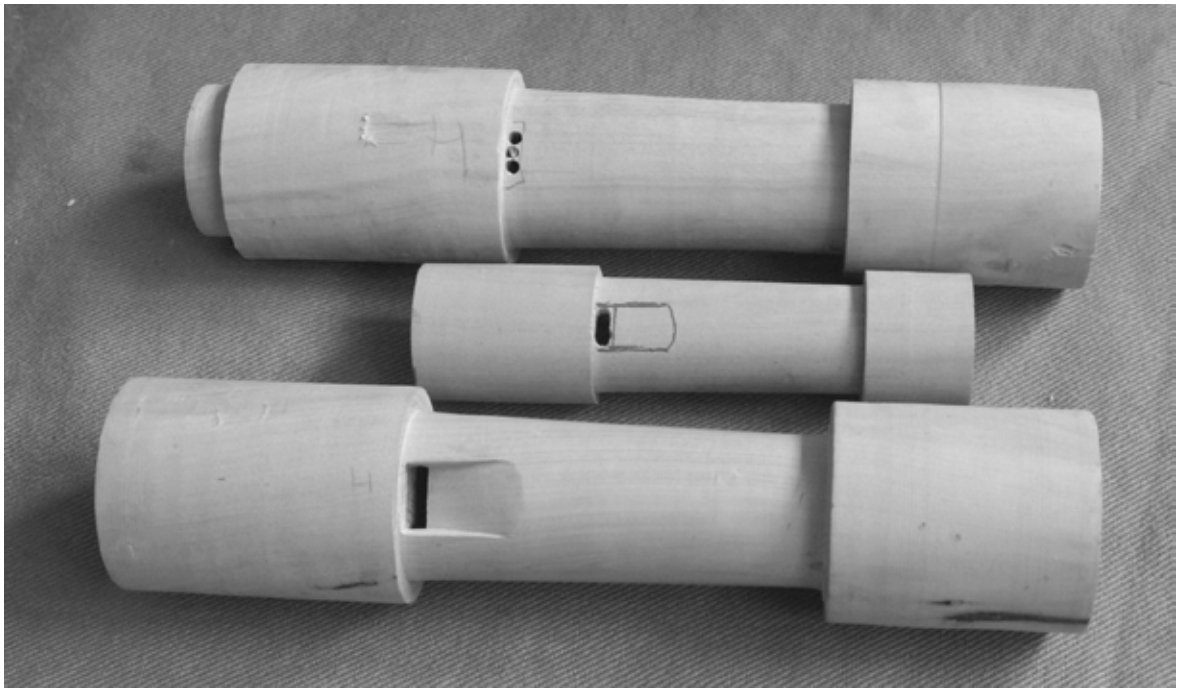
FoMRHI Comm. 2105 **Jan Bouterse**

Making woodwind instruments 11.7-11.10 Recorders

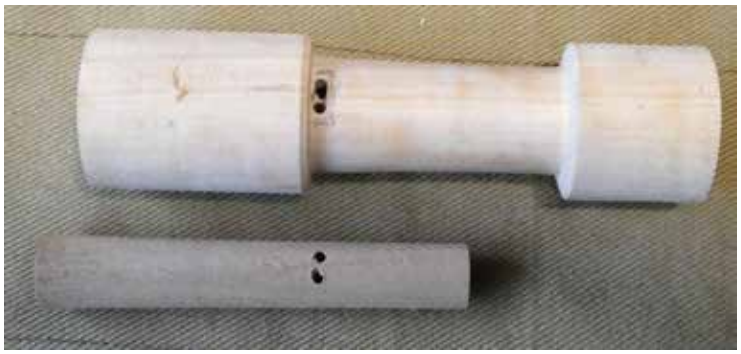
Window, windway, labium and block: operating sequence

This is my usual operating sequence:
1 - Making the window (first phase)
- tracing out and piercing the places for the holes (2 or 3 of them)
- filling the bore with a piece of wood
- drilling the holes (about 1 mm too small in relation to the later size of the window)
- cutting and filing the window, but still a bit too short (N-S) and narrow (W-E)



Three phases of making a window and labium in a 'working head'.

