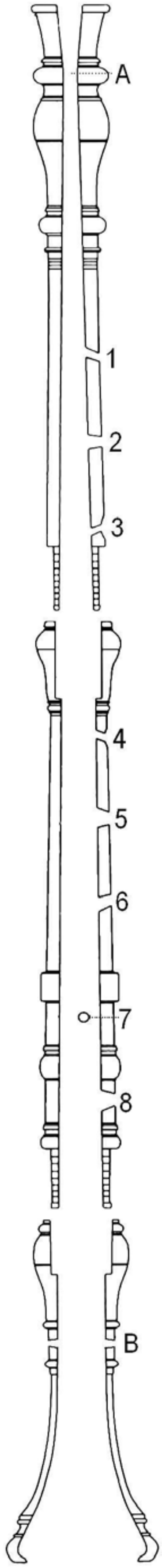
FoMRHI Comm. 2097 **Jan Bouterse**

Making woodwind instruments

10.10 Acoustical aspects of the baroque oboe

Before discussing how to tune the notes of the baroque oboe, we shall first take a look at the acoustical characteristics of the instrument.
What is it what we want to know? There are two main groups of questions. The first group is dealing with the aspects the pitch, sound character and other playing qualities: what you can you tell or predict from measurements (length, bore profile, position and size of tone holes) alone, without playing the instruments? Also important to know: the positions of the nodes and antinodes of the sound waves of the various notes in the bore of the oboes. That knowledge may help us in answering the second group of questions, about the rules of tuning: where to drill the tone holes, how big they have to be, how far they must or can be undercut. Are these rules different from those for recorders and flutes?
For a general introduction to acoustics of woodwind instruments see FoMRHI Comm. 2040 and 2041, in FoMRHI Q 132.



Sounding length of the baroque oboe; nodes and antinodes
Is it possible to predict from the length of the oboe what is its pitch (a1 = 410, 415 or whatever Hz)? For a traverso you can do that to a certain extent; the length from the mouth hole to the lower end of the foot is generally a usable indicator for a pitch of the fundamental, the lowest note. But doing so we have to consider that there is a difference between this measure (the sounding length) and the theoretical length of the sound wave, which is quite a bit longer. For a renaissance flute with a cylindrical bore (diameter 18.5 mm), you must add about 6 mm at the lower end, and at the mouth hole even as much as about 40 mm.

I have these figures from p. 18 of a small book by Otto Steinkopf '*Zur Akustik der Blasinstrumente ein Wegweiser für die Instrumentenbauer'* (Acoustics of woodwind instruments, a guide for the instrument maker), published by Moeck Verlag in 1983, but only available in German. Steinkopf also gives formulas to calculate these end and mouth-hole corrections.

Back to the baroque oboe: what can we conclude from length and bore measurements, and which calculations can be done? Compared with a renaissance traverso, the baroque oboe has a much more complicated bore: very narrow (ca. 6 mm) at the top, and very wide (40 mm or more) at the bell rim. This shape is an irregular cone, or to be more precise: a truncated cone. Steinkopf says that for making calculations (for tone hole positions), you must think this truncated cone elongated to its apex, which theoretical point is according to Steinkopf about 160 mm above the top end of an oboe (without reed/staple).

Fig. 1: Baroque oboe in cross section. A: narrowest point of the bore; 1 - 6: fingerholes; 7: hole of the small key; 8: hole of the great key; B: resonance or vent holes.

Steinkopf calculated this elongation of 160 mm for an oboe with an average cone of 1:40 (he discounts the bell section in this calculation) and the smallest diameter of 4 mm (4 x 40 = 160). Most baroque oboes from before 1750 are much wider at their narrowest point, the angle of the cone seems not vary so much between the instruments. The same calculation for my Wijne copy gives 6 x 42 = 252 mm. But Jem Berry calculated not a longer, but a shorter distance of 145 mm for a Stanesby Senior oboe (this value is mentioned by Marc Ecochard in his article about Golde, see later in this chapter).

An important remark: Steinkopf says that we must think that there is a movement antinode at this theoretical tip of the apex, just as there is a movement antinode at the end of the bell of the oboe. At these antinodes the air molecules can freely move. The same happens for the second harmonic, but there we see a third movement antinode somewhere halfway the apex and the bell end: as a result the pitch of this second harmonic is an octave above the first, doubling the frequency of the fundamental. And I myself can confirm the position of this central antinode in the second harmonic: playing a *d2* on the oboe, which is tuned at the hole of the great key, hole 1 must be opened as an octave hole: that lowers the pressure at that point and result in a new movement antinode, just about halfway between the apex and the hole of the great key.

