FoMRHI Comm. 2070 **Arthur Benade**

Cutting the flute's embouchure

Foreword

The following notes are part of a letter that physicist Arthur Benade (1925-1987) sent to a young maker of early flute replicas. The maker was requesting some help in shaping the flute's mouth hole. In fact, when measuring flutes in museums we gather plenty of information on the outside turning, a lot on the bore, but little when it comes to the mouth hole, because a permission is almost never given to take a cast of it. Neither would it be of much help, since the mouth hole is often ruined by too much tampering by earlier users. So, observation by eye and personal convictions must only be relied upon when we work back in the workshop.

At least we had a decent theory of the relevant parameters…but literature on the subject is very scanty, if it ever existed. This letter was lost in a mess of sheets, notes, scraps of information, and re-surfaced only by chance now, after almost 40 years.

Benade died in 1987 and it is not known if he ever published the following observations, but in the same letter he had made clear that he would like to do so.

So it is better to make sure now, at least to start a discussion on the subject. Only paragraph titles are added to the original text. The drawings are from Benade's letter, in his hand – Filadelfio Puglisi

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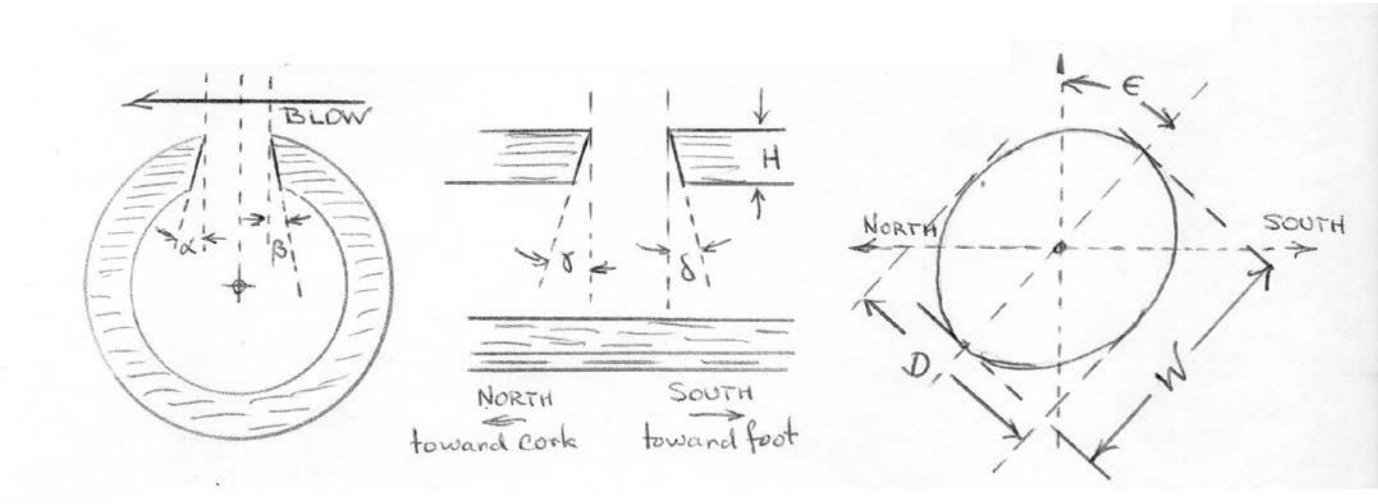
(Page 4 to Page 8 of the letter)

Mouth hole orientation



We begin by noticing that most players do not blow directly at right angles to the axis of the flute; some face a little northward, whereas some face a little southward. If one builds an elliptical or rectangular hole of the sort used in modern flutes, it makes sense to orient the major axis of this embouchure hole so that ε is slightly less than 90° for the first player and slightly more than 90° the second. Mostly it is not worth the very considerable trouble required to do this. Very often as a matter of fact, if ε = 90°± 5°, any civilized player on a good instrument will automatically find a way of flowing that best adapts the structure of his lips and teeth to those of the flute. Other things are so much more important that that I tend to let this orientation find itself.

The ratio D/W matters really very little in either of two cases: (a) if D/W ≈1, as in your renaissance flutes, 5% from round makes more of a difference to the appearance then to the playing provided the area is kept constant and (much more important) the undercuttings are properly proportioned, as outlined below. (b) if D/W≈ 0.8 as in the 19th century and later instruments again there is more constraint against a 5% change via appearance than via playing.

