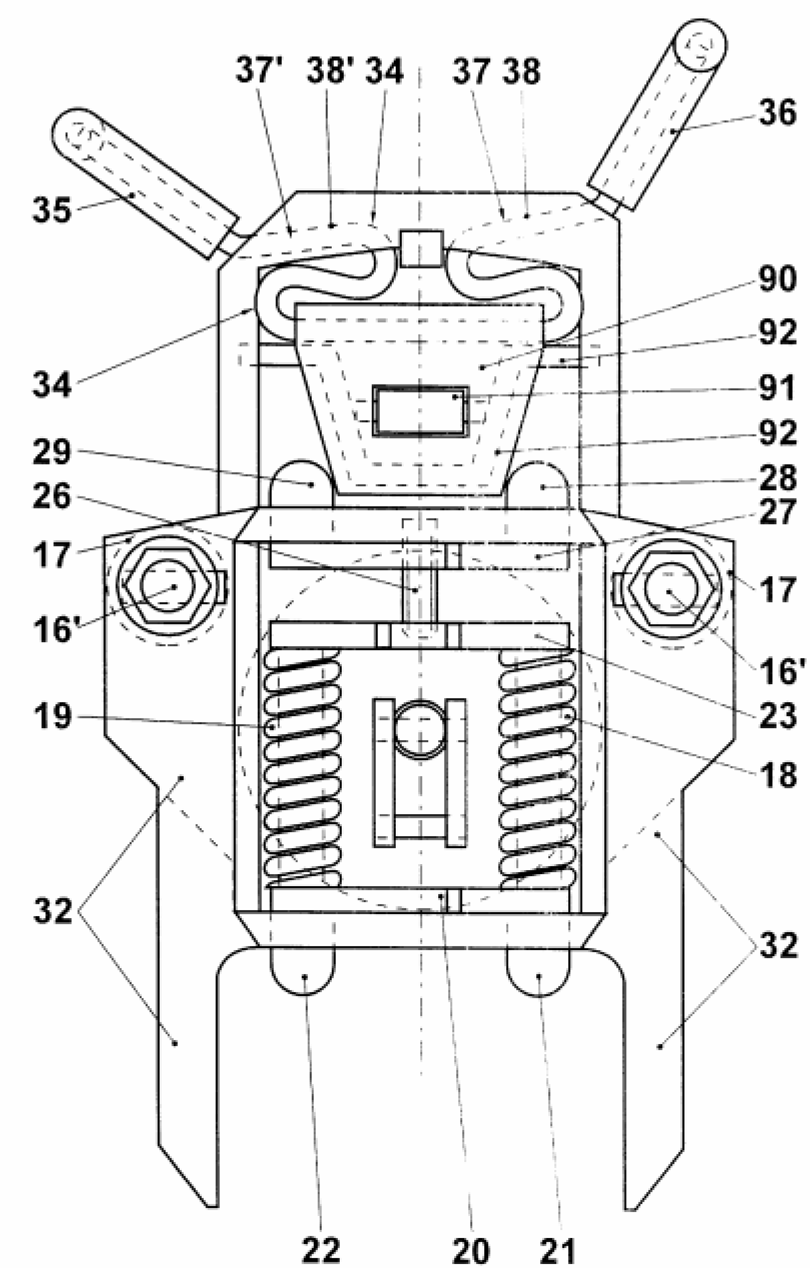

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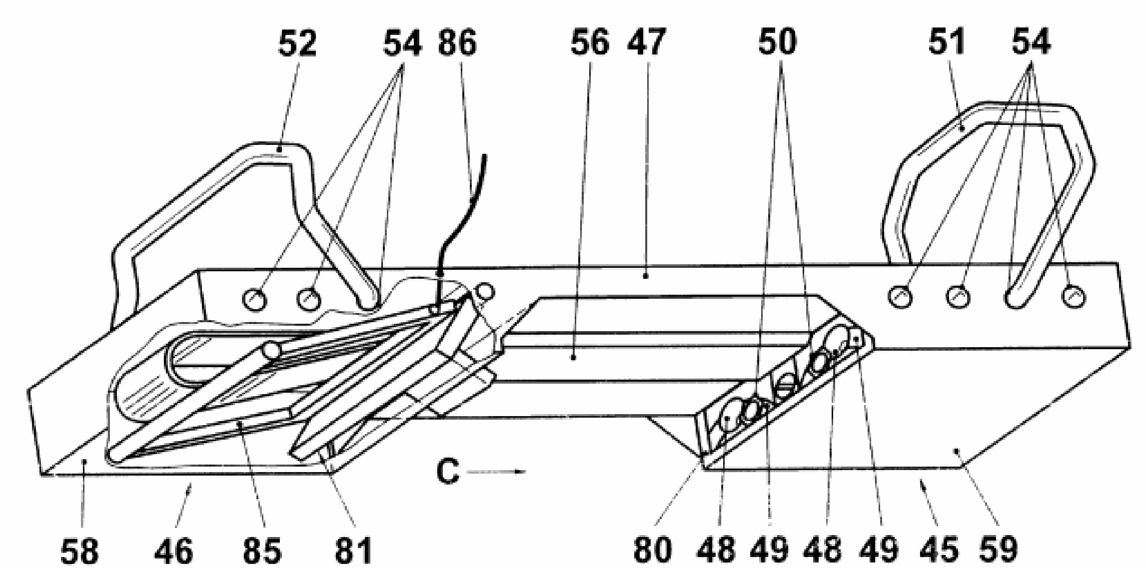


The torque required to allow the boot plate to spring free of the rounded bolts (which act as cam surfaces) can be adjusted. The necessary forces about the longitudinal and lateral parts of the foot are adjusted by preloading the springs priding the compression forces (which is done by a screw mechanism). The amount of torque about the vertical axis that would be necessary for release may be adjusted by the placement of the screw in the groove containing the trough, but would also still depend on the compression force on the rounded bolts as well.

All release forces are coupled, as they are all affected by the compression force set by the springs in the fastening plate. The rotational release about the vertical axis has two design parameters as it adjusted in two ways (by the setting screw in the trough groove and the compression spring preload), which violates axiom two as it provides a larger margin of error. In a sense this binding suffers a coupling closely resembling that of the previous patent, where the moments about the foot axis are also lift-out forces.

The security mechanisms are built under the foot and the design necessitates a riser as housing. In this manner the need for a riser and elevating the foot compared tot eh snowboard is coupled with the need safety mechanism.

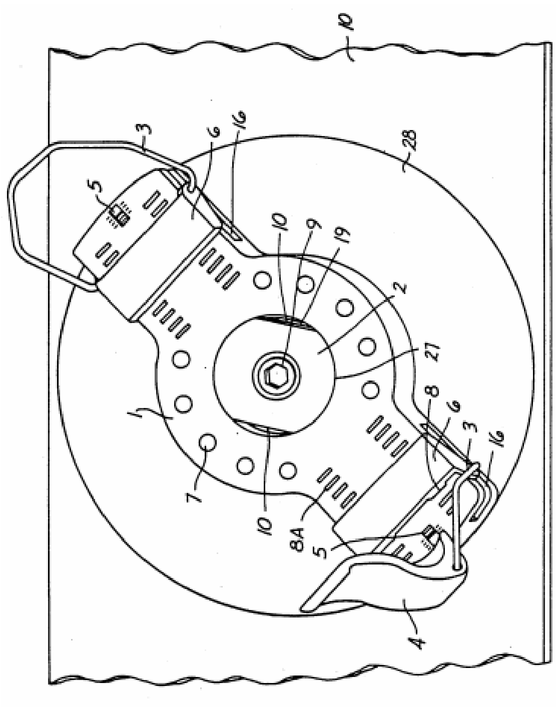
The stirrup clamps do not seem to exclude the possibility of the foot slipping out of the boot plate.

