Making woodwind instruments

11: Recorders

11.1 Introduction: recorders as flutes with a windway
The term ‘recorder’ for the internal duct flute or fipple flute exists only in the English language. In other languages names are used in which characteristics of the instrument are indicated: flauto dolce (‘soft flute’ for its sound), blokfluit and Blockflöte (‘plug flute’ for the block or plug as essential part in the head), flûte à bec or Schnabelflöte (for the bill or beak-like shape of the upper end of the head). See Edgar Hunt’s good old The recorder and its Music (1966) or not so old Wikipedia for more information about the etymology and the history of the recorder. With the reintroduction of historical instruments in the 20th century some original names also reappeared, such as the sixth flute (soprano recorder in d2) and the voice flute (tenor recorder in d1). It is a reminder that in the the 17th and 18th centuries the term ‘flute’, or in other languages: Flöte, fluit, flauto, flûte, was also - or was even mainly - used for the recorder which is a woodwind instrument in the group known as internal duct flutes: flutes with a whistle mouthpiece, also called fipple flutes. Wikipedia discusses the confusion in terminology: until the mid-18th century, musical scores written in Italian refer to the recorder as flauto, whereas the transverse instrument was called flauto traverso. This distinction, like the English switch from ‘recorder’ to ‘flute’, has caused confusion among modern editors, writers and performers. Indeed, in most European languages, the first term for the recorder was the word for flute alone. In the present day, the word ‘flute’, when used without qualifiers, remain ambiguous and may refer to either the recorder, the modern concert flute (Böhm flute), or other non-western flutes.

11.2 From very simple to highly sophisticated: types and sizes of recorders
Recorders are made in many different sizes (lengths and pitches), numbers of tone holes, fingering systems, and in various materials (wood, ivory, plastics, metals). In fact, I think there is no family of musical instruments with so many members, and it is impossible to discuss all types and varieties. On these pages I will give information about experiences with the recorders I have made myself. These are mainly of the baroque and early baroque types: copies after historical instruments as well as adaptations of these instruments for playing at modern pitches and with modern fingerings, and some experimental recorders. I have only a little experience with the so-called Ganassi recorders which are popular amongst players of early (renaissance) music, and I have never made consorts of renaissance or baroque instruments, French flageolets (with six fingerholes: four at the front, two at the back) and tin whistles (with six fingerholes at the front and no thumbhole). But there is enough left to talk about. For instance, recorders are perfect instruments for carrying out experiments and also for making simple, toy-like whistles. You even do not need a lathe to make some types of recorders. But be aware: recorders are - apart from some of those toys - by no means easy to make. It requires a lot of skill and understanding of the acoustics of the recorder for making a fine copy of one of the recorders of the famous woodwind makers of the past. The modelling of the windway, block and labium must be carried out with great care and you have to use special tools, also for measuring (which tools you can make yourself, see chapter 2 - Comm. 2031 and 2032). Also needed: a trained eye to get the desired results. But that applies also for other types of musical instruments.
Terminology of a baroque recorder
11.3 Terminology

Recorders can be made in several parts, for instance:
  - head - middle part (middle joint) - foot
  - or: head – body
  - or: in one piece.

The parts of an instrument are connected by sockets and tenons or by metal tubes. The top of the head is sometimes called a ‘mouth piece’. It is the part of the head with the windway and the block: together with the window and labium it is the (sound) generator of the instrument (see also Ch. 3a, Comm. 2040). The rest of the head and the lower section contains the bore and the tone holes: the (sound) resonator.

About the names of the parts and details in the pictures: it was especially difficult for me to find terms for some details, for instance of elements of the turned profiles, I had to invent some of them in my native language and then to translate these terms into English: not an ideal situation. Other people may use different terminology; it is not so important, the main thing is that you will understand what I write in these paragraphs.

11.4 Acoustics of the recorder: a short introduction

There is much to tell about the acoustics of the recorder, how the air flows through the windway and how it behaves entering the window. I give here only the most necessary information so that you will have the basic knowledge needed for making a recorder.

