Designing Props Having Diameter Constraints

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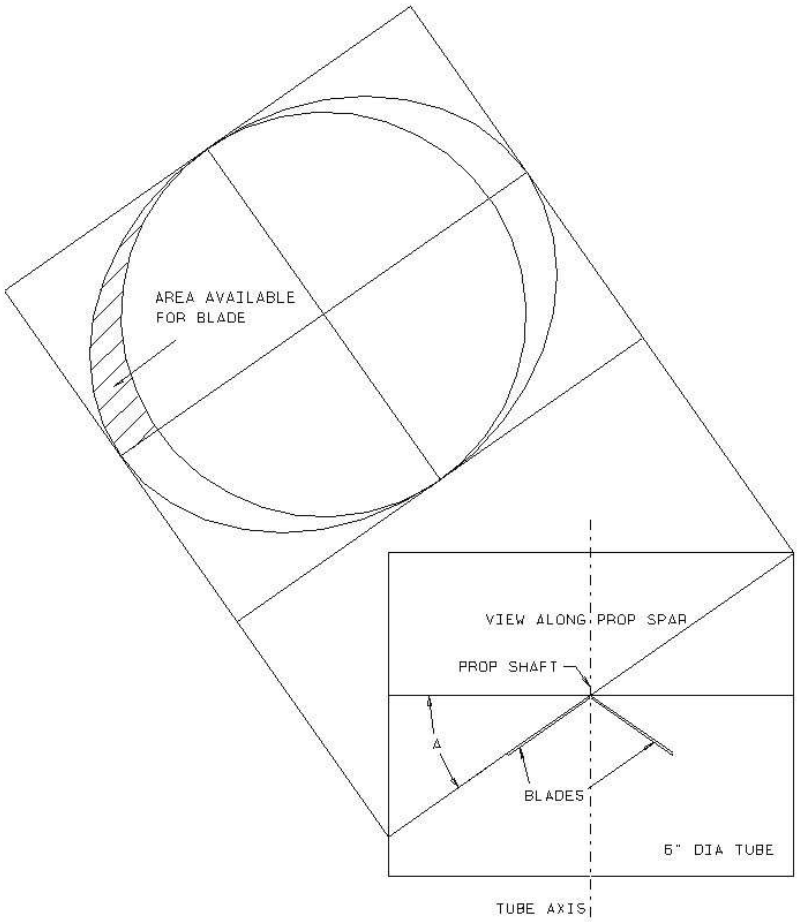
Two Indoor Free Flight events require props to be limited to specified diameters – Limited Pennyplane and A-6. The latter is further restricted to flat sheet blades. It is simple to make the tips of the blades to be arcs of the specified radii. But doing so reduces the actual allowable area along the top of the tip. The rule essentially requires props to fit in a cylindrical tube (6” dia for A-6 and 12” dia. for LPP). Because the blades are set at some pitch angle, there is room to expand the blades a bit inside that tube. For the A-6, with flat blades, the intersection of the plane of the blades and the tube is an ellipse whose dimensions depend only on the angle of the blades to the plane of prop rotation. The drawing below illustrates the geometry. **The tips of the blades only need to be within the ellipse, not a 6” circle**. The larger the blade angle, the flatter the tops can be and the more area is available for the tips of the blades.

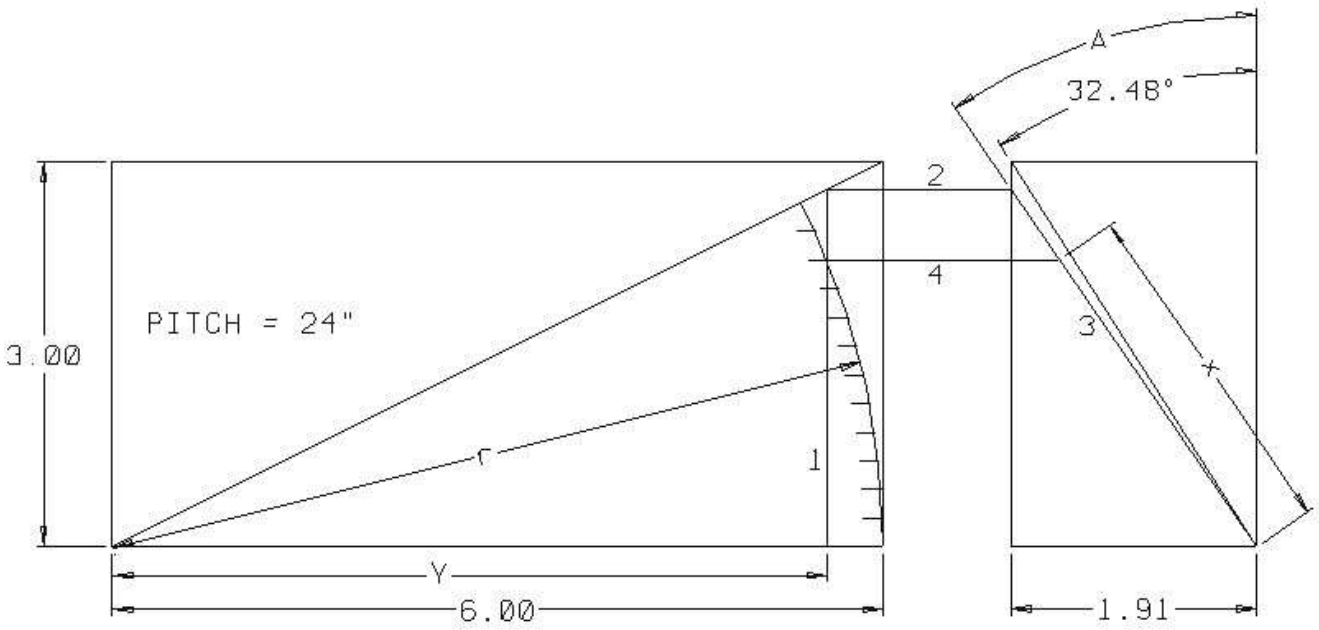


A PDF attached below shows gauges that can be used for a range of angles from 35 degrees to 45 degrees, which should cover A-6 props. The curves are parts of the ellipse for each blade angle. Print it at 100% to make an accurate gauge. There is a reference 6” scale on the drawing.

