FoMRHI Comm. 2068 **Jan Bouterse**

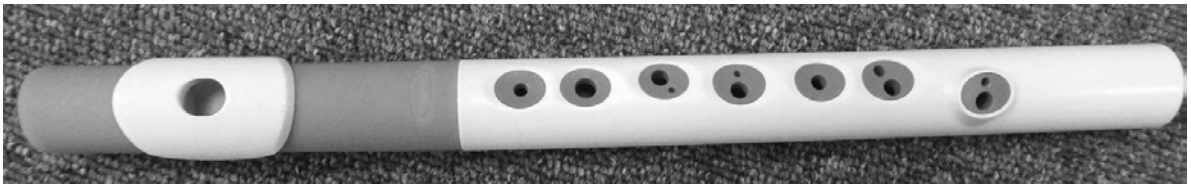
Making woodwind instruments

9: Flutes (traversos)

9.1 What is a flute?

About the name: the term ‘flute’ is in English language generally used for the transversely blown instrument with a mouth hole, also called the embouchure hole. The term ‘embouchure’ is sometimes used for the mouth hole on itself, but means actually the position and shape of the hole between the lips of the player in relation to the mouth hole.

It is likely that that the name ‘flute’ comes from the Italian *flauto*. The same applied to other European languages: *Flöte* in German, *flûte* in French, *fluit* in Dutch. But in the 17th and 18th centuries these terms were used in these countries, in the first place and for a long period, for the instruments which are called ‘recorders’. And ‘flute’ in English can still (or reviving historic useage) sometimes mean a recorder as well. With the reintroduction of historical instruments in the 20th century some original names also reappeared, such as for the *sixth flute* (soprano recorder in d2) and the *voice flute* (tenor recorder in d1).



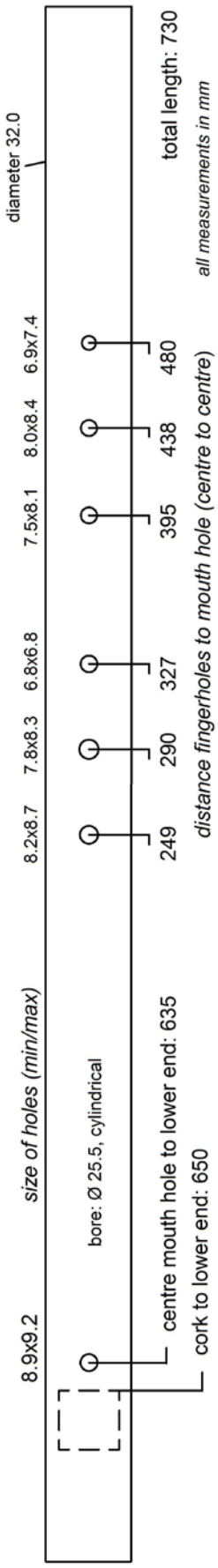
This is a small flute (piccolo) for children. It is made from plastic and has - as a recorder - seven fingerholes on the front and a thumb hole at the back. The mouth hole is about the same shape as that on a modern Böhm flute.

There is even the possibility to play this flute with a short windway device which directs the breath at precisely the right angle. But with this tool you can’t vary that angle and so you cannot so easily influence the pitch and other aspects of the sound as well. That is probably why there are also double holes on this flute, to avoid fork fingering for some notes.

The term *flauto traverso* was often used in the 18th century for the wooden or ivory flute with one key or, later in that century, more keys: four or six. Today many players use the abbreviated term ‘traverso’ for a baroque-type instrument, and so will I on these pages.

It is perhaps not quite correct to use the term ‘traverso’ for older types of flutes, the instruments with a cylindrical bore and without a key, which were played well into the 17th century. Similar types of flutes with a cylindrical bore and no keys are played in other cultures, such as bamboo flutes, for instance in Japan. Some flutes are not, or not entirely, held in a transverse position, for instance some modern bass flutes.

Modern concert flutes (Böhm flutes) are classified as woodwind instruments, despite the fact that most of them are made of metal. Other materials were used as well for flutes and traversos: ivory, crystal glass, and plastic. Comprehensive information about the history and use of flutes can be found in several encyclopaedia and on internet.



