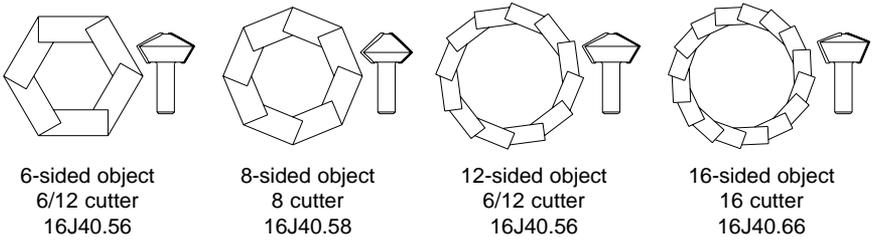



**For better safety, use these bits in a router table only  
— not free hand.**

When making round columns or spars, a bird's-mouth joint can be used as an alternative to a mitered joint. Due to the nesting and increased gluing surface that a bird's-mouth joint provides, it results in a much stronger joint. With these router bits, making bird's-mouth joints has never been easier.

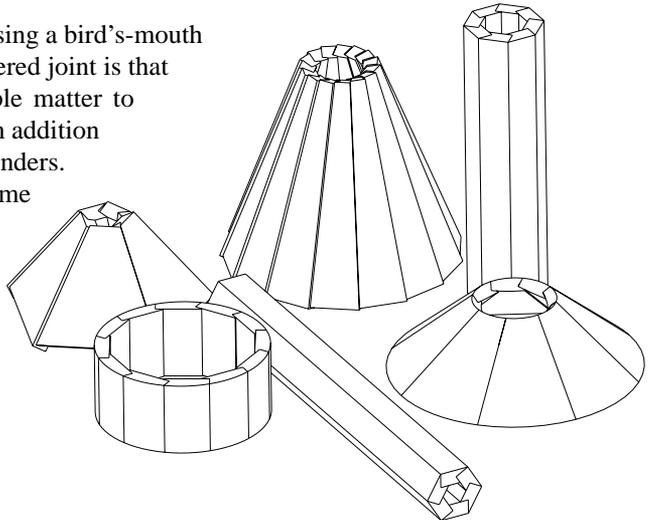
Historically, bird's-mouth joints have been used in the construction of masts, booms and spars for wooden boats. This was the most common application, as the technique allowed for very lightweight, strong and hollow poles. These poles were almost always turned round, but started out as eight-sided columns because they were easy to make with a table saw. With the full set of three cutters it is a simple matter to make columns with 6, 8, 12 or 16 sides. The profile of these columns is shown below as well as the cutter used to make it.



**Figure 1: Profiles of the various columns and cutters used.**

An added benefit of using a bird's-mouth joint rather than a mitered joint is that it is a relatively simple matter to make a faceted cone in addition to parallel-sided cylinders.

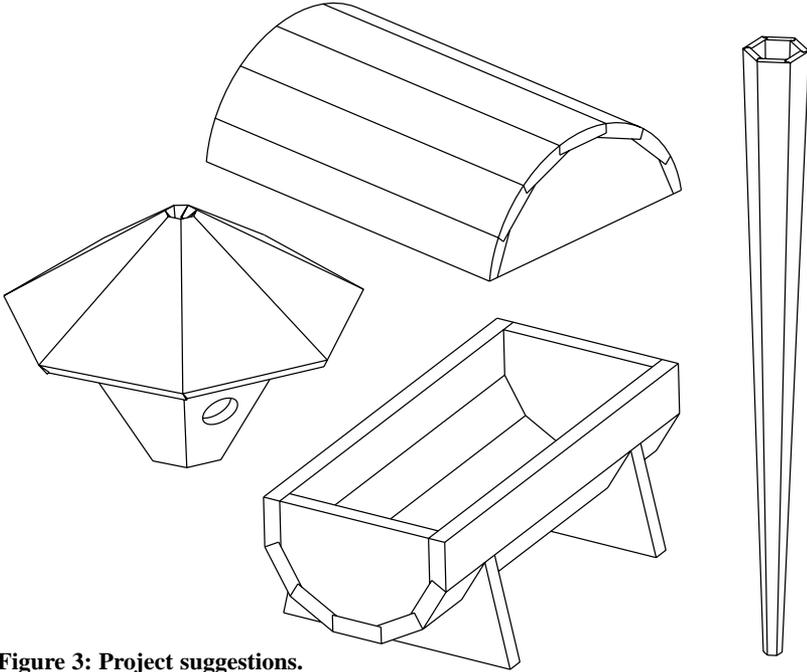
Figure 2 illustrates some cones and cylinders.



**Figure 2: Cones and cylinders that can be made using bird's-mouth joints.**

## **Project Suggestions**

Given the flexibility this type of joint provides, there are numerous projects that could make use of this technique. Some examples are tapered table legs, chest lids, window boxes, wooden gutters, wooden pails, bird feeders, hanging planters, wooden water troughs, etc. Some of these are illustrated in Figure 3.