Due to the twist in the blades for LPPs, designing a gauge is more complex. It is helpful to draw on CAD the block that will be used to make the blades. The picture below shows how it is laid out. We will use a 6” long by 3” wide block. The formula for a “helical” pitch prop is:

$$P/2\pi r = \tan(A)$$

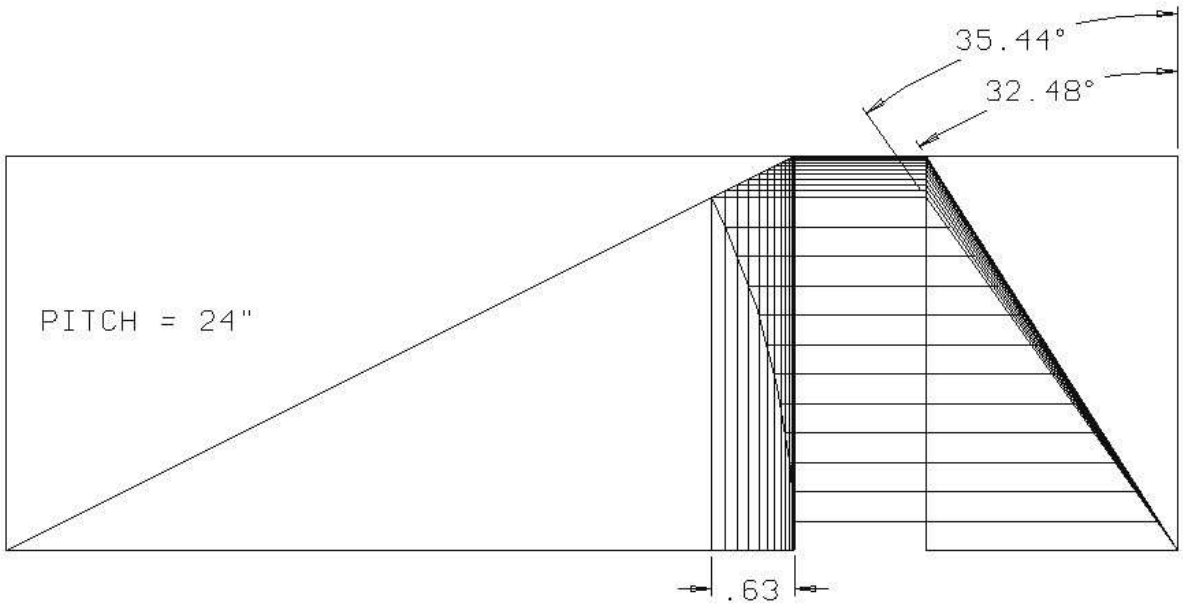
where P is pitch, r is the radius of the prop and tan(A) is the tangent of the blade angle. The drawing below shows these. If we choose 24” pitch and a block that is 6” long and 3” wide, the tangent is .6366 and the thickness of the block would be 3 times this or 1.91” thick. It is best to use a block about 3/4” thicker so you can attach something to hold the prop shaft vertical when assembling the blades to the prop. The blade angle at the tip is 32.48º.



The prop radius is shown in the top view. Now a few groups of projection lines can be drawn to create a table of coordinates to represent the limits of the blades near the tip to stay inside a 12” diameter tube. The radius line is divided into equal parts (12 here) across the width of the block up to the point where the radius touches the diagonal line demarking the boundary of the top of the block and the blade building surface. For each segment, a vertical line is drawn from the demarcation line (1) down to the long edge of the block. The distance from the center of the prop is “y”. Next a horizontal line (2) is drawn from the top of the vertical line to the end view. From that point, a line (3) is drawn to the lower right corner of the end view. That line represents the pitch angle (A) on the block. Next, a horizontal line (4) is drawn from the segment point to the pitch angle line. The distance from the bottom right corner in the end view to the end of this line is the “x” distance in the end view.

These x,y points are the points on the same kind of ellipse that was discussed for the A-6 prop. But each point is on a different ellipse, depending on the pitch angle. The goal here is to make a graph of the allowable tip shape. We don’t need to draw the ellipses because we can untwist them to print them on a flat sheet of paper. Untwisting just means ignoring the z

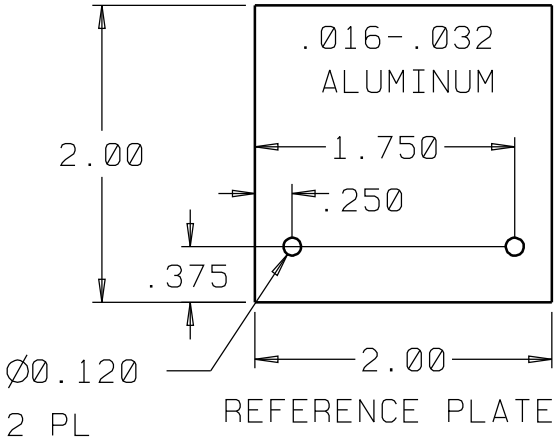
dimensions of a complex 3D model. The drawing below shows all of the pitch angle lines for our 24” pitch block. The parts of the tip that could lie on the 6” radius tube seen on the front view only twist about three degrees, so there isn’t much twisting going on in our example and we can ignore it and not worry how the balsa actually behaves when strapped to the block for baking. We also ignore camber in the blade. If we design the flat blade using our gauges, adding camber would make the chord a little shorter, further ensuring that the prop is qualified.



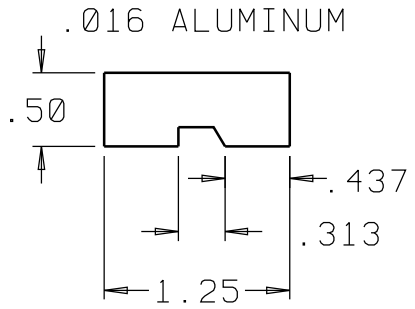
PDFs of gauges for prop pitches 18” through 25” by the inch are attached below. The “x” dimensions are plotted as minuses to put the curve in the correct quadrant for checking blades.

You can build a simple gadget to accurately check your finished LPP props (and also to check A-6 props). It uses common materials, such as milled pine moulding and thin aluminum sheet. This sheet should be about .016” thick, but can be up to .032” The dimensioned drawing is shown below. Dimensions of the base aren’t critical, but should be reasonably close to the thickness shown. There is a thin aluminum (or other metal) sheet attached to the base, the prop shaft backstop. It must be square between the bottom edge and the left edge. It supports the prop shaft when testing a prop. You can use epoxy to glue it to the base. The plate at the back end of the tester can be made of the same material, or a little thicker. It too must have a square corner at the bottom left.

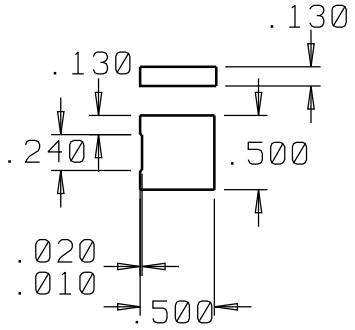
There is a clearance cutout in the prop shaft backstop to clear the prop hook. It can be cut in with a jeweler’s saw or a file, either the shape shown below, or just a rectangle about 1/8”x 5/16”. A second cutout is on the thin block supporting the top of the prop shaft backstop to allow your finger to hold the prop shaft in the tiny corner created by the two parts. It can be filed into the block with a narrow file. It is only .010” to .020” deep and about 1/4” wide. The block is glued to the prop shaft backstop and extends about .010” to .020” past the base to



