11.13 Tuning recorders

A- Introduction

One would expect that measuring the pitch or assessing the sound of recorders would be much easier than that of traversos or oboes, where the result depends so much on the embouchure or the combination of reed and staple. Because that gives the player of those instruments the chance (which they need!) to approach the notes with a portion of flexibility, which the recorder doesn't have in the same degree. But especially with historical recorders, measuring the pitch of the notes is not so straightforward as it seems. See the data in the table below; the frequencies were measured as deviations in cents compared to a1=415 Hz, using an equal tempered scale (that scale gives us the quickest insight into the instrument, as we can directly see the character of the intervals).

Pitch measurements of the alto recorder Ea 31-x-1952 by Terton
tuner set at a-415 Hz, deviations in cents, Dolmetsch-fingerings, nm= no measurement

tone	Schimmel 1991	Stroom 1985	Bouterse 1989/1992	
f1	-35	+5	-5/+5	
g1	-52	nm	-20/-10 (-5 possible)	
a1	-56	nm	-20/-10 (-5 possible)	
b-flat1	-52	-5	-15/-10	
b1	-22	+15	+15/+20	
c2	-48	0	-10/0	Saskia Coolen (2004)
d2	-48	-5	-15/-5	pitch a = 417 Hz
e2	-39	0	-5/+5	
f2	-31	0	-10/0	
f#2	-69	-5	nm	
g2	-26	+15	0/+10	
a2	-31	0	-15/-5 (0 possible)	
b-flat 2	-48	-20	-15/- 5	
b2	-14	+10/15	+15/+20	
c3	-10	0	+5/+15	check: - octave intervals
c#3	-48	-25	-15/-5	a1-a2, c2-c3 d2-d3
d3	-18	-10	-10/-5	- pure thirds (f1-a1)
e3	-48	-25/-30	-20/-10	- second to third register
f3	-31	-30	-20/-10	- fork fingerings

The table shows three pitch measuring sessions of the same instrument, the alto recorder by Engelbert Terton, now in the collection of the Rijksmuseum in Amsterdam (see also FoMRHI Comm. 2032 for a picture of this recorder and some comments about the pitch). The pitch measurements by Charles Stroom and by me indicate an average pitch of a-415 Hz (with a rather flat third register); I gave for most notes a range in the pitch, an indication of what was possible on the instrument. The results of Hans Schimmel's tests are much lower than mine, but he found the third register not too flat in relation to the lower tones. Saskia Coolen played the alto on the audio-CD *Recorders recorded* (Globe Records GLO 5209, from 2004) in a sonata by Elias Brunnenmüller and found that the harpsichord had to be tuned at a-417 Hz. Important: the instrument was then well played-in, and Saskia achieved a fine balance between all registers.

Important things to know when measuring pitches

The results of measurement depend much on how you play the recorder. Bob Marvin wrote in his article 'Recorders and English flutes in European collections' (*Galpin Society Journal*, Vol. XXV, 1972) in the Appendix (p. 57): *It has been my idea to make the balance of a recorder group resemble a string or vocal choir, without a preponderance of the high voices. To this end I tune the upper notes sharp, to be played very softly.*
Another well-known factor is the temperature. An increase of 1^0 gives a rise in pitch of about 3 Cents. And when instruments in collections are allowed to be played (nowadays a rare opportunity), then only for a short time and a few notes, there is not long enough to get the balance of the temperature right: this is especially a problem for long instruments.