Important: The working head must be held steady, placed in a clamp or vice. I use several files, from coarse to very fine, some of them I have ground with a smooth side and/or made thinner so that they fit in the window. With all the work on windway, window and labium, some types or pieces of wood are more brittle than others so work slowly, try to discover the character of the wood, check always what you have done, and look at the result from different sides; good light is important.

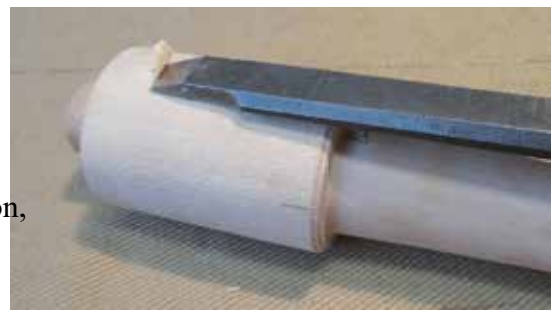


Left: the wooden plug (here taken out) used for filling the bore in the section of windway prevents the wood splintering when the drill goes through the wall into the bore of the head.

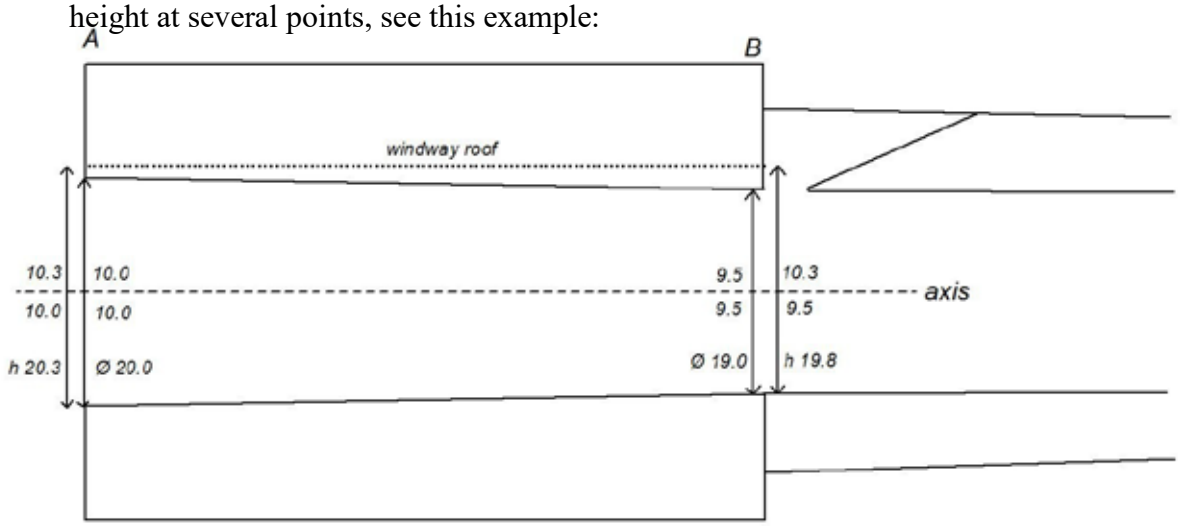
A selection of tools for shaping and finishing the window and labium: small knives, chisels, rasps, files and scrapers (S). I have ground some of the tools with an oblique angle, so that they fit better in the corners of the labium (for instance the side walls); see the marks on the photo. When cutting the labium with a chisel, I put a small piece of wood in the window to avoid damage at the north face of the window (photo, right).

2- Making the windway (first phase), with hand tools or a windway cutting machine.

- never forget: wood that is removed, can't be put back;
- at first you must find the direction of the grain of the wood; you have to decide whether you are going to work with pushing or pulling tools. You can find how the grain runs by cutting the wood with a knife or chisel on the exterior above the windway section (because it is a working head, the wood is thick enough to do that). On this recorder (photo, right) the grain is Likely going a bit downwards in N direction, and thus upwards in S direction, which means I can use pulling windway tools.



