An Evaluation of the Motions of Competition Seesaws—
The Effect of Design on Performance

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INTRODUCTION

The seesaw is unlike any other obstacle on a dog agility course in that the performance *on* the obstacle depends on the performance *of* the obstacle. Variations in plank, fulcrum and base construction directly influence the motion characteristics of each seesaw design. In an effort to insure consistency of performance, the organizational bodies for the sport of dog agility have been quite specific about plank dimensions and pivot height. However, they have been less precise when defining a seesaw's response to varying conditions of load. Because of this, a variety of seesaw solutions have been designed and constructed, each with its own set of performance characteristics. The rate of descent, support base movement, plank vibration and noise are all influenced by the design solution and the materials chosen to execute that design.

Dogs perform the seesaw obstacle with a great deal of precision. Successful performance of the obstacle is judged with equal precision. It is therefore essential that seesaws perform in a predictable and measurable manner so that a competing dog can expect a specific response.

The seesaw used for dog agility is the standard example of a class I lever. In this case, a lever sits on a central pivot (the fulcrum) and motion occurs as the lever rotates on that fulcrum. If the lever is loaded on one side and the induced rotation is abruptly halted, the lever and base experience significant forces. These forces result in a variety of observed seesaw responses including bending and catapulting of the plank and hopping and creeping of the base.

In an effort to understand the effect of design variations on the performance of a seesaw, we evaluated three distinct designs. The purpose of the paper was to determine how each design reacted to an applied load. In addition, we wanted to understand how varying the load and the point of load application affected the response of the seesaw. Finally, we wanted to determine how each seesaw responded to the abrupt cessation of plank rotation.

This was one of many dogs in the ring this day that stopped in a two-on/two-off position, only to have their rear ends lifted into the air by the plank. Photo © Clean Run

MATERIALS AND METHODS

DEFINITIONS

Ascending Arm - for this discussion, the portion of the plank or modified board that rises from a starting position on the ground when a force is applied to the descending arm.

Board - *A long, broad, flat piece of sawed wood; thin plank* [1]

Descending Arm - for this discussion, the raised end of the plank or modified board when it is in the starting position

Fulcrum - *the support or point of support upon which a lever turns* [1]

Modified Board - For this discussion, a board that has been strengthened by adding framing or structural supports of wood or metal

Panel - a *section or division of a surface, or one that constitutes a surface…a flat piece, usually rectangular forming the part of the surface of a wall, door, cabinet, etc., and usually raised, recessed, framed, etc.*[1]

Pivot - *a point, shaft, pin, etc. on which something turns.*[1]

Plank - *A long, broad, thick board* [1]

Seesaw - *A plank balanced on a support in the middle* [1]

Teeter, Teeterboard, Teeter-Totter - *Seesaw* [1]

[1] Webster's New World College Dictionary, fourth edition, 2002

Max 200 (Port Byron, New York), Action K-9 Sports Equipment (Sun City, California) and Premier Agility Equipment (Surrey, England) seesaws, which are used regularly in competition, were evaluated. They were selected because each had distinct design elements.

The seesaws were assembled and the distance from the pivot point to the Agiliflex Plus tile (Group Summit Flexible Products, Oregon) floor was measured. Once the base of the seesaw was set on the surface and the modified board (m-board) was placed in its starting position, the distance from the surface to the end of the descending arm of the m-board was measured. The m-board of each seesaw was then separated from the base and the base and board were weighed five times on a digital scale. An average weight for each m-board and base was calculated.

Three sets of tests were performed. For the first set of tests, the seesaws were stabilized by placing 100 pounds of crushed stone (in 50 pound bags) on the bases. Sandbags of known weights (5, 10, 20, 30 and 50 pounds) were placed on the descending arm of the seesaw, at known distances from the end of the descending arm. Tests were performed with each differently weighted sandbag placed at 1, 2, 3 and 4 feet from the end of the m-board. In addition, the balance point (BP) for a given sandbag was determined as the point on the descending arm of the m-board where, when the sandbag was placed, the board would hold a neutral position (both ends of the m-board level in the air). The distance from the fulcrum to the balance point was measured and 12 inches were added to it to calculate the BP+12 point. This point was selected to simulate dogs that ride the seesaw just past the balance point.

Initially, the descending arm with a sandbag in place was held in the starting position. It was then released and the time from starting position to impact with the floor was measured, to the 100^{th} of a second, using a handheld stopwatch (Seiko). These "drop tests" were performed for each sandbag weight and the results for each "distance from tip" and weight were averaged. Drop tests were repeated five times for each distance from the tip including the BP+12 point. The results were then recorded and plotted (Excel, Microsoft) as "distance from tip" versus "time."