9.2 Some thoughts about making traversos

In this series on making woodwind instruments, I will give information about making the flutes as they were played in the 16th to 18th centuries - thus renaissance and baroque traversos, made of wood or (artificial) ivory. I must begin with a warning: I have never played an original old renaissance flute (I even don't know if any specimens did survive which can be played). And I am very not an experienced player on this type of flute. I only have made some copies and done some experiments. So I can tell you that traversos are at first glance simple instruments to make. You have not - as on a recorder - to cut a windway and make a block, nor you have the difficult job of learning - as for an oboe or bassoon - how to make a reed and staple. It all seems simple: there is the inside (the bore) which is made by drilling and reaming; and there is the exterior which is shaped on a lathe. And then you have to drill a mouth hole and some fingerholes and put a cork in the bore not far from the mouth hole. But that simplicity is deceptive. For a start, it is not so easy for everyone to produce a sound by blowing over the edge of a mouth hole. It took me several days to get it more or less right when, long ago, in 1976, with only some experience as recorder player, |I bought a baroque traverso, a cheap instrument made from fruit wood which came from the former German Democratic Republic. And I had a problem when I gave a course in traverso making , ten years later, when none of the five students were able to produce a sound either. I then had to do all the voicing and tuning myself. My advice, if you have no experience in flute playing: take a bottle (Coca Cola or what ever), close your lips leaving a small hole in the centre and blow over the rim of the bottle. Adjust the direction of the air stream if there is no direct sound. For playing a traverso you need a very similar technique.

One step further is making a flute out of a plastic tube. My first one was made of PVC tube bought in a DIY shop. I could find only one size, with an internal diameter of about 25.5 mm, external diameter 32 mm. That is too wide for a flute with the fundamental d1, but with a length of 635 mm you will get the note b (= a minor third lower than d1) which makes it a *flauto d'amore*. The position of the fingerholes was derived from a photo in a book. Important: the mouth hole must be kept small: 9 mm circular. It is one of the mistakes of some people who are experimenting with making flutes from plastic tubes, that they have the much wider and slightly square size of the mouth hole of the modern concert flute in their mind. It is much easier to get a nice sound from a smaller circular hole! The hole must also be undercut a little bit, the rim must be finished properly with a clean edge.

Left: measurements of my PVC-flute. The actual instrument was made by me in two parts, connected with a coupling (also available in the DIY-shop). Advice if you want to make a copy: take a slightly longer piece of tube and drill all holes at first a bit smaller. Adjust everything when you are voicing and tuning the flute.

PVC is perhaps not an attractive material, but easy to work, for instance to drill holes in. Formerly you could only buy tubes in a dull grey colour, nowadays also in a more interesting white, but only in a restricted range in diameters. A tube with an internal diameter of 17 mm or 18 mm and a wall thickness of 2.5- 3.0 mm should come closer to historical instruments, but I am afraid you must order that from a specialised company, which might be expensive. I have tried also acryl glass, available in more diameters, but these tubes are generally thinner and acryl glass is also much more brittle.

A different approach to music

There is another difficulty in making the traverso: you have to learn the appropriate fingerings. There are similarities, but also important differences from the fingerings for recorders. Traversos have no thumb holes; overblowing the notes of the lower register must be done by blowing harder and slightly changing the direction of the breath. You can change the volume of the sound of the traverso as well, but then you have to make pitch corrections: turning the flute inwards makes the opening of the mouth hole smaller, which makes the note flatter; turning it outwards makes the note sharper. Such corrections are also needed for some notes which are (surely for our modern ears) a bit out of tune.

Playing the traverso means that you have to learn about the differences in character of the keys (modes) in which the music is written. That means that you must develop a new way to look at music, hearing in a different way. We are so lucky now that you can find instructions and fingering tables from old sources in reprints, such as the books of Hotteterre *(Principes de la Flûte*) and Johann Joachim Quantz *(Versuch einer Anweisung die Flöte traversiere zu spielen*) and these are also available in English.