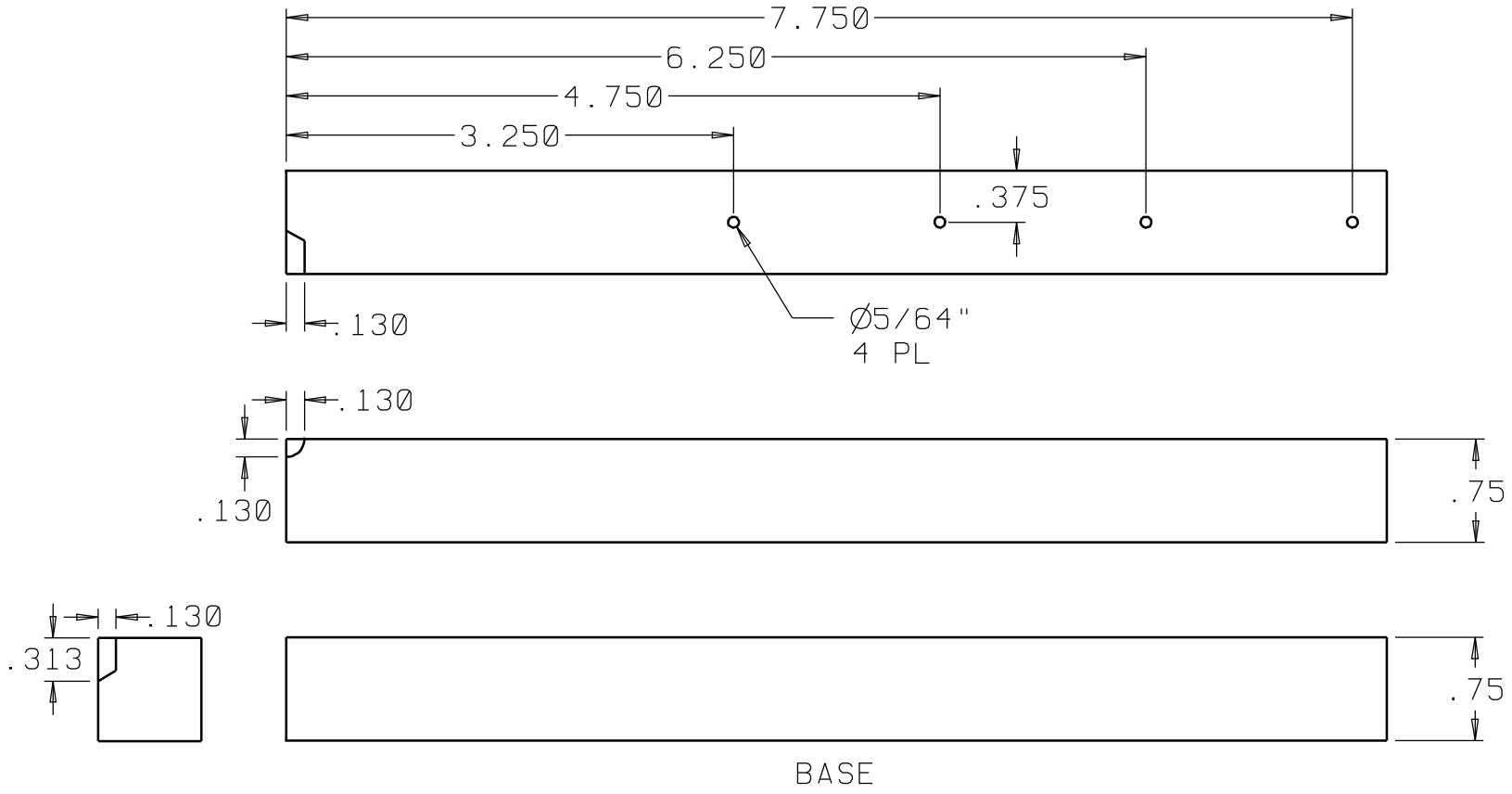
REFERENCE PLATE



PROP BACK STOP

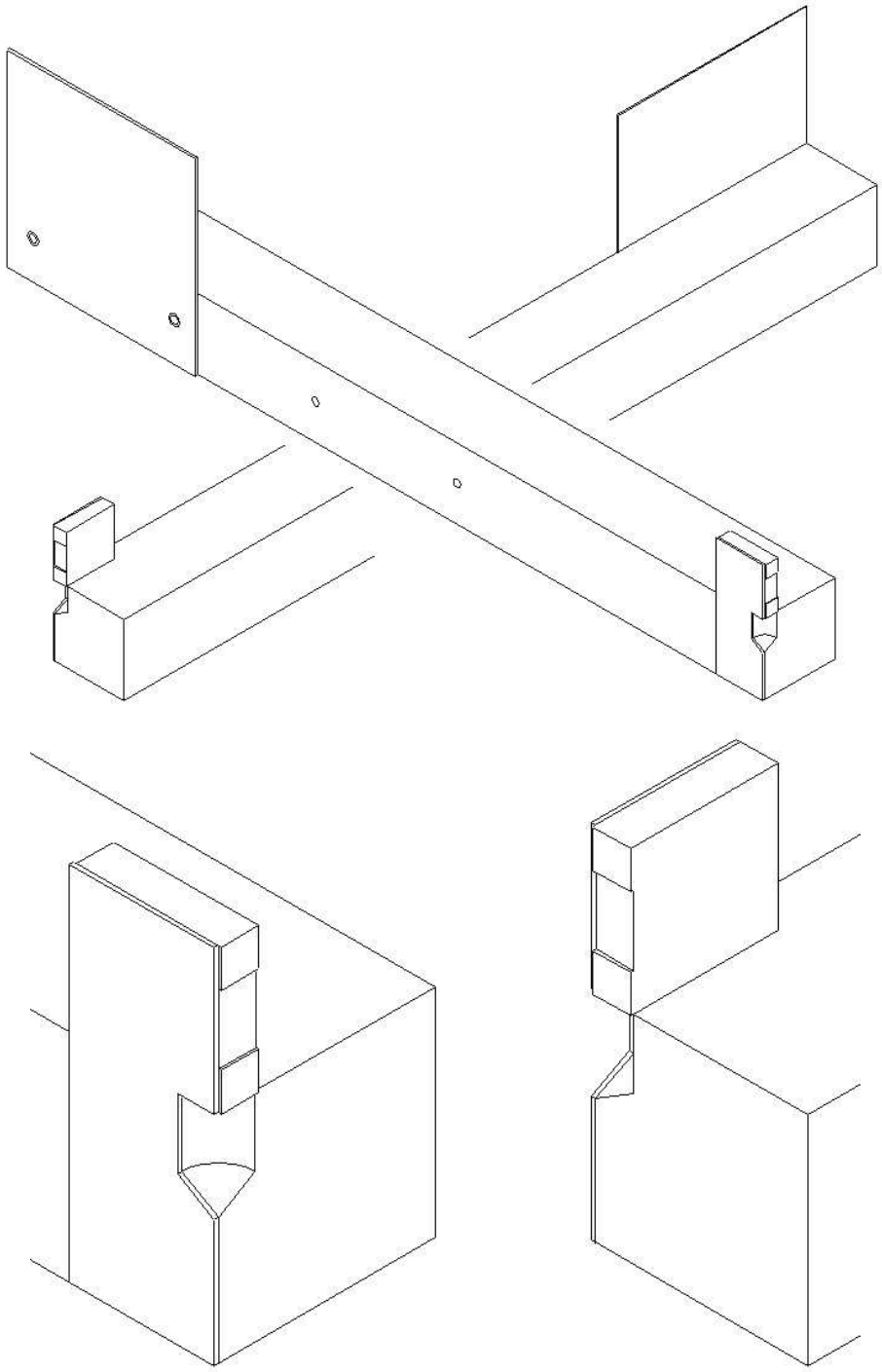


BLOCK

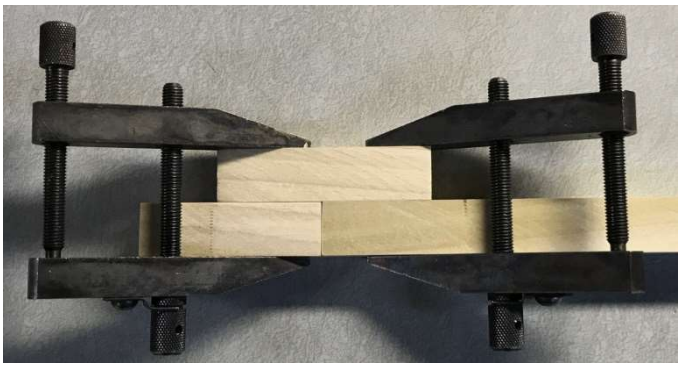


BASE

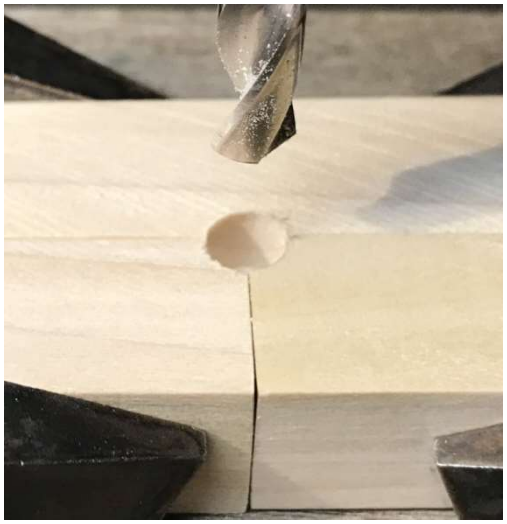
constrain the shaft in a corner. The top of the block should be even with the top of the prop shaft backstop.



There is a clever way to drill the corner cutout for the base. Cut a couple of short lengths of the base material and clamp them to the base as shown below.



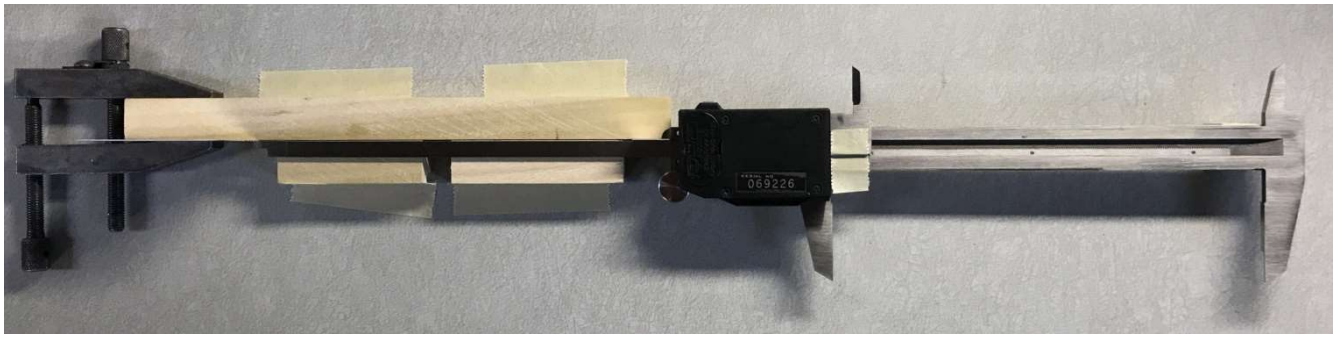
Drill a 1/4” hole about 5/16” deep (from the tip of the drill) at the point where the blocks meet at the end of the base. Remove the extra blocks and the corned will be nicely cutout for the prop shaft.



After the parts have been made, epoxy the prop shaft backing plate to the rear of the base, flush with end, and square to the bottom of the base. Let the epoxy cure.

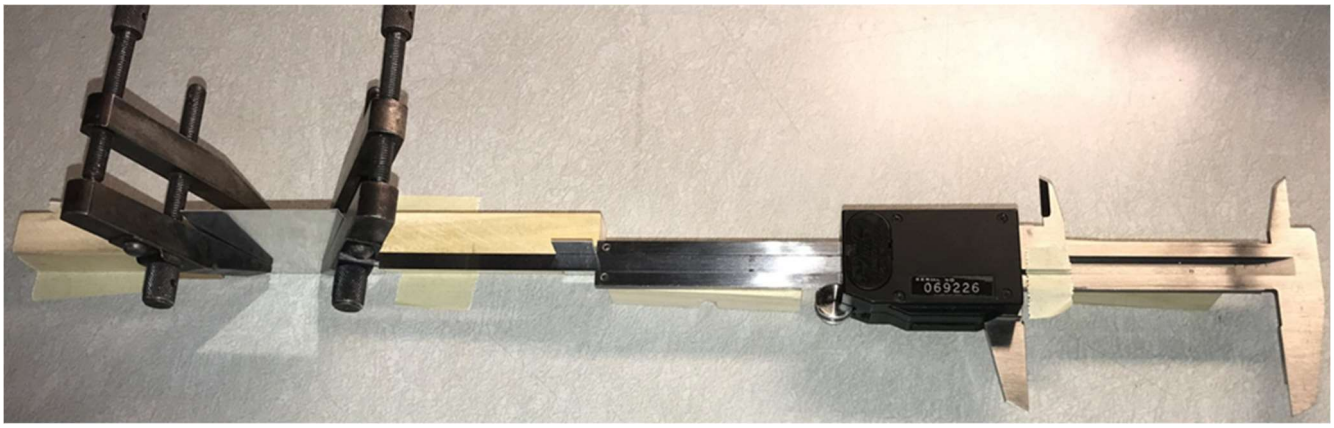
Set the caliper to 5.993” and tape the depth gage to the back of the caliper as shown below. This size takes account of the prop shaft diameter (.012”).

Tape the base to the bench and lay the caliper on the short blocks as shown below. Temporarily clamp the reference plate (2” square plate) against the rear side of the base at the end away from the prop shaft backstop, against the caliper. This is the reference edge to qualify the props.



Cut two 3/4” x 3/4” x 1/16” square pieces of hard balsa or other hard wood. Epoxy one to the base, end grain touching the reference edge of the plate. Let it cure. Tape the plate to the base, with tape on the bottom of the base and around and up onto the rear side of the plate. Use another piece along the rear side of the base, over the epoxied block, tight in the corner, along the plate and around the end of the base. Check with the caliper again after taping. Adjust if necessary. You can drill the two small holes with a 5/64” drill through the plate into the base about 1/2”. Remove the plate and drill the holes to about 1/8” diameter.