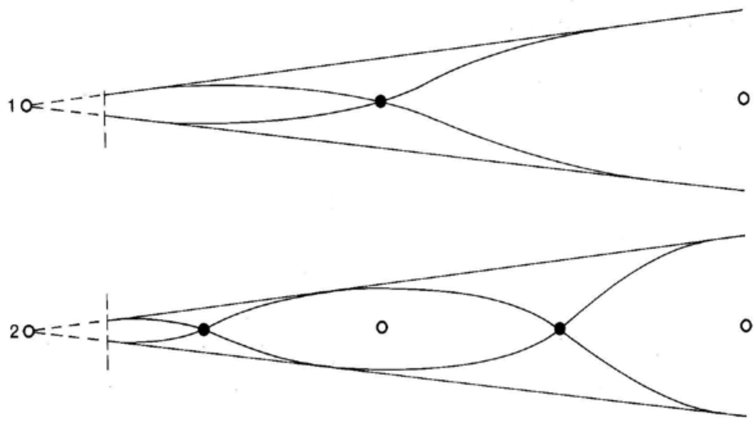


Fig. 2: Schematic diagram of a truncated conical bore, with the first and second harmonic. The open circles represent the (movement) antinodes, the black circles the nodes of the vibrating air column when all tone holes are closed.
From: Otto Steinkopf, p. 39.

Where is the end (theoretical or practical) of the vibrating air column at the other side of the oboe? There is the complication of the resonance holes in the bell. The pitch of the fundamental (c1) depends on the position and size of these holes. And as the sound wave passes by the holes (we must add some distance, which is called 'tone hole correction'), the effective end is as far as about halfway between the resonance holes and the rim of the bell.

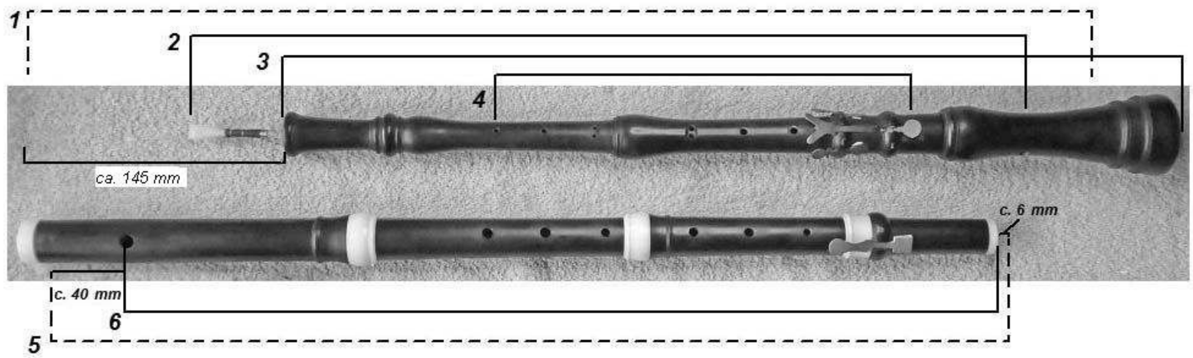


Fig. 3: Comparison of the lengths and sounding lengths of a baroque oboe (copy after Robbert Wijne) and a traverso (copy after Van Heerde), with the fingerholes 1 to 6 about side by side. Both instruments play at about a-415 Hz; the g1 and (overblown) the g2 are played with the upper three fingerholes closed, the other holes (except for the small key) are open.

That means that in fig. 3 the line indicated with number 1 represents the theoretical length of the air column for c1, including the top correction (of about 145 mm) and a tone hole correction for the resonance holes. Line 5 does that in the same way (with mouth hole and end correction) for the fundamental (*d1*) of the traverso. Remark: the lengths of these lines are for both instruments still shorter (6 to 10%) than the wave lengths in the open air for the tones *c1* and *d1*. Line 3 is the length of the parts of the oboe (572 mm), line 2 the length from the tip of the reed to the resonance holes (537 mm). One of the reasons that the sound of the oboe is much lower than expected, is the cavity at the top, between staple end and reed tip. See also the information in the article of Marc Ecochard about Karl T. Golde (French version, on his website).