The aspect of the temperature is also important when tuning a new recorder. Two things may compensate each other to a certain degree when you begin the tuning process (starting at the lower holes): the sharpening effect of warming up of the instrument, and the flattening effect of enlarging and undercutting the holes higher up.
There are some more factors to be considered in the process of making a new recorder:

- drilling the fingerholes (and closing them with the fingers) makes the pitch considerably lower (up to 30 cents) than on an instrument without holes;
- undercutting the fingerholes makes the pitch even lower;
- heavy chamfers also flatten the pitch;
- a thicker wall at the window and labium stabilizes the tone (especially the lowest ones), but flattens the pitch; in my experience the highest notes (f3 on an alto) speak with more difficulty;
- opening (enlarging) the window and removing wood from the die walls of the window and labium will raise the pitch;
- the pitch depends on the dimensions of the bore: making the bore profile wider over the whole length flattens the pitch;
- also important is the condition of the wood surface of the wood: impregnated or superficially treated with oil;
- with the same bore diameters, recorders in a relatively soft type of wood (for instance fruit wood) may sound flatter than those made in a very hard wood (African black wood); this has to do with degree the vibrating air in the bore is absorbed or reflected by the wall of the bore;
- what I don't know is the effect of atmospheric pressure, for instance what happens when you live and play the recorder at a height of 2000 meters.

B- Preparations

Working order

- Before tuning the instrument, the voicing of the recorder head must be in good order. That might be a bit of a problem as for that voicing you must play the head on a completed (or almost completed) set, thus with the lower parts already tuned. When that is not the case, then it will be a matter of alternate actions: at first doing the main actions for the voicing, then working on the lower joint(s) for the first stage of the tuning, then back to finishing the voicing, then continuing the tuning (and so on).
- When you make a new recorder from a drawing and you are not sure about the pitch of the original instrument, do not force the pitch too much in a specific direction (for instance a-415 Hz), but take the time to discover the possibilities of your copy. The same applies to the fingerings. On some recorders, you can be freer than on others

to vary somewhat.
- It is easier when you make a new recorder which you can compare with copies you have made before. For instance, you can measure the pitch of the head and take measurements when that deviates too much. But pay attention; the dimensions of the socket have a great influence of the pitch when you are playing the head alone!

C- Some principles in tuning

- Tuning means enlarging and/or undercutting the fingerholes which you have drilled before; all of them initially a bit too small (e.g. for an alto recorder: 0.5 to 1 mm).
- But it can also happen that the bore of the recorder parts must be changed at some points. Especially when you are making a first copy of a recorder, it can be helpful initially to leave the bore a bit too narrow in some places, for instance at the lower end of the foot and the top section - at the tenon - of the middle joint. That implies that it is not advisable to make (or order) a set of reamers for a recorder when you have not made a first prototype (using other tools).
- Tuning can't be separated strictly from voicing: by enlarging/undercutting the holes, not only will the frequencies of the tones which are tuned at those holes change, but also the sound (becoming stronger and more open).
- Tuning begins at the lower end of the instrument, gradually working from the lowest fingerhole to the top. There is no fingerhole for the lowest tone, but the end of the foot bore acts as such. As we will later see, there are reasons for being reluctant to change too much in the profile of the foot bore.
- On several holes there is more than one tone to be tuned: tones of the first and second register, and the main tones and related fork-fingered tones. It is important to know the relation between these notes for every tuning hole (see also under D-).
- The thickness of the wall of the fingerholes has also an effect on the general pitch (as the space of the hole is part of the bore profile of the instrument), on the relation between the tones of the first and second register (a wall that is too thin easily leads to sharp overblown notes), on the relation between the main tones and the cross-fingered tones and also on the stability and the sound character of the tones. But on instruments with strongly undercut fingerholes you can't remove wood at the outside of the hole, as the opening becomes too wide.
- Making a hole wider makes the notes tuned at that hole sharper. But the effect is stronger on recorders and traversos for the tones of the second register.
- It is therefore unpleasant to discover at the start of tuning a hole that the octave interval is pure, but both tones of that interval are still too low. Enlarging the hole will make that interval too wide. There are in that case two solutions: plugging the hole and drill a new one a bit higher (north, closer to the labium) and also smaller, or changing the bore profile, for instance reaming the bore where a node of the vibration of the second register note is. You can find that place (or those places) by using a 'flute fish' (see FoMRHI Comm. 2040). But do not take action by reaming: you must know the positions of the nodes and antinodes of other tones as well. See the scheme on the next page for some examples.
- Changing the bore profile does also has influence on the secondary nodes and antinodes; those of the harmonics of the tones. A specific tone can be perfectly tuned, but sound badly. The critical places - also for the attack of some difficult notes - can also be found with the flute fish or other devices for a temporary narrowing of the bore. It is a matter of opposite thinking: if things become worse where you narrow the bore,

