FoMRHI Quarterly

BULLETIN 143

COMMUNICATIONS

2095 Why the load of gut for lute bass strings is the only hypothesis that fulfils the requirements of seven criteria arising from a consideration of historical evidence

2096 Report on the construction of a nyckelharpa

2097 Making woodwind instruments: 10.10 Acoustical aspects of the Baroque oboe

2098 Making woodwind instruments: 10.11 Tuning the baroque oboe

The next issue, Quarterly 144, will appear in December. Please send in Comms and announcements to the address below, to arrive by 1st December

Fellowship of Makers and Researchers of Historical Instruments

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This is the third issue of the 2018 subscription year (numbers 141-144), on time and agreeably full of both historical learning and practical workshop expertise. Plucked strings, bowed strings and woodwind are all substantially represented. We already have little material in hand for the December issue, which will also contain annual accounts and minutes of the forthcoming AGM, of which you are hereby notified – although you might well have guessed that it will be the same time and place as last year; see below. In my ‘day job’ as Secretary of the Lute Society I have noticed every year a run of sales of lute builder’s plans in the autumn, as the evenings draw in and people return to the workbench – one hopes that also means that, as memories of the summer holidays fade, attention also returns to distilling thoughts into Communications for the benefit of fellow Formrhí members!

**Welcome to new members**

We welcome one member this quarter: Alan Soares Carneiro.

**Annual General Meeting, 1 pm, Saturday 10th November, Blackheath Concert Halls**

As last year, our AGM will be held at 1pm, in the cafeteria of the Blackheath Concert Halls, on the Saturday of the annual Early Music Exhibition, that is Saturday 10\textsuperscript{th} November (the exhibition which will take place there until the great hall of the Old Royal Naval College at Greenwich is restored). The agenda will be: (1) Reading of the minutes of the last AGM, printed in Q139, (2) Secretary’s report, (3) Treasurer’s report (4) Any other business.

Aside from the legal requirements to hold an AGM, it is a nice opportunity to meet other members and share ideas.

**Baroque trumpet making – appeal for sharing of information**

A new member in Brazil, Alan Soares Carneiro wants to make a baroque trumpet, and is currently trying to find out about bell flare mandrels, any information on this or related topics would be gratefully received. If you can help please contact alansoarescarneiro21@gmail.com.

**Cambridge Woodwind Makers**

Recorder Making with Tim Cranmore | Monday 22nd October | £1000

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The date is set for Long Trumpet Making 2019 too! Monday 24th - Friday 28th June

www.cambridgewoodwindmakers.org
STANDING CALL FOR PAPERS

The Fellowship of Makers and Researchers of Historical Instruments welcomes papers on all aspects of the history and making of historical musical instruments. Communications or ‘Comms’ as they are called, appeared unedited (please don’t be libellous or insulting to other contributors!), so please send them EXACTLY as you wish them to appear – in 12 point type, on A4 paper with a 25mm or 1 inch border all round, or to put it another way, if you are using non-European paper sizes, then the text area must be 160 x 246 mm (or at least no wider or longer than this). Our printers make a good job of scanning photos.

In naming your Communication, remember that people will search for it online using keywords. So if you are discussing, say, a Ruckers harpsichord in Paris, call it ‘Observations on a Ruckers harpsichord in Paris’, rather than ‘Observations on a curious old instrument.’

You can send contributions EITHER on paper, OR as a Word-compatible or PDF attachment. If you really do not have access to a word processor of any kind, we may be able to retype typed or handwritten submissions; send it to our cover address.

The email address for Comms sent as attachments (and other email correspondence) is Lutesoc@aol.com or secretary@fomrhi.org. Non-members will be given a year’s free subscription if they send in a Communication to the Quarterly.

If your interests have changed, and you don’t now want to be a member of FoMRHI, please let us know, to save postage costs.
Why the load of gut for lute bass strings is the only hypothesis that fulfils the requirements of seven criteria arising from a consideration of historical evidence,

For we see, that in one of the lower strings, there soundeth not only the sound of the treble, nor any mixt sound, but only the sound of the base (Francis Bacon, Sylva Sylvarum 1629)

Introduction

Concerning gut bass strings, that were employed in past times on lutes with more than six courses, there are still today many unanswered questions.

The questions start to arise from the second half of the 16 century, when a seventh course was routinely added to the lute, tuned a fourth, sometimes a fifth below the sixth course, as Le Roy testifies in 1574:

The Lutes of the newe invention with thirtene strynges, be not subiecte to this inconvenince, where of the laste is put be lowe: whiche accordyng to the maner now abaies, is thereby augmented a whole fowerth (Adrian Le Roy, A briefe and plaine instruction . . ., 1574).