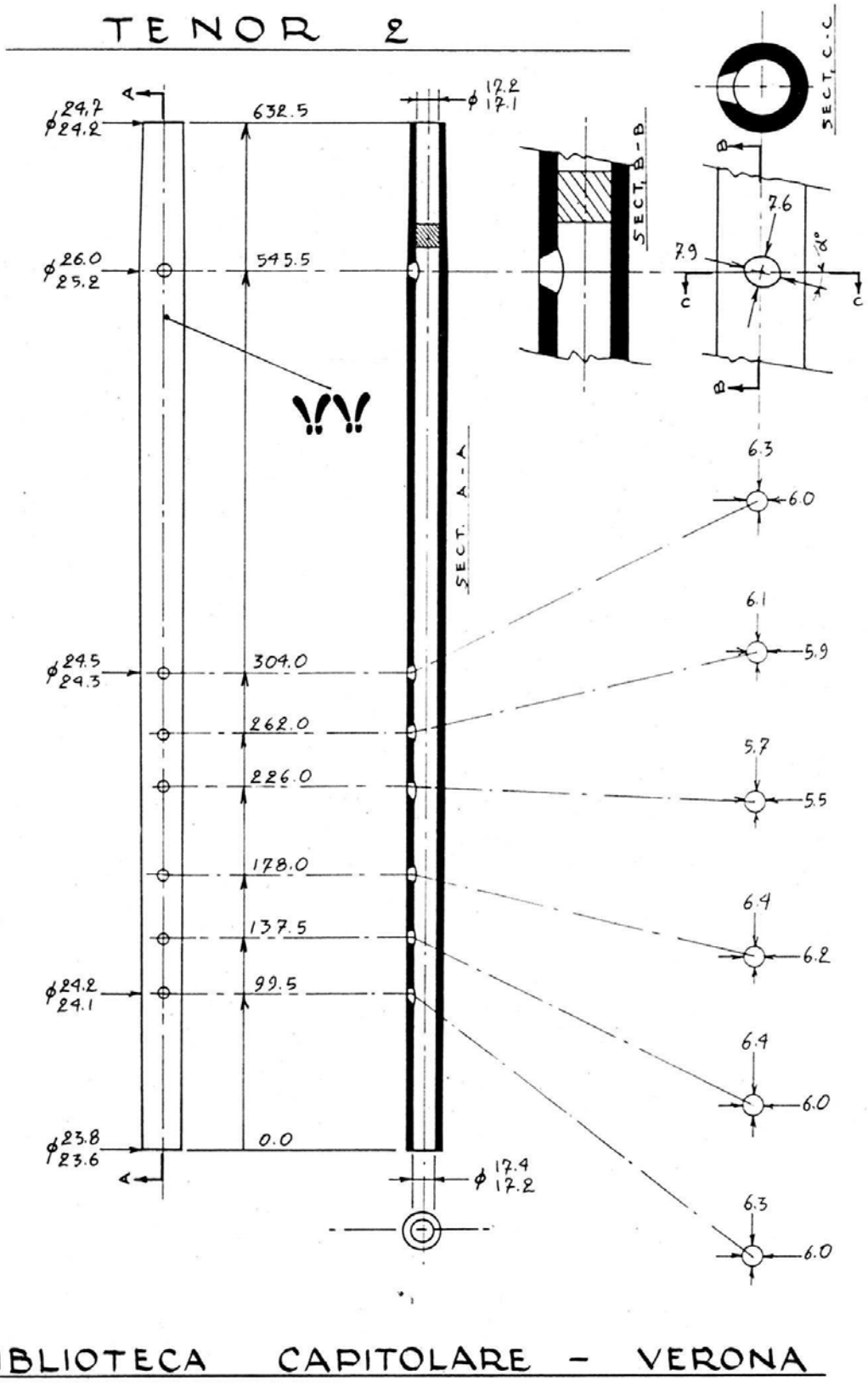
9.3 Historical renaissance flutes

Flutes with a cylindrical bore, with six fingerholes and without a key had a long-lasting tradition in Europe. The instrument were played in intimate settings as well as in armey bands. Renaissance traversos were made in different lengths (consorts). At http://www.flutehistory.com/Resources/Lists/Renaissance_flutes.php3 you can find a comprehensive list of early flutes. There are two famous collections of these instruments, both in Verona in Italy: in the *Bibliotheca Capitolare* and the *Accademia Filarmonica.*

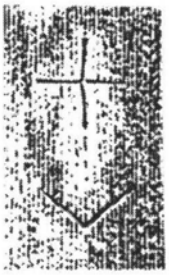
See for more information Filadelfio Puglisi, 'A Survey of Renaissance Flutes', in the *Galpin Society Journal* 41 (1988), p. 67-82. See also his book *I flauti traversi rinascimentali in Italia* (Studio per Edizioni Scelte, 1995). Puglisi published in his book full data of the flutes in Verona - but please be aware that he used for all instruments the same schematical drawing, to which he added the measurements (see example on the next page).

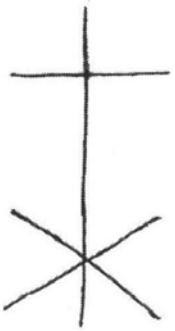
There are roughly two sizes of flutes in the Verona collections: tenors with a sounding length (= the distance from the centre of the mouth hole to the lower end of the flute) of around 540-575 mm, and bass flutes with a sounding length of around 810- 860 mm. He gives no information about pitches and the other playing aspects of the instruments.

Drawing on the following page: renaissance flutes often have mouth holes which are slightly oval, with the longest diameter slightly diagonal to the axis of the instrument. Puglisi doesn't give measurements of the undercutting of the mouth hole and the fingerholes. The holes are generally drilled in a straight line, which allowed the players to hold the flute to the left or to the right. Yet it creates no acoustical problems if you drill some of the holes slightly off-line.



Drawing from Filadelfio Puglisi, *I flauti traversi rinascimentali in Italia* (Studio per Edizioni Scelte, 1995).