A second set of tests was performed to determine the stiffness of the m-boards. Each m-board was removed from its base and was set on top of two concrete paving stones. For the first measurement, the paving stones were placed under the m-board, so that each one was 2 feet from the center of the m-board. The distance from the surface of the m-board to the floor was then measured, repeated three times and averaged. The stones were then moved out toward the ends of the m-board and the distance from the surface of the m-board to the floor was again measured, repeated and averaged. A 50-pound sandbag was then placed on the middle of the m-board and the distance from the surface of the m-board to the floor was measured, repeated and averaged. Using these measurements and the volume dimensions of the individual m-boards, stiffness of the m-board was determined using standard formulas.

In the third set of tests, the amount of ascending arm induced bending ("board whip") was evaluated by tracing the travel of that arm during normal seesaw motion. A permanent ink marker (Sharpie, Sanford, Bellwood, Illinois) was rigidly fixed to the end of ascending arm of the m-board. The shaft of the marker was attached parallel to the surface of the m-board and the tip of the marker was allowed to protrude from the side of the m-board (fig. 1A and B). In this position the marker traced the path of the ascending arm onto a cardboard building form (Quikrete, Atlanta, Georgia) that was oriented vertically and positioned on the floor adjacent to the end of the m-board (fig. 2). A 30-pound sandbag was placed one foot from the end of the descending arm of the m-board and that arm was allowed to come to rest on the floor in the seesaw's final position. With the seesaw at rest, the elevated position of the ascending arm was marked on the cardboard form. The seesaw was then placed in its starting position and the weighted descending arm was dropped, allowing the protruding tip of the marker to trace the path of the ascending arm along the cardboard form. The point of maximum induced bending of the ascending arm was marked and the distance (board whip) from that maximum point to the initial, elevated position of the ascending arm was then measured. The test was repeated three times for each seesaw and the values for the individual seesaws were averaged. A vertical contribution from lifting of the base was prevented by stabilizing each seesaw. Prior to testing, 200-pounds of crushed stone (in 50-pound bags) was placed on each base. Placing bags of crushed stone on both the vertical member and foot components prevented separation of the Premier base.

RESULTS

All three seesaws complied with the specifications for size, height of pivot, construction and speed of descent set by the AKC[2], NADAC[3] and USDAA[4] (Appendix 1). The Max 200 m-board (a plywood board joined to an extruded aluminum beam) weighed an average of 46.8 pounds and the base averaged 31.3 pounds. The Action K-9 m-board (a plywood board supported on the undersurface by a square tube steel frame) weighed an average of 47 pounds and the base averaged 17.2 pounds. The m-board from Premier (a plywood board supported on the undersurface by a wooden frame) weighed an average of 40.6 pounds and the base averaged 21.2 pounds.

Concentric pieces of tubular steel formed the pivot assembly of the Max 200 seesaw (fig. 3A and 3B). The inner steel tube was fixed to the support base. The outer steel tube was welded to a flat plate that allowed for fixation of the outer pivot tube to the m-board. The support base was formed with square steel tubing and was adjustable. For this evaluation the base was assembled and the connector chain adjusted so that the pivot point was 24 inches above the floor. When assembled and in starting position, the tip of the descending arm was 43 inches from the floor.

A square steel tube that rotated on a fixed round steel tube formed the pivot assembly of the Action K-9 seesaw (fig. 4A and 4B). The square tube was firmly welded to the frame of the m-board. The inner round tube extended beyond the square tube and was fixed to the base by pins. The support base was formed by two rigid triangles made of tubular steel, one on either side of the board and pivot assembly. The pivot assembly of the assembled seesaw was positioned 22 ½ inches above the surface. When assembled and in the starting position the tip of the descending arm was 42 inches from the floor.

The pivot assembly of the Premier seesaw was formed by a right angle plate resting on a vertical steel blade and was 24 ½ inches above the ground (fig. 5A and 5B). The assembly was captured on its ends to prevent dislodging. The bottom of the blade was welded to a horizontal plate, which enabled fixation of the blade/plate assembly to a base that was formed from wood. The blade/plate assembly was fixed to a vertical “A” shaped support. The support was held in the vertical position by two wooden feet. The vertical support slid into channels in the feet and was held in the channels by plates that were fixed in place with machine bolts and wing nuts (fig. 6). The fixation in the channel was not rigid. When assembled and in the starting position the tip of the descending arm was 45 ¼ inches above the ground.