The French recorder maker Philip Bolton explains on his website (www.flute-a-bec.com/acoustiqueg.html) with some fine pictures and videos ‘how recorders work’. It is clear - and important to know - that the air that comes out the windway is not simply divided in two parts: one part going into the bore of the instrument and the other part over the top of the labium. The labium edge is in the first place not in the middle of the air flow, on most recorders that edge is - looking through the windway - just visible at the lower side. Which means that most of the air goes out over the labium out of the instrument. Further: the air in the windway is not a regular flow; friction to the walls causes disturbances. The result of that is that the air jet coming out of the windway will oscillate around the edge of the labium, followed by an interaction with the air column in the instrument's bore, see pictures below (from University of Eindhoven, Netherlands, see the website of Philippe Bolton).
It is important for a recorder maker (and player!) to control the direction and behavior of the air jet to get the desired sound and other playing characteristics. However, there is not much information in books, articles and on internet about how to control the air jet and the oscillations. For instance: how to avoid noise (‘undefined sound particles’). I can’t give you all solutions as well, but I will try to show you the direction in which you can work.

There is much resemblance between a recorder and an organ pipe. But an organ pipe has to produce only one tone, and the wind pressure doesn’t vary. On a recorder you can often produce more than twenty notes (two octaves or more) while the wind pressure changes (or has to be changed) going through the scale. It is a challenge for the maker to get a perfect balance between the registers.

See for more information about recorder acoustics for instance:

These books give hardly any practical information for the recorder maker and you must have some experience in reading and understanding mathematical formulas. A consolation: the famous woodwind makers in the past didn’t need that!

### 11.5 Working order in making a recorder

Concerning the working order: some preparations are required before the real work begins. For instance, apart from a plan of an instrument (drawing + measurements) you must have pieces of wood which are sufficiently dry, machines (a lathe) and tools (such as reamers and drills). That might sound not so encouraging, but I started myself with a rather cheap equipment (such as an electric drill which was also used as a motor for a simple lathe, see chapter 6a in Comm. 2056) and made some fine instruments that way.

- The first step: the interior, the bore and the sockets of the parts.

  The traditional way is described in Comm. 2056: turning a massive piece of wood into a round rod and use a lunette for drilling a pilot hole (always working from one end only: you are never sure getting a straight hole when you do the drilling from both ends). With this method the wood is spinning and the drill is pushed against the wood (photo left). I myself prefer to make a pilot hole in a piece of wood when it is still square: the drill is spinning and is pushed into the wood (or the wood is pushed into the spinning drill, photo right).
Warning: drilling long holes can be a dangerous job, the combination of a big lump of wood or a drill is turning at a considerable speed and the force that is needed to make a hole can lead to dangerous situations: the wood or drill becoming loose, the drill getting jammed or becoming hot. I have lost some pieces of wood and a few drills over the years, but still have all my fingers. Important: your lathe must have an emergency stop (I have one which I can also stop with my leg). And I don’t like lathes (or other engines) which are too powerful, or are generate too much speed.

- Second step: the exterior, the turned parts.
  It is impossible (or very unwise) to do the second step first, thus turning a massive piece of wood at first, and then trying to drill a hole through the whole length and perfectly in the middle of the wood.
- Third step: working on or in the wall of the instrument: windway, labium, finger holes.
  Making windway, labium and block takes most of the time (unless you have to make a key system).
- Fourth step: finishing the surfaces, playing in the instrument, making corrections.

I do not always complete each step before I go to the next. For instance I sometimes leave the bore a bit too narrow in some places, doing the final reaming at the end when tuning the recorder. And I turn initially only a part (the middle section) of the head of a recorder and finish the turning after I have made the windway, labium and block.

Never forget at every step when you are making a recorder: just as with other woodwind instruments, making a recorder is mainly a combination of removing wood and finishing surfaces.

When making a head of a recorder, I turn at first only the middle section to the required diameter (I call that a ‘working head’ - in Dutch: werkkop, see photo below). Upper end and lower end are still too thick, so that I can clench it firmly in my workbench.
11.4 Easy starters
a)-A simple whistle with 1 + 4 fingerholes
At excavations in Amsterdam some very simple recorders were dug up: with only a few fingerholes and the window made with the same drill as these holes.

The whistle at the top has been preserved rather well, the other two have suffered during the drying process.