The Nova Zembla flute

This is a picture of another historical renaissance flute. It was found on Nova Zembla (Novaya Zemlya), an island in the Arctic Ocean in northern Russia and the extreme northeast of Europe. In 1596-7 Dutch sailors tried to find a route with their ships to the East Indies, but were trapped by the ice and had to stay there for the whole cold winter. Several artefacts have been found where the sailors made a house. One of these was this flute which - apart from a missing piece of wood at the lower end - has survived rather well. The owner put his mark with a knife at the front of the flute, which is probably made of fruit wood.

The instrument is now in the Rijksmuseum in Amsterdam (see https://www.rijksmuseum.nl/nl/zoeken/objecten?q=Nova+Zembla++fluit&p=1&ps=12&st=OBJECTS&ii=0#/NG-NM-7692,0 for a colour photo.

The bore of the flute is cylindrical, but because of some cracks and distortion not easy to measure, Ø 17.7 mm at hole 5. The wall is very thin; about 1.8 mm at the upper end, 2.4 mm at the lower end.

The mouth hole is 7.2 x 8.2 mm. The fingerholes are not much undercut. Some measurements:
total length: 639; SL (sounding length, from centre of mouth hole to lower end): 535

hole	*A*	*B*	*C*
mouth hole	0	23.0x21.8	7.9x8.2
hole 1	235	23.2x22.1	6.3x6.7
hole 2	272	22.2x21.0	6.5x6.9
hole 3	306	23.0x21.5	6.4x7.0
hole 4	355	nm	6.4x6.8
hole 5	390	23.2x21.8	6.5x6.9
hole 6	427	nm	6.7 (damaged)

A: position of the hole - distance from centre hole to center of mouth hole
B: diameter (min/max) of the flute
C: diameter (min/max) of the hole
nm: not measured

I have made a copy of this flute in palissander wood, with a bore diameter of 17.5 mm. It plays at a pitch of a-435 to 440 Hz (depending on how much you cover the mouth hole), the lowest note is d1. Maybe that with a slightly narrower bore the pitch will be higher. The cork is set by me about 13 mm from the centre of the mouth hole.

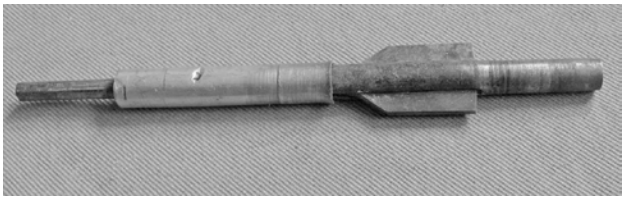
My first wooden renaissance flute

Before this copy of the Nova Zembla flute, I had made a few instruments with thicker walls (exterior diameter about 27 mm), based on a copy of unknown origin. I made these also in two joints, with a socket on the head and a tenon on the lower joint. That allowed me to make the bore in the top of the lower joint a bit wider over some distance: that made it easier to tune the a2 and b2 (becoming a bit sharper). This thicker flute plays (for me) more easily than the Nova Zembla copy, the pitch is also a bit higher, a-440 Hz. Some measurements in mm: Sounding length (SL): 519; head L 255, SL 186; socket: L 29.5, Ø 25. Bore: Ø 17.5, but 18.0 over about 50 mm in the lower section the head. Lower joint L without tenon: 333, tenon L 29. Ø bore: 17.5, but up to 18.0 over about 100 mm in the top section and up to 18.0 over about 100 mm in the lower section. Mouth hole: 8.5x8.8 mm, Ø wood 26.6; tone holes (L to centre mouth hole, Ø hole, Ø exterior) hole 1: 222, 7.0x7.4, 27.2; hole 2: 258, 7.0x7.2. 27.0; hole 3: 293, 6.5x6.6, 26.9; hole 4: 346, 6.5x6.7, 26.8; hole 5: 381, 7.7x72, 26.6; hole 6: 415, 5.7x5.8, 26.3. All holes are moderately undercut.

9.4 Some practical tips for drilling and turning a renaissance flute

Drilling a hole with a length of over 600 mm is not easy. See part 7 of this series (comm. 2060 in *FoMRHI Q* 136) for some methods and tools. It is important to take a piece of wood that is thick enough: if the drill goes slightly off line, you may still have enough millimeters leeway in the wall to rescue yourself.

For my Nova Zembla copy I had a piece of Santos palissander (surely not authentic for this flute, but very practical) that was about 40x40 mm thick. I bored a pilot hole with a diameter of 10 mm, but the drill was far too short, I had to put it on an extension piece for flat bits. But before I could use that I had to widen the bore as far as possible, with a 17 mm flat bit on which I had put an end piece with a pilot (photo, right), again mounted on an extension piece. There was the danger that parts of this combination might come loose and be stuck in the wood. It would have been much easier to buy a steel rod and grind it to a d-bit drill (other photo). After this drilling adventure I had to ream out the bore to 17.5 mm. That must be done before turning the flute on the lathe: the wall will become so thin that reaming is then very dangerous.