Think thoroughly about this; try to visualize what the grain direction is and what the consequences are of using cutting tools against the direction of the grain.
- irregular grain in wood is a often a nuisance and makes cutting more difficult; in that case you can better use files or tools with sanding paper;
- with hand tools: check that the windway goes straight, and (more or less) parallel to the axis. As the beak is not yet cut out, you can check the inclination by measuring the height at several points, see this example:



It is for an alto recorder, with a windway parallel to the axis, and with a step of 0.8 mm. The bore diameter at A is Ø 20.0 mm, at B and C 19.0 mm. We have to do now some calculations. A step of 0.8 means that at point B the height must become 19.8 mm, that is from the roof to the axis 19.8 - 9.5 = 10.3 mm.
That value of 10.3 applies also for point A, the N-side of the windway. But as the bore is wider at that point, we must add the half of that bore (10.0), the height at A will be 10.0 + 10.3 = 20.3 mm. We must thus focus on these two values: 20.3 mm at point A, and 19.8 mm at point B.

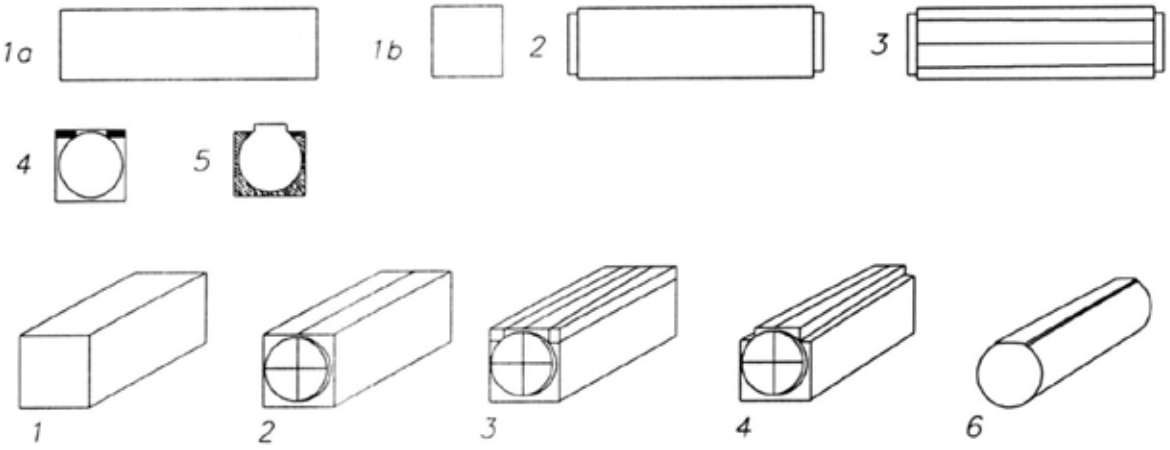
3- Finishing the window in combination with making the labium (outlining, cutting with a knife or chisel along the lines you have drawn), then cutting, filing and scraping (but leaving the labium edge still a bit too thick).
4- Windway, second phase: you have now a better view into the windway, so you can do the first finishing of the windway. That means: making the wood surfaces smooth, the sidewalls with sharp (not rounded) corners; check the profiles (N-S and E-W), they must be regular.
5- Making and fitting the block, phase 1: a bit too long and too high.
6- Finishing the block (phase 2, also intonating phase 1): lowering the surface of the block, until you are just beginning to see the labium edge. The first sound can be produced! The chamfers must also now be made, at first a bit too small, but they must be cut or filed with clean (not rounded) edges.
7- Intonating phase 2. That is mainly removing wood and smoothing surfaces: of the block, windway roof, chamfers, labium, under labium (candle flame). The result can only judged by playing the head in combination with the other parts of the recorder. You need them, complete with the tone holes (it is helpful, but not strictly necessary that they are perfectly tuned).
8- You have now a good idea of the qualities of the head. When you are satisfied, you must now go on with turning and finishing the head. Before cutting the beak, it might be useful to

do some last measurements of the windway.
9- Next phase of intonating, combined with tuning the recorder.
10- The first playing sessions, combined with refinements of intonating and tuning.