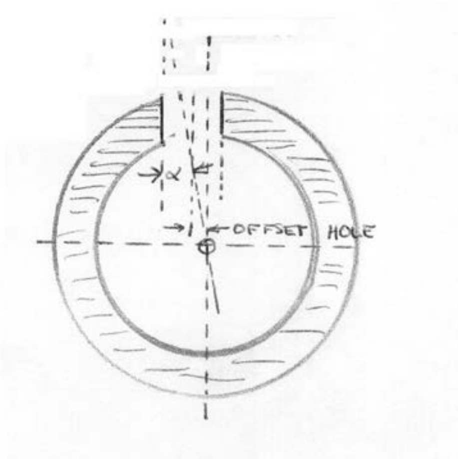
The two tribes (a) and (b) play differently from one another however, mainly because (with ε= 90°) D is fairly constrained by steered—flow air-jet physics, whereas W is controlled more by the player's preferences or ability to manage a narrow or a wide air jet (see wt in my Fig. 22.10 page 490, Fundamentals of Musical Acoustics).
Once again I must emphasize that the freedom claimed depends on one's ability to "get everything else right" in a manner consistent with changes we are discussing.

Longitudinal Undercutting

The choice of whether the undercut angles γ and δ on the north and south sides of the hole are equal or not is almost random, again subject to the general "rightness" proviso.
As long as ($\gamma + \delta$) is roughly constant it doesn't much matter (so far in our discussion) what the sum is, provided the hole impedance reduction associated with the undercutting is taken care of some place.
It is traditional to choose the inequality to favor players who face left or right, but one finds schools of thought that are directly contradictory when you look at what is recommended!
You will see a little better what is involved by the time you have read about the rest of the undercutting business. For many years good flutes have been made in which these two angles are zero. However, one really does get better results if the inner corners are rounded, or undercut part way and then rounded.

Transverse Undercutting

The question of suitable angles α and β has been much vexed.
Look at Figs. 9, l0 and 11 of Miller's translation of Boehm's The_Flute and Flute-Playing (Dover 1964) plus the accompanying text ... Boehm's and_Miller's.
For today's flutes one often finds that $\beta = -\alpha$, (!!) and $\gamma = \delta = 0$ because a straight-sided cutter has been used to form the hole, with the center of the hole being offset from the tube axis.



It is however in this case good practice to undercut to produce a larger (including positive) value for β for at least the inner half of the chimney height.

Analogous part-way undercutting on the forward side (two-valued alfa in this region) is NOT A GOOD IDEA. In fact it can sometimes lead to disaster.

Setting aside the newer flutes where the lip-plate angle gets into the act, let me say that for embochure holes of the sort one sees on renaissance and baroque flutes, the angle α needs to be around 7 degrees.

The modern maker is often confused by what he sees and makes the angle on his old instrument copies considerably bigger than this. Worse yet, he may try generating the whole embouchure hole profile by pulling a rotating conical cutter (fraise) outwards from the inside, so that $\alpha = \beta = \gamma = \delta$. The next paragraph suggests a reason why today's maker is plausibly led to make this mistake
The larger embouchure holes used on classical and modern flutes need less undercutting, mainly because a larger hole drilled into the same head diameter automatically gives the effect of larger α . This is true to an exaggerated extent on the Boehm flute where the bore diameter at the embouchure hole is only l7 mm instead of the l9 mm typical of the conical flute that immediately preceded it. The fact that Boehm's own first design was conical may help us understand the discrepancy between what he said and what his matured experience led him to do.

It may also explain why people tend today to make α too big when trying to make a baroque or renaissance flute -- it looks drastically undercut to someone used to today's instrument. Also they may be thinking of the $\alpha = 90°$ of a recorder!

All this talk, and I have not said what is the symptom of a overlarge α : The stupid thing will not speak well. The tone is gutless, no dynamics, no power, wobbly pitchs, poor attack. You cannot pounce on a note, even when the headjoint alone is tested.

The fact that uncovering a lot of the hole will make it play less badly is often a clue to too big an α since rolling the flute away will reduce the angle between the wind and the edge against which you blow. Notice that this angle α is the only thing that I have discussed that has relatively close tolerances, and is not negotiable via trade-offs with other parameters.

I will not take time here to say why it is on the other hand that much can be gained by increasing beta (as mentioned earlier), even to an extent that at first looks absurd.