Reset the caliper to 2.994 and tape the depth gage to the back of the caliper as before. This is for A-6 props. Clamp the plate to the rear edge against the caliper depth gage. Again check location with the caliper and adjust as necessary. Repeat epoxying the 3/4” square piece in front of the reference plate. When cured, use the 1/8” drill to spot drill the holes in the base. Remove the plate and drill 5/64” holes, 1/2” deep. Use #4 sheet metal screws to hold the plate.

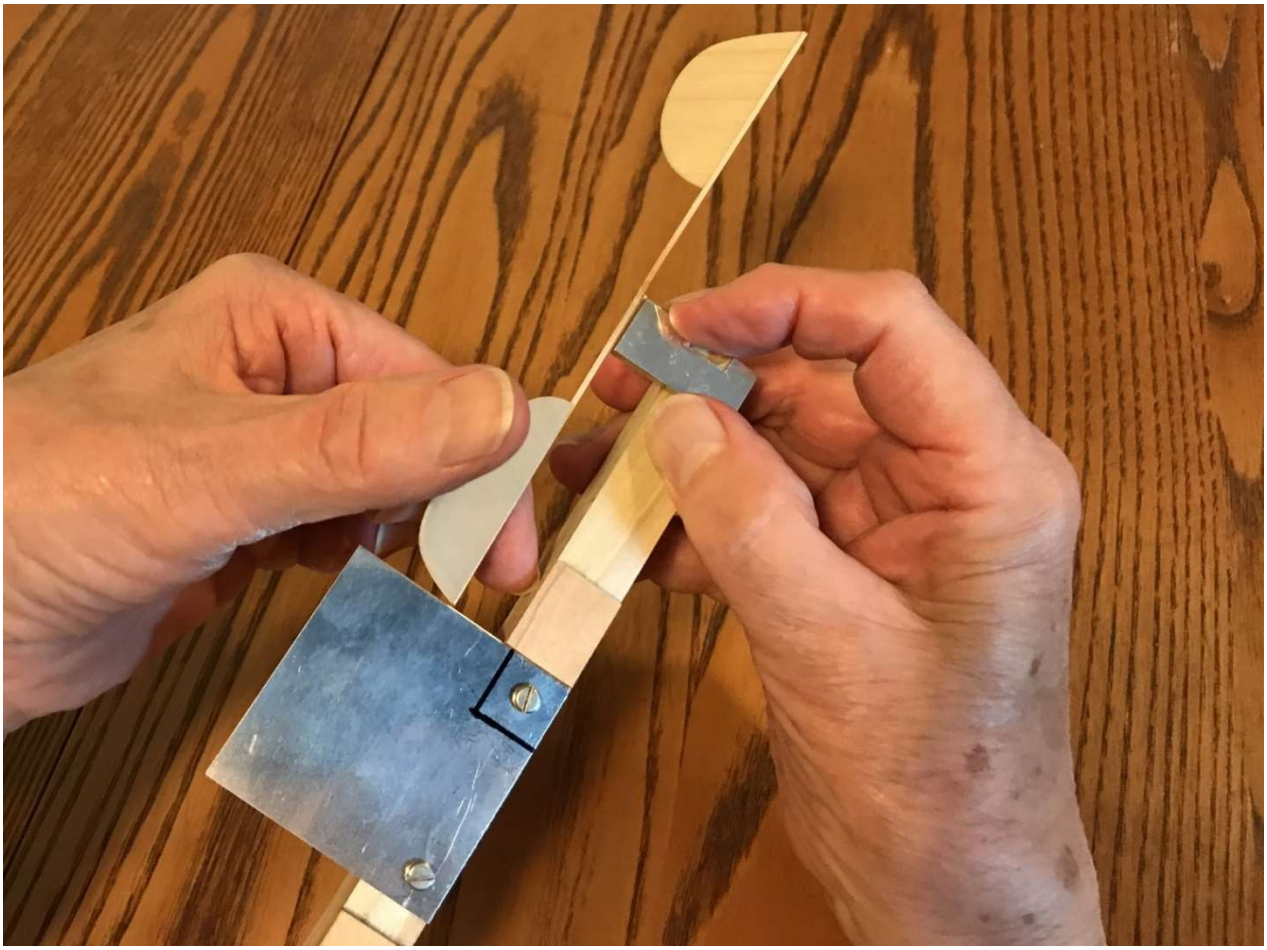


Now it is time to attach the block. Epoxy it against the prop shaft backing plate and to the top of the base, extending about .010” to .020” in front of the edge of the plate. Keep any epoxy out of the corner where the prop shaft will be.

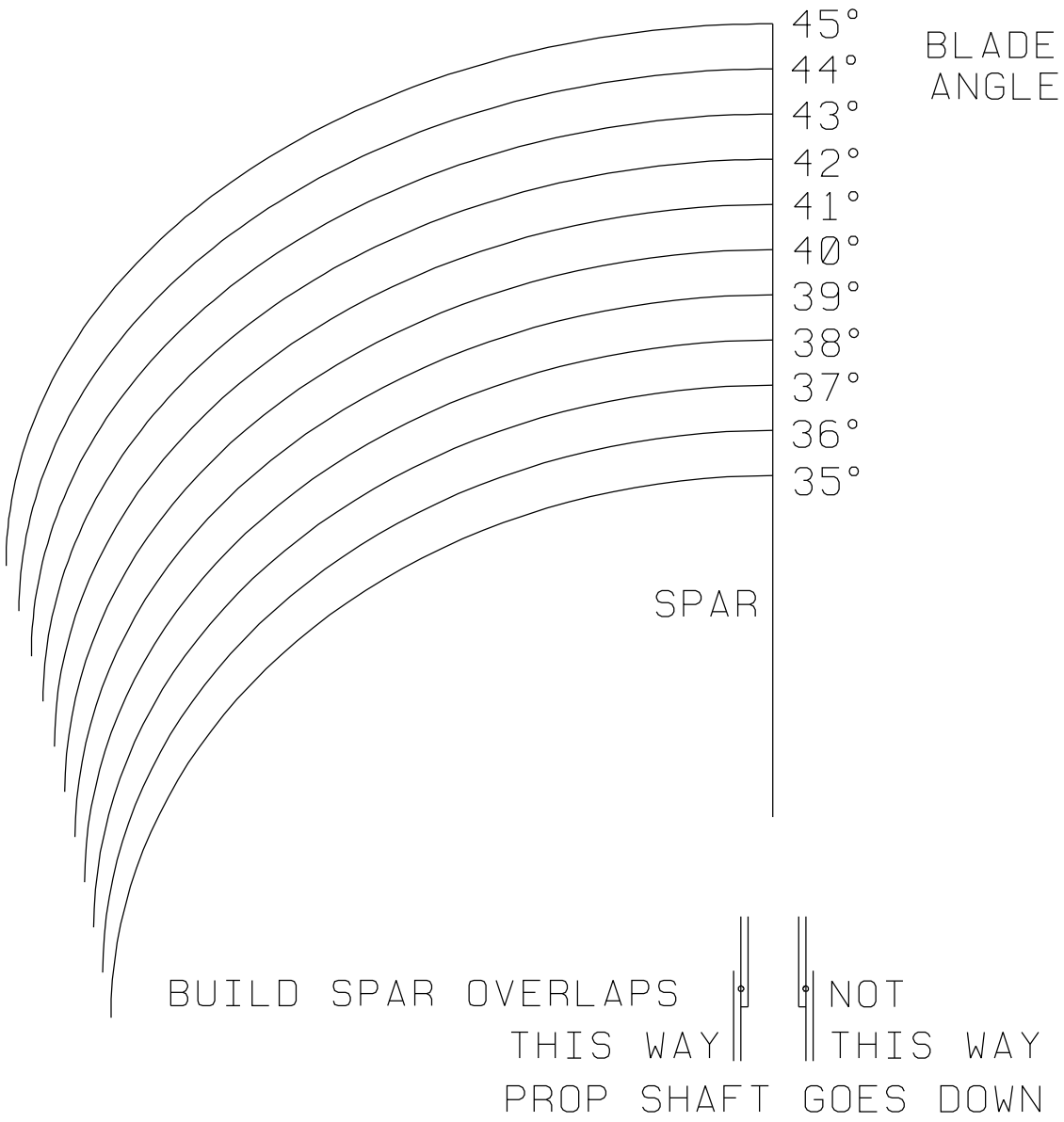
The tester is ready to use. Place the prop shaft in the corner and let the spar rest on the block. Hold the shaft in place with a finger.