These steps in the working process are here listed and described as separate items. But they in reality very much linked to each other. Some steps are executed in combined in a co-ordinated operation.

Making the block

Block is the German name for a piece of wood. On modern recorders (*Blockflöten*) blocks are often made of a softwood, of one or another kind of cedar wood. That can be *Juniperus virginiana*, known as red cedar (actually a juniper species). What did they use on historic instruments? The woods of their blocks is often hard to determine; it is sometimes not even sure if they are made of softwood (pine, fir, etc.) or hardwood (perhaps fruitwoods). Wood for blocks must be stable and 'waterproof', finishable to very smooth surfaces, not swelling too much when wet, and not too hard to work. And not poisonous, or causing allergic reactions (which sometimes happen with cedar woods).



A block is only partly round; you can't turn it on a lathe, so you must cut it from a square piece of wood (1). But a lathe is used to turn the collars at both ends (2), which will have the diameters of the bore of the head at the N and S-end of the windway. That is followed by tracing the outlines of the block surface (3), with a fine saw and chisels you can make the shoulders of the block (4). Then comes the job of making the 'body' of the block round, with chisels, knives, files and sanding paper (5 and 6). After a while, you can knock the block some way into the bore. But the body of the block is still too thick; you see that on the surface of the wood from pressing marks. Then you know that on (or from) that place you have to remove more wood. And knock the block in again, a hundred times (or more). Don't use too much force with this knocking, or the wood of the head will crack. It is better to put a hose clamp tightly around the head (photo right).

At the end, when there is not so much knocking on the block required, I remove the surplus of the wood (the collar) at the south end. On most historic recorders the bore of the upper section is slightly conical, for instance going from 20 to 19 mm for an alto (see the example mentioned before). That conicity gives us the possibility of getting a perfect fit with the block. If by chance you have removed somewhere a bit too much wood, the block can knocked a bit further. But you have to make the block initially a bit too long, of course.

For more information about making a block (including attention to safety aspects), see www.flute-a-bec.com/bouchongb.html, which has good pictures and several tips (also about other aspects of making recorders), generously presented - and translated in English - by French woodwind maker Philippe Bolton.

Some thoughts about intonating recorders

An organ pipe produces only one note; the average recorder twenty or more. That is one of the reasons that recorder windways are so different in constructions from the feet of organ pipes. Another difference: the air that goes through a recorder windway is much more moist (and often warmer as well), which has also consequences for the construction. There is usually an increase in air pressure when you play from the lowest tones to the upper registers of a recorder. That is also the case on a flute (traverso), but there you have to change the direction of the wind as well: by moving the chin and lips a bit forward, the wind blows at a bit steeper angle to (the upper rim of) the mouthhole. My theory is that a similar (but smaller) change of direction of the wind might happen on recorders with a windway roof that has a curved N-S profile. But I can't prove this theory, I have not the equipment such as was used in some tests to visualize the tone production of a recorder, see for instance (but only in Dutch): www.flute-a-bec.com/miko-fluit.html where Avraham Hirschberg explains in a video what happens when the air coming from the windway bumps against the labium. See the same video on the website of the French recorder maker Philippe Bolton, on his pages about recorder acoustics (English available). But this video shows only what happens when one note is played, not when one changes to another note or register.

The theory of tone production of the recorder´s sound is rather complicated and Hirschberg gives this warning: 'Some models have been presented in the past where a problematic phenomenon is explained by somebody with a theory that wasn't quite understood by the person explaining.' That warning is the reason that I will be reluctant to give easy explanations of the function of some parameters, despite my desire to visualize the effects of some operations on windway, block and labium.