the likely solution is a reaming operation at that point. You must think carefully how much and over which distance material from the wall of the bore must be removed. It is not ideal when the bore profile becomes very irregular, for instance with multiple steps or even sections where the bore is wider (which can only be made with special tools). All of these aspects must be taken in account in the operations! That sounds rather complicated, and it is indeed so. Bob Marvin describes in his *GSJ* article from 1972 why and how he changed the bore profile of his copy of a renaissance tenor recorder to get some intervals right.

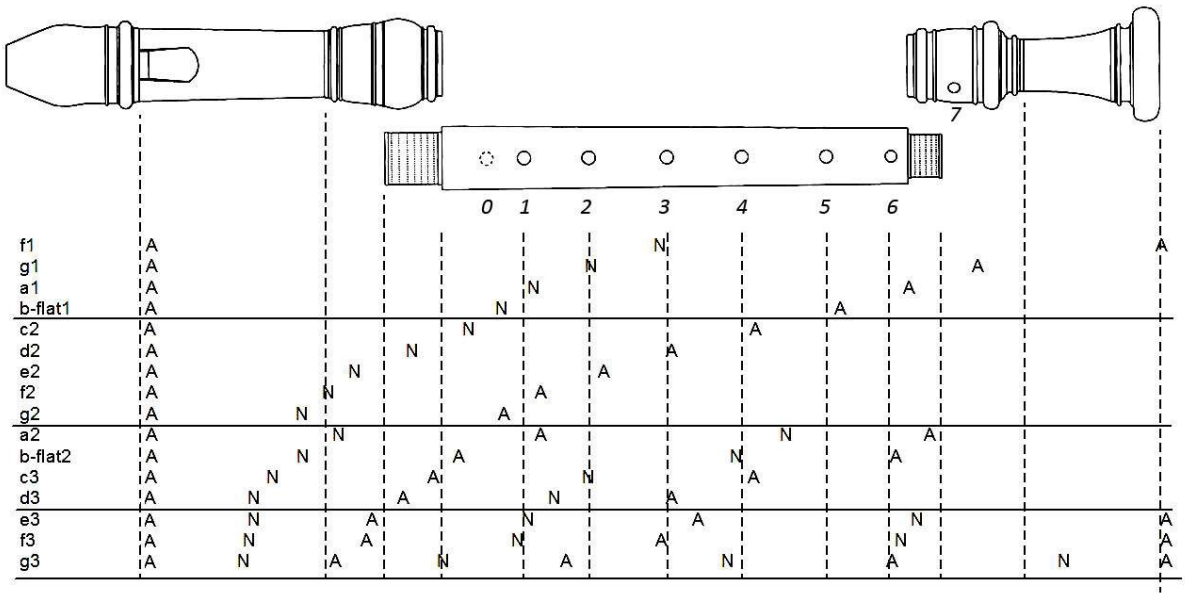


Diagram 1

Diagram 1 shows the positions of the movement nodes (N) and antinodes (A) of the vibrations of the most important notes of a baroque alto recorder. All positions are approximate and may vary from instrument to instrument. See Ch. 3a (Comm. 2040) for the acoustical backgrounds of sound waves in wind instruments.

Counting the number of nodes gives a clue to which register a tone belongs. From f1 to g2 is only one node for each of these tones, they are in the first register. From a2 up to d2 is the second register; e3 and f3 are in the third register. For the g3 four nodes are counted, that is a fourth register tone.