Rotate the prop so the first blade swings past the reference plate. If there is no interference, swing the second blade past the reference plate. If it does hit the reference plate, sand off the excess until it clears. You probably will need to do some sanding on the second blade.

When changing between LPPs and A-6s, be sure the reference plate touches the 1/16” square blocks when tightening the screws.



PDFs of the A-6 and LPP prop gauges are attached below.



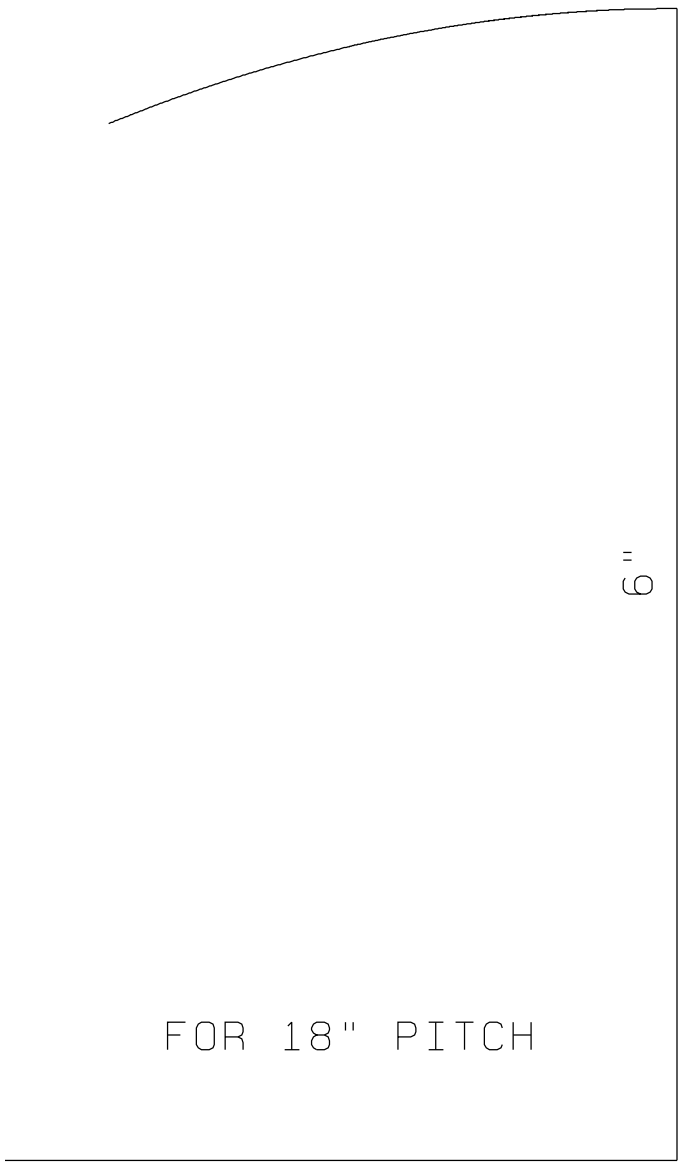
AN A-6 PROP MUST FIT IN A 6" DIAMETER TUBE. SINCE THE BLADE IS FLAT, THE INTERSECTION OF ITS PLANE WITH THE TUBE IS AN ELLIPSE. EACH BLADE ANGLE RESULTS IN A DIFFERENT ELLIPSE. WE CAN USE THESE ELLIPSES TO DEFINE THE OUTER LIMITS OF THE BLADE SHAPE.

CHOOSE THE ELLIPSE FOR THE ANGLE OF YOUR BLADE. IF THE ANGLE IS BETWEEN TWO OF THE ELLIPSES ABOVE, USE THE SMALLER ANGLE ELLIPSE TO CHECK YOUR PROP TIP.

A-6 PROP BLADE GUAGE

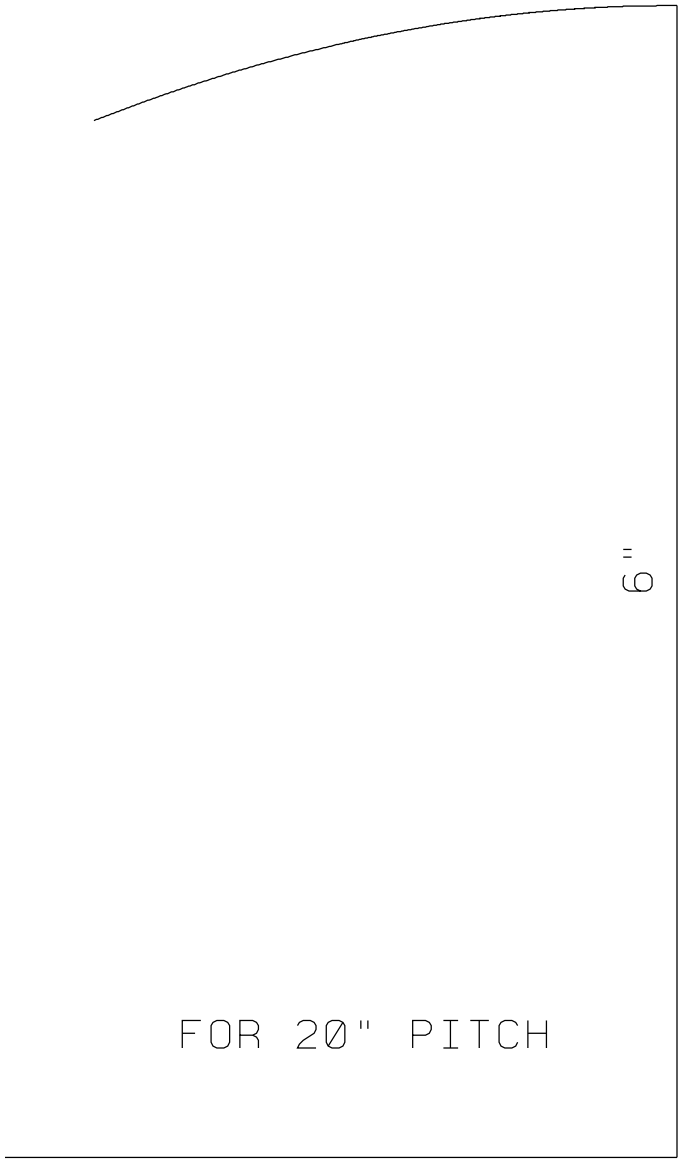
0 6"