One question in particular overshadows all others: were these new basses as powerful and efficient as historical sources would have us believe? Considering that they are made of pure gut, this question is indeed a crucial one.

At present there are only two hypotheses as to how these strings were made: the first hypothesis is the use of rope construction (either leaving the roped appearance visible or giving the string a smooth finish); the second assumes that the density of the gut was increased by treatmeant with heavy metal compounds or a very fine metal powder; so-called ‘loaded strings’; these can be made either with a high twist, or roped (with a smooth finish).

In this paper I will examine these two hypotheses in the light of seven criteria derived from a considered reading of historical sources. These seven criteria are:

1) the size of string holes on old lute bridges,
2) the improvement in the acoustic performance of bass strings in the seventeenth century over those of the early sixteenth as recorded in contemporary sources,
3) equal tension / equal feel: general implication for string thicknesses,
4) the colour of gut bass strings,
5) when roped strings were introduced,
6) lute basses: smooth finish or bumped construction?
7) paintings attesting the pliability and smoothness of lute bass strings.

1) The size of string holes on old lute bridges

At the beginning of the 1980s, first Ricardo Brané of Florence and then I myself, discovered that the bridge holes on the bass side of many surviving lute bridges were actually too narrow to permit a suitable working tension (more than around 2.5 Kg). There are some exceptions to this evidence but the exceptions are the minority.

In the matter of the holes, one should take into consideration the way they were made. In most of cases, the holes were conical, not cylindrical. It is evident that they were not made in the way that they are made today: I have the idea that the old luthiers employed a very hot, sharp, conical iron tool. In fact, on several bridges I have seen, around the hole (and sometime inside), traces of burnt wood. However, in the face of this initial evidence, I have made a thorough investigation over many years
studying the surviving lutes of nearly a dozen museums with the intention of collecting all the gauges of the holes on the bass side of the bridges. In total I have collected the bridge-hole diameters for about 100 lutes or more.

Measuring lute bridge holes                Johann Seelos 11-course lute. X-ray of bridge, showing narrow and conical holes in the bass side.

However, for the final calculations, I have considered only around half of them: those with significant indications of the bridges being the original ones. I have written two articles showing all the measurements/data and the related calculations.¹,²

After this first task, I obtained some further measurements taken on lutes from some private collections. Then in 2005 I had a chance to visit an Austrian convent close to Linz and took the hole gauges on some very interesting 11- and 13-course Lutes (I have not published any article yet on this matter, however, the bridge holes of most of these lutes confirms the evidence that they are too narrow for pure gut basses):

‘Magno Dieffoprichar 1604’                  ‘Hans Frey Bologna/Fux 1683’
Example of a schedule with the hole gauges (Kremsmünster, 2005)
It will be worth mentioning that a bridge-hole diameter is obviously not the actual diameter of the old string passing through the hole. The hole was made, of course, with a certain empirical oversize. Based on all my data, Ephraim Segerman then calculated a range of tension from 1.1 to 1.8 kg. In his work, the actual maximum string diameter was considered as equal to 85% of the maximum string-hole diameter. I think that this was a good figure.\textsuperscript{3}

It is also good that these calculations were done by him and not by me: in fact, he is the scholar who introduced the roped string theory in the 1970s; he thinks that the loaded gut theory has no historical evidence.

There is one more open question concerning these holes: can the original diameters become enlarged or shrink over the time? I have put this question to some famous wood restorers here in Italy (in Florence and Milan) and the answer was that wood, generally speaking, becomes weaker over the time and even under bacterial attacks, weather changes etc etc; so one can expect the holes to become enlarged under this effect over the centuries.

What about the dust in the inner portion of the holes? Might it contain traces of metals or oxides that were added into the string? In fact I have taken the decision not to take samples: after all these centuries it is easy to come to wrong conclusions.

I discovered a ‘mistake’ in Segerman’s work, however: he only considered low twist gut in his calculations, with a density of more or less 1.3 (but low twist gut does not work at all in the basses: their stiffness, in other words, their inharmonicity is too high), so we should consider the only other plausible explanation for the historical gut lute basses; i.e. ‘bumped’ roped strings, whose density is around 1.1, instead 1.3 of the low twist plain gut.\textsuperscript{4}

After my corrections, the new value of tensions ranges from 0.9 to 1.5 kg or thereabouts. Maybe some of you have no idea what this means. Try for yourself: drop the tuning of your lute that is probably around 3.0 Kg tension (the most common value in use today) by 9 to 11 semitones and thus you will have an idea what it means to play at 1.0-1.5 kg or so on: is it still possible to play the lute in such conditions? How would they perform? It will be clear to everybody that the strings become slack like rubber bands: no power, no round, clear and prompt sonority, no control of the fingers over the strings, you have pitch distortion, all the strings buzzing on the frets etc. You should do this test once in your life, especially if you have little confidence in the loaded gut theory!

