How flutes are made: the headjoint

The last of the series

By Jim Phelan

In my years making flutes, I have only been an observer of the headjoint making job. To make top notch headjoints, one really must play the flute and I don't. I don't regret this. In fact, I feel that it gives me a unique perspective on the job.

This article is filled with observations. We'll start with Harry Gatos. Harry Gatos, professor emeritus of MIT and amateur flutist, contended that one could not define a perfect headjoint because every flutist's idea of that perfect headjoint is different. If one could define the perfect headjoint, a company could spend the requisite time and money to make 'the perfect headjoint' every time and command the marketplace. Quite the opposite is true. There are several 'one-man shops', Lafin, Sheridan, Mancke, Willy Simmons, Ian McLauchlan and a few others, for example, that specialise in making one-off headjoints.

The great British flutemaker Albert Cooper admitted that every flutist has a different idea of the ideal headjoint, but he noted that 'if you put twenty headjoints in front of twenty flutists and asked each which one was their favourite, they'd pick twenty different headjoints. However, if you asked them which one they would buy, they'd all pick the loudest one.' Given that only 1 or 2 percent of the energy put into a flute is converted to acoustical energy, particularly efficient headjoints, that is, loud ones, certainly appeal to many flutists.

Finally, I've observed that headjoint makers 'make headjoints in their own image'. What I mean is a particular maker's headjoints reflect his or her strengths and weaknesses as a flutist. Hence, I consider it imperative that headjoint makers play the flute and play the flute well.

Having set the stage, let's see what the headjoint making process is.

There are fewer parts to the headjoint than either the centre or foot joints. There are typically six. They are the tube, the riser, the embouchure plate (or lip-plate) and the cork assembly that includes the threaded rod and plate, the cork and the crown.

The first step is to impart a taper to the headjoint tube which is received as a cylindrical tube. Why a taper? The headjoint taper is similar in function to the bell of a brass instrument. It tricks the standing wave into believing the tube is longer or shorter than it actually is depending on the frequency that is being played. A headjoint made with a cylindrical tube will not play beyond the first two octaves.

Through experimentation, flutemakers have found that the headjoint works best if (1) the inside diameter of the tube at the centre of the embouchure hole measures between 17.0mm and 17.5mm and (2) the distance from the centre of the embouchure hole to the stopper is equal to that diameter. Now, from the first article we learned that the inside diameter of the flute tube is 19mm. So, from the top end of

Jim Phelan started making flutes in 1976 for a venerable Boston firm. He published the first edition of *The Complete Guide to the Flute* in 1980. That book is now in its second edition and sixth printing. He left the flutemaking world in 1989 and spent six years working in high-tech and the medical instrument industry as a mechanical engineer. In 1996 he joined his wife, Lillian Burkart, to make the Burkart flute. Even so, they are still happily married.

A headjoint mandrel on a hydraulic press, preparing to make a tapered tube. The once-only sheet steel die is visible on the right. The traditional method of forcing a tube onto a mandrel was through a lead ring. Makers today use dies as above, or else dies made of other metals or even plastic.

the headjoint tenon to the centre of the embouchure hole, the tube must taper 1.5 to 2mm. Again, through experimentation flutemakers have found that a non-linear—or curved—taper works best. We'll look at this again at the end of the article.