As baroque oboe bells vary rather much in length, bore profile and position and size of the resonance holes, it is better to use the distance from hole 1 to hole 8 (line 4) to get an indication of the pitch; it is a practical length for comparing oboe sizes.

There is for me one complication in the representation of nodes and antinodes as suggested by Steinkopf. The university of New South Wales in Australia has a website (http://newt.phys.unsw.edu.au/jw/pipes.html) with some excellent information about acoustics of musical instruments. There you can find a representation of the harmonics of wind instruments with a conical expending bore (see fig. 4) which is (or seems to be) different from Steinkopf's theory. There is always a pressure antinode (black line) and a movement node (grey line) for all harmonics at the place of the (tip of the) reed. But there is no mention of a hypothetical movement antinode (corresponding with a pressure node) to the left. In the diagrams of Steinkopf (he also gives in his book graphs for upper harmonics) the position of the upper pressure antinode (farthest left on the diagrams) is more variable. However, the position of the movement antinode at 0.4 (40% of the length) for the second harmonic, fits rather well when applied for the *d2* with hole 1 as the octave hole.

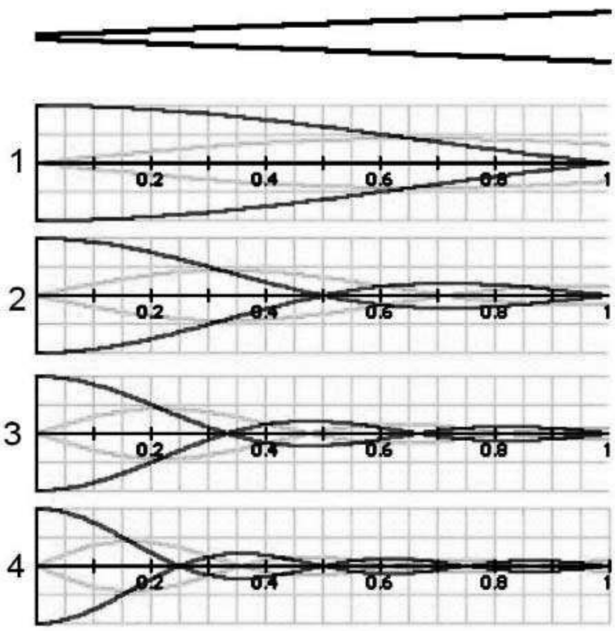


Fig. 4: diagrams of the standing waves in a tube with a conical bore (website of the University of New South Wales).

The other interesting observation: the pressure antinodes become lower to the bell, and very high close to the reed. That must have repercussions for the accuracy which you need to make the bore profiles in this part of the instrument. Traversos have a much more regular pattern of the peaks of the nodes and antinodes. In these instruments it is also easier to find the position of those peaks, for instance by moving a 'flute fish' (see Comm. 2040) in the bore and listening what happens with the pitch of the tones.

Remarkable in fig. 4: the pressure nodes are not always in the same place as the movement antinodes. See for instance at the lower end of the bore, where the pressure is at a minimum, but where there is no movement antinode. That has to do with the bore profile (from very narrow to very wide), but it is altogether no so easy to understand.

There is much more to discuss about the diagrams, for instance about the character of the harmonics. Why does an oboe overblow into the octave (as a flute), and not as a clarinet, which instrument has also a pressure antinode at its reed, in the duodecime? It is not the type of reed which matters: the acoustic engineer Cees Nederveen made a small single reed for his oboe, and there is almost no difference in sound and overblowing with a traditional double reed.

The bore profile is subsequently more important for the type of harmonics: the clarinet with its cylindrical bore over the greater part of its length has only the odd harmonics (1, 3, 5 etc.). The saxophone, blown with a similar single reed but with an expanding conical bore, overblows like a traverso (with the harmonics 1, 2, 3, 4 etc.). But at which point does that change; how much can you expend a cylindrical (and over which length) to change the clarinet into a saxophone?

And another question: what happens when you put a double reed on a cylindrical bore? I have tried that, but that was not so easy as I had to use a type of bassoon reed and had to make an attachment to a rather narrow tube - which happened to be rather short before I could produce any sound at all (fig. 5). The result: overblowing into the octave. But really understanding, no, I am afraid that is not the case.

