Making woodwind instruments

8- Reamers for woodwind instruments

8.1 Introduction

The dimensions of the bore are of the greatest importance for the acoustical properties of woodwind instruments, which means that much care must be given to the reamers which shape the borehole into the desired profile. Bore profiles of woodwind instruments can have all kinds of shape: cylindrical; conical expanding or conical narrowing (both regular or irregular), or else - and this is often the case - with combinations of these profiles. Cylindrical bores can be made with drills only, but they must be of very good quality and used with care, to be sure that the diameter is the same over the whole length of the bore, and that the walls of the bore are round in cross section, smooth and clean (concerning drills see the remarks in chapter 7 of this series of articles). Conical bores must be made with reamers, which come in several types, fixed or adjustable.

Diagram: three types of conical bore profiles

- Type A is a parabolic shape, where the bore is narrowing more strongly in the lower half (and often most pronounced in the lower fourth) than in the upper section. These parabolic profiles are very common in historical recorders, traversos and oboes and match with the shape of many traditional spoon reamers. Looking through a bore (from the wide end) with good light from the other end, the places where a bore is constricting are often clearly visible (‘reamer ends’). But it is better to make a graph where the diameter is on a 10:1 scale with the length.
- Type B is a straight cone, which I found on only a very few old traversos and oboes.
- Type C is a what I call a ‘hyperbolic profile’, rarely found in parts of recorders and traversos, but common in oboe bells where the bore follows the profile of the exterior (the scale in the graph should therefore be closer to 2:1).
8.2 The choice of reamers

Several types of reamers and ways of reaming are used by woodwind makers today. The choice between them depends - for instance - on what you are doing: making a large number of the same instrument model, for which it is convenient to have fixed reamers that give the desired profile in one operation with great repeated accuracy. Or - what I do - experimenting and making only small numbers, for which I need flexibility, so that I can use adjustable or multiple short fixed reamers for one instrument part.

After the preparatory work (drilling) on the lathe or using an electric drill, I prefer to do the reaming by hand. It is safer for me and I can feel better how the wood is reacting.

8.3 Spoon reamers

Spoon reamers are the traditional tools for woodwind makers. They are not so different from spoon drills (see chapter 7) and can be made by forging a piece of steel: using heat and hammering with the right tools. That is not so easy as it may seem when you see a blacksmith at work; and for him or her it must also be rather difficult to get the dimensions right.

8.4 Round reamers with a turned metal or wooden body

Photo: these are modern spoon reamers by Joseph Böhm (see www.boehmtools.de/uploads/media/reamers.pdf how to order them). They are surely not made by forging, but are turned on a lathe after which the hollow shape is milled. These tools can be used when the wood is turning (not too fast) on a lathe, or by hand where the wood is clamped in a bench.

I have made some reamers on my metal lathe, using a technique which is described by Gary Cook in an article (‘Hand tools for recorder making’) on the Recorder Homepage (http://members.iinet.net.au/~nickl/tools.html). This drawing is from that article:

Machine a series of small "steps", about 0.1mm per step (equivalent to 0.2mm reduction in diameter per step)

Smooth with a file and finish with emery cloth and metal polish
There are other methods for turning a profile in the metal, but the main problem is how to make a cutting edge, and what the ideal shape is for that cutting edge. I found some interesting information, ten years ago, on a website (which is not online anymore) of Markus Gäbel and published that - with his kind permission - in an article for *De Bouwbrief*.

Gäbel explains: for the cutting edge of type A a quarter of the reamer is removed. Because the edge is 90 degrees, a burr must be made on the edge. Reamer A2 has a positive cutting edge (< 90 degrees) and can be used without that ‘brim’.

In type B a groove is made in the reamer, which automatically gives a positive cutting edge. However, sharpening the edge is not easy, and there is not much room for the chips. Because the cutting edges are so close, there is rather much friction between the steel and the wood and reaming is not so easy with this type of reamer.

Type C: this reamer will cut more easily, as there is less friction. There is only one cutting edge. It is better to make the reamer with two or three cutting edges; they will stay sharp for a longer time and chip clearing is easier. Some advice: it is better to mill the cutting edges with a slight assymetry, to avoid resonance when you do the reaming.