I have found the positions of the nodes and antinodes by moving a 'flute fish' in the bore, listening what happened to the tone: becoming sharper or flatter, sounding more or less full, or also speaking worse or better. Reaming the bore at the place of the nodes and antinodes has the opposite effect from narrowing. But you have to be aware of the length of the nodes and antinodes. An example: the central position of the node of the tone f1 is at about hole 3, so the f1 will be made sharper by removing wood from the inner wall of the bore. But you must do that for that tone over some distance: the effect stretches from about hole 1 to hole 6, with a maximum between hole 2 and 4. As can be seen in the diagram, the tones d3, e3 and f3 have an antinode at about hole 3. These tones may become sharper when you are reaming out the bore over there to flatten the f1. It is also important to know that all notes have an antinode at the window, but these stretch out there over some distance. The same applies to the antinodes at the tuning holes of the tones. That gives us the chance to play cross-fingered notes as the antinode stretches over lower tone holes.

About 60 years ago, Friedrich von Huene made a prototype of an alto recorder for the Moeck factory in Germany. He based that on an historical instrument by Jean Hyacinth Rottenburg (Brussels, Belgium). For his research he examined the effect of narrowing the bore, which was published (in German) in Tibia (1982, No. 3) and in Günther Dullat, *Holzblasinstrumentenbau* (Edition Moeck). Von Huene divided the recorder in 12 sections, see diagram 2 below:

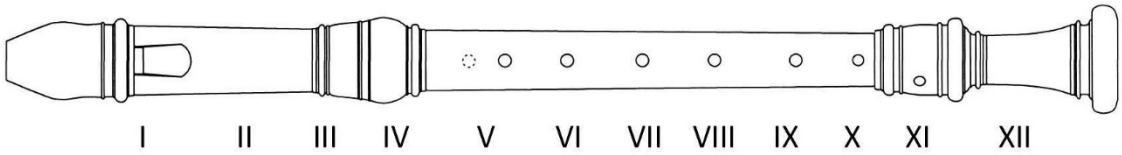


Diagram 2

He discovered that narrowing the bore in these sections had the following results:

- I- g1 and e2 become worse; e3 and f3 (speak) better
- II- g1 weaker
- III- g1 becomes unstable; d2 to g2 becoming sharper
- IV- a1 weaker, f2, f2 and g2 becoming sharper; octave intervals c2-c3 and d2-d3 becoming smaller
- V- a1 weaker; g1 stronger; octave intervals c2-c3 and d2-d3 becoming smaller
- VI- g1 much stronger; a1 weaker; octave intervals c2-c3 and d2-d3 wider
- VII- g1 and a1 stronger; e3 and f3 lower
- VIII- g1 i
- IX- unstable or much stronger with burbles; a1 and b-flat1 weaker
- IX- g1 worse; a1 better
- X- f1 and g1 worse; a1 better
- XI- g1 better and sharper; a1 better
- XII- f1 and g1 flatter; a1 better

It is clear for me that Von Huene was especially trying to solve some problems with the g1 and a1. His observations make clear that tuning and voicing (making the sound better) can't be strictly separated.

D- Relations between the tones; functions of the toneholes

Before beginning with operations on the toneholes, you have to know about the relations between the tones; this because several of them will be tuned together.
Unlike on a traverso, you can't overblow the tones into their octaves on a baroque recorder on all holes. But some of the 'false' harmonics can be used for other tones: the low f (with all holes closed) can be overblown to g2 by fully opening hole 0. The g1 (0 1 2 3 4 5 6) can be overblown to g#2 by opening holes 0 and 1.
Several tones are played with forked or cross fingerings, which means that below an open tuning hole one or more holes are covered to lower the pitch of the main tone, for instance from e (0 1) to e-flat (or d-sharp, with 0 1 . 3 4).
For some tones, a hole must be opened (or half opened), not to raise the pitch of a note, but for help in overblowing one or more tones. Hole 0 has a double function: as a tuning hole for some tones (f#2 and g2) and overblowing hole for several others. Hole 3 is an overblowing hole for e3; hole 2 and 5 have to be opened for the g3.
For some types of renaissance recorders and some of the newest generation of modern recorders (often with keys on the lowest holes) there are other possibilities.