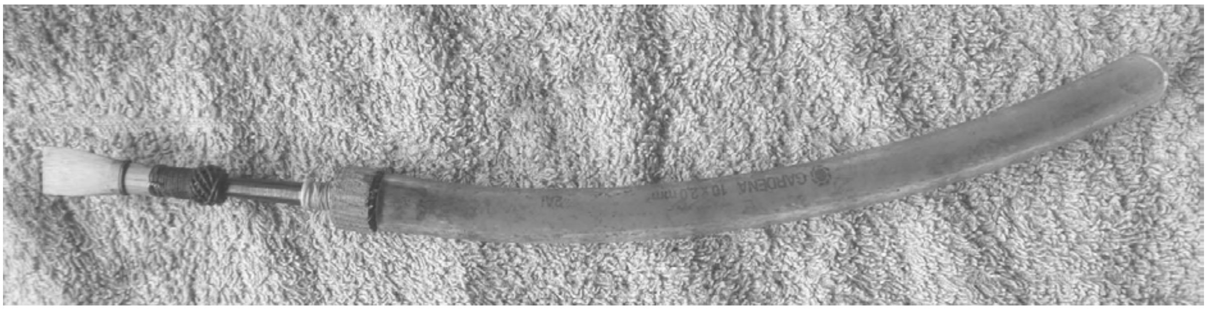


Fig. 5: bassoon reed on a plastic tube (internal diameter 10 mm, length c. 190 mm)

There is, however, one consolation: we don't have to understand all those theoretical things completely if we want to tune a baroque oboe. However, it is always interesting to do some research. Or to read about research. Jem Berry carried out a test, which he published on www.hautboy.org/direct-mapping. From his test report (summarized): *a tone generator programme was used to generate sinewave tones. These were fed into the bore using an old earphone as a speaker and a specially made staple. If the frequency of the sine wave tone was appropriate to the fingering, then the air column in the bore resonated producing a standing wave and an audible ringing. The loudness of the tone was measured using a lap-top microphone fitted to the end of a long thin brass tube which was inserted into the bore from the bell end. The signal was analysed using a frequency spectrum analyser on a computer.*

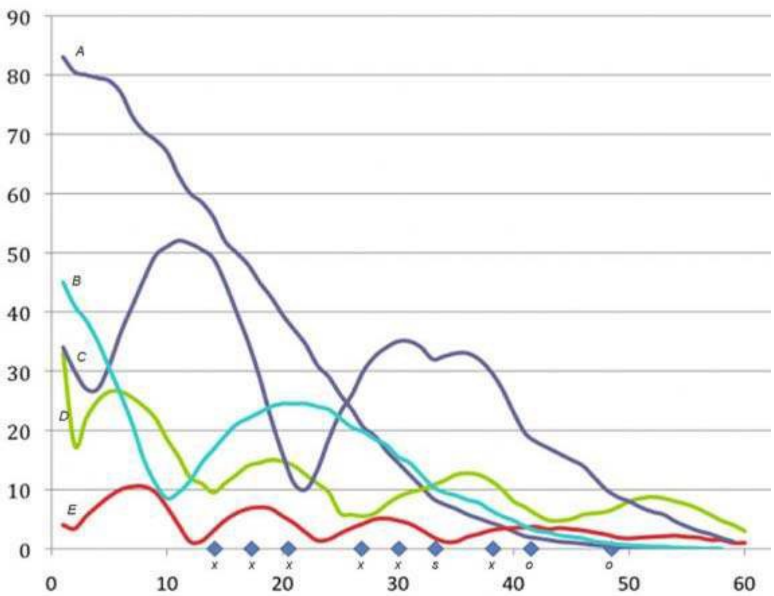


Fig. 6: diagram of the harmonics of the tone e1, from a test by Jem Berry.

The diagram (fig. 6) shows directly measured standing waves of the first 5 harmonics (A to E) of a Stanesby Sr oboe copy fingered for the tone e1. The position of the (pressure) nodes and antinodes relative to the bore of the instrument are shown along the horizontal axis. ‘0’ on the X scale represents the top of the instrument, and the distance from the top is shown in cms. Finger hole positions are shown as blue diamonds, for the *e1* are the first 5 holes and the hole of the small key closed, hole 6 is the tuning hole.