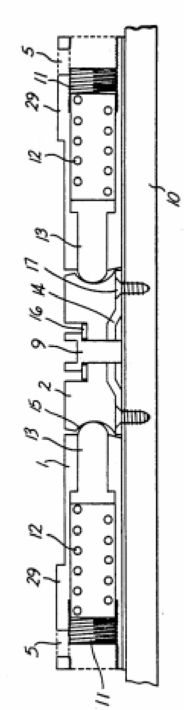
Patent # 5,044,654 USA: Plate Release Binding Winter Sports Device

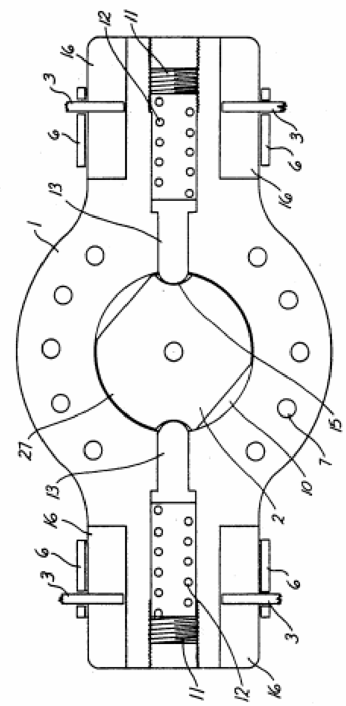
In this early incarnation of the release binding, the binding plate is locked into place by a step in and twisting motion. The plate itself is held by a central hub, which has recesses on each side along the longitudinal axis of the foot (when the binding plate is locked in). The binding plate has two compression springs built internally which provide compression force for two pistons (whose rounded ends act as cam surfaces) located on the longitudinal axis located on the surface that interacts with the hub (guiding hole). The hub itself has flat surfaces in the areas where the binding plate would be in a radially offset position. These flat surfaces have grooves to guide the pistons and prevent vertical movement. In this fashion the user, with the binding plate attached to the boot, can inset the binding plate onto the hub in a radially offset position, then apply torque on the binding plate by twisting until the pistons, guided by the grooves in the flat surfaces of the hub, click into the recesses, securing the boot. As the pistons are spring compressed and act as cam surfaces interacting with the curved recesses of the hub, an appropriate amount of lift-out, pivotal, or rotational force would cause the pistons to compress the spring and release the binding. The compression force provided by the springs can be screw-adjusted (preloaded).

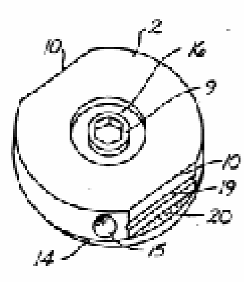
The ratio of the lateral pivot release force to the torsional release force can be adjusted by adjusting the width of the binding plate. Attaching widening elements is recommended to increase the pivotal release force compared to torsional.

The mechanism also has a safety break in case of release; however this is currently out of the scope of our project. The bindings are not coupled for dual release.









Patent # 6024375: Quick attachment/release binding

This patent is designed to allow the device outlined to be attached to any snowboard binding, and accept any snowboard boot. To lock the boot into the binding, the boot is inserted, and then strapped into place. On initial insertion of the boot, tension straps which hold the boot to the binding must be adjusted to the user's foot size. However, after initial insertion, the binding will not require any additional adjustments.

The safety release mechanism designed into the binding is easy to explain. While the boot is held in place by the binding straps, quick disengagement is required for this design, and must be able to be achieved through a single stroke movement, even with the user wearing thick gloves or mittens. To do this, the design incorporates a front and rear clip, placed on the lower, outer part of the binding. A spanning bar is engaged with the currently used binding straps, and is pulled taut by a closing lever. To secure the boot, the closing lever slides into the front clip, and snaps into the rear clip. This allows the lever to be firmly secures, which also secures the boot within the binding.

Fig. 4.

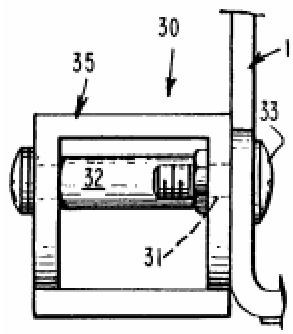
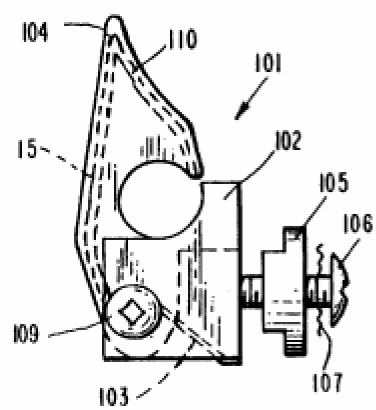
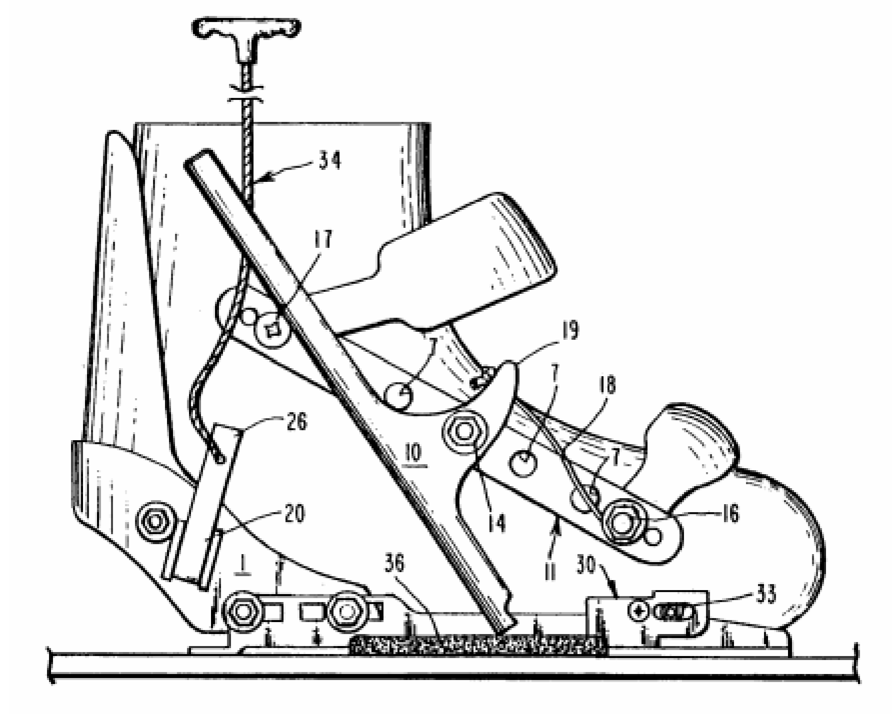


Fig. 7.