The way many instrument makers are working is very much empirical: they know (more or less) what happens, or better - in which direction an effect of an operation will be, e.g. lowering a block or widening a window. But they can't explain exactly why or how strong that effect will be, and at what moment to stop interfering. I have heared many times, from makers of various musical instruments: removing bit by bit some wood from a block (or sound board or whatever) the sound gradually improves, but only to a critical point. Going past that point means disaster: the sound has become suddenly very bad, and there is no way back. And that means on a recorder, with so many points where you can do something (and that is always removing material and finishing surfaces), that many things can go wrong. However, by working carefully, you will discover that there are also rather wide margins within which you can make fine instruments.

Points of attention (in random order)

The step (between windway roof and labium)
How do we know the perfect height of the step? First: by studying drawings with measurements of excellent historic recorders, and/or taking measurements yourself from instruments (factory-made recorders, or copies after old instruments) which you like. Secondly: by making a recorder, starting with a rather low step (say 0.5 mm) and then - after making a block and playing the instrument - gradually make some more space, for instance up to 0.8 mm (for many altos a good height) or a bit more (1.0 or 1.1 mm). Indeed, it is a matter of tenths of a millimetre. You can - with a trained eye - see the differences, but your ear is the best tool.

It makes a difference making a recorder that is intended to be played for 6 or 8 hours a day. The wood in the head will swell a bit more and you can better make the step a fraction higher (1.0 instead of 0.8 mm) and/or the block surface a bit lower. And, of course, it makes a difference whether you are making a sopranino or a bass recorder. However, that doesn't mean that the step for the bass recorder is 4 times higher than that of the sopranino.

Straight or arched windways
Does it makes any difference - a straight or arched windway? Or how strongly that arch is curved? It´s rather strong in renaissance recorders, see right, photo of the tenor recorder SAM149, Kunsthistorisches Museum in Vienna (photo from the catalogue of the collection of renaissance recorders, Vienna 2006).
On most baroque recorders is the arching less strong, or even almost flat (some recorders by Willem Beukers).

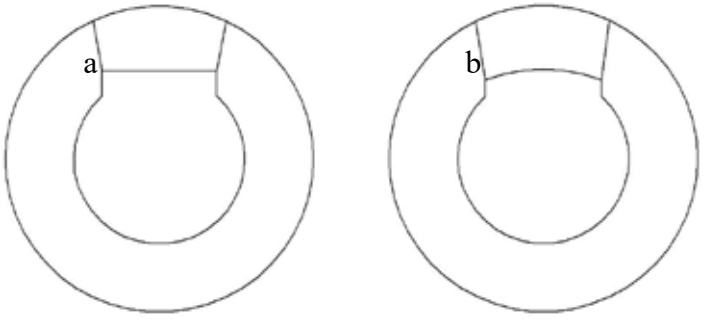


Diagram: cross sections at labium edge

The consequences of a flat windway at the S end are that with the same diameter of the exterior the sidewalls are lower with a flat windway (a) then with a curved one (b).
The height of the sidewalls has an effect on the pitch of the recorder and also on the sound, such as the stability of the notes. There is an easy way to test these effects, by putting some plasticine besides the window.

There might also be (but I have not tested that) an effect of the windway shape on the behaviour of the condensation water, which inevitably will form in the windway when you play the recorder and which not must form droplets which clog the windway up.It is best when the moisture becomes a thin film that gradually disappears in the direction of the windway, without disturbing the sound. The condensation problems might be bigger in a flat windway.

The height and profile of the block, the chamfers

The point of departure is that the block fits in the head of the recorder, but is still a bit too high. The sound is not good, resistance is high, some notes do not speak.

The next step is gradually lowering the block, which can be done with files or a fine quality sanding plate. Many blocks (on historic recorders as well as modern instruments) have a slight concave (hollow) profile. I have adapted a file and a sanding plate (photo, right) to be a bit curved, which makes it easy to make that hollow profile.