From the conclusion in the article: *The increased amplitude of the peaks towards the top of the instrument is due to the conical bore, and is not due to increased proximity of the microphone to the sound source. This can be demonstrated by using a non-resonating frequency when the amplitude of the signal in the bore does not approach that of the resonant frequencies. The general shape of these curves is exactly that predicted in the literature by calculation.*

And indeed, there is much resemblance between this diagram with that of fig. 4. And for some tones (such as the *e2*) it is possible to tell the position of the nodes and antinodes in the bore: important points where you might alter the bore profile to improve the tone. More graphs of tones of the Stanesby oboe with explanation are published in the article on internet.

Back to the questions at the opening of this chapter: is it possible to predict to general pitch (frequency of the *a1*) from the lengths of the parts and distances between the tone holes on a baroque oboe? Yes, I think that is possible, but only when you compare instruments which are made in about the same way, and played with (about) the same reed and staple. The distance from hole 1 to hole 8 (the great key) is a then a usable measure. For instance: Richard Haka (c. 1646-1705) made oboes in several sizes, some of them 6% shorter than others. From playing these oboes we found that there was also about 6% difference in pitch (which is actually a half tone). But there is also the observation that one particular oboe can be played very much lower or sharper using other reeds and staples: it is not possible to predict a pitch from the dimensions of the instrument only.

Secondly: is it possible to find the positions of (movement and pressure) nodes and antinodes in the bore of the oboe? Yes, it is - or must be- possible for most tones, but as Jem Berry showed it is a rather complicated operation to do that. I tried it with a ‘flute fish’ but get no useful results. Knowing those positions might be helpful for tuning the oboe (for instance in which direction to enlarge or undercut a tone hole for getting an octave interval perfect). It seems to me that especially the bore profile in the upper part of the instrument (between A and hole 1 in fig. 1) is very important and that small changes might have a huge impact on many tones. And there is still another complication: the bore profile of the staple also affects the width of the octave intervals. A more strongly conical bore gives wider octaves. That makes tuning of a baroque oboe more complicated than that of a traverso of a recorder.

Intensity of sound and tuning rules

Otto Steinkopf gives general rules about tuning woodwind instruments at p. 49 of his book. At first, he introduces the term ‘intensity’, of which he says that it is difficult to give a precise physical definition (*physikalisch schwer zu definieren*). He describes it from the point of the player: recorders and flutes have in the lower register no intensity, but much more in the upper registers. The same applies to the clarinet. But there is a different situation for the oboe, saxophone and bassoon: they have a more intensive low register, and less intensive upper registers (Steinkopf, p. 9). He gives a warning: do not confuse this intensity with the volume of the sound: it is possible to play on an oboe *ff* in the highest tones and *pp* in the lowest tones. And I can add: do not confuse this intensity of sound with the amount of pressure which must be

applied with your lips when playing these (often difficult) high tones on an oboe.
Back to p. 49 of '*Zur Akustik der Blasinstrumente*': Steinkopf says there that the more intensive tones need more space for their development. And that means that these tones react more strongly to the size of the tone holes. Making a (tuning) hole smaller has the effect that the tone of the intensive register flattens more than the tone of the other register that is tuned at the same hole. And also: making that hole wider has the opposite effect: both tones become sharper, but the tone of the intensive register more so than the other tone.

With this knowledge, decisions can be made in which direction to enlarge or undercut a hole on an oboe when that - what most makers do - is initially drilled a bit too small.
What we hope to see before we start:

- first register: a bit flat - second register: a bit more too flat
  solution: enlarge and/or undercut the tuning hole at all sides

These situations can also be corrected:

- first register: a bit flat - second register: much flatter
  solution: enlarge the tuning hole mainly upwards
- first register: flat - second register: less flat
  solution: enlarge the tuning hole downwards

What we don't hope to encounter:

- one of the tones of the first and second register is too sharp, because enlarging or undercutting the tuning hole makes the situation worse. You have to move the hole upwards if the octave interval is too small, and downwards if that interval is too wide. And/or you must make corrections in the bore, or change the staple design - that is the best you can do when other octave intervals on the instrument have the same problem.

Comment: I have not seen this concept of 'intensity of sound' in other publications about acoustics of musical instruments. Have all recorders a low intensity low register? And is it possible to measure that intensity in decibels?

But I have to say that I have read only a small number of acoustical publications; the problem is that doing so you often have to conquer a lot of abstract formulas, for which you need a lot of concentration. And for all the efforts you put into that, the results are rarely satisfactory.

The publication of Otto Steinkopf has surely its limitations, but he was very much a practical man, involved in designing reconstructions of old types of woodwind instruments. I do trust his observations.