To release the lever, the user presses on the upper portion of the rear clip, freeing the lever and disengaging the binding. When latched and unlocked, the rear clip is designed for a quick release of the closing lever, which in turn allows the lever to pop out of the front clip as well. A cable connected to the rear clip can also be designed, which runs up the user's leg, and allows for quick release of the closing lever when the user pulls on the cable.



There are several positive and negative attributes with this design. The ability to adapt to any boot or binding, and the capability to be attached to a quick release tether are both great advantages. However, one big disadvantage is that the design incorporates a lot of external, small parts, and they would run the risk of getting choked with ice and snow, which could cause the contraption to fail. Also, this design was originally meant for quick, non-moving releases, and not for accident prevention when riding down ski slopes. Furthermore, if a quick release was attempted while in motion, the user's boot still runs the risk of getting caught in the binding, which could lead to even more serious injuries.

Patent # 5145202: Snowboard Release Binding

The design for this patent incorporates a quick release mechanism which separates the user from the snowboard in the event of harmful external forces being applied on the legs or feet. The boot is connected to a boot holding plate by being secured at both the toe and heel. When any force on the lower extremities becomes too great, however, both the boot and holding plate are released, allowing the user to escape injury.

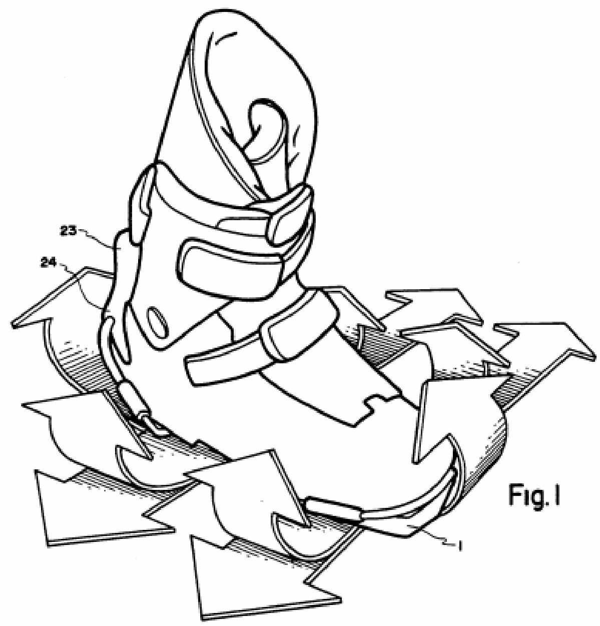
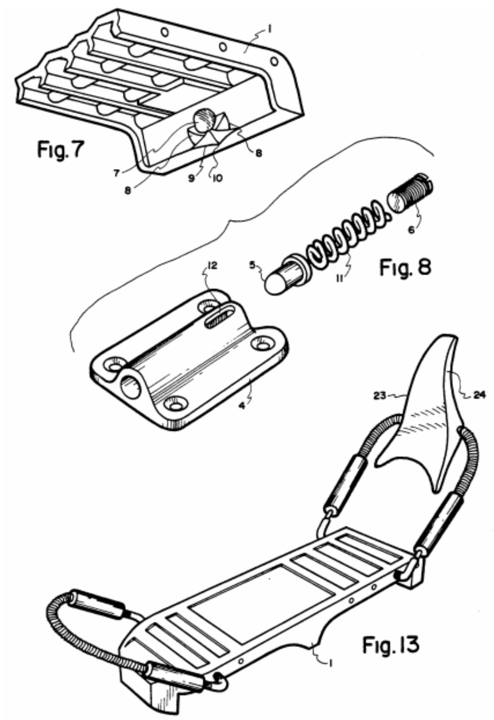
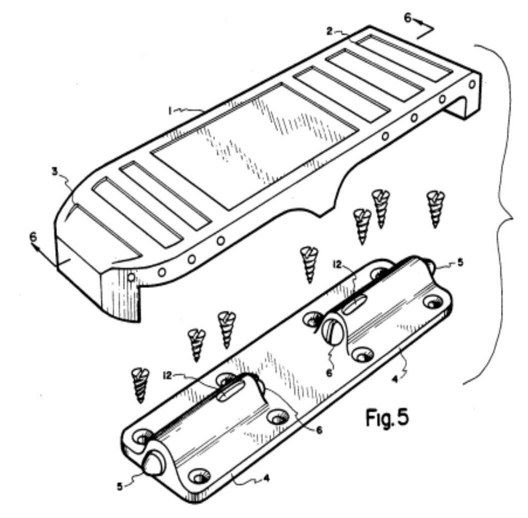


Fig. 1

Unlike most release designs, this one has a great many fewer parts than others, which also allows an easier understanding of how the safety mechanism works. When connected to the release unit attached to the board, the holding plate is designed with indents underneath both the toe and heel which engage spring loaded pegs located in the release unit. When the boot plate is placed over the release unit, the pegs depress, and then pop out into the boot plate indents, securing the plate to the release unit. If the boot plate is twisted, turned or lifted with enough force, it will cause the peg to depress again, allowing the plate to release. The pegs are allowed to depress due to wall extensions located around the peg indents in the boot plates. Also, the release units of each foot are connected both to each other and a ski brake, so when one foot is released, it will immediately release the other foot, as well as spring the brake to prevent further travel of the snowboard.





The pro to utilizing this design is that it can help with quick releases while moving, which will help to prevent injuries to the user's legs. Also, the addition of a ski brake is useful, in order to stop the snowboard from moving once the user is disengaged. However, the issue with this patent is that there are no indications of research as to what specific amounts of force would constitute a release of this binding. Have release forces been accurately measured? Does this design guarantee to prevent accidental release? For these reasons, this design should not be implemented until there is more specific research on the forces incurred while snowboarding.

Patent # 5820155: Step-in binding system for retro-fitting to a snowboard boot binder

This design is unique in that it can be utilized for two binding types: a "snowclaw" adaptor plate, and a solid member binding. The boot connects to the board through a step in binding, and is locked in place at both the heel and toe. To release, the binding is designed with a manual quick release mechanism that allows the user to disconnect the upper part of the binding from the rest of the board.

To engage the safety mechanism, a cable which runs up the user's side is connected to the bottom part of the releasable binding. When the cable is pulled, it moves a lever arm located under the boot, which in turn causes a latch pin to be pulled forward. As the latch pin is moved forward, it pulls a striker part out from beneath the binding's latch plate, which is what connects the two parts of the binding. Once the latch plate is disengaged, the part of the binding directly connected to the boot is released, which allows the users to separate from the snowboard. Additionally, by connecting the latch plate with a battery, solenoid, and RF receiver, the user can separate themselves from the binding through the use of an RF transmitter attached to their wrist, in an electro-mechanical approach.