SCALE TO CHECK PRINT SIZE

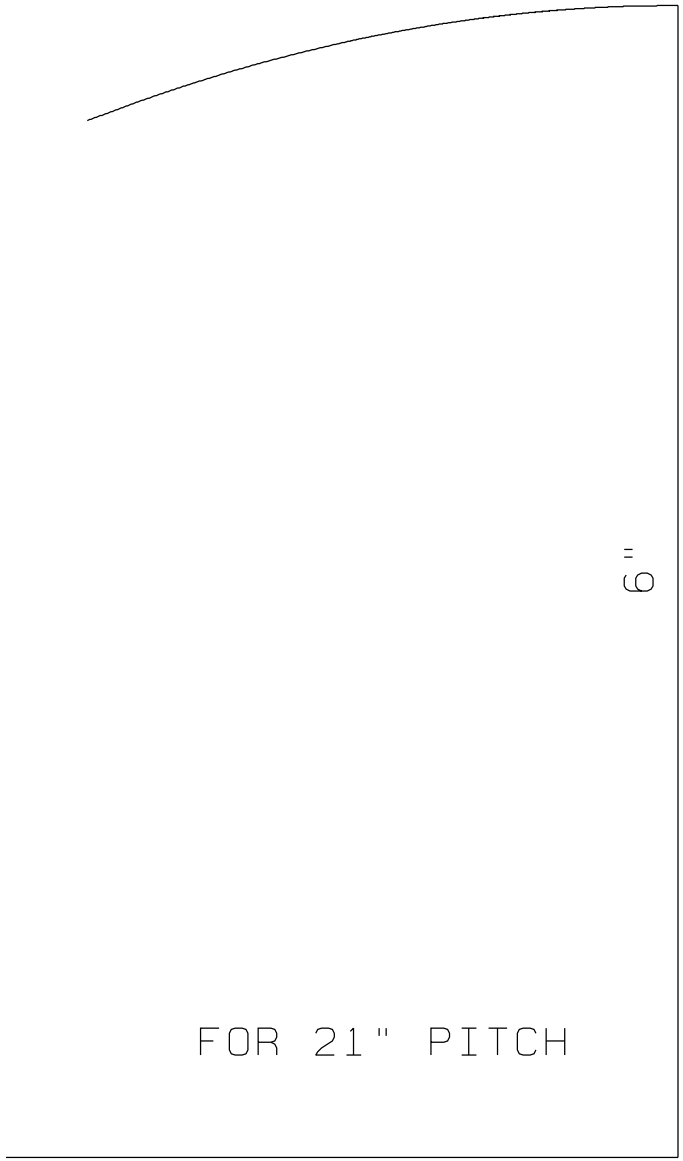


FOR 18" PITCH

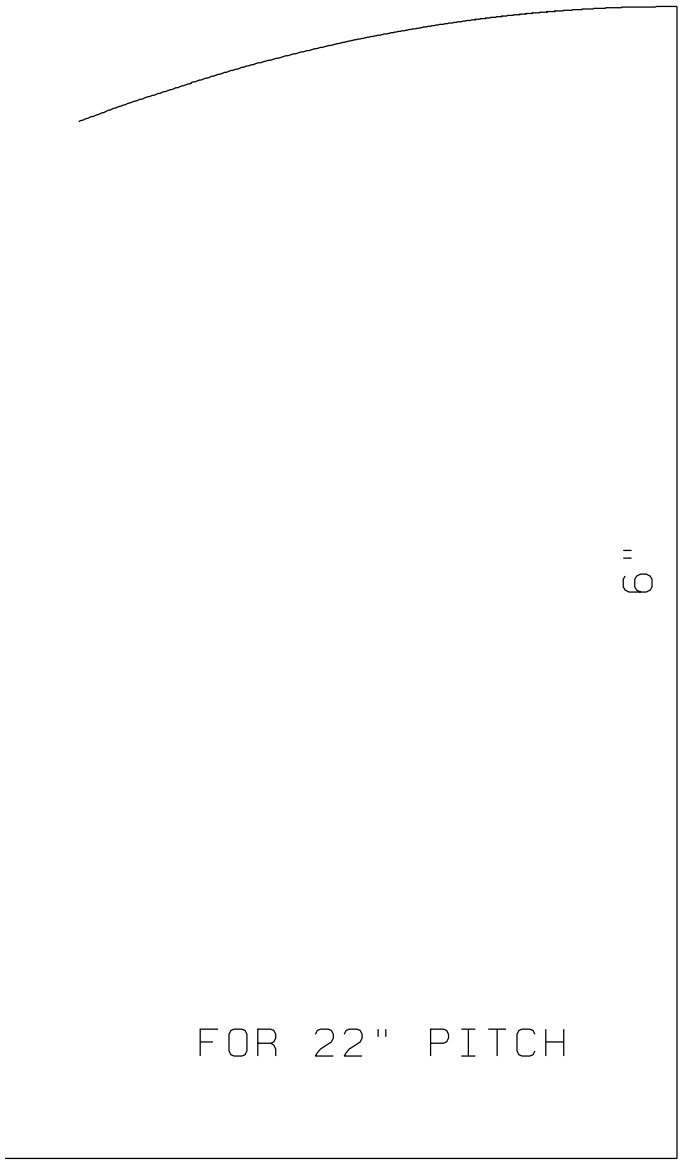
FOR 19" PITCH



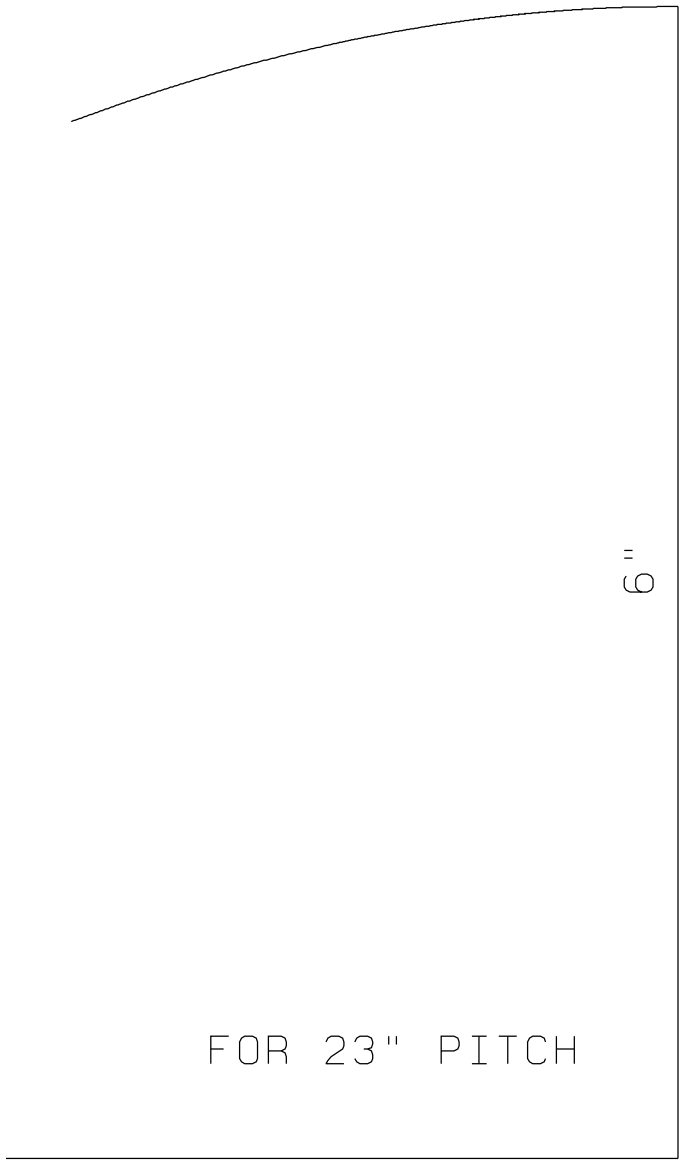