Karl F. Golde and his tuning instructions
No information exists from contemporary sources as for the way the makers of the 17th and 18th centuries tuned their instruments. We know, however, from the 19th century about one German instrument maker, Karl (or Carl) T. (Theodor) Golde, who wrote instructions how to tune an oboe. The original manuscript of this letter in German is now lost. But we know about it because it was first mentioned and transcribed by F. Drechsel in an article entitled 'Uber den Bau der oboe' issued in the *Zeitschrift für instrumentenbau* 52, 1932, p. 258-259.

A translation in English of this letter was made by Cary Karp, who quoted it in an article in the *Galpin Society Journal*, XXXI, May 1978, p. 19-21. Despite of the relatively late date of publication (*c*.1850) of the letter, the instructions are important also for understanding how to tune the baroque oboe. The French oboe maker Marc Ecochard wrote an article about the Golde manuscript, including his original letter and a full translation, with comments and additions, which is published on his website (www.grandhautbois.com/c_publications/objet

.php?reset=1&p_ ftype=3) in French, with a shorter English adaptation of the article ‘A perspective on original tuning and modern adaptations’ on (http://en.grandhautbois.com/c_publi cations/ objet. php?reset= 1&p_ftype=3). Marc Ecochard kindly gave permission to use information from his article.

Marc says that the fundamental interest of his letter lies in the way that the author describes the tuning of an oboe (which could be a baroque oboe, nowadays often called with its original French name: *hautboy*) using the close relationship between the bore and the tone holes. The main work involved in making final adjustments to tuning is done by expanding or chambering in specific places, and by simultaneously undercutting the tone holes.

For that chambering Golde probably used spoon drills, which results in what Cary Karp translated as ‘sword profile’ (*gewölbte Bohrung*). Which means that the bore profile is not shaped as a regular straight cone, but is more parabolic (or with parabolic sections). Golde asserts then that oboes which do not have such parabolic profiles have a thin, nasal sound (like French and Viennese oboes). A remark: Lucas van Helsdingen told me that a well-known oboe by Anciuti (in the possession of Alfredo Bernardini) has straight conical bore profiles, and does not have a thin sound at all.

Golde makes some interesting remarks about the choice of wood in relation to the sound of the oboe and the pitch of some tones: *clear knot-free boxwood, preferably soft rather than hard, is best suited. It gives a mild soft tone, whereas hard firm wood gives a hard tone. Hard wood can sooner be used for the upper joint than for the lower, as this is responsible for resonance and the tone becomes milder through the soft vibrations. With hard wood the vibrations are shorter and lighter and this is why many notes which naturally tend to be flat, as for example the middle D, become more in tune when hard rather than soft wood is used.*

Golde gives also his opinions about undercutting and the direction (angle) in which some tone holes must be drilled. I mention some of his ideas in chapter 10.11, which deals with tuning instructions of the baroque oboe.