Type D is better for small diameters (< 10 mm).

There is a problem with milling the cutting edges: the shape of the reamer might change, because of tensions in the steel. That is why the steel has to be treated (annealed*) before it is milled, but that means also that the reamer must be hardened afterwards, which is not an easy operation. *See on the internet (for instance Wikipedia) writings on the various heat treatments of steel.

I have made for the top joints of baroque oboes (diameter from about 11 to 6 mm over a length of about 240 mm) a few reamers from silver steel. I made the cutting edge on my grinding wheel (see drawing), which gives a nice positive
It is important not to grind away too much: a bit more than half of the circumference of the rod must be left. I didn’t harden the reamer, or give the steel a heat treatment before I started the operations.

Photo: four reamers, turned from a metal rod. The upper one is for an oboe top joint, the cutting edge made with the grinding wheel. The second one has two opposite grooves, the milling was done by a local metal workshop, but I am not so happy with the result. The other two reamers (for a Rottenburgh-traverso) have two cutting edges (see picture right for as cross section) which means that these reamers can be used in two directions; they cut rather well, but the steel has not been hardened. Instead of a massive rod, you can also use steel tube for making a reamer. Grinding a cutting edge will then be a lot easier (or faster), but the tube must have enough wall thickness for the turning of a tapered profile in it.

Photo: this is a reamer where a blade of steel is screwed on a piece of hardwood, which is turned on a lathe in the desired bore profile (I discovered recently that this reamer scraps the bore of a ring of artificial ivory really well). It is possible to move the blade a bit, to make small adjustments to the profile of the reamer. The weak point of this reamer is where it is attached to the shaft. Some cracks appeared and I had to reinforce the connection with a brass ring. And for strength you must have enough body in the wood, so for small diameters (< 15 mm) this type of reamer is not appropriate. The screws (parkers) must be tightened firmly. Blades from a metal saw are generally fine for the cutting blade; a grinding disc is essential for making the slots in the blade for the screws. However, blades from industrial planing machines are often too hard to be grinded and can’t therefore be used for reamers.
There is much more to tell about spoon reamers and turned metal and wooden reamers. There are several articles about reamers in FoMRHI-Quarterlies from the eighties and the nineties, written by people who have much more experience with these tools than I have, or ever will have. See the website of the FoMRHI (www.fomrhi.org/pages/communications) and use the search box with ‘reamers’ as keyword.

### 8.5 Flat reamers

With flat reamers I have much more experience. They are not too difficult to make and cut as a rule more easily than round reamers. They have, however, one disadvantage: these reamers can’t be sharpened without losing their cutting profile.

These two drawings are again from the article by Markus Gäbel.

The profile of the bore must be scratched on a flat piece of steel; then begins the process of grinding the steel into its shape, with a trapezoid cross section.

Left drawing: at 1 and 2 are the cutting edges, the angle is negative (> 90 degrees), the reamer is more scraping than cutting. But that is sometimes an advantage for harder types of wood and artificial ivory. The reamer in the other drawing has a gully which results in a positive cutting edge.

This drawing shows how a bore profile (in this case of a lower joint of baroque soprano recorder) can be transferred to a flat reamer. The important points on the graph are where
there is a change of angle in the profile. Grinding the profile means that you have to check the result a thousand times, and also that you must use your eyes: the reamer profile must become exactly symmetrical.

Photo: the upper four flat reamers are for a baroque alto recorder. For the head I have only one short reamer, going from Ø 19.7 to 18.5 (the rest of the bore is cylindrical). For the middle joint I made two reamers, which have an overlap. I find it much easier to ream a long joint with two or more reamers than with just one. Not so much force is needed and I can use each of the shorter reamers also better for other instruments. I put the second reamer in a slot in a metal rod so that I can reach the lower part of the bore.

Most of my flat reamers are 3 mm thick; for bores wider than about 24 mm it is better to use thicker steel, for instance 4 mm.