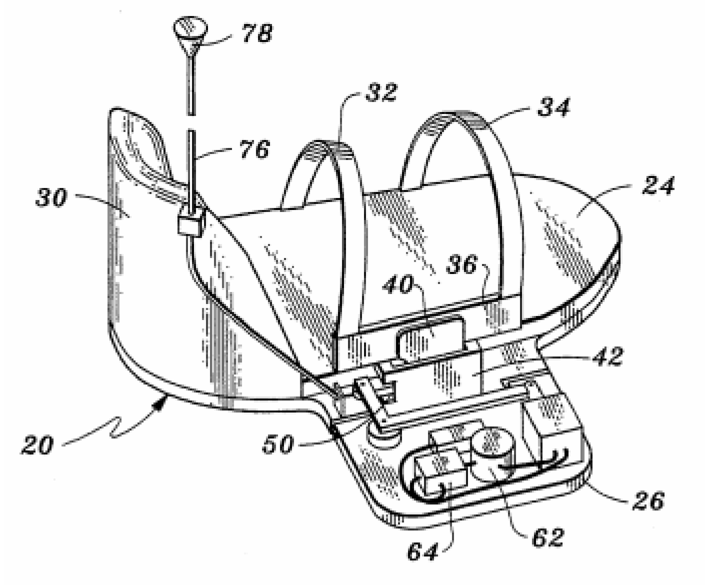


Fig. 3

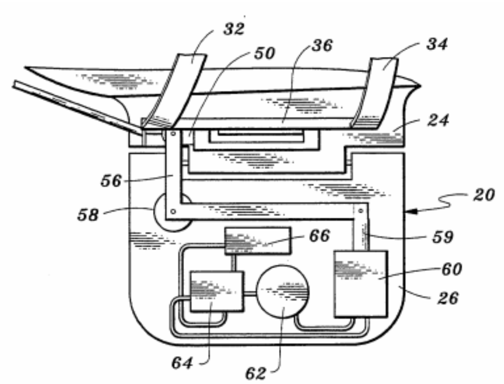


Fig. 4

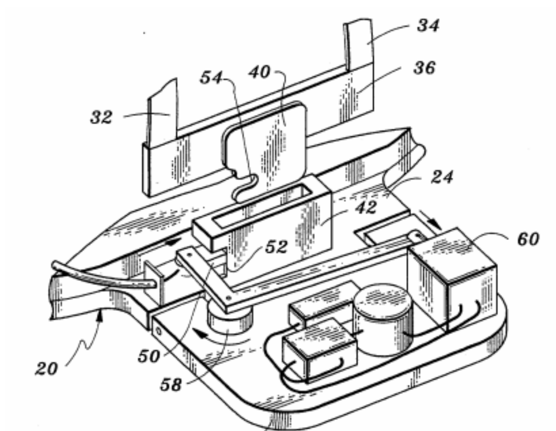


Fig. 5

One advantage to this design is that the binding can incorporate either hard or soft snowboarding boots, making it accessible to everyone. Also, the quick release mechanism can help to greatly reduce the danger of certain snowboarding situations, such as falling and getting stuck in tree wells. However, the main concern with this design is the chance that the quick release tether can be pulled or the transmitter release can be pushed accidentally. Also, if the user mostly depends on the transmitter to release themselves from the binding, the design suggests that it won't be too easy to replace the battery or solenoid if they expire. And again, this type of binding was designed for non moving quick releases, and may not be effective at helping to prevent injuries sustained while in motion.

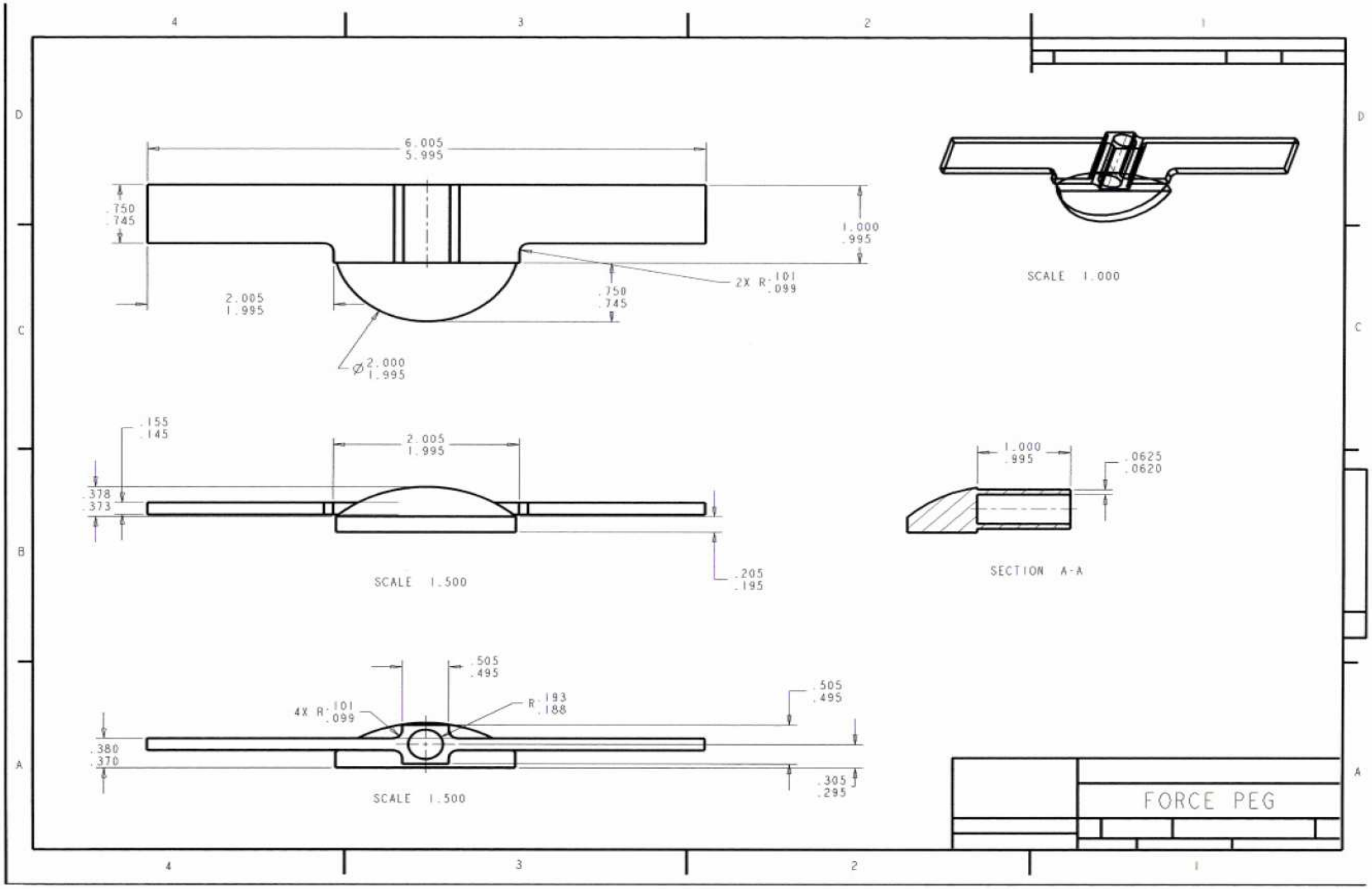
Patent # 5362087: Snowboard binding release apparatus