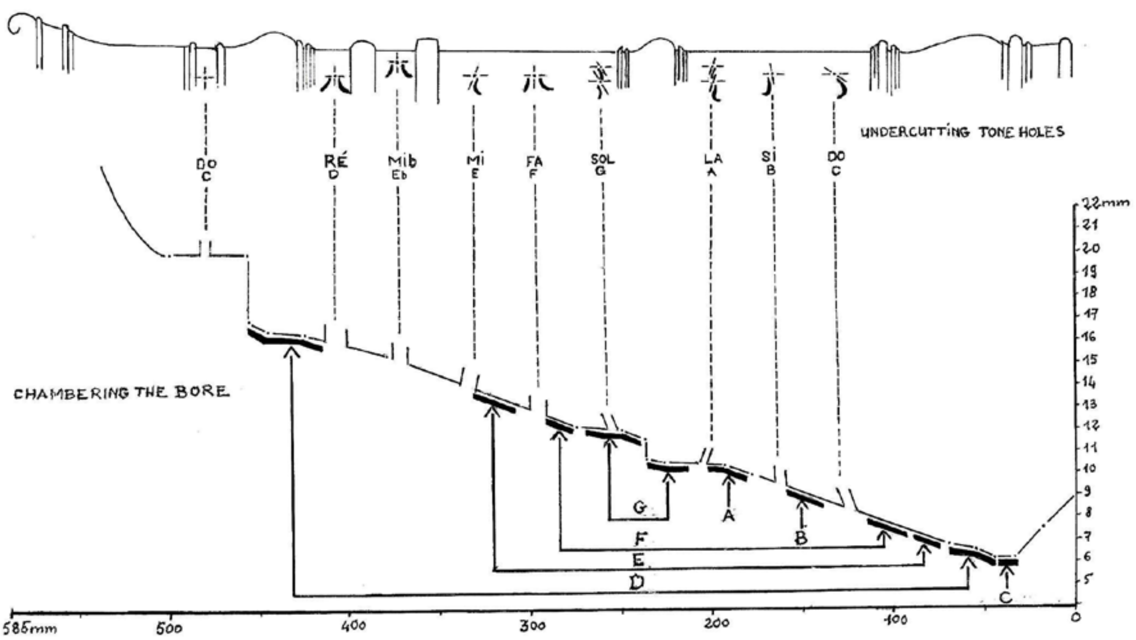


Fig. 7a: Diagram by Marc Ecochard, from his article about Golde, with the bore profiles of the three parts of a baroque oboe, indicating the relation between tone holes and sections

where you can widen the bore for improving or correcting the pitch or response of the tones which are tuned at those holes. The tone holes are indicated just as Golde did: from right to left with C (1), B (2), A (3), G (4), F (5), E (6), Eb (7), D (8) and C (resonance holes). There is a more or less similar diagram in the English version of the article, of which Marc Ecochard wrote me that that was more a first draft and I should not use that. However, I found that diagram (fig. 7b) a bit easier to understand - see below.

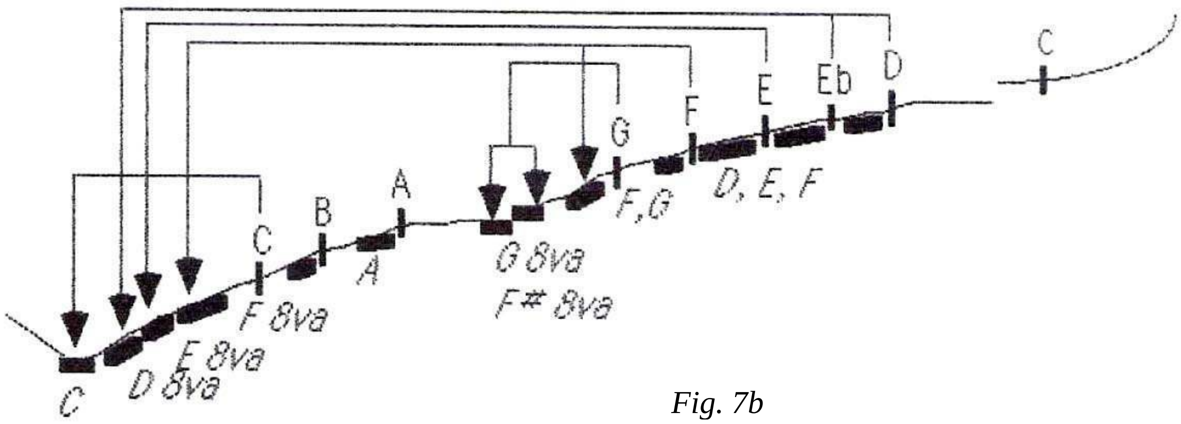


Fig. 7b

What can we observe in fig 7a and b? The upper section, from the smallest bore diameter up to hole 1 is very critical for the intervals of such important as d and e. I can see here some similarities with the upper section of the bore of the upper middle joint of a traverso, but also differences. What the effect of reaming these sections in an oboe bore actually are, will be explained in the following chapter.

Does the diagram of fig. 7 make everything clear? I couldn't find obvious relations between the critical bore sections and possible positions of nodes and antinodes of the sound waves of the tones. As I mentioned before, it is very difficult to find these positions in an oboe by using a flute fish. An example of a problem: making a copy of what looks as a fine and well-preserved instrument, and discovering that one (and only that one) octave interval is too wide. What is the best strategy to tackle that problem?

And what happens to the pitch of an oboe when we make the bore wider, for instance with 2%, over the whole length? For a recorder and a traverso I know the effect: the pitch becomes lower. For the oboe, I don't know.

Acknowledgements: I wish to thank some makers and players who were so kind to read these paragraphs and who gave practical tips and consent to use parts of their publications: Piet Dhont (Utrecht), Lucas van Helsdingen (Amsterdam), Jem Berry (UK) and Marc Ecochard (France). I hope that I handled their information in a correct way.