The tuning holes, in the order in which they are approached are as follows:

- The end of bore (of the foot) can be seen as a tuning hole for f1, the lowest tone of the recorder.
- Hole 7 (or 7a/7b on recorders with double holes) is the main tuning hole for the g1 (or f#1 and g1), but has effects also some other tones, especially the a1 and its related tones.
- Hole 6 (or 6a/6b on recorders with double holes) is the main tuning hole for a1 (or g#1 and a1) and its related tones (a2, e3 and f3).
- Hole 5 is the tuning hole for b-flat1 and b-flat2.
- Hole 4 is the tuning hole for four tones: c2 and c3, combined with the fork-fingered b1 and b2.
- Hole 3 is also needed for four tones: d2 and d3, combined with the fork-fingered c#2 and c#3.
- Hole 2 is the tuning hole for e2 and, as we will see, also for the f3.
- Hole 1 is the tuning hole for f1.
- Hole 0 is the tuning hole for g1 and f#1.

Note: some tones are not mentioned in the list above, such as g#2, g3 and the tones above the g3. These tones can't be properly tuned on the fingerholes.

E- Tuning the tones

First a remark: I here give instructions mainly for tuning a 'modern alto baroque recorder', in other words a recorder where there is no difference between enharmonic tones such as f# and g-flat. But as such differences do occur in historic tuning systems, I will give some information as to how to get the tuning of such enharmonic tones right.
A point of departure: all toneholes are drilled at about 90% of their expected size, the voicing of the head has a satisfactory quality, the instrument parts are all reamed.

f1: the fundamental (0 1 2 3 4 5 7)

- f1 flat: the end of the bore is the place where you can make an adjustment: reaming the bore of the foot (making a counter bore over some distance*). More drastic is reaming the foot over a greater length, or even shortening the foot. But before doing that, it is better to leave the f1 for what it is and go on with the g1 and check if that tone has also the tendency to stay low. The problem may be found at the other side of the instrument, in the voicing of the head which - for instance - sounds too low on its own**. You must think about that: changing the dimensions of or around the window or leaving the situation as it is and continue the tuning of the f1 and other tones, but all of them at a flatter pitch.

  *: many historical instruments have such a counter bore, but I have seen them much less on modern recorders.

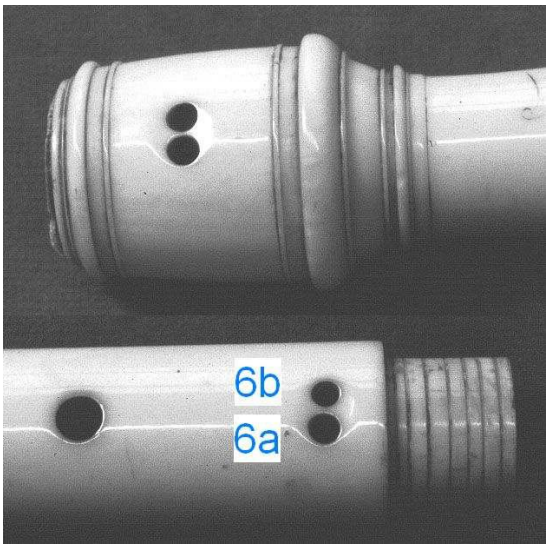
  **: I never found this specific pitch measurement in drawings of historical recorders.

- f1 too sharp: that is a more difficult problem. It sometimes happens when the bore of the middle joint is too narrow (between hole 1 and 6); it might help to widen the bore in that section, but that affects many other tones as well and you might end up with a quite different instrument than you intended. Another solution is making the bore down in the foot temporarily narrower, for instance with a rolled up piece of paper, and continuing with the g1, and see how that tone will do. A general remark: pushing up the

pitch of the whole recorder often causes a few problems: the tone holes following tone holes have to be made bigger, and several important octave intervals are likely to become too wide.
- f1 too weak: the problem is probably in the voicing of the head. But check also leakage at the tenons and the surface of the wall of the bore of instrument parts: a bit of oil sometimes helps instantly.