[Diagram of whistle components]

[Photo of whistle]
Some measurements (in millimetres):
- L: 120, L to block line 105; L windway 14; window: 4.6 (L) x 4.8 (W); total length of labium + window: 9
- Windway: width from c. 5.5 to 4.8, made with a file (to about 0.5)
- Bore: Ø 10 mm over whole length
- The block is a round piece of wood, just a bit flattened at the side of the windway.
- Thickness of the wood: Ø at block line, 15.5 to 16 at fingerholes, at lower end c. 20.

Fingerholes (L from centre of hole to block line, Ø of hole)
0 - L 41.5, Ø 5.0 (= thumb hole at the back)
1 - 41.5, 5.2/5.5
2 - 55.5, 5.2/5.5
3 - 69.7, 5.0
4 - 84.5, 5.2/5.5

Fingerings:
- e₂ 0 1 2 3 4
- e₃ 0h 1 2 3 4 (h means: hole only partly opened)
- f#₂ 0 1 2 3
- f#₃ 0h 1 2
- g#₂ 0 1 2
- g#₃ 0h 1 2
- a₂ 0 1 . 3 4
- b₂ 0 . 1
- c#₃ . 1 2
d#₃ all holes open, or closing 2 or 3

With these 1 + 4 holes you can play a more or less precise diatonic scale. It is possible to make this type of whistle a bit longer, or the bore narrower (for instance 9 or even 8 mm Ø), or to make it (with other fingerings) with 3 or 5 fingerholes at the front.

b)-a wooden ocarina
Ocarinas have about the same ‘generator’ as recorders, with a windway, window and labium. The resonator is, however, quite different. This can be any kind of shape: like an egg, a sweet potato, a thick cigar or torpedo, fish, bird, small sculptures, even a pretzel. Ocarinas come in all sizes.

From Wikipedia: the modern European ocarina dates back to the 19th century, when Giuseppe Donati from Budrio, a town near Bologna, Italy transformed the ocarina from a toy, which only played a few notes, into a more comprehensive instrument (known as the first ‘classical’ ocarinas). The word ocarina in the Bolognese dialect of the Emiliano-Romagnolo language means ‘little goose.’ The earlier form was known in Europe as a gemshorn, which was made from animal horns of the chamois.

Ocarinas are often made from clay. But metal, plastic and as we will see wood are perfect materials for the instrument.

About the acoustics of the ocarina (see https://newt.phys.unsw.edu.au/jw/Helmholtz.html for more information): when all fingerholes are covered, unlike on recorder which has an open end, the resonator body is completely closed (apart from the window opening). The body acts as a Helmholtz resonator, which is a container filled with air and an open hole (or neck or port). A volume of air in and near the open hole vibrates because of the 'springiness' of the air inside. A common example is an empty bottle: the air inside vibrates when you blow across the top. The frequency of the tone that you will hear depends of the volume of the container and the size of the window, plus the size of other openings which are drilled on the body and act as fingerholes. Unlike with the recorder, the position of the
holes on an ocarina is not critical, the frequency of the note depends mainly on total amount
of the surface of the opened fingerholes.

There are no soundwaves with nodes and antinodes in the body of the ocarina: the air
vibrates evenly in the whole space of the body. That also means that there are no harmonics
in the sound and that involves that you can’t overblow into the octave or other intervals.

And that reduces the range of the ocarina: you can’t generally play more notes than the
number of fingerholes on the instrument. The only way to extend the scale is adding keys
which must then be operated with other parts of your hand. But there is a limit to what you
can do: the quality of the sound goes down when the opening surface is becoming bigger.

With double holes you can play (some) chromatic tones and in fact it is possible to apply
various types of fingerings to the instrument. I myself have applied fingerings after Hotte-
terre, which implies that hole 6 (which is covered by the ring finger of the lower hand) is for
most holes closed. Doing so makes my type of ocarina more stable when I play it, because
there are no notes where all the holes have to be open.