Sanding plates were twenty years ago sold by Sandvik, in qualities from fine to coarse. They do not make them any more. The depicted plate is by the Japanese firm NT Dresser, but they have only one (fine) quality. You can do most of the finishing with this stuff, but the sanding plates by Sandvik were better, I could work faster with them. I still have some pieces, and use it only for blocks.

How far to go with lowering the block? At the South end until I can see the edge of the labium, at first at about step height, or slightly (0.1 or 0.2 mm) more. The opening at the north end is generally a bit higher, for instance 1.2 to 1.5 mm. I discovered that for alto recorders it works well when the surface of the opening is about 1.5 to 2 times more then the exit at the other end. An example: a windway entrance with 13.5 x 1.25 mm makes an opening of 16.875 square mm. The surface at the exit (south end) is 11.8 x 0.9 = 10.62; the quotient of both values is 1.59.

Heiko ter Schegget, a professional recorder player and teacher at the conservatorium in Utrecht who makes his own instruments, told me that the best sound is produced when the block is as high as possible - of course all tones must speak well, especially the critical ones such as f3 on an alto recorder. Perfect finishing of all aspects of the windway, window and labium helps improve the sound as well as the speaking of the notes. Heiko is especially critical about the finishing of the chamfers. The surfaces must be perfectly smooth (no burs!) with well defined edges (not rounded!). However: when your recorder produces some unwanted noise (a 'wolf', for instance on g1 on an alto recorder), it helps sometimes to soften the edges of the chamfers a bit with the finest polishing paper. Philippe Bolton gives detailed instructions how to make the chamfers, with chisels/knifes or with files.

If you make a block too low, the window too long and the chamfers too big, you will lose control over the tone: the sound becomes loud and noisy. But I can't give detailed rules about how big the chamfers must be. I can only say here: make the chamfers initially not as big as on the historical instrument that you are copying, but initially smaller. Begin with the block chamfer, then with a small top chamfer, and listen well to what happens. The problem is that you are also working on lowering the block, it is difficult to separate these actions. On recorders by some Italian makers there are no chamfers at all. Jewgenij Ilarionov, a recorder maker from the Ukraine. wrote about that in an interview with Nik Tarasov (see www.windkanal.de/mastering-the-chiff). He says: 'Thinking of drawings of instruments

from the 17th century like the Rosenborg recorder or the Kynseker recorders from Nuremberg, there is another point in the construction or realization of the voicing: unlike instruments from the 18th century there is no chamfer. And this is no wonder, because in my experience, chamfers make the function of the 'chiff' weak. And secondly, big chamfers make the attack slow. On the contrary, there seem to have been a taste at least until the middle of the 17th century for the fast attack'. See also below in the following paragraph.

Size and shape of window and labium

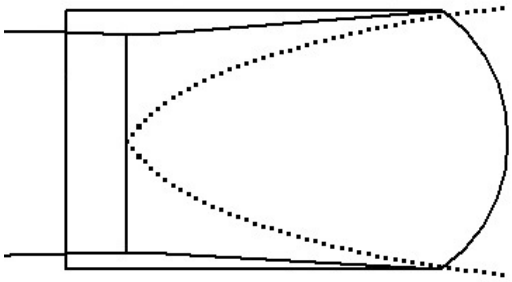
Herbert Heyde wrote in his book 'Flöten', a catalogue of the recorders and flutes in the collection (as it was called then) of the *Musikinstrumentenmuseum der Karl-Marx-Universität Leipzig* (nowadays Grassi Museum Leipzig) and published in 1978 in Leipzig, about the relation between the width and length of the windows of recorders. And he says (p. 15) that there is a connection with organ pipes, where there is a preference for relationships such as 1/6, 1/5, 1/4, 2/11 and 2/9. I don't think that his observation is very helpful, if it is correct at all. A larger size of the window gives a bigger sound, and raises the pitch of the recorder. I found for alto recorders at about a-440 Hz windways averaging about 4.0 mm long, for altos in a-415 from 4.0 to 4.5, and for altos of about a-405 from 4.3 to 4.7 mm. It is best to make a window as a start (when you have not much experience as a recorder maker) a bit short; by working very neatly you can make a window a bit longer without the occurence of negative effects (a noisy tone).