f#1 and **g1**: 0 1 2 3 4 5 6 7a and 0 1 2 3 4 5 6 7ab (7b being the left and smaller, and 7a the right and larger of the two holes)

Discussion: there are players who say that single holes on 6 and 7 produce better (or easier) sounding/speaking tones. I can only say that on many of my altos I have no problems at all with double holes, all tones sound well. But recently things did not go so well on a copy of a voice flute; I still have to discover what caused the problem. There are not so many historic recorders with double holes. I had the chance to see an alto by Steenbergen, a fine instrument in ivory, where there is only a very small difference in size between the left and right holes on 6 and 7 (photo right). The bridges between the left and right holes are both very narrow: by covering one hole, the other is shadowed a bit. It is likely that that was the intention of the recorder maker, otherwise the f1# and g1# were a bit sharp.



When I made a copy after a Bressan alto recorder, I changed the single hole 7 (which had a diameter of 5.2 mm) into double holes, 7a becoming 3.2 and 7b 4.1 mm.
- Hole 7a and 7b are on most recorders drilled at a downwards angle, thus avoiding the holes coming in the socket of the foot. But I have seen one or two instruments where that accidentally happened, without any negative effect on the pitch of sound of the tones.
- It is best to tune 7a and 7b together, beginning with 7b (for f#1) and continuing with 7a when 7b is almost at the desired size and then finishing both holes together.
- Hole 7 (or hole 7a and 7b) is on most recorders not, or only very moderately, undercut.
- Always check the pitch of the g1 in relation with f1 and a1. Keep the g1 a bit flat on recorders with are tuned in meantone pitch, where the third f-a is much smaller than on instruments in an equal temperament.
- The size and position of hole 7 have also influence on a1/a2 (which are tuned on hole 6) and e3. Drilling hole 7 lower on the foot makes the e3 (and f3) sharper. But there is not much space to move hole 7; it must stay in reach of the finger, unless you mount a key.
- g1 is rarely weak, but is on some instruments a problematic not, because of unwanted noises (burbles, or whatever). This can be caused by the design (bore

profile) or also by the finishing of elements of the generator (chamfers, labium). The problem can on such instruments generally not be solved by manipulations on hole 7.

g#1 and **a1/a2**: 0 1 2 3 4 5 6a (g#1), 0 1 2 3 4 5 6ab (a1), 0h 1 2 3 4 5 6 (a2; 0h means: hole 0 only partly opened). Hole 6b is the left and smaller of the holes, 6a is right and larger.

- g#1 is note on hole 6b; the problem is often not with getting it to the right pitch, but with the sound. Making the hole a bit wider may help: it is better to have the g#1 a bit too sharp than sounding very weak.
- The g#1 and a1 are tuned together (in the same way as is described with f#1 and g1), but also together with a2. Enlarging/undercutting hole 6 (or 6ab) makes a1 and a2 sharper, but does that to a larger extent when doing so in downwards (south) direction. This means that you have a problem when at the beginning of the tuning process: a1 is still flat, and a2 already at pitch (or almost there). Undercutting in an upwards (north) direction helps only a little bit. The problem may be in the bore, for instance when the section close to hole 1 is too wide. It is very difficult to narrow the bore there; it is easier to ream out the bore at the lowest node of a2, between hole 4 and 5. That lowers the a2, without affecting a1.
- Hole 6 (6ab) on most historical recorders only little undercut.
- On many historical (alto) recorders the a1 is low to very low, giving a pure third to f1. If you don't want that on your copy, you have to move hole 6ab a bit upwards, and make then trying to find the right size of the hole(s).
- The tone e3 is as an overtone of the a1, and making a1 sharper does the same with e3. It is, however, not, or hardly possible to tune e3 on its own. Hole 3 functions as an overblow hole, its dimensions have no effect for the e3. To get a good impression of the behavior of e3, you must at first continue with tuning the tones b-flat, c and d in both registers. Only then you will get an idea of the amount of air (pressure) that is needed going from the lowest to the highest tones, and also how far hole 0 must be opened to get the octave intervals perfectly tuned.