Turning such long and thin pieces of wood is another issue. It is inevitable that the wood will vibrate, which will result in ripple marks that destroy the surface. You must somehow support the wood, giving it counter pressure close to where the chisel does its work. See Comm. 2056 in *FoMRHI Q*. 135 for some solutions to this problem. I can tell you that I had to use a lot of sand paper to get a clean surface.

It is of course not always necessary to use a lathe to get a round flute. As most renaissance flutes have a simple smooth surface, without decorative patterns (rings, rims, grooves or whatsoever), you can plane the wood into its round shape. It is not unlikely that this technique was used in the past, also for instance for making crumhorns (which are made from straight pieces of wood; the bending is done in a later phase, after the finishing of the bore and the surface).

9.5 Fingerings for the renaissance flute in d1

d1	1	2	3	4	5	6	
d2	.	2	3	4	5	6	
e1 and e2	1	2	3	4	5		
f1 and f2	1	2	3	4	.	6	- turn flute inwards or lower breath pressure to make this note a bit flatter
f#1	1	2	3	4			- turn flute outwards to make this note a bit sharper
or:	1	2	3	.	5	6	- turn flute a bit inwards
f#2	1	2	3	4			- turn flute a bit inwards
or:	1	2	3	.	5	6	- turn flute a bit inwards
g1 and g2	1	2	3				
g#1	1	2	.	4	5	6	- turn flute a bit inwards, if necessary
g#2	1	2	.	4			- turn flute a bit inwards
a1	1	2				(6)	- hole 6 might be covered for a better stability
a2	1	2					
or:	1	2	.	4	5	6	- this fingering is a bit sharper than the other one, and sounds louder; it is actually the third harmonic, an octave + fifth above the d1
b-flat1	1	.	3	4	(5)		- covering hole 5 lowers this note a bit
b-flat2	1	.	3				- is often rather flat
or:	1	.	3	4	5	6	- is often rather sharp, turn flute inwards
b1	1	.	.	.	.	(6)	- hole 6 might be covered for a better stability
b2	1	.	.	4	5	6	- covering 4, 5 and 6 makes this note a bit sharper (otherwise the b2 is a bit flat)
c2	.	2	3	.	.	(6)	
or:	.	2	.	4	5	6	- may give a clearer sound
c3	.	2	.	4	5		- other fingerings possible
c#2	.	.	.	(4	5	6)	
c#3	.	2	3	4			
d3	.	2	3	4	.	6	
e3	1	2	.	.	5	6	- higher notes (third regsiter) are possible, for instance g3 with 1 . 3

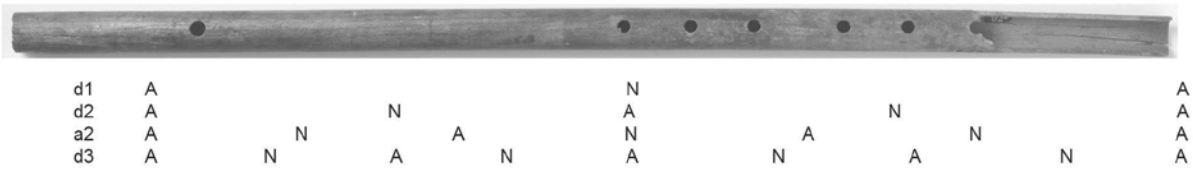
These fingerings are based on my experiences with the copy of the Nova Zembla flute. Some notes tend to be sharp or flat, but sometimes it is supposed that they are sharp or flat in meantone tuning, when compared with equal temperament. Fork fingered notes often sound a bit muffled, turning the flute inwards or outwards changes not only the pitch but also the quality of the sound. See for further fingerings on internet: http://www.oldflutes.com/charts/ren/

On Youtube there is a film (http://Youtube.com/watch?v=-sGJiNXl_9g) with a superb demonstration of the possibilities of the renaissance flute: Hans-Joachim Fuss playing a recercata by Aurelio Virgiliano on a flute after Bassano (made by Philippe Allain-Dupré from Paris). There are no muffled sounds at all, and especially surprising is the third register of this instrument.

9.6 Tuning the renaissance flute

a - some theory

The d1 (the first harmonic) cannot be tuned on one of the fingerholes: the only way to change its pitch is by widening the bore at the lower end of the flute, or shortening the flute at that point. For d2 (as the first overtone, or second harmonic), and even more the d3 (the fourth harmonic), we need to push the cork into the right position. Moving the cork closer to the mouth hole makes the octave interval d1 to d2 wider, and does that even more so with the interval d1-d3. For playing d2 you have to open hole 1, and for d3 hole 5 as well. Opening these holes (and blowing harder) makes that in the bore of the flute new antinodes can be formed, which correspond with the harmonics.



