Tube, Tip, and Aperture: The Functional Geometry of your Bassoon Reed

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It is fun to go shopping for shapers or shaper tips—reed-making bassoonists never seem to tire of it. Through the single act of choosing a particular shape, however, the bassoonist is making multiple design decisions about how the resulting reeds are going to respond. If the player is completely happy with his or her results—ideal response, ideal tone quality, and ideal dynamic range, then there is no reason to complain, or to question the choice. But assuming that a bassoonist might like to improve on one or more of these qualities, how can we evaluate all these different shape possibilities?

A given shaper has a primary characteristic called the tip-to-tube ratio. Once you commit to a particular shape, this ratio can be varied only within narrow limits. Within a range of practical blade lengths, a given tip-to-tube ratio has a predictable effect on the reed's aperture—the opening at the tip. The basic personality of your reed's response can be predicted from the shape of its aperture. This discussion will focus on the geometric interplay of these elements—tube, tip, and aperture—and on some significant surrounding conditions.

The user of a given shape sometimes takes for granted certain other important factors—wire placements, the trim or scrape, the cane quality, the gouge thickness, for example—which also are part of the recipe. These factors, which allow the reed maker to make successful use of a favored shaper, are little discussed here. They are important management tools, although they will not negate the underlying tendencies and relationships described below.[1]

Aperture, Tip, and Tube

The bassoon reed is comprised of two blades (comprising the "northern" half of the reed), and a tube (comprising the "southern" half). The geometric relations of these halves occur in two different dimensions: the transverse dimension (east vs. west), which is discussed here in terms of the tip-to-tube ratio, and the longitudinal dimension (north vs. south), discussed here in terms of leverage and wire adjustments. These two mechanical systems, intersecting in a complex fashion in the reed's aperture (and further complicated by the persistent influence of the cane's original curvature) give the reed many of its response characteristics. The effects of these elements, which can be separated and predicted, are discussed here within the framing question of the bassoonist's chosen reed shaper.

The **aperture** is a two-dimensional void—the planar open space between bottom blade and top blade, as viewed from the player's customary vantage point. The cyclic opening and closing of the aperture serves as the tone generator of the bassoon.

The length of the blade is a factor in the size of the aperture: the longer the blade, the more closed the tip will be, other factors being equal. If we view the unshortened blades in profile, they form a triangle; when we shorten the blades with a knife or tip cutter, we remove the apex of triangle, creating a gap, which we call the aperture. The more the blank is shortened, the taller the gap in the center of the aperture tends to be.

Apertures have traditionally been described along a spectrum, its extremes being a wholly convex shape (traditionally called "French") and a shape with "collapsed corners" (traditionally called "German," although these stereotypes are now outdated). To speak in dichotomous terms, a convex shape has a lively sound and a sudden attack, while a shape with collapsed corners has a more subdued sound and more resistance, making the attack a more deliberate process.

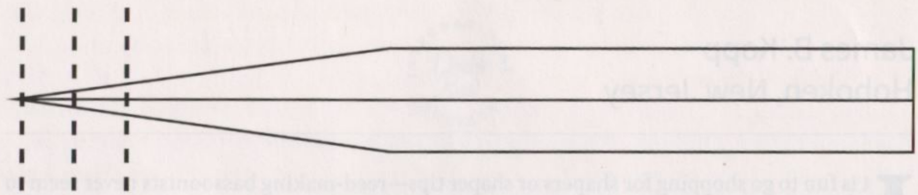


Fig. 1a. The reed blank viewed in profile. The more the blank is shortened, the taller the aperture becomes.

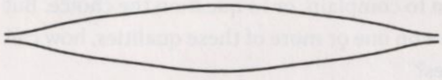


Fig. 1b. Aperture with convex shape.

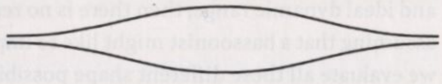


Fig. 1c. Aperture with collapsed corners.

The **tip** is the cane that surrounds the aperture. We are concerned here only with the width of the tip, although the thickness of the tip is a contributing factor in the reed's functioning. The portion of the blades south of the tip have a separate and important function: as the point of contact between the player's embouchure and the reed, they allow the player to influence both the timbre and pitch of the reed response.