I have seen on many recorders (mainly cheaper factorymade instruments) a big difference in sound quality between the g1 (very full) and a1 (very bleak). This is surely caused by the bore profile, as you can see in the text to diagram 2. Undercutting of the tone holes may sometimes diminish some of the problems, but will never solve them completely.

b-flat1 (0 1 2 3 4 . 6 7) and **b-flat2** (0h 1 2 3 4 . 6)

These are 'modern baroque' fingerings, also called Dolmetsch fingerings. On old baroque recorders we find often 0 1 2 3 4 . 6 for b-flat1 and 0h 1 2 3 4 . 6h or 0h 1 2 3 4 . . 7 for b-flat 2. But hole 5 is the tuning hole in both systems. Hole 5 is (or can be) more strongly undercut than holes 6 and 7. Undercutting or enlarging hole 5 downwards is more effective for the b-flat2. Undercutting this hole means also widening the bore in this area. That might help to lower a sharp a2 a bit, but I am not too sure about the amount of that.

- Tuning on hole 5 is seldom a problem. On some modern factory recorders hole 5 is placed rather low, closer to hole 6 than to hole 4. I do not like that myself (unpleasant spread of the fingers), and I also do not directly see the need of that.
- On my Bressan copy with double holes on 6 and 7, the b-flat2 plays nicely with the fingering 0h 1 2 3 4 . 6h. On the original ivory Steenbergen alto with both holes double, the b-flat2 can be played with 0h 1 2 3 4 . 6. On other instruments, such as the soprano recorders by Terton and Wijne, I am not sure about which fingerings were intended. As a player you have to be flexible!

c2 (0 1 2 3), **b1** (0 1 2 3 . 5 6), **c3** (0h 1 2 3) and **b2** (0h 1 2 3 . 5)
All these notes are tuned on hole 4. Hotteterre gives in his *Principes de la Flûte* for c2 a fingering where hole 6 is also covered. That has hardly any effect on the pitch, a little bit more on the sound of the tone.

- Hole 4 on recorders with the Dolmetsch fingerings is always smaller than holes 3 and 5. You have to be very careful with enlarging or undercutting.
- The b2 is more critical than b1, as you can't put an extra finger down in the fork (which is possible for b1, and is often necessary when you play on old instruments).
- Making the hole larger has more effect on the c3 and b2; undercutting does a bit more for the b2 than the c3.
- On old recorders is b2 often a bit sharp, which is caused by the larger size of hole 4. Shadowing hole 6 (or 6a) is a solution when you want a flatter b2. The b1 has the same problem; there you can cover hole 7 (or only 7a) to lower that tone.
- When the octave interval c2-c3 is rather narrow and does not improve by enlarging hole 4, you must look at the bore in the top (hole 0 and upwards) of the middle joint. Reaming there makes the octave wider. But it is better first to know if you have the same problem with the d2-d3 octave: if that is also narrow, you can widen the bore from the top of the middle joint over the whole section of the tenon (be careful: the wood is thin there!).
- The opposite situation, where the octave is too wide: find the node of the c3 (in the section at about hole 2) and ream the bore there over a short distance. Or you have to move hole 4 a but upwards (north).

When you have arrived here at hole 4, you can play several groups of tones, for instance f1-a1-c2, or e2-c3. It is good to listen carefully, and not only looking at the output on your tuner!

d2 (0 1 2), **c#2** (0 1 2 . 4 5 6h), **d3** (0h 1 2) and **c#3** (0h 1 2 . 4)
These tones are tuned on hole 3, which can be undercut quite a lot. Covering hole 6 (Hotteterre fingerings) hardly affects the pitch and sound of d2 and c#2.