The results of the drop tests for a known load for each seesaw were plotted as “distance from tip” versus “time” (fig. 7, 8 and 9). Drop tests at 5 and 30 pounds were compared for the three seesaws and illustrated on a single plot (fig. 10). For sandbag weights of 20, 30 and 50 pounds, all three seesaws descended in less than 1 second for all positions except for the K-9 seesaw at the BP+12 point at 20 pounds where the descent time was greater. Descent times for 5 and 10 pound sandbags were longer at all "distances from tip" and increased by as much as 300% at the larger distances. Only the blade/plate fulcrum construct had descent speeds, for the lighter weights, that approached those for the heavier weights (fig. 10).

The bending of each m-board was determined and recorded for no load, board load and at 50 pounds of load. The stiffness of each m-board was determined. The Premier m-board had the greatest stiffness and the Action K-9 m-board the least. The Max 200 m-board was only slightly stiffer than the Action K-9 board (Fig. 11).

"Board whip" was measured at 30 pounds for all three m-boards. The averaged K-9 "board whip" value was 14 cm., the averaged Max 200 "board whip" value was 10.4cm and for the Premier m-board, 9.3 cm.

DISCUSSION

Observations of the seesaw's motion suggest that this obstacle responds differently to varying loads. Not only does a single design react differently to load variations, but also different designs perform differently. The demand for increased speed on an agility course has created the need for a seesaw that performs quickly and predictably. If dogs are to rapidly and safely traverse this obstacle, then board bend," board whip" and base response must be consistent from design to design. In addition, methods need to be in place to accurately assess the performance of the seesaw obstacle so that predictable motion can be assured. It was the goal of this study to understand the factors that influence a seesaw's performance, to determine how to evaluate that performance and, lastly, to develop a set of criteria for the design of an optimal competition seesaw obstacle.

Each seesaw incorporated a modified board; each board stiffened using a different structural solution. The Premier m-board construct is stiffened by using wood supports, fixed on their longer dimension, to the periphery of the board. The K-9 board is stiffened with a steel square tube ladder. Transverse members give the ladder dimensional stability but contribute less to stability along the length of the board. The Max 200 m-board was stiffened using a longitudinally oriented extruded aluminum member. The similarity of this aluminum support to an "I" beam is notable and stiffens this m-board with a very low profile.

"Board whip" appeared to be a function of the stiffness of the m-board. In this study, the less stiff m-boards (K-9, Max 200) were associated with greater amounts of "board whip" resulting in *catapulting* of their loads-the sandbag bounced off the end of the m-board. All three m-boards still had to dissipate the energy developed in the ascending arm. This energy was transferred to the base, which resulted in hopping of two of the seesaws. However, in one case, the Premier seesaw, the linkage in the base dissipated the upward force, and whipping, catapulting and hopping was minimal.

Each seesaw used a different fulcrum design. The Premier seesaw used a captured blade/plate assembly, whereas the K-9 and Max 200 obstacles used tube within a tube designs. The concentric round within a round tube used by Max 200 was closely fit whereas the round within a square used by K-9 was less snugly fit. These approaches resulted in three different interactions at the fulcrum assembly.

Fulcrum design influences the speed at which the m-board descends. For two designs (fig. 10) it is evident that smaller loads take longer to fully displace the descending arm. For the fulcrums with square on round tube or round on round tube assemblies, as the leverage decreases (the distance of the load from the end increases), the descending arm slows even more. When light loads were applied at increasing distances from the end, the descent of the m-board slowed considerably. In contrast, the low resistance fulcrum had less effect on the rate of descent of the m-board for both light and heavy loads, applied at varying distances from the board end (fig. 10).

Finally, the degree to which a seesaw obstacle is anchored to the ground is no small matter. The more rigid the fixation of the seesaw to the surface, the more energy stays in the board, enhancing “board whip” and catapulting. When the seesaw base is less firmly fixed, lifting of the base dissipates board energy. Hopping of the obstacle can be a by-product. In one design (Premier), internal movement of the base components enabled the dissipation of board energy while virtually eliminating base hopping.

All three seesaws tested were well designed and carefully constructed. All three were easily assembled or taken apart for transport. Each seesaw was consistent in its performance but varied when compared to each other. And that is the issue. For dogs to perform reliably, equipment needs to perform in a predictable way. The sport is evolving past the days where the subtleties of a venue were part of the challenge. High speed and precise technique demands predictable and reliable performance from the equipment used in the game. It is important that the governing bodies narrow their specifications so that designers and manufacturers can build seesaw obstacles that perform similarly for all dogs.

RECOMMENDATIONS

1. It is important that the sport's governing bodies establish a more precise set of specifications for the seesaw obstacle that include the stiffness of the board and the response of the obstacle to a variety of load conditions. This will allow a dog to anticipate a predictable performance from the obstacle. A single maximum time limit for a single load does not adequately characterize the performance of a seesaw obstacle.