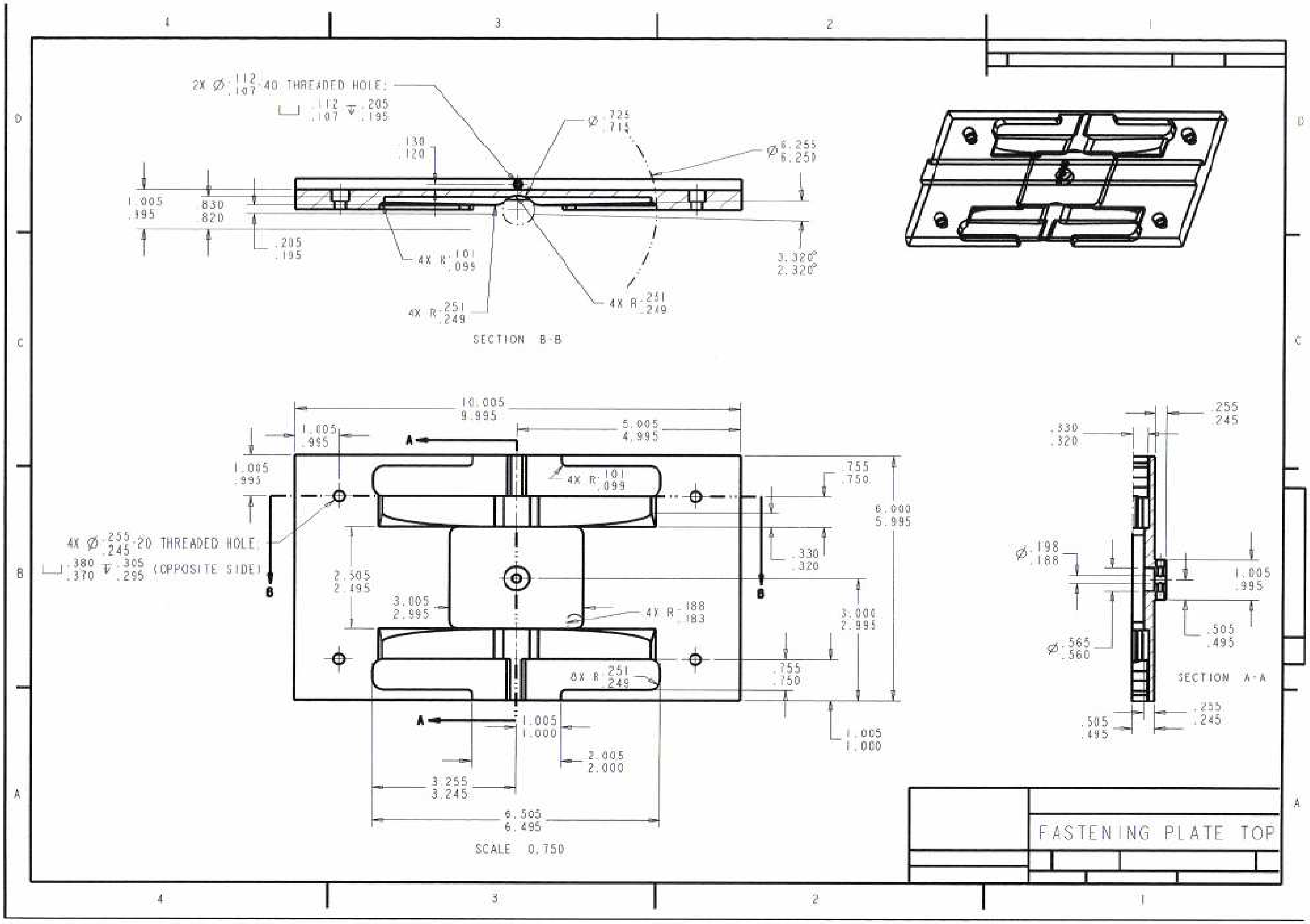
Like the previously explained patent, this design also incorporates the release of a binding through either a manual or electro-mechanical quick release mechanism. However, this design locks the user's boot into a stiff backed binding, and holds the foot in place with a series of straps, as opposed to locking the boot in at the toe and heel. And while the concept may on releasing the boot may be the same, this design sports a much more simple approach on how to configure it.

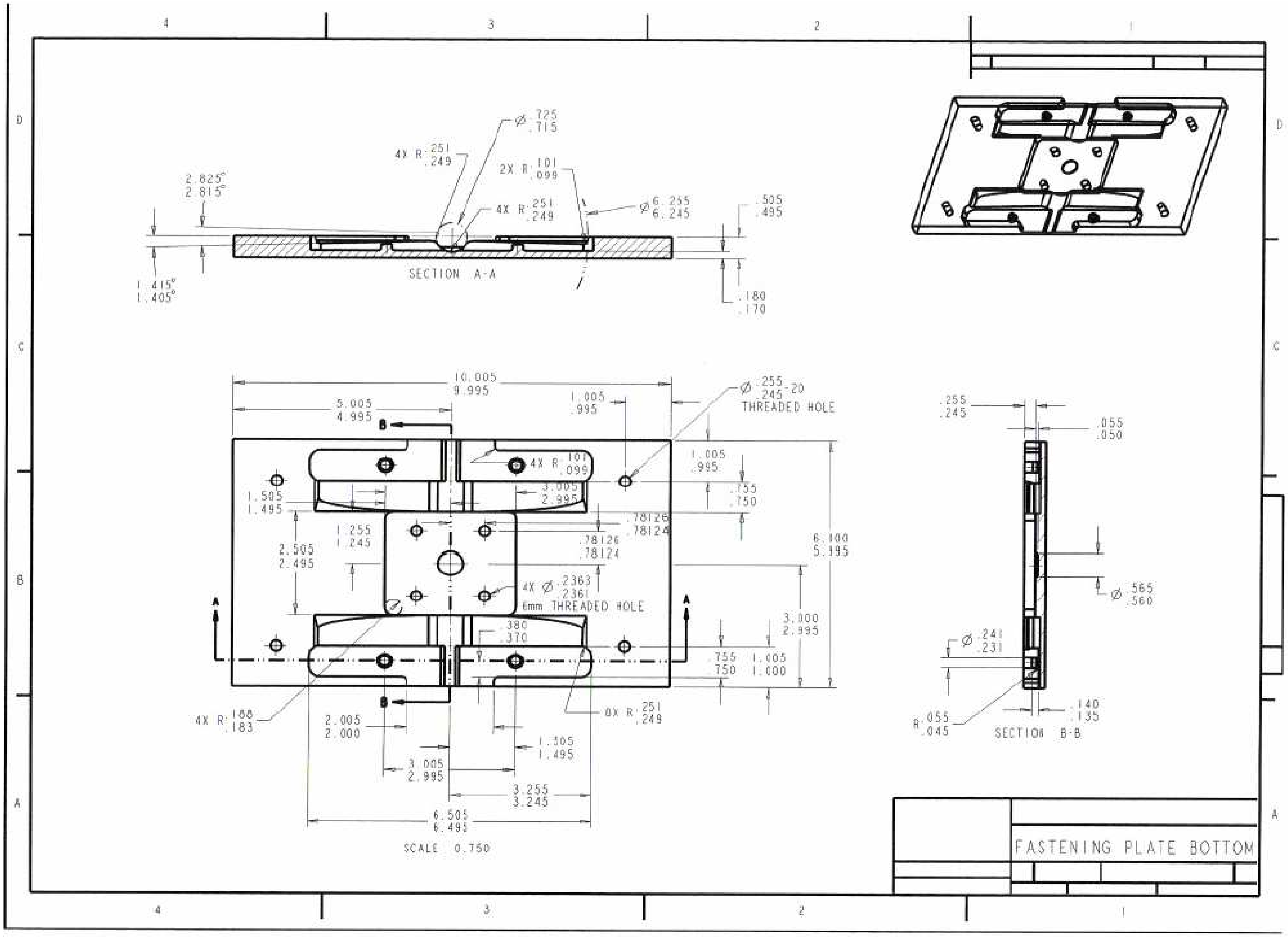
As mentioned earlier, the user's boot can be released by either a tether cable attached to the binding, or through the electro-mechanical use of an RF transmitter. In order to release the binding manually, the user pulls on a tether cable, which in turn pulls a locking member from a recess located in the binding. This in turn releases the latch connected to the binding straps securing the boot in place. Once released, the boot is allowed to be freed from the binding. And, similar to the previously mentioned patent, the inclusion of a solenoid, battery, and RF receiver allows a secondary release of the binding through the use of the RF transmitter.