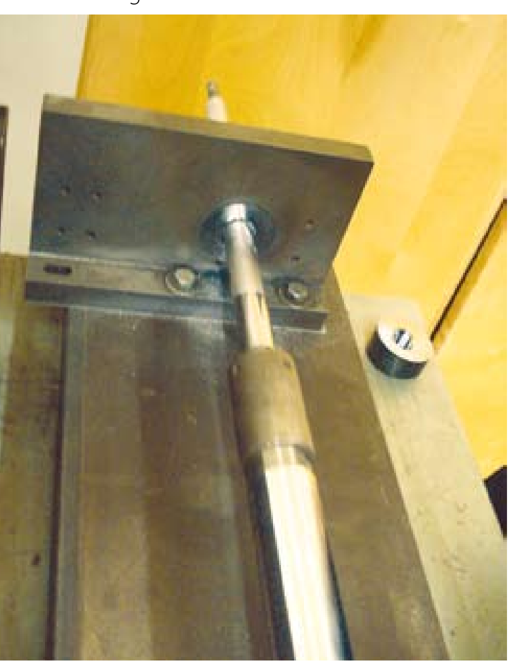
There are many ways to impart this taper. Most flutemakers use a drawing process wherein the metal is shrunk onto a tapered, steel mandrel placed inside.The reader might be inspired to ask, 'Doesn't this thin the metal?'. Well, of course it does, but by how much? Using the conservation of matter principle, it is easy to calculate. If the tube is shrunk without any lengthening, the wall thickness *increases* by 0.05mm. However, the process that is usually employed does indeed lengthen the tube so the change in wall thickness is, for all intents and purposes, zero.

In most cases, the lip-plate is formed from sheet metal using a die. The riser, also known as the wall or chimney, is forged or cast. These two pieces are silver-soldered together, because the contacting surface area is rather small. Once the two pieces are assembled, the embouchure hole is roughly cut out from the lip plate material Then, that assembly is soldered to the tube such that the centre of the embouchure hole lies over the point in the tube where the inside diameter is 17.3mm.

Some makers cast the lip-plate and riser together. This is a perfectly valid way of manufacturing and eliminates the making of two separate pieces and soldering them together. Some metal flow issues may arise, but they can be resolved through creative design.

Now the material for the embouchure hole is cut out of the tube. Some manufactures can, at this point, bring the hole very close to finished specifications using computer-controlled machinery. Otherwise, the headjoint maker has to start opening up the hole using files, scrapers and a variety of polishing tools.

The headjoint almost through the die.



Needless to say, the ideal size and volume of the embouchure hole is quite well understood by now. Note that I say volume. The volume of the embouchure hole is a very important parameter because the impedance, a measure of acoustical resistance, must match that of the rest of the flute tube. Those of you who are audiophiles will recognise the term 'impedance matching'. This first came to my attention in the early 1970s with my brief association with Albert Cooper and longer-term associations with the acousticians Cornelius Nederveen and John Coltman.

One of Albert Cooper's many contributions to flute design was his experimentation with undercutting. Undercutting is the process of blending the side walls of the embouchure hole into the inside wall of the tube. Doing so increases the volume of the hole. Albert, realizing this either by experimentation or by others' suggestions, made the other measurements of the hole smaller and therefore kept the volume constant.

As his headjoints became more popular on the American side of the pond, flutists with older headjoints asked headjoint makers to undercut their headjoints. The results were for the most part disappointing because the volume of the hole, and the subsequent loss of impedance, was now too big.

Because it is the volume of the hole that is important, there are many shapes of hole that will satisfy this requirement. Flutists' desire to find the headjoint that works best for them keeps quite a few talented folks employed around the world.

The function of the cork assembly is to stop up the top end of the headjoint. Earlier we said that it should be placed such that its bottom plate is 17.3mm from the centre of the embouchure hole. This space between the embouchure hole and the cork assembly is for acoustical compliance. As I'm afraid a complete discussion would put many of our readers asleep, suffice to say, this volume of air allows the second and third octaves to be better in tune.

The crown, our last part to consider, is where flutemakers can express their individuality. Again, there is a lively discussion about the effect the crown and cork assembly have on the flute's playing characteristics. Without a doubt, however, those who specialise in making crowns and cork assemblies make small works of art from a dazzling array of materials.


The top and bottom halves of the press tool that stamps out lip-plates.

Once the headjoint is complete, it is stored to be matched up with a flute or to be presented to customers looking to buy one.

How it works:

The flute's closest relative in the musical instrument family is the pipe organ. All the other wind instruments, brasswind or woodwind, have a vibrating membrane, typically reeds and lips, that sets up the standing wave. The flute and the organ only use air.