2. In an effort to insure that a seesaw obstacle's performance is similar for both small and large dogs, we recommend using blade/plate fulcrums. Their use will avoid the frictional effects of the tube on tube assemblies and the variations in response to different loads that are a byproduct.

3. Although stiffer m-boards exhibit less "board whip" (and "catapulting"), "launching" of the base remains a problem. Incorporating force attenuators into the base can eliminate launching.

APPENDIX 1

AKC Specifications[2]

The Seesaw consists of a plank (or panel) made of wood or a fabricated material that can be properly surfaced and is supported near the center by a base that acts as a fulcrum. The plank is 12 inches wide with a 1-inch tolerance, and 12 feet long. The base extends at least 2 inches past the sides of the plank with a gap not to exceed 4 inches so that dogs can see the pivot point, with the exception of the ground support, which may be wider. The plank is balanced so that it hits the ground in less than 3 seconds when a 3-pound weight is placed 12 inches from the raised end. The height of the Seesaw measured to the top of the board at the pivot is 24 inches plus or minus 2 inches. The top surface of the plank is painted and has a rough, non-slip surface. Glossy paint is not allowed. Alternating layers of sand and flat, latex paint is recommended.) Slats are not allowed on the seesaw. Contact Zones, 42 inches long, are painted on each end of the plank with a 1/4-inch tolerance, using the color specification described for the A-Frame.

= As of September 2006.

Contact Obstacle	Ramp Length	Ramp Width	Height	Contact Zone Length
Seesaw	12 feet	12 inches	24 inches to top of board at pivot	42 inches

NADAC Specifications[3]

Contact obstacles should always provide good traction for the dogs without being too rough as to damage the dog's pads. Surfaces must be maintained on a regular basis so that dogs will not slip when performing these obstacles.

Most equipment builders have found that products such as Skid-Free, No-Skid, Skid-Tex, Deck-Tec or other such products will provide a better traction surface than using a large, coarse sand mixture. Most of these products, when mixed heavily with paint, will provide a non-slip surface that also works well when wet.

Rubber surfacing may be used, but MUST be first approved by NADAC.

All contact zones shall be painted yellow, with the remainder of the ramps painted a contrasting color.

Slats are not allowed on the contact equipment.

A good, non-slip surface is required, so dogs have traction on the ramp surface.

Contact Obstacle	Ramp Length	Ramp Width	Height	Contact Zone Length
Teeter Totter	12 feet	12 inches 12 inches is required after 8/1/2006	24 inches at the center of the top of the teeter board	42 inches

USDAA Specifications[4]

The see-saw (sic) shall consist of a sturdy plank measuring approximately 12 feet (365cm) in length and measuring between 11 inches (28 cm) and 12 inches (31cm) in width. The plank shall be supported in the middle by a sturdy base that may be capable of being securely anchored or weighted to the ground and that shall be visible to the dog when approaching the ramp from the front on a straight line. The elevation at the plank's pivot point shall be between 24 inches (61cm) and 27 inches (68cm) above the ground.

The last 36 inches (915mm) of each end of the plank shall be designated as a safety contact zone, shall be painted yellow and be a significant contrast to the primary obstacle color to form a distinct top line. The edge of the zone shall be on the top of the ramp, extend a reasonable depth onto the sides and have no other banding, insignia or other markings within twelve inches of the top line. White is not a permissible color.

The plank surface shall be roughened for adequate traction under wet conditions but shall not be hazardous to dogs' pads. Rubber or similar matting shall not be permitted. Flat paint is strongly recommended so that traction is not compromised.

Contact Obstacle	Ramp Length	Ramp Width	Height	Contact Zone Length
See-saw*	12 feet	11 inches-12 inches	24 inches – 27 inches	36 inches

*See-saw base must be visible on approach.