**Figure 3: Project suggestions.**

## **Making a Round or Faceted Cylinder**

To make a round or faceted cylinder you will need to choose or calculate the following parameters:

1. The number of sides (or staves) required
2. The diameter or distance across the faces
3. The stave width
4. The material thickness

### **Cylinders: Choosing the number of sides**

When making a cylinder, determining what the number of sides will be is rather simple. If you have only the 8-side bit (16J40.58) you will be making an 8-sided object. Similarly, the 16-side bit (16J40.66) makes only 16-sided objects. The 6/12 bit (16J40.56) can be used to make either a 6- or 12-sided object. If, however, you have the complete set of three bits, you will need to choose how many sides you want to use (6, 8, 12 or 16).

## **Cylinders: Choosing the diameter**

The diameter, or distance across the faces, of a project is the main dimension that determines how big the object will be. It is important to decide what this dimension will be early on, as it is used to determine the stave width and thickness. When choosing the diameter, keep in mind that for larger values, a 12- or 16-sided object will use significantly less material and is easier to shape round than a 6- or 8-sided object. For projects that are left faceted, it doesn't matter what the diameter is. In Figure 1, all four shapes are the same size, but it is easy to see that the 16-sided shape uses much less material than the 6-sided shape, and is already very close to a cylinder.

## **Cylinders: Calculating the width of the staves**

Once the number of sides and diameter have been determined, the width of the staves can be calculated. You can use one of the formulae below to determine this dimension.

6-sided object:	Width = Diameter $\div$ 1.7
8-sided object:	Width = Diameter $\div$ 2.4
12-sided object:	Width = Diameter $\div$ 3.7
16-sided object:	Width = Diameter $\div$ 5.0

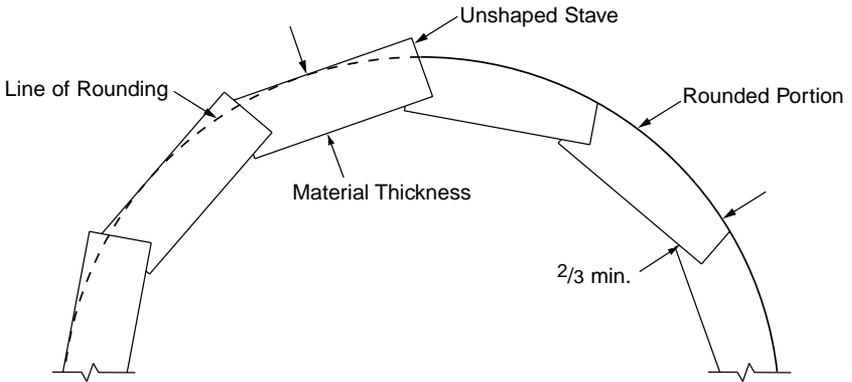
In practice, staves that are about  $1/16$ " wider should be used to allow for error and finishing.

## **Cylinders: Calculating the material thickness**

The last parameter that needs to be determined is the material thickness. You will need to choose whether you want to plane and sand your project round or leave it faceted. If you choose to leave the project faceted, any material thickness may be used. On the other hand, for a given cutter and outside diameter, there is a minimum material thickness that can be used and still made round. This thickness can be determined by using one of the formulae below.

6-sided object:	Thickness = Diameter $\div$ 6.3
8-sided object:	Thickness = Diameter $\div$ 10.1
12-sided object:	Thickness = Diameter $\div$ 20.9
16-sided object:	Thickness = Diameter $\div$ 36.0

Note that these formulae allow for a minimum wall thickness equal to  $2/3$  of the initial minimum material thickness. This occurs at the joint once the item is made round and is illustrated in Figure 4.

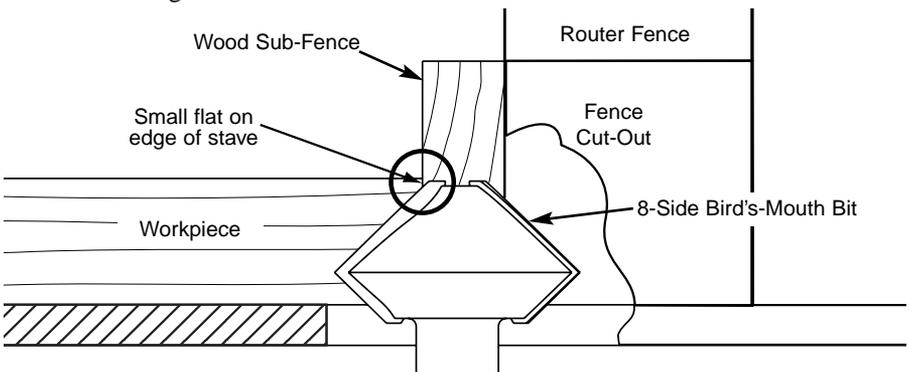


**Figure 4: Partially rounded profile.**

### **Cylinders: Construction**

Once you have determined the number and dimensions of the staves you now have all the information needed to make a round or faceted cylinder. Plane and rip the staves down to the thickness and width determined. You should also make one or two extra partial-length staves to use to set and test your router and fence settings. These need be only 6 or so inches long.