- It doesn't make any difference placing hole 3 a bit to the left side ('east') for easier fingering; it is all about the position (i.e. distance) to the block line.
- Everything said concerning notes tuned on hole 4 applies also for hole 5.
- c#3 is sometimes a difficult note. With a flute fish you can find critical places in the bore where narrowing might give improvement; or the opposite: worsening things for instance at about hole 1. Reaming there might solve the problem, but I can't say over which distance and how much you must do that, and what the effect is on other notes.
- The c#3 is on many historic recorders I have played rather flat, but is - thanks to a bigger hole 5 - better to our modern ears on instruments with Dolmetsch fingerings .

e2 (0 1) and **e-flat2** (0 1 . 3 4), also **f3** (0h 1 . . 4 5)
These notes are tuned on hole 2, which can also be undercut quite a lot.

- We have now arrived in the upper regions of the first register (e2 to g2). These tones are played with only a few fingerholes closed and are because of that are more flexible, more sensitive to changes in breath pressure than the lower tones on the recorder. That means that you must play e2 in relation with other tones, to get that pressure right.
- In Hotteterre fingering, all upper tones of the first register are played with hole 6 closed. But that is mainly a 'cosmetic' point, to give the player a bit more support to the instrument.

- For e-flat 2 you can put a finger less or more down in the fork.
- e2 can be tuned a bit flat, giving a pure third coming from the c2.
- The tone f3 must be seen in relation to e3 (0h 1 2 . 4 5). By opening hole 2 the nodes and antinodes of f3 will move up a little but, enough to produce that semitone higher. The f3 is a sensitive tone, its speaking depends hugely on the dimensions and finishing of the generator (for instance the size and angle of the chamfers) and of some places in the bore. Narrowing the bore in the middle of the head makes the f3 easier, and also reaming in the sector of the upper tenon of the middle joint (but too much reaming there gives to wide octave intervals of c and d). The dimensions (length and bore profile) of the foot are also important, as there are nodes and antinodes of the tones of the third and higher registers down there. Pulling out the foot a little bit lowers e3 much more than the f1.

f2 (0 . 2)

This tone is tuned on hole 1. Be sure that e2 is tuned well before you begin with f2.
- There is an alternative auxiliary fingering for e2 with 0 . 2 3, also tuned on hole 1. This fingering doesn't work on many historic recorders (and was not used in the past) but is fine for the modern type of instruments.

f#2 (. 1 2) and **g2** (. . 2)

These tones are tuned on hole 0, the thumb hole. Both fingerings can be seen as fork fingerings for all holes open, which gives an unusable tone.

g#2 (. . 2 3 4 5 6 .)

This is a 'false' overtone (octave + minor second) of the g1 (0 1 2 3 4 5 6) and can't be tuned on hole 7, the g1 being much more important. The fingering 0h 1 2 3 4 5 6a will work well on some instruments, or even better (a slightly more modest sound).

e3 (0h 1 2 . 4 5), **e-flat3** (0h 1 2 . 4 5 6 7a) and **f3** (0h 1 . . 4 5)

The e3 is a third register overtone (octave + fifth) of a1, closing 6 and 7a flattens the tone to e-flat3. Because of the relation with a1, the tuning hole should be 5. As we first have to tune a1 and a2 there, we can't tune e3 separately. But e3 (with e-flat3 and f3) are more strongly affected by the dimensions and positions of hole 7 and the length and bore of the foot. Problems with the e3 can best be solved there. The e-flat3 can be corrected by fingering: closing or opening holes 7a and 7b. See under e2 the remarks about the f3.

g3 (0h 1 . 3 4 . 6 7a) and **f#3**

This is also a false overtone, from the f1(two octaves + major second). It can't be tuned, but there is the possibility to open or close hole 7 for tone corrections. The f#3 is a notorious difficult tone on the alto, best played as g3 with shadowing the end of the foot bore.

Some higher tones are possible on baroque altos, such as g#3 (0h 1 . 3 . . 6 7a, other fingerings are possible), a3 (0h . 2), b3 (0h 1 2 . 4 5) and c4 (0h 1 . . 4). These tones must be forced by blowing hard and cannot be tuned by manipulating the fingerholes.