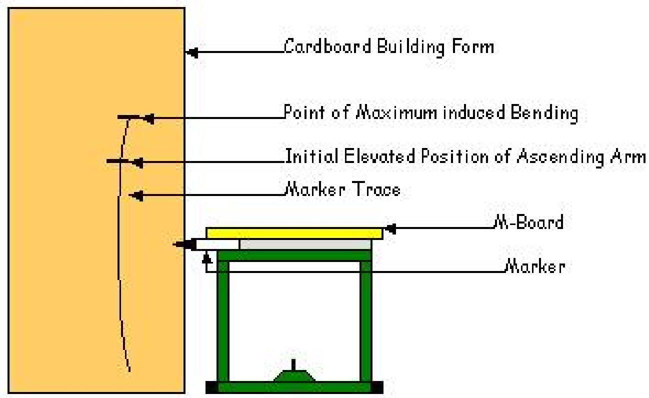


Figure 1A-End View of Test 3 Setup

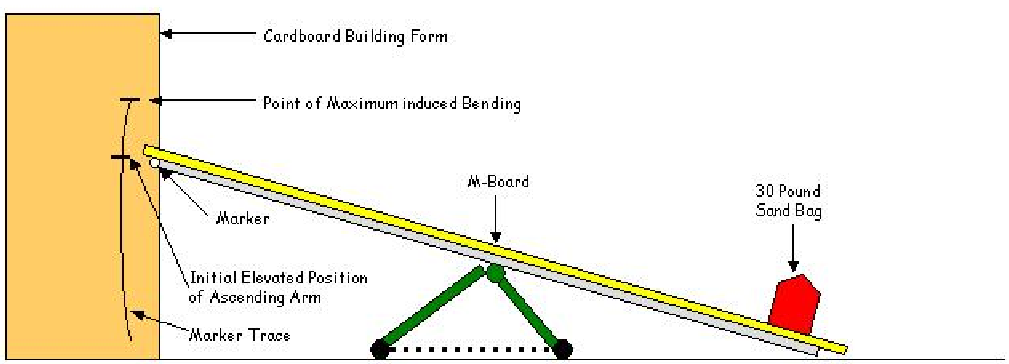


Figure 1B-Side View of Test 3 Setup

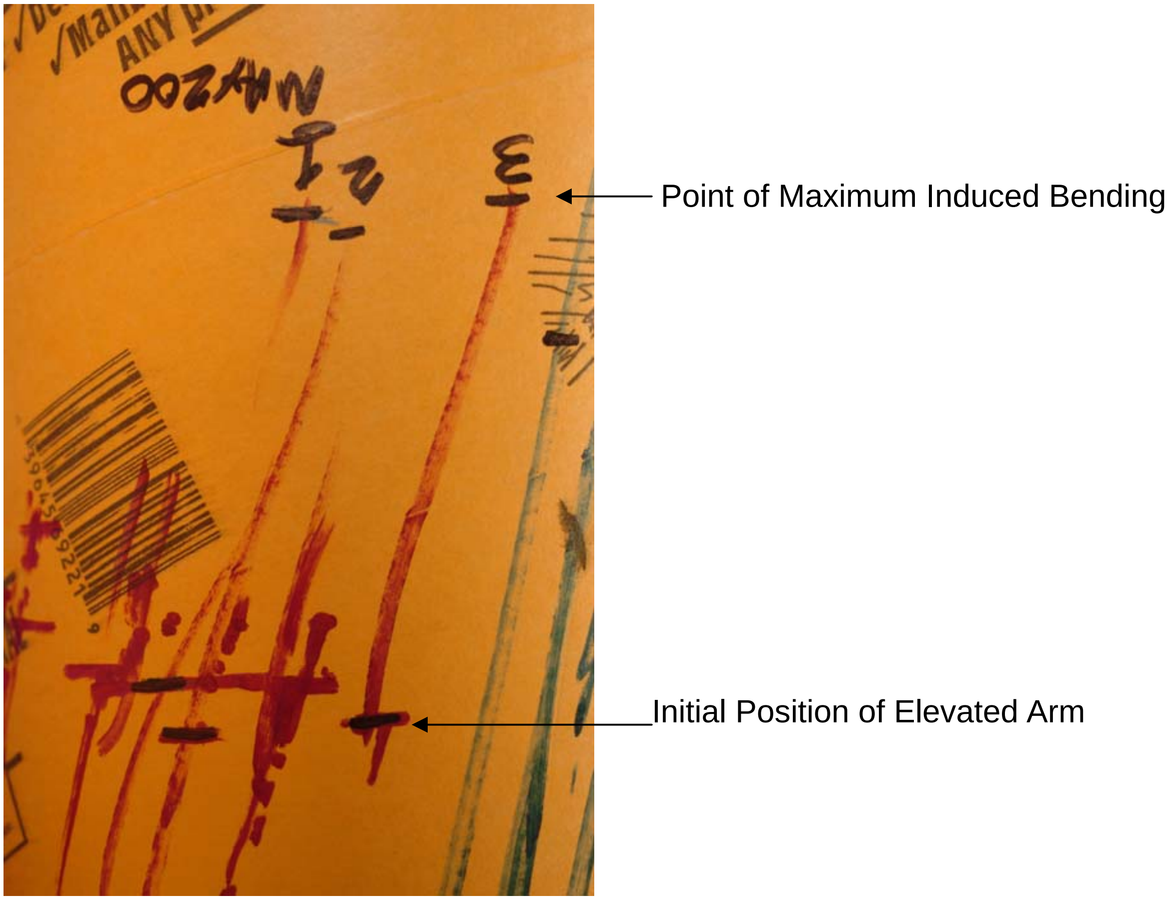


Figure 2
Marker Trace on Cardboard Building Form

Figure 3A
Max 200 Base

Figure 3B
Max 200 M-Board Attachment Plates