From Alec Loretto (who was our teacher in the early eighties at courses of the Bouwerskontact) I learned that it is better to have an extra touching point for the reamer. That can be realized by screwing some bolts with a rounded tip at different positions on the reamer. You must make holes in the reamer and tap a screw thread in it (which is not difficult to do). But it is not so easy to get the dimensions right (length of the bolt, in combination with rounding the top). And as I have no problems using flat reamers without that device, I never put these touching bolts in my flat reamers anymore.
This is an adjustable flat reamer, with two blades which can be moved over some distance and fastened with two bolts. That must be done firmly, but as there is a big force on the blades when you are reaming, it is also better to make a system with two small sloping grooves (B) in which the small bolts are turned very tightly. With this reamer you can make cylindrical bores, or bores with various conical profiles. The adjustable flat reamer has only one cutting edge (the simple flat reamers have 2), it is important to make the lower end a bit tapered. The reamer has to be mounted on an extension, similar to that on the photo on the previous page.

These are two cross sections of the adjustable flat reamer, at the position of the big and the small bolt. It is important when you want to design this tool to draw a precise plan on graph paper, where all dimensions are enlarged (for instance 5 times). It is the best way to calculate exactly the minimum and maximum diameters which can be made by this reamer.
8.6 Adjustable metal reamers

Adjustable metal reamers have blades that move within tapered slots in the reamer body. To adjust these reamers the blades are moved within these slots by loosening the nut at one end and tightening the nut at the other. Movement permits the reamer to be set to any desired diameter within the range of the size adjustment.

These reamers are hand tools and are constructed to do their work in (not too hard) metals: a cylindrical bore can be made a bit wider by pushing and turning the reamer into the hole. The surface of the blades run parallel to the axis of the reamer, which means that you can actually only change the diameter of these cylindrical bores into a slightly wider, but still cylindrical bore. However, these adjustable reamers can be used in woods as well and are perfect for reaming the bore of the head of a baroque traverso from (for instance) Ø 19.0 to 19.3 mm. In boxwood or ebony you will get a perfect, smooth bore.

It is also possible to make conical bores with these reamers, and I use them sometimes in that way for ‘copy reaming’. That means that I put the reamer as far as it goes in the conical bore of the model, and then I ream out to the same length the piece of wood of the copy. The next step is to change the position of the blades, for instance to a diameter which is 0.1 or 0.2 mm wider, and start the same operation. This has to be repeated several times (up to 30 times for a bore which goes from 16.0 to 19.0 mm), after which the bore profile is finished. The conical bore is actually composed of a series of short cylindrical sections and looking through the bore, you might see small steps between these sections. That doesn’t harm the acoustical proportions of the instrument so much, but it is better to avoid these steps by slightly grinding the blades of the reamer a little bit at the lower end. The result is a perfect smooth surface of the conical bore.

In this schematic diagram I have only drawn the blades and the nuts of the adjustable reamer. At the arrows the blades have been ground down a bit.
Most adjustable reamers are too short to do their work properly. You must find a method to make them longer. One is welding a steel rod to the shank. The other one (which I often do) is using a box spanner (or two combined box spanners). But as most adjustable reamers have a square end to the shank and box spanners are six sided, you must do some grinding (at the shank) to make them fit.

There is also the question of adjusting the reamer to the desired diameter. On adjustable reamers with six blades, you can measure the distance between two opposite blades with a calliper. But you must check the result in a piece of wood; there might be some difference. And this checking is the only way to know what will be the diameter for adjustable reamers with only five blades (there are no opposite blades).

There is something else it is important to know. Sometimes, some ‘resonance’ will happen during reaming, which result in a bore which is in cross section not perfectly round. A reamer with 3 cutting edges will give then a pattern with 4 arc elements, one with 4 edges 5 arc elements, and so on. It looks more or less like in this diagram (right), where the four arcs are a bit exaggerated (the dotted line is an ideal circular cross section). This problem can easily be avoided by taking out one or two of the blades. The important point is that there must be an asymmetrical placing of the blades on the surface of the reamer.