Transitions beetwen Undercut Angles

We are now in a position to describe something that is crucial to the proper working of an embouchure hole, regardless of its basic style or vintage: the way in which one arranges the transitions between the undercut angles specified so far (front and back, north and south).

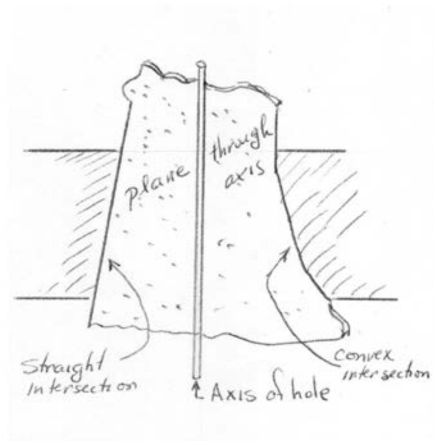
If we define an azimuth angle θ measured counterclockwise from a blowing direction normal to the flute axis, then your angle α defines the undercut at the azimuth $\theta = 0$, γ defines it at $\theta = 90°$, β at 180°, and δ at 270°.

Our problem is to specify the transition behavior between these 90°azimuths.
First and foremost we consider azimuths lying in the region one blows against, running counterclockwise from about $\theta = 300°$ (= —60°) and $\theta = +60°$.

In this region the embouchure wall must have a profile such that at every angle θ the intersection of the hole surface with a plane containing the hole's own axis is a straight line.

An attempt to generate this part of the profile with a file is doomed to failure since any convexity of the intersection leads to fluffy tone and slow response. The tool to use is a stubby, straight edged scraper with a large round handle.

The diagram below shows how I use the word "convex" and "concave" .
It also shows a perfectly acceptable undercutting profile in the azimuth region that lies outside the magic 60°.



To give you an idea of the touchiness of a flute regarding convexity (especially in the regions centered at about θ = 45°) let me give an example from a few years ago.

Scraping out patches of convexity the size of the capital O of this typewriter, located about 3 mm down into the hole, one at θ =+45° and one near -45° made one otherwise good flute "wake up" enough that my son who is not a wind player but has good ears come downstairs to see what had happened. He asked what I'd done to make such an abrupt change in what he heard of my music ... "it sounded as though the flute was let out of jail"...! I will grant that you sometimes see flutes that play ok with a little convexity in the region I'm talking about, and that sometimes removing it does not make a dramatic change. In every case however, closer examination shows that (a) if the flute is otherwise good it can be made to play better, (b) if it is not good the change of profile has its effects masked by other things (c) the player doesn't know how to really exploit the instrument and so fails either to notice or to display the change.

Important! The foregoing is not intended to suggest that you take a knife to a famous old flute to correct the hackings of some idiot who thinks a little scraping around the rim will improve things. There are many such vandals, and the results of their destructions should be left to their shame, unless you propose to make a proper restoration. This requires inlaying an entirely new piece within which a hole will be cut.

To do less is merely to saddle the museum curator or collector with yet another flute with an oversize embouchure hole for which its other proportions were not designed. Such instruments are unfortunately not rare, in part because some ignorant souls have tried by such mayhem to raise the pitch of A-435 instruments to A-440 (etc., etc.).

Rounding of Edges

The question of suitable rounding (or not rounding) of the inner and outer ends of the embouchure hole is in part easy and in part hard to answer.

At the inner end of the hole, all the rounding your courage permits will lead to freer and stronger blowing at the loud end of the dynamic range, without loss of control at the pianissimo end.

As usual the caveat holds that one must be sure that the overall acoustical structure of the instrument is consistent with the slightly reduced impedance of a well rounded hole as compared with an unrounded one.

At the outer end of the hole things are more complicated: The region <u>outside</u> the central region defined by θ ± 6O° can be rounded almost as vigorously as the inner end, although it tends to look sloppy if carried as far as I would otherwise prefer.

Within the magic region one works a fairly sharp edge, finishing it with many trials <u>very slowly</u>

using only an ink eraser to get a smooth edge that flows continuously and neatly into the more rounded north and south ends of the hole.

Be careful not to more than just barely let the rounding increase for angles less than about $\theta = \pm 50°$ lest the response get fluffy.

The player's taste has a lot to do with what you try for in this central region, but be careful to leave him wishing it is more rounded rather than less rounded than his present taste. One reason for this is that wear and later adjustments can still move things in the direction he wants.
Another reason is that as he gets used to the profile his ability to get a clean unwiry sound increases greatly, so that he tends to shift his preferences with experience.

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