The next step is to cut the bird's mouth. You will need a router table equipped with a fence. Insert the bit in your router. A wooden sub-fence, such as the one that comes with the Veritas® Router Fence, is highly recommended. Adjust the bit height so that the cutter will leave a small flat (approximately  $1/32''$ ) on the top edge of the staves. Without this small flat, the shaped portion of the stave will have nothing to bear against the outfeed area of the fence. The height at which the cutter should be set will depend on which cutter you are using and the style of the outer profile desired: faceted, rounded or ribbed. Refer to the section entitled *Controlling the Fit* for a detailed explanation of bit heights. Setting the bit height and depth of cut is illustrated in Figure 5.



**Figure 5: Setting the bit height and depth of cut.**

Run one of the extra staves through the cutter. Check the fit with one of the uncut staves. You may need to adjust the bit slightly to get the exact fit you want. Once you are satisfied with the way the pieces fit together, make the bird's-mouth cut on only **one** edge of each remaining stave.

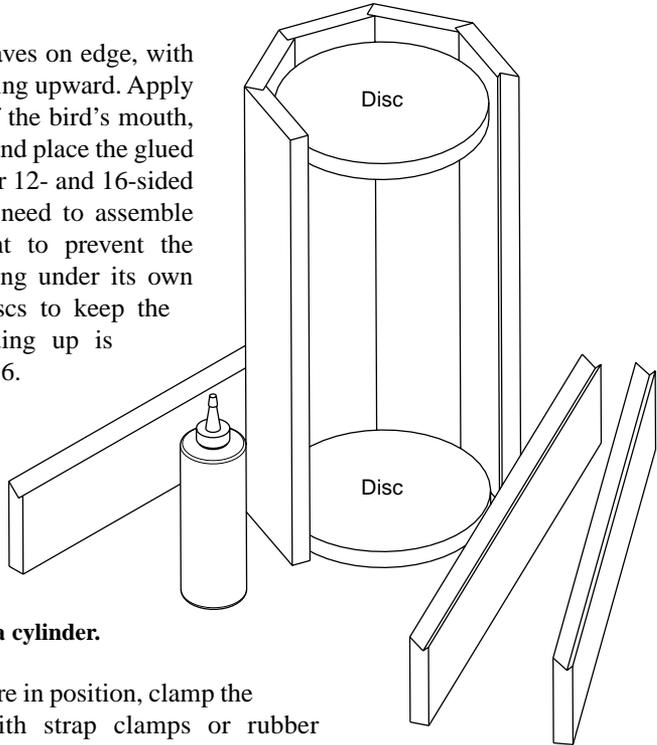
### Cylinders: Assembly

The last step is gluing up the cylinder. This can be tricky for long spars. Enlisting the help of another person or persons will make this a much easier task. To make sure the cylinder remains round, especially for shapes with 12 or 16 sides, cutting a set of discs to fit within the cylinder is quite useful. The diameter of the discs should be equal to the outside diameter of the cylinder minus two material thicknesses.

$$\text{Disc Diameter} = \text{Cylinder Diameter} - \text{Thickness} - \text{Thickness}$$

In practice, making the disc about  $1/16''$  to  $1/8''$  smaller will allow for some error in set-up and assembly.

Lay down all the staves on edge, with the bird's mouth facing upward. Apply glue to the inside of the bird's mouth, one stave at a time, and place the glued stave in position. For 12- and 16-sided cylinders, you will need to assemble the cylinder upright to prevent the shape from collapsing under its own weight. Use the discs to keep the shape circular. Gluing up is illustrated in Figure 6.



**Figure 6: Gluing up a cylinder.**

Once all the staves are in position, clamp the entire assembly with strap clamps or rubber tubing. Getting a second (and maybe a third) person to hold the assembly while the clamps are applied will prevent the shape from becoming distorted.

Once the glue has cured, the cylinder may be shaped and sanded to the final shape (round, faceted or a combination of both).

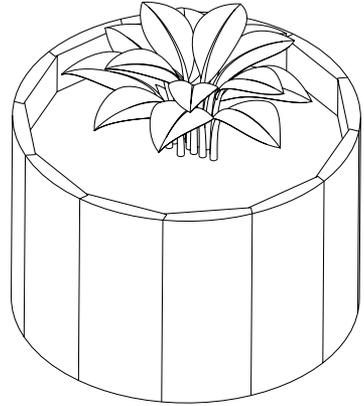
## Cylinders: Example

You are planning to make a small planter like the one illustrated in Figure 7. Your project is going to have an outside diameter of 15". It will be made using the 12-side cutter and will be rounded. This example will illustrate all the steps that are required to make this project.

As you have already chosen the diameter and number of sides, the next step is to calculate the stave width and thickness. Given that the number of sides is 12 and the diameter is 15", the stave width is calculated as follows:

For a 12-sided shape:

$$\begin{aligned}\text{Width} &= \text{Diameter} \div 3.7 \\ &= 15" \div 3.7 \\ &= 4.05" \\ &= 4\frac{1}{16}"\end{aligned}$$



**Figure 7: Example cylinder.**

This should be rounded up (by about a 16th) to  $4\frac{1}{8}"$  to allow for finishing and error.