This picture with the approximate positions of the nodes (N) and antinodes (A) of the fundamental d1 and its overtones makes it clear.

d1: fundamental (first harmonic) d2:
first overtone (second harmonic)
a2: second overtone (third harmonic)
d3: third overtone (fourth harmonic)

The upper (most left) antinodes in the picture are placed several millimetres above the mouth hole. Are they really there? In traversos the mouth hole is much smaller than the diameter of the bore at that place. That means that at that spot there is no equalisation of pressure. This antinode is actually a fictive antinode, which is supposed to be (if you want to do calculations etc.) around 40 mm outside the mouthhole (see Otto Steinkopf, *Zur Akustik der Blasinstrumente*, Moeck Verlag 1983). At the lower end the soundwave is also a bit longer than the length of the tube (about 6 mm).

We see the importance of opening hole 1 for producing d2 and d3. Opening hole 4 just helps to produce the a2, played as second overtone of the d1, fingered 1 2 3 . 5 6. Opening hole 1 destroys however this a2, because it needs there a node of the sound wave. When these holes have the function for overblowing the note in one of the upper harmonics, the size of it has no influence of the pitch of these notes.

The other (and easier) a2 is played as 1 2, as the first overtone (and second harmonic) of the a1. But the nodes and antinodes of the a2 with this fingering is quite different compared with the third harmonic of the d1!

b - about tuning holes

Tuning the following notes implies that the holes on which they are tuned must be drilled in the right place and have the right size; unless you are very sure and accurate: drill all holes initially 0.5 to 1.0 mm too small. Doing that, it is better to put a piece of wood in the flute that fills up most of the bore, this to prevent that the drill causes splinters when it breaks through the wall.

Another problem is to get the fingerholes precisely at their positions on the flute, preferably on a straight line. What I normally do is to put a piece of writable adhesive tape over the

length of the flute, draw a straight line on the tape and indicate on that line the positions of the holes. After checking the distances, I pierce small points on the hole positions. Another method is to make a template (in metal or plastic) in which the hole positions are drilled, and attach that to the flute.

These are the tuning holes:
- d1, d2 and d3: no tuning hole (or the open end of the bore is to be regarded as a hole)
- e1 and e2: hole 6
- f1 and f2: hole 5, together with and f#1 and f#2
    These notes have to be corrected with your embouchure: f1 and f2 (1 2 3 4 . 6) are always too sharp, and f#1 and f#2 (1 2 3 4) too flat with the usual fingerings. Both groups of notes are tuned on hole 5. Making that hole bigger means that these notes all rise in pitch, with hardly any effect on the difference between f and f#.
- g1 and g2: hole 4
- a1 and a2: hole 3, together with g#1 and g#2
- b1 and b2: hole 2, together with a#1/b-flat1 and a#2/b-flat2
- c2: hole 1, together with c#2
- higher notes can rarely be tuned at the fingerholes; you must know to which lower harmonics these notes are related.

On all holes of the flute you can overblow the related note into the corresponding second harmonic, that is an interval of an octave. The same applies to the baroque traverso.

But there might be problems on longer types of renaissance flutes to overblow all the notes of the first register into a useful octave interval. On these instruments you must then use alternative fingerings.

c - tuning rules

Tuning means enlarging the fingerholes which have been initially drilled a bit (for instance 1 mm) too small. But the cork position must be absolutely correct before you do that: the notes d1, d2 and d3 must have the correct mutual relations. When tuning a baroque traverso, you can make some adjustments to the bore profile; this is not, or only in a very resticted way, possible for a renaissance flute with its cylindrical bore.

As we tune the flute from hole 6 to hole 1, we have to be especially careful to the get the first notes right, after the d1/d2/d3 that e2/e3, f and f#, and so on. We saw in the list above that on each hole more than one note has to be tuned. Most important is that the octave intervals (e1 to e2, f1 to f2) are correct. We already knew to begin with the right position of the cork. Before you start with the work on the tuning holes for the other notes. But playing octave intervals correctly depends also on your embouchure and breathing technique. Be aware that you can change the pitch of most tones with your embouchure up to about a quarter of tone (20 cents or more).

The main rules:
- a flute without fingerholes is pitched several cents higher than when the holes are drilled and closed by your fingers (this because the empty hole spaces in the wall of the flute add to the volume of the bore of the instrument);
- making a hole wider means that the related notes become sharper; but the note of the second register (the first overtone) responds more to the size of the hole than the note of the first register; and it does that even more so when you enlarge a hole in the direction of the lower end of the flute.