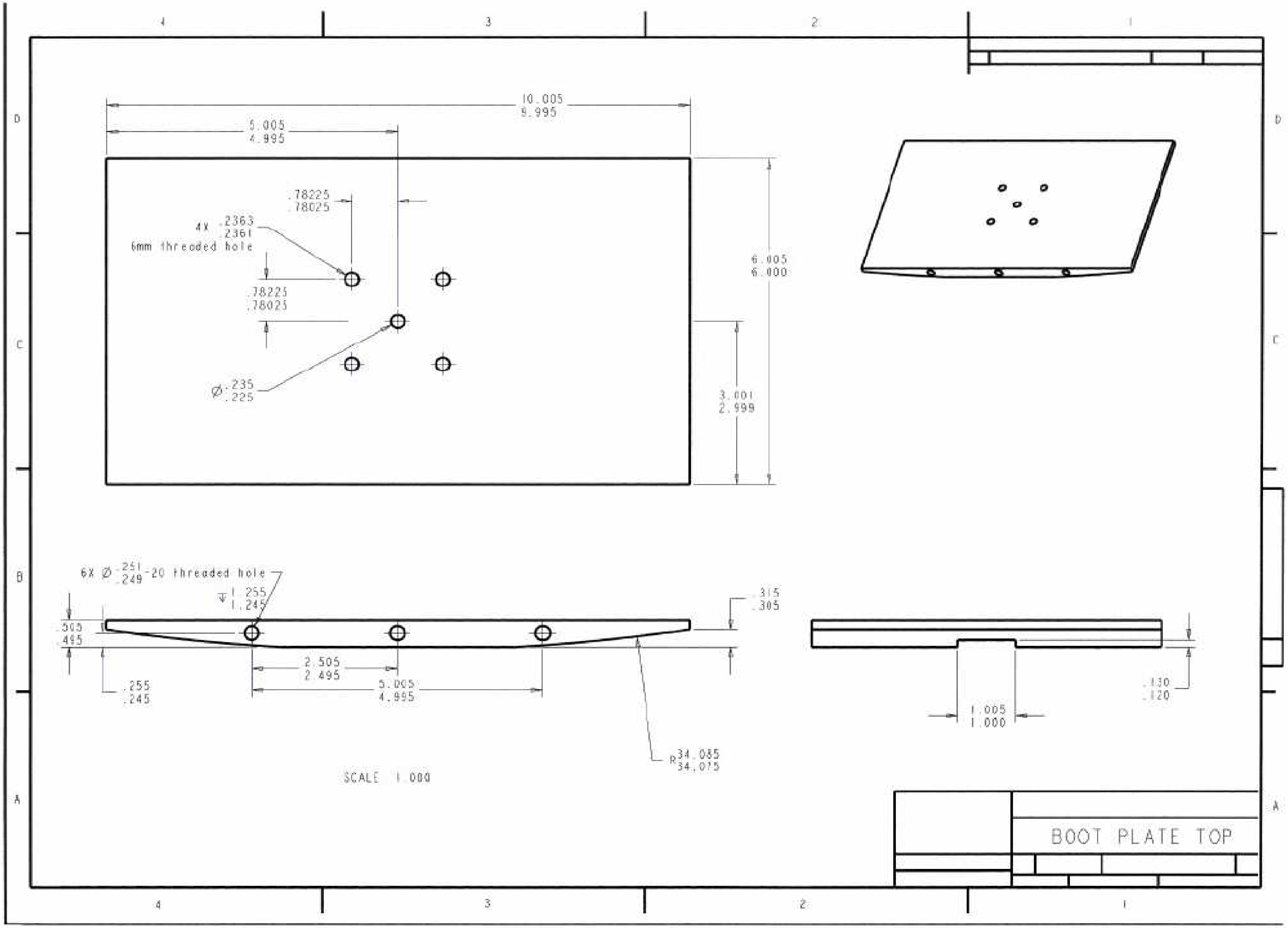
There are a couple of advantages that this patent design has over the previous one. As well as being just as useful in the same situations, this design is not only simpler, and would therefore only require quick and easy repair when needed, but also is arranged in such a way that the battery and solenoid are much more accessible, and therefore easier to replace. However, this design also shares some disadvantages with its predecessor. The issue of accidental release can also be a problem with this design, both through the release tether and RF transmitter. Also, this is yet another design created for a non-moving release, and though release while moving may be attempted in extreme situations, the placement of the binding straps might cause more injuries to the user than it would prevent, as it could possibly trip them as they went to step out of the binding.