The size of the labium has also an effect on the chiff. It is actually what you hear in the first milliseconds of the sound, as I mentioned in Comm. 2041. Some organs have a very clear attack (in German: 'spucken'), with some higher frequencies in the sound spectrum. That is related to the size of the window, but I can't tell you exactly how it actually works. I was told that in organ pipes a very short (organ makers say: low) window as well as a long (high) window can cause the *spuck* effect. And, as we saw above, chamfering plays an important role as well.

Labium side walls are generally slightly flared, both north-south and in cross section. The exception: some recorders by Abraham van Aardenberg, such as (see photo right) this soprano from the Boers collection. The labium is short, wide, with slightly curved sidewalls.

The labium of the bass recorder by Richard Haka in the city museum of Gothenburg (photo left) has a completely different labium. In relation to the diameter of the exterior much smaller, and the sidewalls are much more 'shadowing' the labium. I suppose designed by Haka to keep the pitch of this bass as low as possible in regarding to its length. Otherwise he would have had to make the instrument longer, with more awkward fingerhole positions.

The ‘underlabium’ (candle flame)



The ‘underlabium’ is the underside or inside of the labium, in the bore of the head of the recorder.
The dotted line in the diagram shows the shape of such an underlabium, also called a ‘candle flame’, because of its shape: a conic section as a transition from the arching of the labium edge to the curvature of the bore of the head. If the labium edge has the same curve as the bore, then there is no (need of) a candle flame. A square (flat) windway with ditto flat labium has generally a long candle flame.

Photo left: after removing the block, a view down the bore with windway roof (with some strange damage - woodworm?), window and underlabium. The outline of the candle flame is clearly visible. The photo is from the only surviving part of an alto recorder by Engelbert Terton (city museum of Brielle, Netherlands).

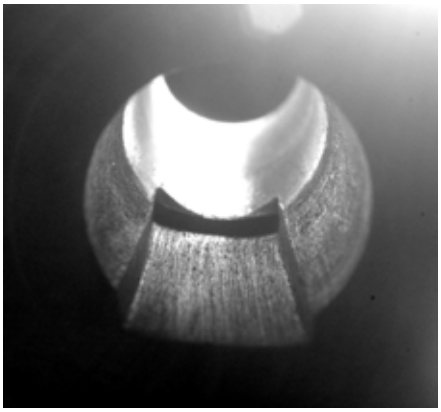
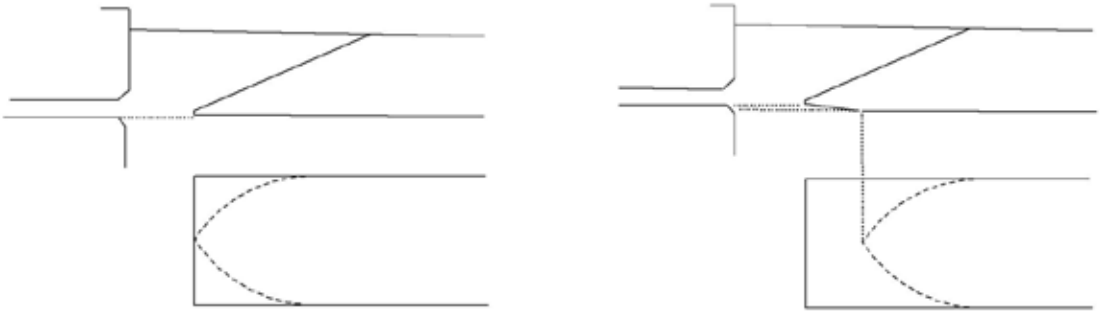


Photo right: the much shorter candle flame in the head of one of my (still unfinished) recorders. The windway roof is here in much better condition, but the sidewalls of the windway are still a bit sloppy.