The **tube** is defined here as including the collar, the throat and the butt. The primary function of the tube is to couple the blades to the crook or bocal. (An important secondary function is described below.) The blades end just north of the "bark" or rind of the tube. This rind may end just barely north of the top wire (wire 1), or it may, in some reed designs, extend up to 3 mm north of wire 1. Any portion of the tube extending north of wire 1 is called the **collar**. (The difference in elevation between the collar and the blade can be called the "step," to avoid confusion.) The step and collar, marking the southern border of the blades, reflect most longitudinal vibrations of the blades back towards the reed's tip. (But not quite all; loosening wire 1 on a reed often has an effect on the reed's response. This operation, which is an ingredient in some reed designs, demonstrates that wire 1, when taut, provides a second point of reflection, in addition to the collar.) The **throat** is the portion of the tube having the narrowest inside diameter; this is typically located at the second wire, or between wires 1 and 2.

The **tip-to-tube ratio**, as defined here, refers to the width of the tip (of the finished reed), divided by the width of the tube (measured with a caliper above the collar (when present) or first wire.[2] Most such ratios will fall within the range 1.5:1 to 2:1. For example, a tip width of 15 mm, divided by a tube width of 8.5 mm, gives a ratio of ca. 1.76. (Calculating the exact ratio is less important than understanding this general principle.)[3]

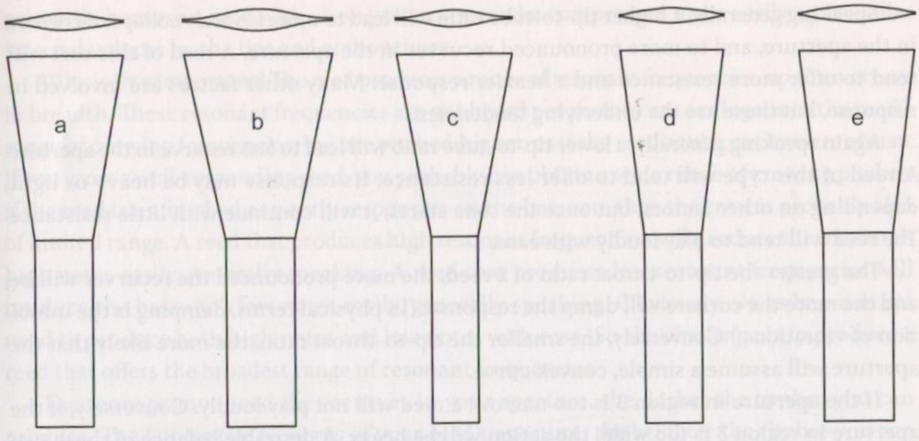


Fig. 2. Shapes with contrasting tip-to-tube ratios (below) and the resulting apertures (above). Shape (a) has an average ratio. The ratio is larger in shapes (b) and (c), and smaller in (d) and (e). The principle is more important than the specific numerical ratios.

The shape, thickness, and hardness of the cane within the tube contribute to the reed's aperture shape and response in predictable ways. These too are discussed below.

What Your Aperture is Trying to Tell You

Let's look into the aperture of a moistened reed and divide it into five regions; from left to right these are the left corner, the left mid-portion, the center, the right mid-portion, and the right corner.

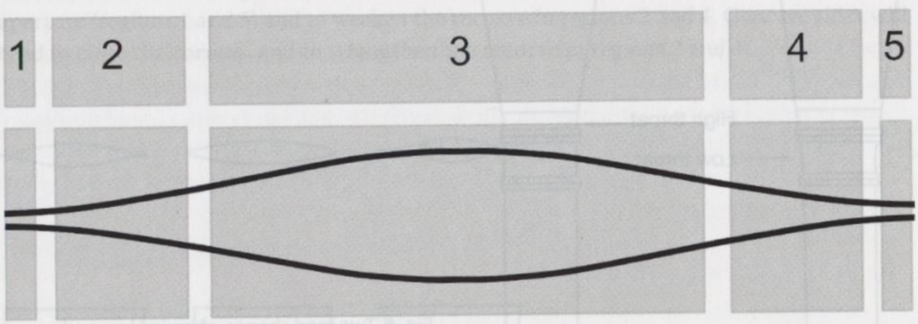


Fig. 3. The regions of an average reed aperture (after moistening). Regions 1 and 5 are the corners; region 3 is the center or primary curve; regions 2 and 4 are the mid-portions, sometimes containing secondary curves (recurves).