As you have decided that the planter is to be rounded, it will be necessary to calculate the minimum material thickness. This is done as follows:

For a 12-sided shape:

$$\begin{aligned}\text{Thickness} &= \text{Diameter} \div 20.9 \\ &= 15" \div 20.9 \\ &= 0.718" \\ &= 23/32"\end{aligned}$$

As this is the minimum thickness required that can be made round, there is no problem rounding it up to  $\frac{3}{4}"$ .

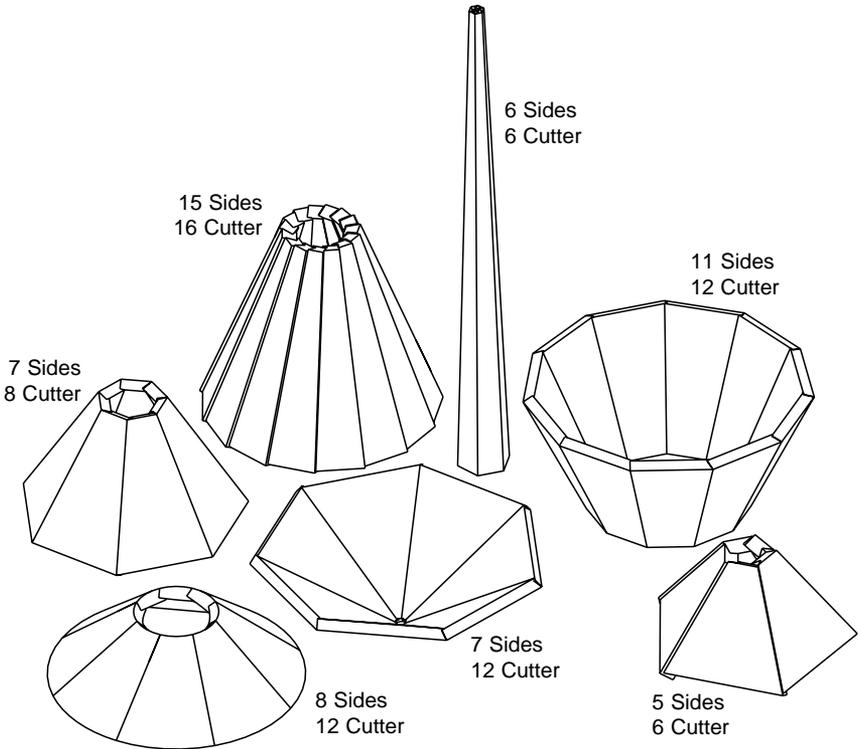
The next step is to prepare the staves and cut the bird's mouth. Since this project has 12 sides, you have decided that gluing up would be made easier if you cut some discs to fit within the assembly. Given that the diameter is 15" and the material thickness is  $\frac{3}{4}"$ , the size of the discs is calculated as follows:

$$\begin{aligned}\text{Disc Diameter} &= \text{Cylinder Diameter} - \text{Thickness} - \text{Thickness} \\ &= 15" - \frac{3}{4}" - \frac{3}{4}" \\ &= 13\frac{1}{2}"\end{aligned}$$

Given that the project is quite large, the diameter of the discs will be rounded down to  $13\frac{1}{4}"$  to allow for error.

## Making a Cone

The procedure for making a cone is very similar to that of a cylinder, with the exception that the staves required to form a cone are tapered. Figure 8 illustrates some of the different types of cones that can be made using these bits.



**Figure 8: Different types of cones that use bird's-mouth joints.**

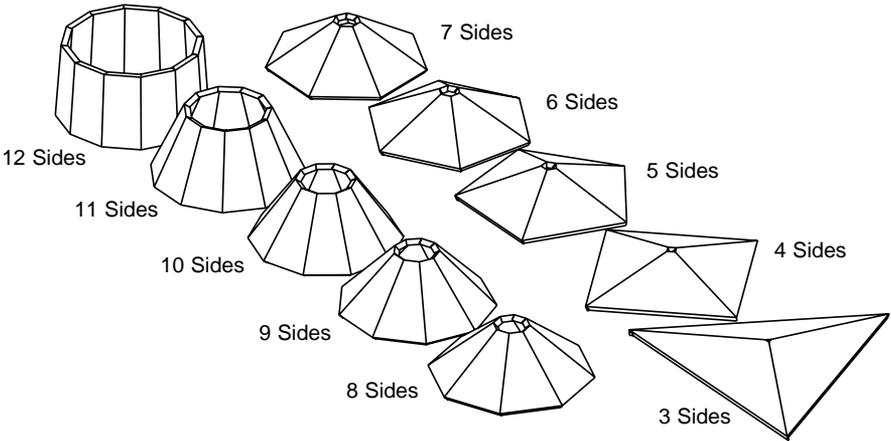
Note that for cones that have a large taper (e.g., pyramid shaped), one or more of the intended number of staves has not been used; the number of sides in the cone is less than the number of sides that the cutter is designated for. This is the other difference between cylinders and cones.