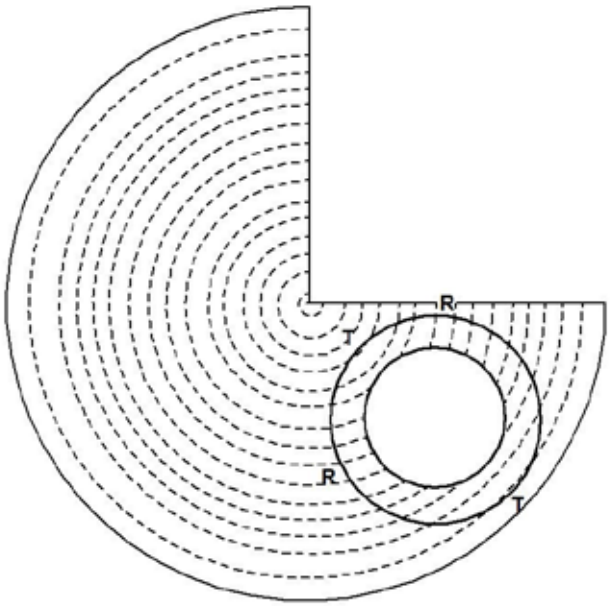
There are two ways to make a candle flame: as the first phase of cutting the windway, or you can make it after (most of) the windway is finished. The same tools are used for windway and candle flame.
The top of the candle flame reaches usually the labium edge. But there is sometimes a bit of distance, which means that there is some undercutting of the labium edge.



On the left diagram: candle flame with its top reaching the labium edge. On the right diagram: the labium is undercut over some millimeters. It is a way to make the step which is too big a bit smaller.

11-10 The working of the wood

Woodwind makers in the past usually sawed (or split) the wood in quarters, so that the radial surface (the 'stripe') was displayed on the front of the sections of the instruments. The advantage of that way of working is that it is easier to give that side of the wood a smooth finish, and also the chance of cracking is greater on the other side, the tangential surface (the 'flame') of the wood. But I have seen a few exceptions, for instance the recorders of Willem Beukers stamped with a fleur de lis. Philippe Bolton gives the advice of choosing the radial side at the top for the block (windway side) as well, because that will improve moisture absorption. I can't tell if the makers in the past did that as well. I have seen some recorders by Van Aardenberg with the tangential surface of the wood visible at the windway side.



This is a diagram of a cross section of a wood stem and the position of an instrument part with R (radial side) and T (tangential side) of the wood. On most historical instruments the radial side is in front of the parts. That has some consequences in the long term. Wood shrinks (in cross section) over the years more between Rand R than between T and T: shrinking cracks always run perpendicular to the growth rings. Which means that the bore of instrument parts become somewhat oval, with the result that windways are now narrower than when the recorder left the maker's workshop. This knowledge can help you with the rescue of a windway made with a slightly too big step: after some years of playing (or a treatment with some forced drying), the step will become - with some luck - just perfect.

Some final remarks

The instructions on these pages are somewhat condensed and far from complete. Other instrument makers with much more experience surely know more about acoustical and technical questions. But as a lot of that knowledge has an empirical character and that makes it, in combination with the complex matter of the subject, difficult to pass on to other people. My approach is far from scientific and I prefer working with simple techniques and not too expensive (e.g. self-made) tools. That means a bit more flexibility and improvising. The advantage is that I have learned to make all sorts of corrections, the disadvantge is that it is more difficult to produce series of recorders with precisely the same dimensions and exactly the same character. If that is what you want, you have to invest in machines which can copy exactly the main features of the instruments. But what I know from factory-made recorders is that there is still variation in sound (and other features) within their series.

I still have several questions about recorder acoustics. I am sometimes dreaming how scientific research in this field might be carried out, for instance with a test recorder with all kinds of adjustable features. But I have not yet found how to make a test set for which measurement equipment is needed. We have to rely on our eyes and our ears. They have to be trained and kept in good order. Work safely!