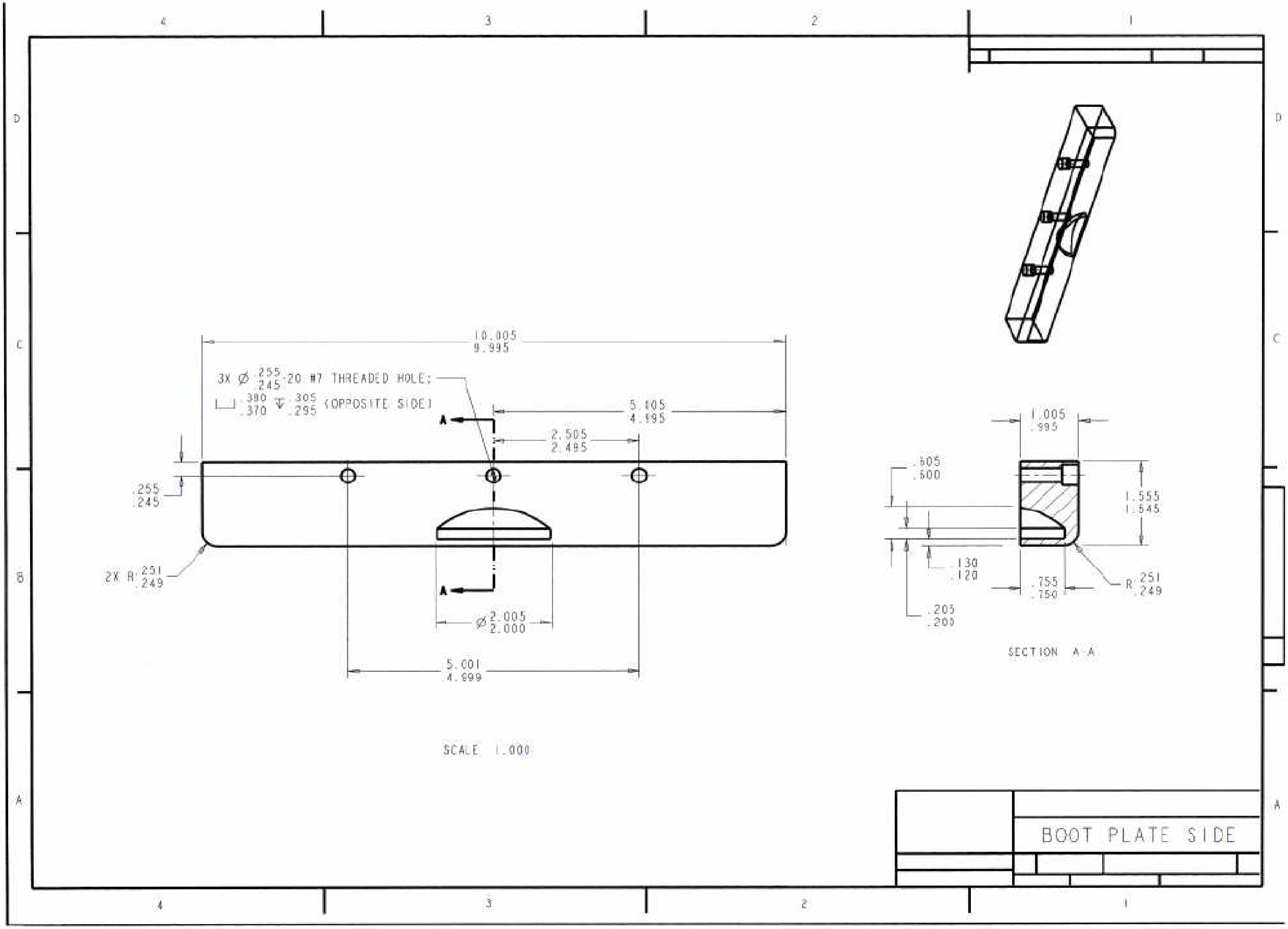
Appendix C – CAD Drawings

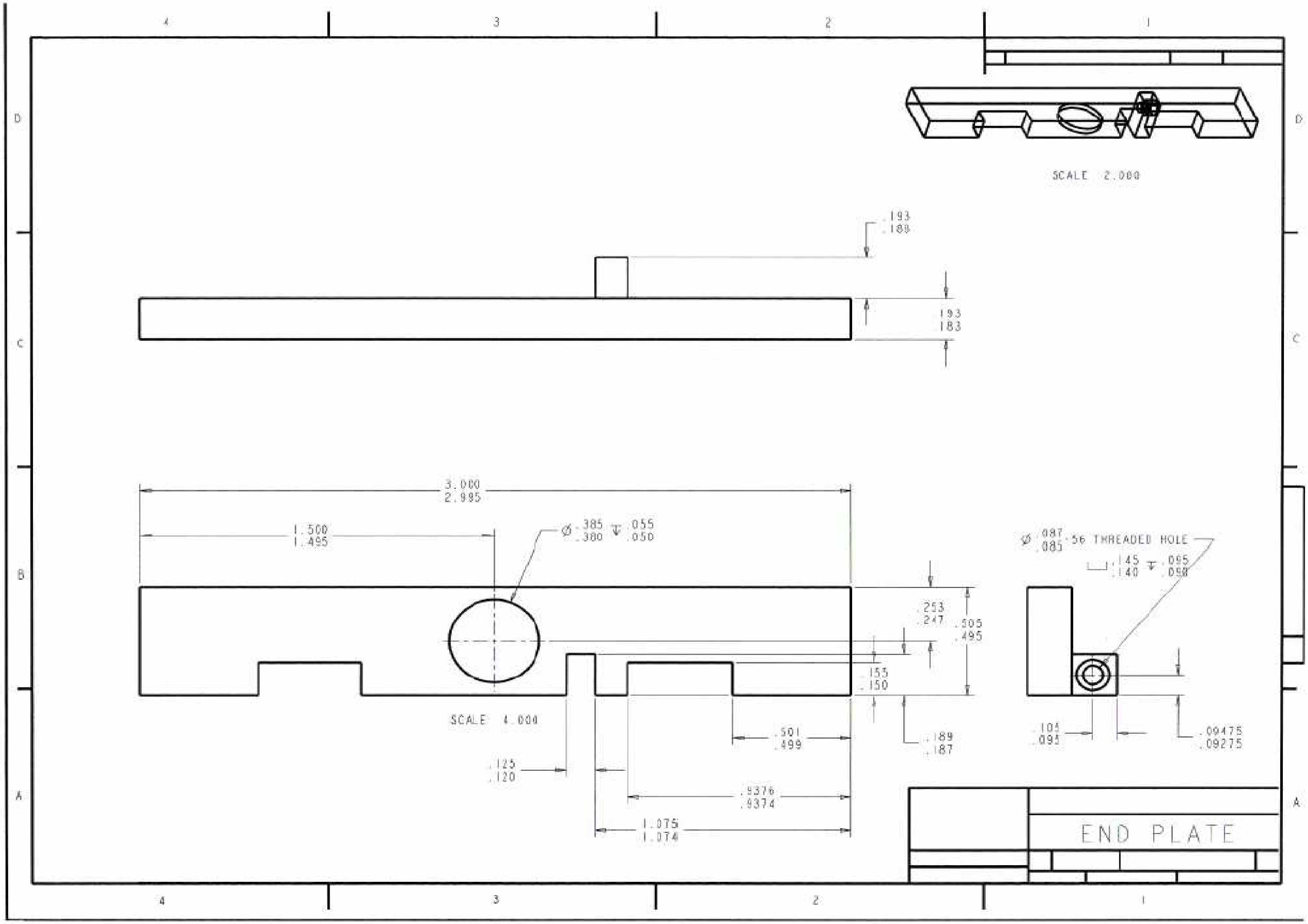



2X Ø .112/.107 -40 THREADED HOLE;
.112/.107 ↧ .205/.195
Ø .725/.715
Ø 6.255/6.250
.130/.120
1.005/.995
.830/.820
.205/.195
4X R .101/.099
4X R .251/.249
4X R .251/.249
3.320°/2.320°
SECTION B-B
10.005/9.995
5.005/4.995
1.005/.995
1.005/.995
4X R .101/.099
.755/.750
6.000/5.995
4X Ø .255/.245 -20 THREADED HOLE;
.380/.370 ↧ .305/.295 (OPPOSITE SIDE)
2.505/2.495
3.005/2.995
.330/.320
4X R .188/.183
3.000/2.995
8X R .251/.249
.755/.750
1.005/1.000
1.005/1.000
2.005/2.000
3.255/3.245
6.505/6.495
SCALE 0.750
.255/.245
.330/.320
Ø .198/.188
1.005/.995
.505/.495
Ø .565/.560
SECTION A-A
.505/.495
.255/.245
FASTENING PLATE TOP