If we number from left to right, the corners are regions 1 and 5, the center is region 3, and the mid-portions are regions 2 and 4. The primary curve of the aperture is the convex curve present at region 3. The secondary curve of the aperture, present in most but not all bassoon reeds, will be visible in regions 2 and 4. This secondary curve is concave rather than convex; in other words, it reverses the direction of the primary curve. If pronounced enough, it is sometimes compared to a "cupid's bow," which an archer would call a recurve bow. We'll borrow this term, recurve, to describe the secondary curves found in the aperture. (They could also be called reflex curves; some authors, including **Hugh Cooper** and **Jean-Marie Heinrich** have used the term degenerative curve.)[4]

Speaking generally, a higher tip-to-tube ratio will lead to more severely collapsed corners in the aperture, and to more pronounced recurves in the aperture. A reed of this sort will tend to offer more resistance and a heavier response. Many other factors are involved in response, but these are the underlying tendencies.

Again speaking generally, a lower tip-to-tube ratio will lead to less recurve in the aperture. A reed of this type will tend to offer less resistance. Its response may be heavy or light, depending on other factors, but once the tone starts, it will continue with little resistance. The reed will tend to play loudly with ease.

The greater the tip-to-throat ratio of a reed, the more pronounced the recurves will be, and the more the corners will damp the response. (In physical terms, damping is the inhibition of vibrations.) Conversely, the smaller the tip-to-throat ratio, the more likely that the aperture will assume a simple, convex curve.

If the aperture in region 3 is too narrow, a reed will not play loudly. Conversely, if the aperture in region 3 is too wide, the action will be heavy. A desirable balance of these two response issues can be addressed through the trim or through wire adjustments, but an underlying tendency is created through the chosen shape.

Location of the Throat

Different shapers locate the throat higher or lower within the tube. These factors affect the tip-to-tube ratio in predictable ways. The shape of the tube at wires 1 and 2 will vary according to where the throat is located.

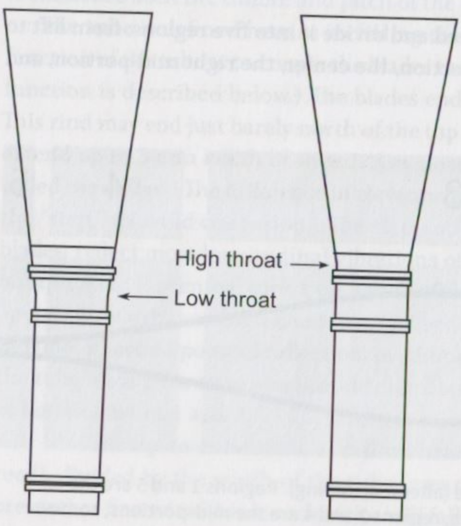


Fig. 4. Two reed shapes, showing low and high locations for the throat.

If the throat is low (below the placement of wire 1), then the tip-to-throat ratio will be slightly higher, and the "neutral" condition of wire 1 (that is, before adjustments) will probably be more or less oval. If the throat is high (at the placement of wire 1), then the tip-to-throat ratio will be slightly lower, and wire 1 will be round, or nearly so. A shaper with a low throat will have weaker recurves, other conditions being equal, than a shaper with a high throat.

Effects of the Secondary Curves of the Aperture

The secondary curves of a reed (the recurves) also affect the reed's overblowing and timbre. If the recurves are pronounced, the reed will tend to play higher notes more easily. This is primarily because a reed with strong recurves can be compressed more easily to a smaller internal volume by the lips and embouchure.

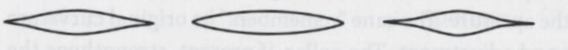
Why is this important? The reed produces a range of resonant frequencies, up to an octave in breadth. These resonant frequencies are not heard per se; they are analogous to the reed's range of crowing frequencies, but are pitched higher, as if the reed's tube cavity were absent. If you crow a well-responding reed, you probably can obtain a wide range of crowing pitches; if the reed is unfinished or poorly responsive on the bassoon, then the crow is probably also of limited range. A reed that produces high resonant frequencies will produce the bassoon's high notes easily, generally speaking. A reed that produces low resonant frequencies will produce the bassoon's low notes easily, generally speaking. Obviously, we as bassoonists need to produce both high notes and low notes with ease. So the challenge is to produce a reed that offers the broadest range of resonant frequencies.

The more pronounced the recurves in your aperture, the darker the timbre you can produce. The fainter the recurves of your reed's aperture, the brighter the timbre you can produce. Most bassoonists will prefer a result somewhere between the two extremes.