The fingerings for an instrument in C:

- c1: 0 1 2 3 4 5 6 7
- d1: 0 1 2 3 4 5 6
- e1: 0 1 2 3 4 5
- f1: 0 1 2 3 4 . 6; f#1: 0 1 2 3 . 5 or 0 1 2 3 . 6 7
- g1: 0 1 2 3 + 6; g#1: 0 1 2 . 5 or 0 1 2 . 6 7
- a1: 0 1 2 + 6; a#1/b-flat1: 0 1 . 5 6
- b1: 0 1 + 6
- c2: 0 + 6, c#2: 1 + 6; d2: only hole 6 covered
I made my ocarina from pieces of so-called FSC-certificated tropical hardwood, from a DIY shop, probably meranti. But it is not a pleasant type of wood for fine work. Making a smooth finish of surfaces is difficult. It is important that the parts of the body are perfectly fitting; even the smallest leak can destroy the sound of the ocarina.

The two parts with labium and windway, here presented upside down.

The generator (windway & labium) is made in two separate pieces of wood, which are attached with screws so that they can be easily removed and replaced. The windway (A) is cut in the top piece. The ‘floor’ of the windway (C) is in line with the surface of the body. That is why I had to cut a small ‘underlabium’ (see B). The hole in the body (left from C) must be sufficiently big. Apart from screws, I used strips pieces of thin double-sided tape (such as used for photo prints) around the sides for a leak-free attachment.

The ocarina from the picture on the previous page is actually not in c, but has as its lowest note d (like a voice flute).

About the dimensions (in millimeters): length of body: 198, width 51 height 39. The boards are about 6 thick, which means that the dimensions of the interior of the body are about 186 x 40 x 26.

The window is 12 (width) x 9.5 (length/height). The windway: width/height 15.5 x 1.5 (at top) to 12 x c. 1 (at window). Length of the slope of the labium: c. 15.

Regarding the placement and the size of the fingerholes: the position of the holes is not critical, you can place them so that they can easily be covered by your fingers. Hole 0 is at the back of the body, not too far from the (opposite) position of hole 1. It is obvious that the holes are becoming bigger going from 7 to 1 (and 0). For each other size of ocarina you have to try out the size of the fingerholes, it is not easy to give a formula (the size depends also - and very much so - of the fingering system that is applied).

I have drilled at first the holes a bit to small:

hole 7: 3 mm  hole 6: 3.5 mm  hole 5 and 4: 5 mm
hole 3: 6.5 mm  hole 2: 8.5 mm  hole 1: 7.5 mm  hole 0: 10 mm

and enlarged them (from 0.5 up to 1 mm) in the process of tuning.
c)- a square soprano recorder

Alec Loretto designed a square soprano recorder. It has the common ‘English baroque fingering’, the pitch is $a=440 \, \text{Hz}$.

I changed the construction of the resonator for my copy, much as I did with the wooden ocarina. But the block of the recorder is now a massive piece of wood. The height of the block can be altered by putting a piece of thick paper below (see drawing).

The four wooden panels must be absolutely flat and smooth at the sides where they are glued together. And that is perhaps the most difficult part of making this type of recorder! Leaking panels make playing the recorder impossible.

The fingerholes on my copy are a bit smaller than on the Loretto plan, maybe because I have made the walls a bit thinner. It is always good to drill the fingerholes a bit (0.5 mm) too small, and then widen them during the tuning process. Begin at hole 7, then 6, 5 etc. I have also undercut some of the holes. Doing so, you can manipulate a bit the relation between the main tones and the fork-fingered tones (esp. on holes 3 and 4).

See Comm. 2040 (FoMRHI Q 132) for an introduction with general rules for tuning woodwind instruments.
c)-a PVC recorder

This is a very simple soprano recorder (a-440), made from PVC tube (16 x 13.5 mm) from the DIY-shop. The block is a round piece of wood, flattened at the windway side. I didn’t find rods of that diameter (or slightly thicker) in the shops, so I turned a piece of wood on the lathe (other solution: make the block from a piece of cork).

The photos show the construction of the windway: using a small saw with fine teeth and/or a sharp knife, files and pieces of sanding paper. It is not easy to finish the surfaces very smoothly, as you can see on the photos! The ‘roof’ of the windway is formed by a U-shaped piece of the tube. It is best to remove a few millimeters, otherwise the piece is too stiff and can’t be pushed over the rest.

I had to make several attempts before I found the right place and size of the fingerholes: these dimensions are quite different from those on the square recorder. My PVC recorder plays rather well, but with a bit of noise. The highest notes are a bit flat, unless you play them with some force.