Figure 4A
Action K-9 base

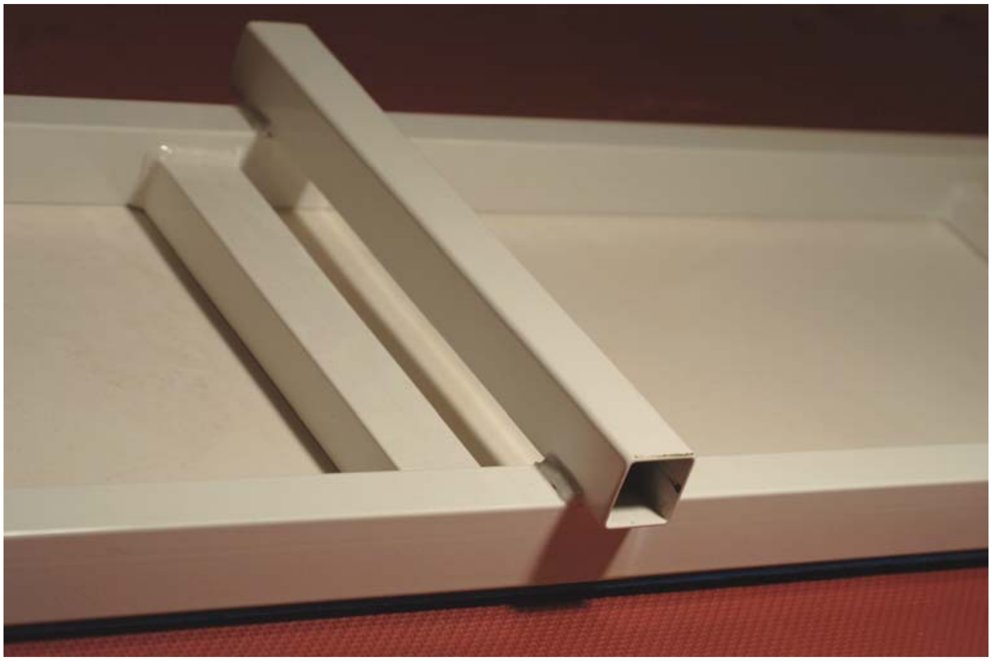


Figure 4B
Action K-9 M-Board Attachment to Outer Component of Fulcrum

Figure 5A
Premier Base

Figure 5B
Angle Plate Component of Fulcrum of Premier Board

Figure 6
Close-up of Premier Base

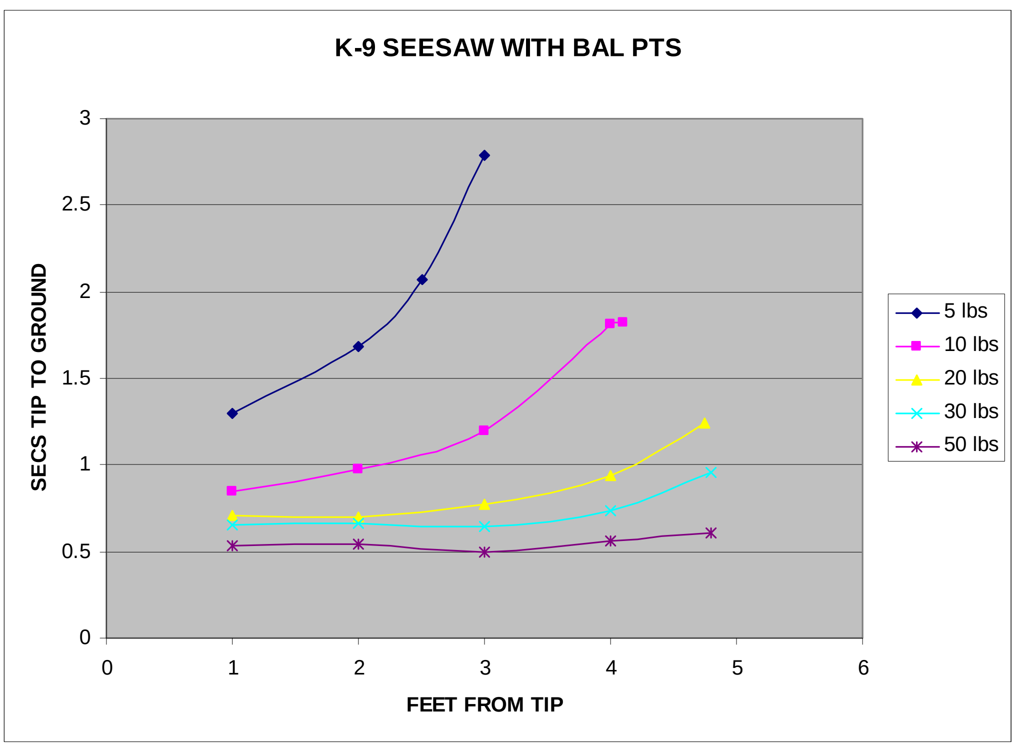


Figure 7