The larger the aperture in region 3, the greater the maximum obtainable volume. But this desirable effect must be balanced with another factor, also at work here: the resistance. If the recurves (regions 2 and 4) are strong, the resistance to blowing will be strong, and the player will have to work harder to produce the obtainable volume. Some players will welcome this heavier response, and others will not.

Sides of the Blade: Straight, Concave, or Convex

We've been speaking as if the long sides of the blade are always straight. This is a common characteristic, but some shapers produce blades with that have convexly or concavely curved sides. The curves will have predictable effects on the aperture, exaggerating or mitigating the basic effect of the tip-to-tube ratio. Convex sides will tend to open the corners of the aperture (regions 1 and 5) and to weaken the recurve in regions 2 and 4. Concave sides will tend to close the corners, and to strengthen the recurve in regions 2 and 4.



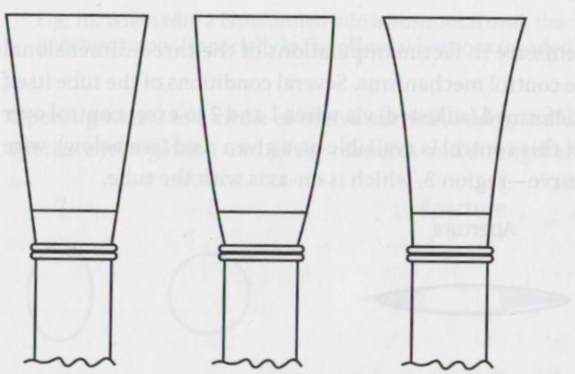


Fig. 5a Fig. 5b Fig. 5c

Fig. 5. Three shapes having identical tip-to-tube ratios, demonstrating the effects of curved sides (rails). From left, the blades of shape (a) have straight sides; the blades of shape (b) have convex sides; the blades of shape (c) have concave sides.

Lingering Influence of the Original Arc

The formed reed is an artificial deformation of the cane's original cylindrical shape. The original curvature is in fact present in the blades at some latitude, usually at or south of the midpoint. South of this "equator," the cane is progressively rounded into the tube; north of the equator, the cane is progressively flattened into the fold. In the unopened blank, the blades-to-be meet in a single plane, in contrast to the original arc of the gouged cane. The broader the tip, the longer the arc that has been flattened.

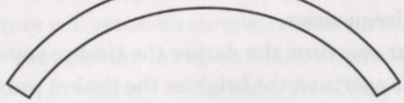


Fig. 6a. The natural arc of a piece of bassoon cane before forming.

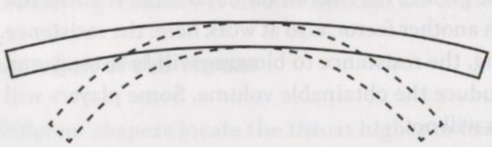


Fig. 6b. The flattened arc at the tip aperture of the same piece of cane, shown after the reed blank is formed and opened. Dotted lines show the original arc.

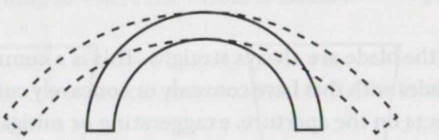


Fig. 6c. The tighter arc of the tube portion of a formed bassoon reed blank, shown at the first wire. Dotted lines show the original arc.

Clipping the tip prior to trimming allows the two blades to make a partial return to their original arc. This resilience – the tendency of the cane to revert to its original cylindrical shape – strengthens the blade's primary curve. Further trimming (or scraping) of the blades tends to introduce more recurve to the aperture. The cane "remembers" its original curvature throughout the phases of finishing and adjustment. The collar, if present, strengthens the effect of the original curvature.

The Tube: Enhancing Wire Adjustments

What we often call wire adjustments are in fact manipulations of the three-dimensional tube; we simply use the wires as the control mechanisms. Several conditions of the tube itself govern whether it can be usefully deformed (adjusted) via wires 1 and 2 to exert control over the aperture shape. Assuming that this control is available on a given reed (see below), wire 1 will tend to affect the primary curve—region 3, which is on-axis with the tube.

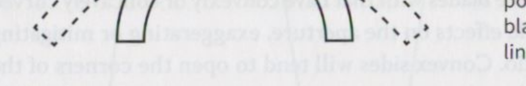


Fig. 7a. Schematic representation of the effects of wire deformation on the reed's aperture. In this "neutral" adjustment, wire 2 is round, wire 1 is round, and the aperture is a medium ellipse.