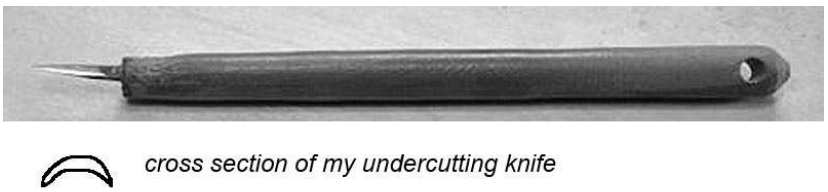
- formulated in a different way: when a hole influences a note and its octave, the position will have more influence on the lower note, while the diameter will have more influence on the upper note;
- that means that you have a problem when as at the beginning the e2 is already correct, but the e1 still too flat; in that case the position of hole 6 is wrong: it should have been drilled higher on the flute (more close to the mouth hole);
- sometimes a correction is possible by filling the hole in (with wax, nail polish etc.) at one end, and filing out at the other side;
- enlarging a hole has a quicker (sharpening) effect on the fork-fingered note than on the simple fingered one (for instance: the fork-fingered f with 1 2 3 4 . 6 and f# with 1 2 3 4)
- undercutting a hole has more or less the same effect as giving the whole a bigger diameter, but has a bit stronger effect on the fork-fingered notes;
- enlarging a hole has a strong effect on its related notes (for instance hole 4 for g1 and g2), but much less so for higher notes (for instance hole 4 for a1/a2 and b1/b2);
- enlarging and undercutting a hole means that the bore profile of the flute in that place is changed: that might have some influence on notes of the second and higher registers; to find these relations, you must make a complete scheme of the nodes and antinodes of all tones of the instrument (see part 3a of this series: Practical acoustics for woodwinds: sound waves and tuning, Comm. 2040 in *FoMRHI Q* 132).

d - tuning techniques

The French recorder maker Philippe Bolton gives on its website interesting information (also in English http://www.flute-a-bec.com/accordgb.html) about the tools and techniques of enlarging and undercutting fingerholes. He recommands as the safest tool for enlarging holes a coarse round file, because fine files are not efficient in wood. Finding the right type of files (which are not too coarse and have the right diameters) is, however, not easy. I am always nosing around for these tools.

An alternative is working with a piece of sandpaper (or better, emery cloth) wrapped around a small stick. You can buy that in several qualities, from fine to coarse. I work often with emery cloth with a grid of 150, for finishing a higher number is needed.

Most professional woodwind makers have one or another type of undercutting knife. Bolton writes about that tool: this technique needs learning. A 3 mm double-bevelled blade is perfect for this. The top and bottom areas of the hole must be cut separately, beginning on one side and working around to the other, stopping before the blade gets parallel to the fibres, when it will start splitting the wood instead of cutting it.



Undercutting knife of Philippe Bolton; with a cross section of the blade of one of my own under-cutting tools.

Always start cutting at the top or bottom end of a hole, working around to the side. That means that you begins with cutting straight through the fibers and stop before the blade gets parallel to the fibres, where it will start splitting the wood instead of cutting it.

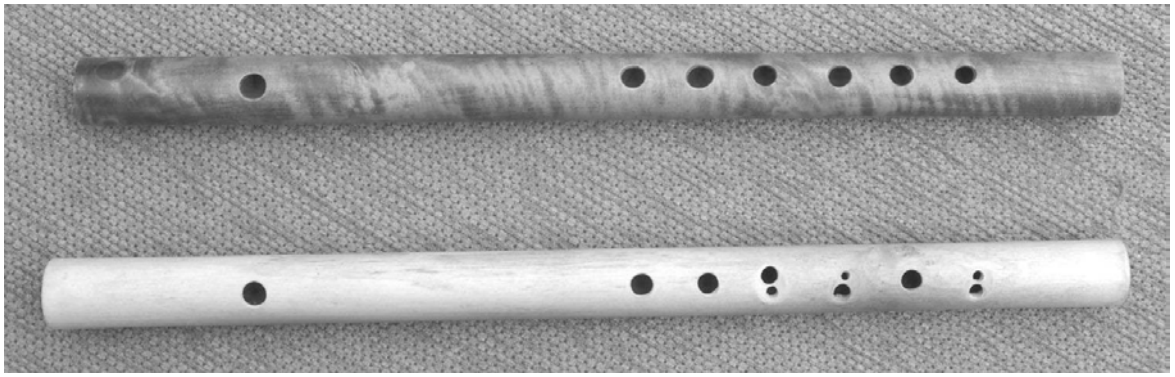
Some instrument makers use a Dremel mini-drill, with a small milling fraise. But you have to be very experienced to make a regularly shaped undercutting with such tools.