The air is blown across an edge at an angle that allows some of the air to enter a tube and some air to escape. To better understand what is happening I find that the analysis of a soft-drink bottle is useful.

Lip-plate parts: A complete lip-plate, a silver casting for the riser and a silver blank ready to be stamped into a lip-plate.

I expect every one of us has blown across a soft-drink bottle to produce a tone. Let's look at the conditions as we do this. Before we start blowing, the air pressure inside the bottle is exactly the same as outside. Let's call this P1. As we start to blow, some of the air molecules enter the bottle and some escape. More air molecules inside means higher pressure that we'll call P2. Obviously P2 is greater than P1. Since our bottle is open to the atmosphere, the pressures immediately want to equilibrate and some of the air molecules inside escape reducing the pressure back to P1. (Mathematical models suggest that the pressure probably dips slightly below P1 but I have never been able to measure this.) At this point our cycle is ready to start again. The smaller the air volume inside the bottle, the more rapidly the cycle repeats itself. This is the natural frequency of this volume. Frequency is measured in cycles per second, or Hertz. Drink a little of the liquid making the air volume greater and you can stuff a few more air molecules into the bottle before it wants to equilibrate. Hence, the larger volume has a longer duration between cycles. Fewer cycles per second means lower frequency, exactly what we hear. On the same note (pun intended) the reader might have noticed that when in a car moving with one window open slightly, there is a pulsing sensation, sometimes quite pronounced. If another window is opened, it disappears. This is

exactly the same phenomenon we just examined. We don't hear a pitch because the frequency is simply too low.

The only difference between the soft-drink bottle and the flute is that the flute is an open resonator. As bizarre as it may seem, the standing wave that pulses through your flute reflects off the openings whether they be open toneholes or the end of the foot joint, as in the case of low C or B. This is due to the change in impedance at the openings.

Things to consider when choosing a headjoint. I always urge players to use a new headjoint in a familiar performing or playing venue before making a decision to buy. Ask other flutists or musicians to listen to you on both your old headjoint and the one you are considering. We can be easily swayed by one feature of a headjoint, perhaps a big sound or a very easy low range, and not take into consideration its shortcomings. I like to say, 'When the cue comes, you have to play all the notes'.

An observation. There is a marvellous book in German that documents some 150 headjoint tapers. It is not a scientific study but simply documents the tapers various makers have used over the past century or so. The tapers are almost straight, capable of being described as an angle, but not quite. The word 'parabolic' is often used to describe the shape, but I have a hard time with that because a parabola is a well-defined mathematical concept. Non-linear or curved are better.

Many years ago we made a couple headjoints with a simple angular taper. All other geometries held constant, they didn't play very well.

This and too many other pieces of information have led me to the observation that if you think something is linear with regard to musical instruments, you are probably wrong.

A random thought or two about headjoints. I will be puzzled to my dying day about a couple of things. First, why does a platinum riser make such a big difference in the playing characteristics of a headjoint. All things being equal, when we cut a headjoint with a platinum riser, it is very often chosen as the better playing headjoint of its style in a selection of headjoints. I haven't done double-blind tests of this, though I should, but I have observed this phenomenon so many times over so many years that the data overwhelms my natural scepticism.

I also will be puzzled as to why a wave headjoint works. Yes, I know all the hypotheses, but frankly I find them unconvincing. We make a wave style piccolo headjoint that is very popular. Lillian (my wife and partner in Burkart-Phelan) designed it quite a few years ago and we just replicate that design. I've been asked many times to make wave flute headjoints but I won't. I won't because I don't know what the critical features are.

It is too bad that we flutemakers cannot spend more time in our working careers investigating questions like these.

A final word. I want to thank Robert Bigio for asking me to write these articles. My association with him, prompted by this effort, has enriched my life. I hope you have found the articles useful. I have enjoyed writing them.