Flattening wire 1 to a horizontal oval will tend to close the aperture in region 3, weakening the recurves.

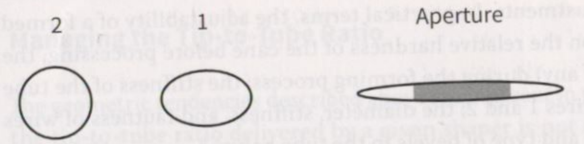


Fig. 7b. When wire 1 is deformed into a horizontal oval, the aperture closes, especially in the axial portion (shaded).

Opening wire 1 to a circle or a vertical oval (not always possible) will tend to open the aperture in region 3, strengthening the recurves.

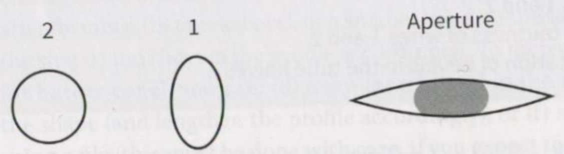


Fig. 7c. When wire 1 is deformed into a vertical oval, the aperture opens, especially in the axial portion (shaded).

Wire 1 also acts as a fulcrum, inverting the effect of wire 2 and lending it a sort of leverage that can be used to control regions 1 and 5 (the corners); these regions, being off-axis with the tube, are little affected by wire 1. Regions 2 and 4 will mediate the tendencies of the other regions, producing a stronger or weaker recurve according to the wire adjustments and the tip-to-tube ratio.

Flattening wire 2 to a horizontal oval will tend to open the aperture in regions 1 and 5 (the corners). The recurves will be weakened, and the opposing corners may, in some reed designs, stand slightly open.

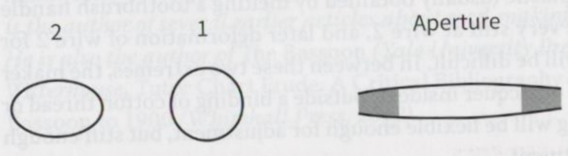


Fig. 7d. When wire 2 is deformed into a horizontal oval, the aperture opens, especially in the off-axial portions (shaded).

Opening wire 2 to a circle or even a vertical oval (not always possible) will tend to close the aperture in regions 1 and 5 (the corners), and strengthen the recurves.

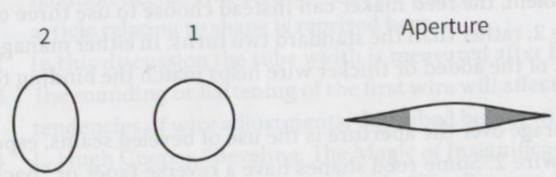


Fig. 7e. When wire 2 is deformed into a vertical oval, the aperture closes, especially in the off-axial portions (shaded), often increasing the secondary curves (recurves).

Managing the Tube Stiffness

Several characteristics of the tube will have predictable effects that tend to maximize or minimize the effects of wire adjustments. In practical terms, the adjustability of a formed bassoon reed tube will depend on the relative hardness of the cane before processing, the further hardening of the cane (if any) during the forming process; the stiffness of the tube binding; the distance between wires 1 and 2; the diameter, stiffness, and tautness of wires 1 and 2; and the presence (if any) and type of bevels in the tube halves.[5]

The leverage of a bassoon reed's tube over the aperture depends on:

- relative hardness of the cane before processing
- further hardening of the cane (if any) during the forming process
- stiffness of the tube binding
- distance between wires 1 and 2
- diameter, stiffness, and tautness of wires 1 and 2
- presence (if any) and location of bevels in the tube halves

If the cane selected for the reed is very hard, it will be resistant to deformation, and the tube's effect on the aperture will be minor or non-existent. If the cane selected for the reed is very soft, then it can be readily deformed, but the soft tube will not be stiff enough to transmit the deformation efficiently to the aperture, and the effect will again be minor or non-existent. The tube's maximal effect on the aperture is achieved when the cane is somewhere in a middle range—soft enough to be deformable, but hard enough to transmit the deformation over the fulcrum (wire 1) to the aperture. The reed maker may, without realizing it, effectively harden the cane during the process of forming the reeds. This tends to happen if the chosen forming process involves a lot of kneading the tube with pliers.