To make a cone you will need to determine the following parameters in a similar manner as for a cylinder.

1. The number of sides (or staves) required
2. The taper on the individual staves
3. The diameter or distance across the faces
4. The stave width
5. The material thickness

## **Cones: Choosing the number of sides**

Choosing the number of sides is trickier when making a cone, for you are not limited to making and using all sides normally required for a given cutter. For example, the 12-side cutter can be used to make a 12-sided cylinder as well as cones with 12, 11, 10, 9, 8, 7, 6, 5, 4 and 3 sides. The number of sides in the cone will determine the overall taper. In the example illustrated below, the 12-sided cone will be very tall with little taper but, as fewer segments are used, the cones will become increasingly flatter and might be more appropriately called pyramids. Figure 9 illustrates the different cones that can be made with the 12-side cutter. You will note that the required taper of each segment changes as fewer segments are used. This is explained below.

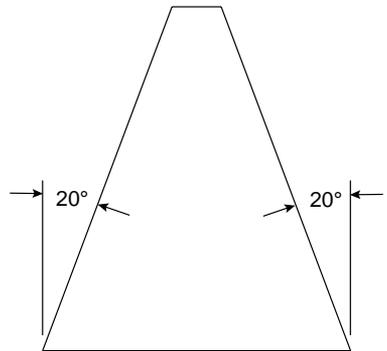


**Figure 9: Cones that can be made with the 12-side cutter.**

The number of sides you choose will be determined by your design.

## **Cones: Calculating the taper on the staves**

The number of sides on the cone will also determine what the angle of the taper should be on the staves. Table 1 can be used to determine what this angle should be for a given number of sides. For example: You are using the 8-side cutter to make a 6-sided cone. Therefore, the taper needed on the staves is  $20^\circ$ . This is illustrated in Figure 10. Table 1 can also be used to determine what the total angle of the finished cone will be.



**Figure 10: The taper on a staff.**

Note that for projects where only a slight taper is desired, refer to the section entitled *Dealing with very shallow taper*.

## **Cones: Calculating the width of the staves**

Calculating the width of the staves for cones is done in a similar manner as for cylinders. Based on the number of sides in the cone and the maximum diameter, the staff width can be calculated using one of the formulae below. Note that the choice of formula to use is based on the number of sides in the cone and not on the cutter used.

16-Sided Cone:	Width = Diameter $\div$ 5.0
15-Sided Cone:	Width = Diameter $\div$ 4.7
14-Sided Cone:	Width = Diameter $\div$ 4.4
13-Sided Cone:	Width = Diameter $\div$ 4.1
12-Sided Cone:	Width = Diameter $\div$ 3.7
11-Sided Cone:	Width = Diameter $\div$ 3.4
10-Sided Cone:	Width = Diameter $\div$ 3.1
9-Sided Cone:	Width = Diameter $\div$ 2.8
8-Sided Cone:	Width = Diameter $\div$ 2.4
7-Sided Cone:	Width = Diameter $\div$ 2.1
6-Sided Cone:	Width = Diameter $\div$ 1.7
5-Sided Cone:	Width = Diameter $\div$ 1.4
4-Sided Cone:	Width = Diameter $\div$ 1
3-Sided Cone:	Width = Diameter $\div$ 0.6

As with cylinders, staves that are about  $\frac{1}{16}$ " wider should be used to allow for error and finishing.

## **Cones: Calculating the material thickness**

As before, deciding whether you want to sand the entire shape round or leave it faceted will determine what material thickness to use. One of the following formulae can be used to calculate the minimum material thickness for rounded cones. Note that once again the choice of formula to use is based on the number of sides in the cone and not on the cutter used.

3-Sided Cone:	Thickness = Diameter $\div$ 2.7
4-Sided Cone:	Thickness = Diameter $\div$ 3.6
5-Sided Cone:	Thickness = Diameter $\div$ 4.8
6-Sided Cone:	Thickness = Diameter $\div$ 6.3
7-Sided Cone:	Thickness = Diameter $\div$ 8.1
8-Sided Cone:	Thickness = Diameter $\div$ 10.1
9-Sided Cone:	Thickness = Diameter $\div$ 12.4
10-Sided Cone:	Thickness = Diameter $\div$ 14.9
11-Sided Cone:	Thickness = Diameter $\div$ 17.8
12-Sided Cone:	Thickness = Diameter $\div$ 20.9
13-Sided Cone:	Thickness = Diameter $\div$ 24.3
14-Sided Cone:	Thickness = Diameter $\div$ 27.9
15-Sided Cone:	Thickness = Diameter $\div$ 31.8
16-Sided Cone:	Thickness = Diameter $\div$ 36.0

## **Cones: Assembly**

Gluing up a cone is done in the same manner as a cylinder, a single stave at a time. However, due to some of the strange angles being dealt with, there are a number of items that may be useful to have handy:

- Rubber tubing
- Masking tape
- Pinch dogs
- An assistant

## **Cones: Example**

You are planning to make a birdhouse like the one shown in Figure 3. This project has seven sides. The roof uses the 12 cutter and the body uses the 8 cutter. To calculate the taper on the staves, use Table 1. For the roof, a 7-sided cone that is made with the 12-side cutter will have staves that are tapered by  $21^\circ$ . For the body, a 7-sided cone that is made with the 8-side cutter will have staves that are tapered by  $13^\circ$ .