I bought between 1980 and 1982 a set of second-hand adjustable metal reamers, but then I couldn’t find them for a long time. But in recent years you have been able to buy sets of these reamers for very reasonable prices (I suppose they are produced in China), see for instance the websites of Ali Express (USA) or RDG tools (UK). The reamers come in sizes from 6 mm to 80 mm. The smaller ones not surprisingly have only a limited adjustment (6 to 7 mm), and the bigger ones there have more, for instance I have one which goes from 16.5 to 18.5 mm.

A set of 11 reamers (from 12 to 35 mm) costs about about 100 euros in Holland. But be aware that the blades of the reamers are not serrated, but smooth (as in the photo).
8.7 Other ways of reaming bores or drilling sockets

Long ago I made this tool with an adjustable cutter for drilling a socket in a bass recorder (which I never have finished. . .). The diameter of the rod is 22 mm, that of the cutter 6 mm. I had to think about the shape of the cutting edge, as I had no examples (it was before the internet era). It is a rather dangerous tool when it turns. It is better is to push the cutter on the lathe against the spinning wood.

One - big - step further is to make a system where this type of adjustable cutter is connected with a device that scans the bore of an instrument that you want to copy. By moving the scanner through that instrument part, the cutter automatically adjusts to the diameter at each point. It is actually turning out a bore, more than reaming. It is also possible to copy sections where a section of the bore becomes wider, what you can’t do with the aforementioned reamers. The recorder maker Hans Coolsma has designed and used such a system when he produced in the early eighties a series of traversos after Stanesby Junior.

Nowadays you can avoid the scanning procedure and guide the cutter with a computer. But I do not know if there are woodwind makers (or factories) who do this that way.

8.8 Bore corrections

It is sometimes necessary to make an adjustment in the bore, just in one place. That might be under a tone hole or where a node or antinode of a particular tone is found (see about that in my article ‘Practical acoustics for woodwinds: sound waves and tuning’ in Comm. 2040 in FoMRHI Q 132). You can make a section of a conical bore wider with adjustable metal reamers, but it is not possible to do that in a cylindrical bore. Then you can take a ‘scraper’, just as in the picture below.

Instead of making this adjustable scraper, some woodwind makers use a set of simple ones, made from wood where the (metal) blade is sticking out just 1 or 2 millimeters. These scrapers are hand tools, they are not very accurate and the (acoustical) result is often a bit unpredictable. But you’ll need them now and then.
8.9 Conclusion

These articles about drilling and reaming are written by me to give the starting maker a survey of the possibilities and some of the problems. But I hope that also experienced instrument makers find some useful tips in these pages. It is an important part of the job: finding the right tools for making woodwinds. My point of departure has always been to find simple alternatives to expensive equipment, such as tools I can make myself and which are often my favourite ones. Much thinking goes in the designing and that sharpens our mind.

Tools - especially the old historical ones - have often their own beauty. But remember: the purpose is to use them for making woodwinds. I have seen people with the most sophisticated tools and machines, but who were not able to make instruments of the same quality.

Two so-called cobra bits, from the toolbox of my late father-in-law: beautiful drills from the recent past when we all the boring was done without electric engines - and people had the skills to sharpen this type of drills.

A confession must be made: I can’t often remember which solutions I have discovered myself, and which I have ‘stolen’ from other people or where I have invented something that was already known to other woodwind makers. And I haven’t mentioned my mistakes, such as when I tried the adjustable drill (photo right), which doesn’t work well (or not at all) in hard woods. But I am also sure that I have forgotten some other types of tools which might work well, or which can easily be adapted in the process of woodwind making. Therefore my appeal to the readers of the FoMRHI bulletins: please write with your reactions, don’t hesitate to be critical, I am really eager to know about your techniques for making woodwinds.

Don’t be afraid: try to improve yourself!
The aforementioned Wim Somsen made his first (tenor) recorder, turning and reaming the instrument parts mainly with sandpaper (for the bore he glued sandpaper on a rod, in combination with an electric drill). But for his next instrument, he made a reamer. And that is important: trying to improve yourself. Some people avoid specific operations because they are afraid (or too lazy) to apply the essential techniques. You must be aware of your weak points (for me is that for instance: soldering and also sharpening tools). Don’t continue to evade these problems, but be eager to learn and to practise. It is just the same as playing the instrument of your choice.