The effects of different bindings will be analogous to the effects of the stiffness of the tube itself. If the reed has no binding, or only a soft binding (shrink-wrap tubing or uncoated cotton thread, for example), the binding will contribute little or no stiffening to the tube. If the maker adds a binding of hard plastic (usually obtained by melting a toothbrush handle in acetone), the tube will become very stiff at wire 2, and later deformation of wire 2 for purposes of aperture adjustment will be difficult. In between these two extremes, the maker may choose to add coats of cement or lacquer inside or outside a binding of cotton thread or nylon thread. The resulting binding will be flexible enough for adjustment, but stiff enough to reinforce the chosen wire adjustment.

A greater distance between wires 1 and 2 will tend to lead to increased leverage in wire adjustments to the tip[6] (as long as the cane, wires, and binding are in the desired ranges of hardness and flexibility). If the wires are not stiff enough to give leverage over the aperture, the reed maker can substitute a thicker-gauge wire (especially at wire 2), increasing control over the aperture. A heavy wire sometimes does not conform perfectly to the surface of the reed tube. To circumvent this problem, the reed maker can instead choose to use three or four complete turns of wire at wire 2, rather than the standard two turns. In either management strategy, the stiffening effect of the added or thicker wire helps match the binding to the stiffer piece of cane.

Another means of gaining leverage over the aperture is the use of beveled seams, especially a bevel located at or below wire 2. Some reed shapes have a reverse taper or "back flare"—a widening of the shape near the butt (the southernmost part of the reed, providing the socket for insertion of the crook or bocal tip). This flare, if present, will usually require that the reed maker undertake beveling under wire 3, in order to arrive at a suitable inside

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diameter of the butt.[7] A full discussion of bevel types and their particular effects is beyond the scope of this article. For a systematic discussion, see L. Hugh Cooper, "Beveling: The Magic of Insignificant Splinters," *The Double Reed* 28/4 (2005): 77–84.

Managing the Tip-to-Tube Ratio

The geometric tendencies described above are inherent in your chosen shape. But in practice the tip-to-tube ratio delivered by a given shaper is not absolutely consistent, due to the variability of the cane supply. Cane compresses most easily in the axial dimension—from outside to inside. Softer cane will tend to form a tube of smaller diameter than hard cane. As a result, we can predict that softer cane will lead to an increased tip-to-tube ratio, while harder cane will lead to a decreased tip-to-tube ratio.

A few late-stage techniques are available to decrease the tip-to-tube ratio (within limits, and at a cost of some inconvenience). To manage for softer cane, you can: (a) narrow the tip after forming, (b) use no bevel, or a smaller bevel on the tube, or (c) locate the wires higher on the shape (and shorten the profile accordingly). To increase the tip-to-tube ratio (managing for harder cane), you can: (d) use a larger bevel in the tube, (e) locate the wires lower on the shape (and lengthen the profile accordingly), or (f) narrow the throat prior to forming, using a file (this must be done with care, if you expect to maintain precise work tolerances).

Predictability is the reed maker's friend. The geometrical aspects of reed shapes described above make for reliable predictions about important response characteristics. If you are seeking a specific result from a different shape or shaper, these known tendencies will help you make informed choices.

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*Thanks to **Barrick Stees**, who read this article in draft and provided several helpful comments.*

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Endnotes

1 The trim of the reed, the gouge thickness and the gouge shape are aspects of the reed's axial dimension, which is discussed in James B. Kopp, "Physical Forces at Work in Bassoon Reeds," *The Double Reed* 26/2 (2003): 69–81. Some discussion from the 2003 article relating to shape is reprised here.

2 In this discussion the tube width is measured after forming.

3 The rounding or flattening of the first wire will affect the tip-to-tube ratio, but the basic tendencies of wire adjustments, described below, will be more important.

4 L. Hugh Cooper, "Beveling: The Magic of Insignificant Splinters," *The Double Reed* 28/4 (2005): 77–84; Jean-Marie Heinrich, "The Bassoon Reed," *Journal of the International Double Reed Society* 7 (1979): 17–43.

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5 Stiffness is not the same quality as hardness, at least in concept. But in the broad range of Arundo donax available for making bassoon reeds, the qualities of stiffness and hardness appear to be strongly correlated. For practical purposes, we will equate the two qualities in this discussion.

6 But this is sometimes negated if wire 2 is close to the end of the inserted bocal tip, which will then tend to round the tube near wire 2.

7 For discussion, see James R. McKay, Russell Hinkle, and William Woodward, *The Bassoon Reed Manual: Lou Skinner's Theories and Techniques* (Bloomington and Indianapolis: Indiana University Press, 2000): 61–2.