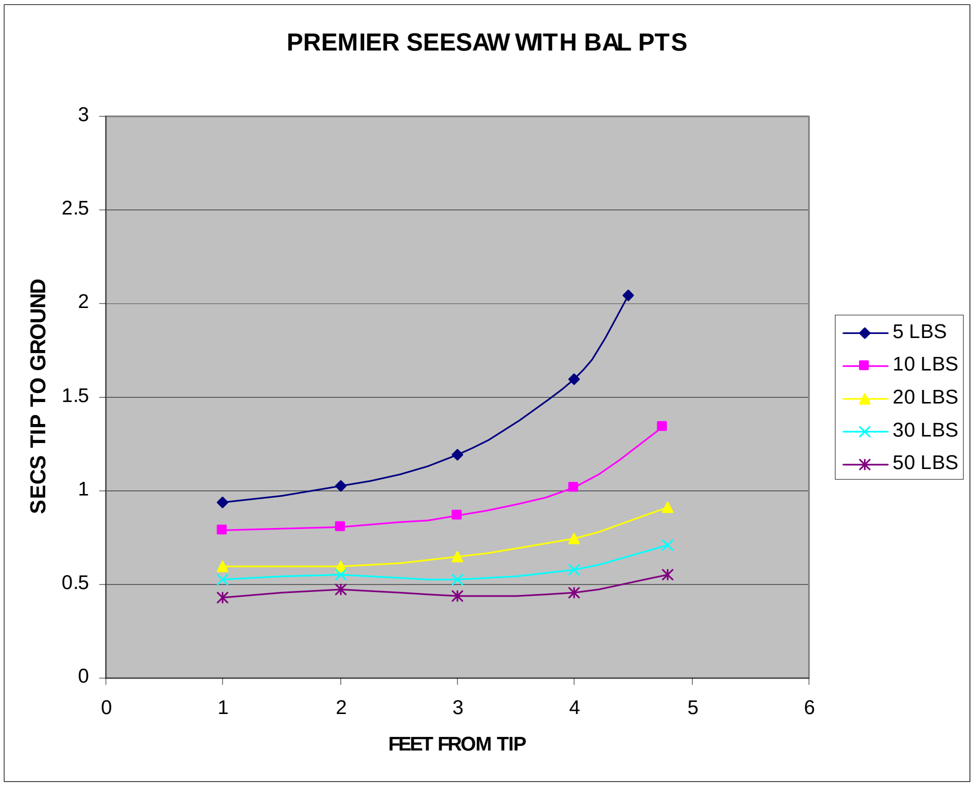


Figure 8

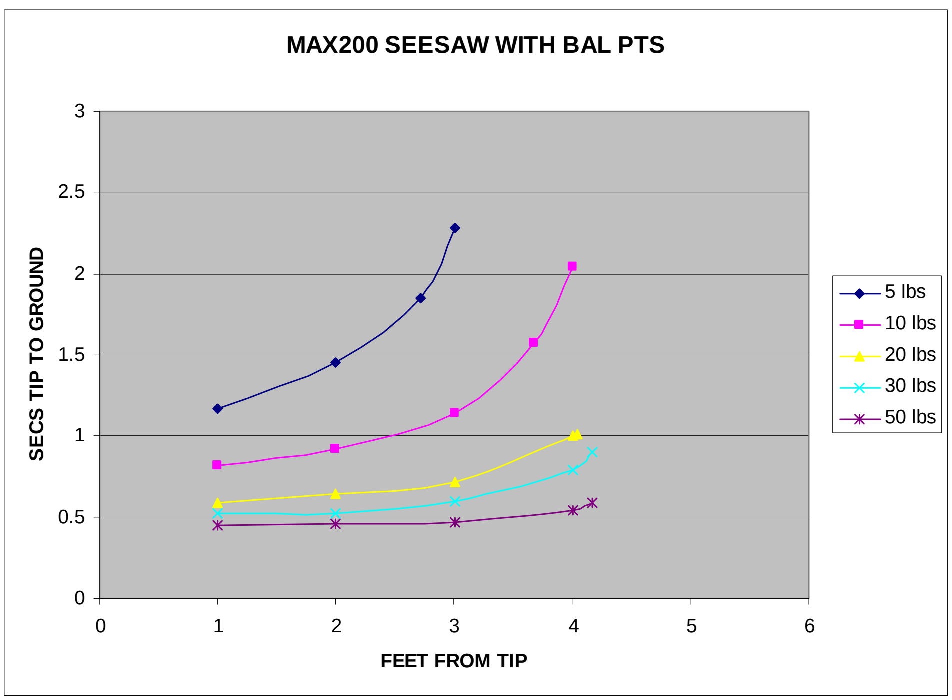


Figure 9

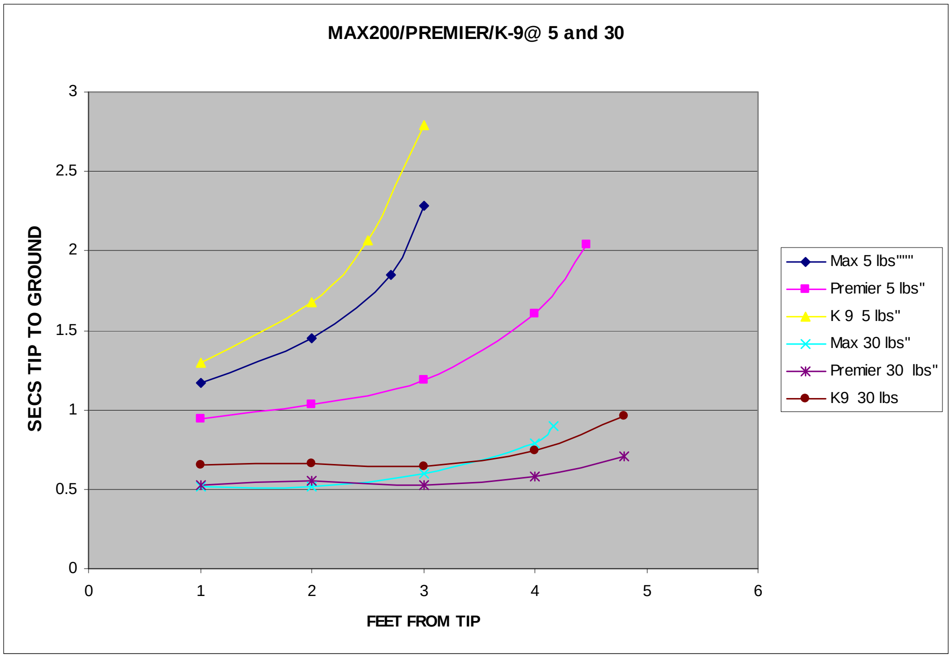
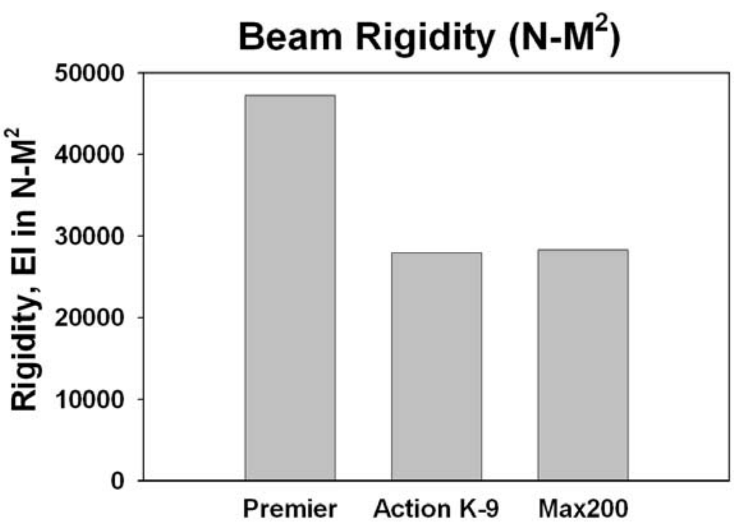


Figure 10



Premier	EI = 47,235 N-M^2
Action K-9	EI = 27,991 N-M^2
Max200	EI = 28,341 N-M^2

Figure 11

REFERENCES

1. Webster's New World College Dictionary-Fourth Edition, Michael Agnes Editor in Chief, Wiley Publishing, Inc., 2002, Cleveland, Ohio.

2. Regulations for Agility Trials, published by the American Kennel Club, Amended February 11, 2005.

3. NADAC website.

4. USDAA website.

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