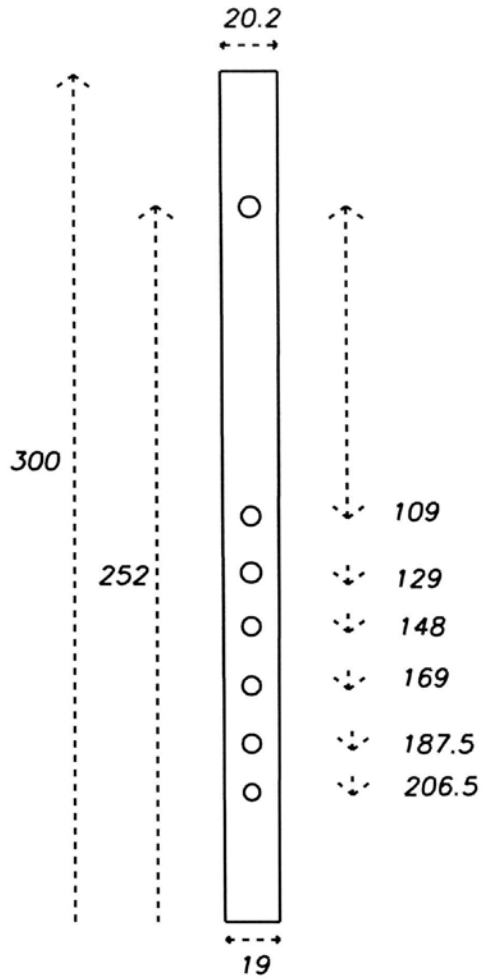
9.7 The Schweizer Pfeif

'Schweizer Pfeif' (Swiss pipe) is in German language the name for the piccolo flute as it was played in the bands of Swiss soldiers who fought as hirelings in foreign armies.

I do not know about finds of early small flutes from the 17th century and earlier, there are some baroque types with one key from the 18th century.

This piccolo flute is still used today in bands and had also found his way to the modern orchestra, after it had undergone the same development as the longer flutes: with a bigger mouth hole and a key system.





I have made a simple Schweizer Pfeif, the upper one in boxwood, the lower one in elder wood. The fundamental tone is d2, the pitch a-440 Hz, the bore is cylindrical (Ø 12 mm), the cork is set at about 12 mm of the centre of the mouth hole. All holes are widely undercut. Hole sizes (max/min): mouth hole: 7.2x7.2; hole 1: 6.3/6.6; hole 2: 6.6/7.3; hole 3: 6.4/6.5; hole 4: 6.2/6.4; hole 5: 6.2/6.3; hole 6: 5.5/5.6.

The double holes make the instrument more practical for modern music (and for modern ears): you can play now d#/e-flat with 1 2 3 4 5 6a. The f2 and f3 are played 1 2 3 4 . 6 (fork fingered), whereas for f# you have to cover only the bigger of the two holes at position 4 (1 2 3 4a), making it a bit sharper than the flat mean tone f# with hole 4 fully covered. There is also an easier g#/a-flat with 1 2 3a. The b-flat3 sounds best with 1 2 . 4 5 6a.

Elder wood is surprisingly useful for smaller flutes as you can drill a hole through the soft pith in the centre of the stem (or branches). The problem is to find pieces which are long and straight enough for this flute. I oiled the wood heavily with linseed oil; the flute sounded nicely.

Some measurements of the double holes (in fact: the diameter of the drills which I used, before tuning with files): hole 3a: 4.5 mm; hole 3b: 3.2 mm; hole 4a: 4.5 mm; hole 4b: 2 mm; hole 6a: 4 mm, hole 6 b: 3 mm.

One warning: playing the piccolo too much can harm your ears!

9.8 Some conclusions

The renaissance type of flute with a cylindrical bore and 6 fingerholes is in interesting instrument for the amateur woodwind maker. It is not too difficult to make and you have not to buy expensive tools. However, playing these flutes is a different matter, for instance when you are accustomed to the modern Böhm flute. It is not so much about the new fingerings which you have to master: the embouchure you have to use is really different. You must not fill the tube with energy as on the modern flute. With traversos (from renaissance and baroque) you have to develop another, more intimate type of relation: it is more a question of listening to the instrument, to what it gives back to you.

I certainly believe that the renaissance type of flute has great possibilities for modern music. You can play the instrument in equal temperament with some simple adaptations to the fingerholes. See the instructions in par. 9.7 where I applied these ideas to the piccolo flute; see also the middle instrument on the photo, left, which is a tenor in d1 with the same type of double holes.

From left to right:
- modern Böhm flute (white metal)
- renaissance flute (acryl glass)
- 'modern renaissance flute' in two parts in santos palissander, with double holes
- renaissance flute in two parts in santos palissander, single holes
- baroque traverso in four parts in boxwood
All flutes tuned at a-440 Hz.