Calculating the width and thickness of the staves is done using the formula for 7-sided objects listed in the *Cones: Calculating the width of the staves* and *Cones: Calculating the material thickness* sections. Note that even though you are using the 8- and 12-side cutters, the choice of formula to use is driven by the number of sides in the object, in this case, seven.

## **Cones: Dealing with very shallow taper**

For some projects, the desired taper of the cone will be very low. Boat masts and flagpoles are perfect examples of this type of project. In both cases, the taper of the object is less than  $5^\circ$ . When this occurs, the number of sides in the object will be the same as the cutter designation and Table 1 cannot be used to determine the taper on the staves (it would be 0.) Instead, Table 2 should be used. However, before you can look up the taper on the staves, you will need to decide what the entire taper of the object should be. On masts and flagpoles, this can be as little as  $1^\circ$  or  $2^\circ$ . For convenience, Table 2 also lists what the horizontal deviation will be over a 10" length.

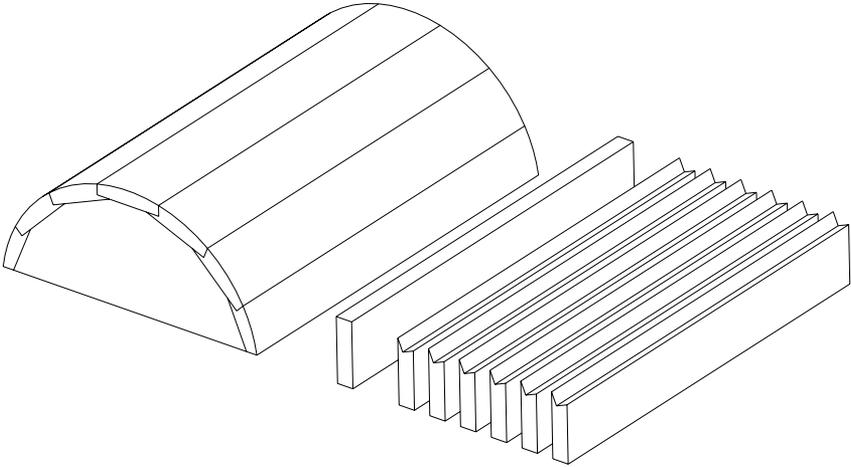
For example, you are planning to make a mast for a boat. The desired taper over the length of the mast is  $1^\circ$  from vertical. The number of sides in the mast will be 8. Thus from Table 2, the taper required on each stave is  $0.8^\circ$ . For this type of object, Table 2 lists the total taper required on the stave. This taper can be applied entirely to one side of each stave or divided in two and applied to both sides.

In order to facilitate the cutting of such a small taper, Table 2 also lists the horizontal deviation over 10". Thus in the case of the mast, for each 10" of length, the staves

will get narrower by  $\frac{9}{64}$ ". If the mast is going to be 120" long (10') the total deviation over the length of the mast will be  $1\frac{11}{16}$ " ( $12 \times \frac{9}{64}$ ").

### **Making a Chest Lid**

The third application of the bird's-mouth joint is for a chest lid. The procedure for making a chest lid is exactly the same as that for making a cylinder. The key difference is that fewer staves are required. Figure 11 illustrates an example of a chest lid and the set of staves used to create the lid.



**Figure 11: Example chest lid.**

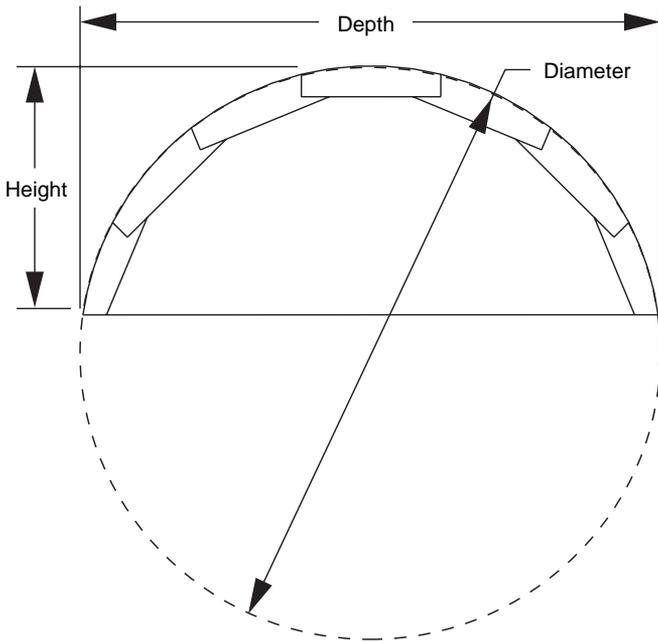
To make a chest lid, you will need to choose or calculate the following items:

1. Which cutter you will be using
2. The depth of the mating chest
3. The desired height of the lid
4. The diameter of the lid
5. The number of staves required
6. The stave width and thickness

### **Chest Lids: Calculating the diameter**

By working out what the diameter of the lid will be, you can use the cylinder formula to determine stave width and thickness. To calculate the diameter you will need to know the depth of the chest and the desired height of the lid. Once you know these two dimensions, you can use the formula below to calculate the diameter.

$$\text{Diameter} = \text{Depth} \times \text{Depth} \div 4 \div \text{Height} + \text{Height}$$



**Figure 12: Equation dimensions.**

### **Chest Lids: Calculating the number of staves**

When using the bird's-mouth cutters, a chest lid is very similar to a cylinder, the only difference being that fewer staves are used than would be required for a full cylinder.

To figure out the number of staves required for the lid, use one of the following formulae based on the cutter you will be using.

- 6-side cutter:    Number of Staves =  $6 \times \text{Height} \div \text{Depth} + 0.2$
- 8-side cutter:    Number of Staves =  $8 \times \text{Height} \div \text{Depth} + 0.3$
- 12-side cutter:   Number of Staves =  $12 \times \text{Height} \div \text{Depth} + 0.4$
- 16-side cutter:    Number of Staves =  $16 \times \text{Height} \div \text{Depth} + 0.5$

This will give a number with a decimal place. Simply round the number up to the next whole number to determine the number of staves required.

### **Chest Lids: Calculating the stave width and thickness**

To calculate the stave width and thickness for chest lids, the same formulae that are used for cylinders can be used. Keep in mind that the choice of formula to use is based on the cutter and not on the number of sides in the lid. So if the 16-side cutter is being used and the number of staves in the chest lid was 6, you would use the cylinder equations pertaining to 16-sided objects.

## Chest Lids: Example

You are planning to make a chest lid using a 16-side bird's-mouth cutter. The chest is 24" deep and the lid is to be 8" tall. Thus the diameter will be 26", calculated as follows:

$$\begin{aligned}\text{Diameter} &= \text{Depth} \times \text{Depth} \div 4 \div \text{Height} + \text{Height} \\ &= 24'' \times 24'' \div 4 \div 8'' + 8'' \\ &= 26''\end{aligned}$$

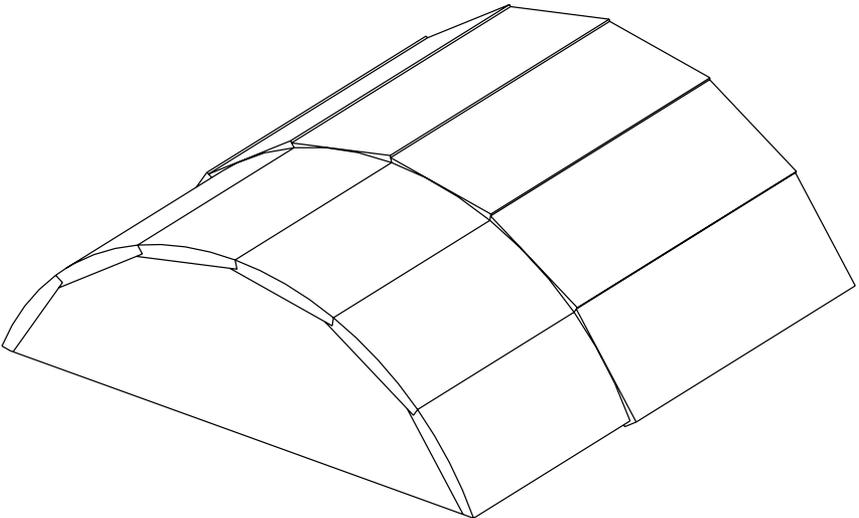
Using the above formula for the number of staves and the stave width formula from the cylinder section, you will find that 6 staves, 5.2" wide, are needed. These numbers are calculated as follows:

For a 16-side cutter:

$$\begin{aligned}\text{Number of Staves} &= 16 \times \text{Height} \div \text{Depth} + 0.5 \\ &= 16 \times 8'' \div 24'' + 0.5 \\ &= 5.83 \text{ rounded up to } 6\end{aligned}$$

$$\begin{aligned}\text{Stave Width} &= \text{Diameter} \div 5.0 \\ &= 26'' \div 5.0 \\ &= 5.2''\end{aligned}$$

As before, the width of the stave should be increased by about  $\frac{1}{16}''$  to  $5\frac{1}{4}''$  in order to allow for error and finishing. Figure 13 illustrates what this lid will look like. The first part of the lid has been shaped round.