FOR 20" PITCH



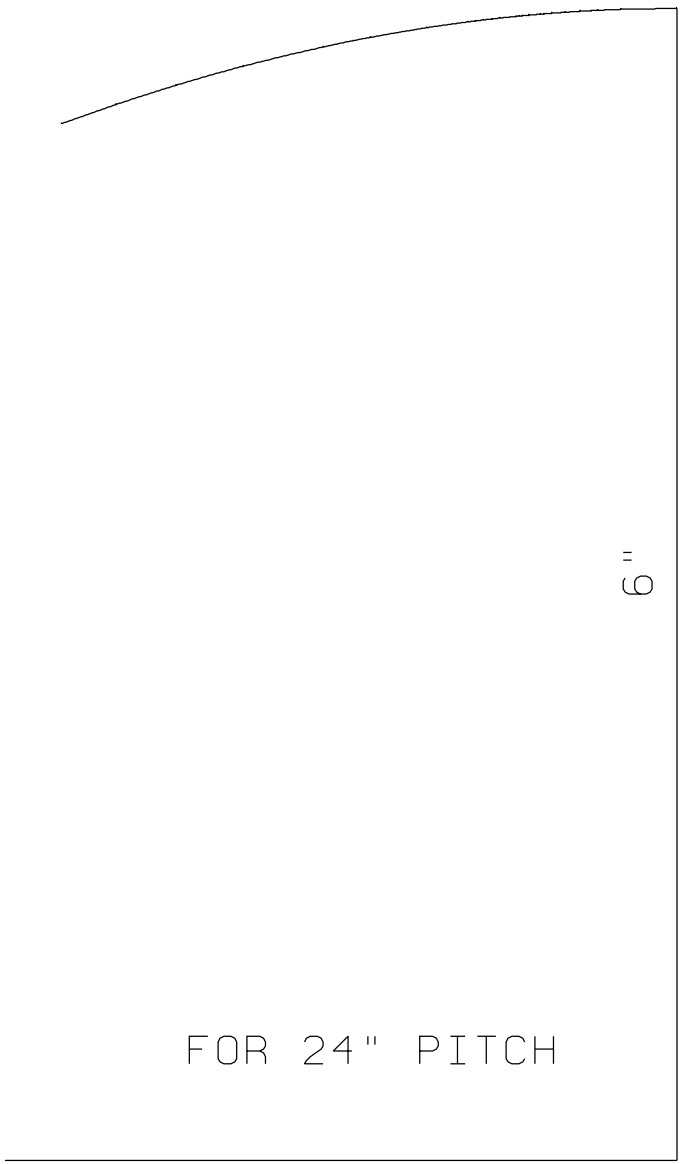
FOR 21" PITCH

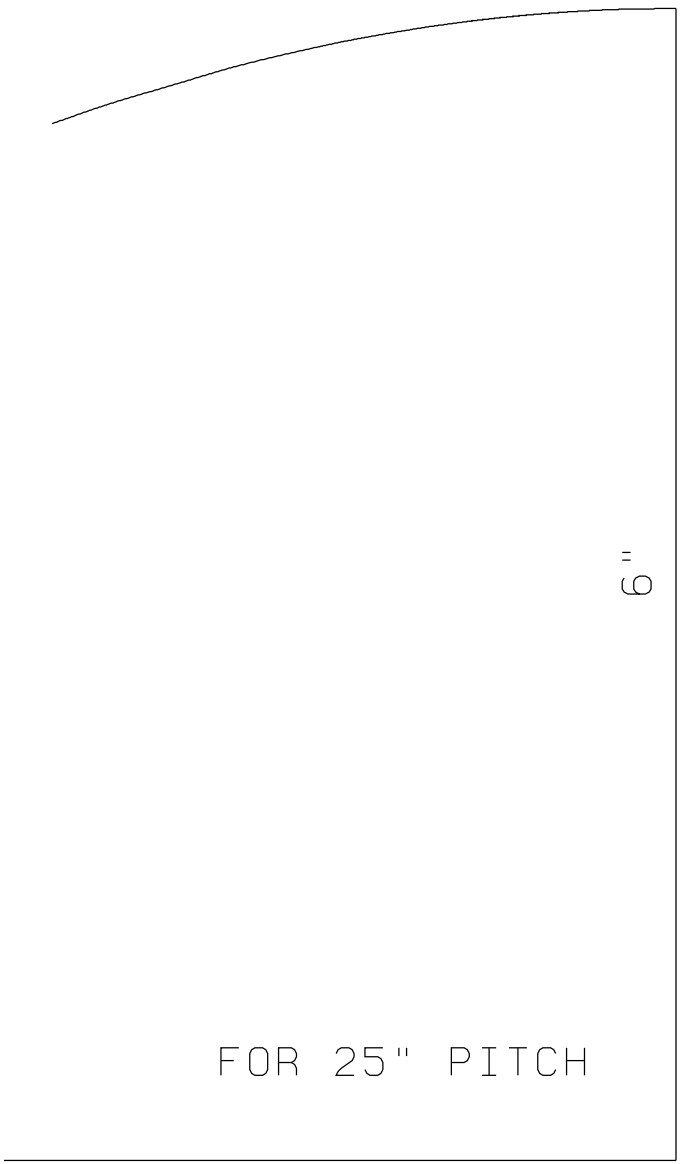


FOR 22" PITCH



FOR 23" PITCH


9"
FOR 24" PITCH


9"
FOR 25" PITCH