SECTION A-A
SECTION B-B
SCALE 0.750
Ø .255 .245 -20 THREADED HOLE
4X Ø .2363 .2361 6mm THREADED HOLE
FASTENING PLATE BOTTOM


10.005
9.995
5.005
4.995
.78225
.78025
4X .2363
.2361
6mm threaded hole
.78225
.78025
Ø.235
.225
6.005
6.000
3.001
2.999
6X Ø .251/.249 -20 threaded hole
↧ 1.255
1.245
.505
.495
.255
.245
2.505
2.495
5.005
4.995
.315
.305
R34.085
34.075
.130
.120
1.005
1.000
SCALE 1.000
BOOT PLATE TOP


10.005
9.995
3X Ø .255 .245 -20 #7 THREADED HOLE;
⌴ .380 .370 ↧ .305 .295 (OPPOSITE SIDE)
5.005
4.995
2.505
2.495
.255
.245
2X R .251 .249
Ø 2.005 2.000
5.001
4.999
1.005
.995
.605
.600
1.555
1.545
.130
.120
.755
.750
R .251 .249
.205
.200
SECTION A-A
SCALE 1.000
BOOT PLATE SIDE



SCALE 2.000
.193
.188
.193
.183
3.000
2.995
1.500
1.495
Ø .385 .380 ⊽ .055 .050
Ø .087 .085 .56 THREADED HOLE
⌴ .145 .140 ⊽ .095 .090
.253
.247
.505
.495
.155
.150
SCALE 4.000
.501
.499
.189
.187
.105
.095
.09475
.09275
.125
.120
.9376
.9374
1.075
1.074
END PLATE

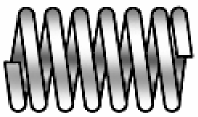
Appendix D – Images of “Flyswatter effect”

Appendix E – Detailed Data from Colorado Snowboard Injury Survey

Ref	Time	Ski/ SB	Wrist %	Knee %	LLeg %	Ankle %	# Inj	Source	Location
1	85/86	SB	16.9	15.8	7.0	36.9	59	Ski Patrol	VT, NH, CO
		Ski	2.2	27.2	12.6	11.5	16877		
2	86/87	SB	14.0	13.0	10.0	29.0	110	Self Report	OR/USA
3	88/90	SB	10.0	14.0	1.0	28.0	132	Clinic	Alberta Canada
		Ski	1.0	27.0	7.0	5.0	Unknown	Unknown	ME/USA
4	89/90	SB	24.8	14.6	3.3	19.1	424	Clinic	CA/USA
5	89-92	SB	16.0	23.0	6.0	23.0	276	Clinic	Australia
		Ski	4.0	44.0	11.0	6.0	423		
6	88/90	SB	20.2	16.9	4.3	22.4	1194	Ski Patrol	US wide
		Ski	2.8	32.7	7.7	6.1	21817		
7	88/91	SB	19.7	9.1	4.4	17.3	937	Clinic	CO/USA
12	88/95	SB	21.0	15.5	5.0	15.0	3696	Ski Patrol	CA/USA
		Ski	2.0	37.0	5.0	7.0	15323		
13	90/95	SB	13.0	13.0	5.0	8.0	40	Clinic	VT/USA
		SKI	2.0	45.0	14.0	1.0	238		
16	88/96	SB	20.0	15.0	1.4	12.0	4390	Clinic	CO/USA
18	96/98	SB	29.0	6.0	2.0	4.0	1224	Ski Patrol	Norway
		Ski	4.0	26.0	10.0	4.0	2049		
22	98/00	SB	27.0	6.0	2.0	5.0	2313	Ski Patrol	Norway
		Ski	4.0	28.0	10.0	4.0	2942		
23	00/02	SB	26.0	6.0	3.0	6.0	2762	Ski Patrol	Norway
		Ski	4.0	28.0	10.0	5.0	3008		
24	88/05	SB	32.1	5.9	0.9	7.1	2053	Clinic	VT/USA
		Ski	3.4	28.5	1.8	3.0	8740		

Snowboard and Skiing Injury Studies Summary Table (Shealy 2006)

Appendix F – Choosing Compression Springs



Part Number: 9657K225

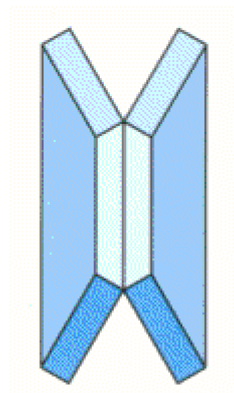
Type	Compression Springs
Material	Steel
Steel Type	Spring-Tempered Steel
System of Measurement	Inch
Outside Diameter	3/8"
Wire Size	.054"
Overall Length	3"
Ends	Closed
Wire Type	Round Wire
Load	22 lbs.
Deflection at Load	1.38"
Rate	16 lbs./inch
Compressed Length	1.62"
Specifications Met	Not Rated

www.mcmaster.com

An issue with the compression springs was finding ones strong enough so that the threshold shear stress is not negligible, but able to deflect enough for full depression of the force peg to allow release. This spring was chosen as a balance. The compression force need not be large, just enough to prevent easy inadvertent release, as the moment lock should prevent such occurrences. This spring, allowing 16lbs/in, or 32 lbs/in for two springs used in unison (as they are in a completed model), was considered enough for such a purpose and allowed the necessary deflection. The shear release without moments actually turned out to be higher than the expected 32 lbs, most likely due to the friction on the CAM surfaces.

Appendix G – Disc Spring Stacking

In our design, the disc springs used to pre-load the moment lock mechanism are stacked in series. This form of stacking is defined by the springs being assembled in an alternating fashion; The top of one disc spring is matched to the top of another, whose bottom (the wide base) is attached to the bottom of another, and so on in this fashion.



Disc Springs Stacked in Series
(Belleville Springs, 2006)

This series formation allows the deflection of the disc springs in question to be multiplied by the number of disc springs in the stack, while the force required for such deflection remains the same as if only one disc spring was used (Belleville Springs, 2006).

Other configurations are available to also change the amount of force required to deflect the disc springs, or both force and deflection. However, these were not necessary for our design and they will not be discussed here.

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- Knunz B, Nachbauer W, Schindelwig K, Brunner F. Forces and Moments at the Boot Sole During Snowboarding. *Department of Sport Science, The University of Innsbruck,* Innsbruck, Austria.
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