**Figure 13: Partially rounded chest lid.**

If you have decided that you want to shape the lid smooth, by using the thickness formula in the cylinder section, you will see that the minimum stave thickness required is 0.72". This is calculated as follows:

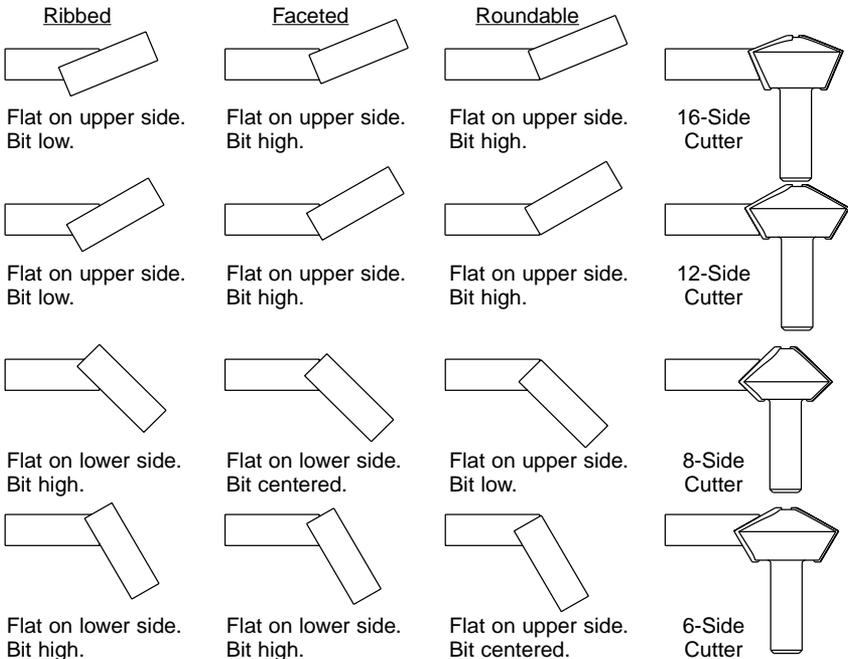
For a 16-sided object:

$$\begin{aligned} \text{Thickness} &= \text{Diameter} \div 36.0 \\ &= 26'' \div 36.0 \\ &= 0.72'' \end{aligned}$$

Once you know the stave width and thickness, the shaping and assembly is the same as that for cylinders. Glue up the arc first, then make the end pieces to fit. This will ensure that there are no gaps.

### Controlling the Fit

When using the bird's-mouth cutters, the position of the cut has a significant effect on the size and finishing requirements of the resultant shape. By optimizing the position of the cutter the amount of overhang can be minimized, thus resulting in the largest shape possible and the least amount of work required to shape it faceted or round. However, if your design calls for a fluted or ribbed shape, overhang minimization is not required. For the 16-side and 12-side cutter, overhang is minimized when the bit is raised quite high. When using the 8-side or 6-side cutter, overhang is minimized when the bit is lowered. This is best illustrated in Figure 14.



**Figure 14: Positioning the cutter.**

## Reference Tables

Number of Sides On A Cone	6-Side Cutter		8-Side Cutter		12-Side Cutter		16-Side Cutter	
	Stave Taper	Cone Taper	Stave Taper	Cone Taper	Stave Taper	Cone Taper	Stave Taper	Cone Taper
3	55	55	57	64	59	73	59	77
4	35	45	40	57	43	69	44	74
5	21	32	29	49	33	64	34	71
6	0	0	20	40	26	59	28	67
7			13	28	21	53	23	63
8			0	0	17	47	20	59
9					13	41	17	55
10					10	33	14	51
11					7	23	12	46
12					0	0	10	41
13							8	35
14							6	29
15							4	20
16							0	0

**Table 1: Angles for cones.**

Taper From Vertical (degrees)	6-Side Cutter		8-Side Cutter		12-Side Cutter		16-Side Cutter	
	Stave Taper (degrees)	Deviation over 10" (inches)	Stave Taper (degrees)	Deviation over 10" (inches)	Stave Taper (degrees)	Deviation over 10" (inches)	Stave Taper (degrees)	Deviation over 10" (inches)
0.25	0.3	3/64	0.2	1/32	0.1	1/64	0.1	1/64
0.5	0.6	3/32	0.4	1/16	0.3	1/32	0.2	1/32
0.75	0.9	9/64	0.6	3/32	0.4	1/16	0.3	3/64
1	1.2	3/16	0.8	9/64	0.5	5/64	0.4	1/16
1.25	1.4	1/4	1.0	11/64	0.7	7/64	0.5	5/64
1.5	1.7	19/64	1.2	13/64	0.8	1/8	0.6	3/32
2	2.3	25/64	1.7	9/32	1.1	11/64	0.8	1/8
2.5	2.9	1/2	2.1	23/64	1.3	7/32	1.0	11/64
3	3.5	19/32	2.5	27/64	1.6	17/64	1.2	13/64
4	4.6	51/64	3.3	37/64	2.1	23/64	1.6	17/64
5	5.8	1	4.1	23/32	2.7	29/64	2.0	11/32

**Table 2: Angle for shallow cones.**



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