However, the right experiment must be done using roped gut strings, not modern wound strings or the fluorocarbon ones, which both have higher density than gut because they have, of course, better performance than the historical option which is always centered on pure, unloaded gut. Despite that, even with modern basses, you can have a good feel about the whole situation.

My clear and polite question is why did the luthiers of those times not make these bridge holes a bit bigger? This job is indeed very easy to do: many players today enlarge them when they want to switch to thick gut roped strings instead of the ‘traditional’ nylon wound ones.

We must consider that all those bridge holes were certainly made by the lutemakers of the 17th century to a size able to accommodate any sort of bass gut strings then available on the market. What other explanation is left to us than to assume that the technological matrix common to Lyons, Pistoys and maybe, in Dowland’s case, also the lowest Venice Catlins, must have been the loading of gut?\textsuperscript{5}

\begin{center}
\begin{tabular}{cc}
\includegraphics[width=0.4\textwidth]{smooth_rope} & \includegraphics[width=0.4\textwidth]{bumped_rope} \\
Smooth roped structure & ‘Bumped’ roped structure
\end{tabular}
\end{center}
Conclusion: if the bass gut strings were not loaded, or made denser in some way, it is not possible to reach an adequate degree of tension, and the same feel of tension in the upper strings implied by historical sources (we will consider below why this is important).

2) The improvement in the acoustic performance of bass gut strings in the 17th century over those of the early 16th as recorded in contemporary sources

There is strong evidence that the lute gut bass strings of the 17th century (from the sixth down to the twelfth course) had better acoustic performance than the basses (fourth, fifth and sixth courses) of the very late 15th century until the 1560s. Johannes de Tinctoris wrote:

An arrangement of five, sometimes six, principal strings was first adopted, I believe, by the Germans: viz. two inner ones tuned in a third, and the other ones in fourths [. . . .]. Furthermore, in order to obtain a louder sound, another string tuned an octave higher can be added to each of the principals, except for the first one.6

Sebastian Virdung, in his *Musica Getutsch* (Basel, 1511) says:

... to all three basses (Prummer) are added strings of medium thickness . . . one octave higher. Why that? Because the thick strings cannot be heard so loud in the distance as the thinner ones. Therefore, octaves are added, so that they be heard like the others,7

Vincenzo Galilei, in his *Fronimo* (1568) moreover implies that strings below the sixth course at that time were poor:

... and God knows how well one can hear them . . . and . . . although they are perceived by the ear as not very sweet, because of their poor sound . . .8
By contrast, Mace (1676) and the Burwell lute tutor (1670s), wrote that the all-gut basses of their time, installed on a lute with a (short) extended neck, were powerful enough to cover and ‘confound’ the sound of the upper strings. Burwell speaks of ‘... the confusion that the length of sounds produce’ and ‘... every bass cannot make a concord with every small string ... ’ and, talking about the eleventh course, ‘... the lutemasters have taken away that great string because the sound of it is too long and smothers the sound of the others’.9 Maces says that “This inconvenience [i.e. the power and persistence of sound of the basses which causes confusion and dissonances with the higher registers] is found upon French Lutes, when their heads are made too long; as some desire to have them. . . ’10

This is the short-extended neck probably mentioned by the Mary Burwell lute tutor in ‘English’ [Jacques] Gaultier’s portrait.

Be aware that this is not a subjective opinion but a comparison between the upper strings and the basses: in practice, the same comparison can be made even today; this is not a subjective matter of feeling and is not affected by the personal sensibility or the tastes of the players of those times. Today anybody can check that even the best roped strings do not ‘cover and confound’ the sound of the upper strings at all; instead, they are dull and weak, in comparison with the upper strings.

There are other less well-known sources that describe, in a subjective way, the performances of the new lute basses. Giulio Cesare Brancaccio’s letter (26 February 1581) addressed to the cardinal Luigi d’Este concerns the purchase of a lute as gift for his brother Alfonso d’Este:

L’altro è che potendosi trovare un leuto à otto ordini, come li suol fare perfettissimi un Maestro Tedesco ch’è in Padova nomato Mastro Venere Alberti faria piacere à S. Altezza [Alfonso d’Este] di presentarglielo: il qual leuto havendo poi à servir per me, desidero che sia delli ordinarij, in quanto alla grandezza, et que’ dui ordini bassi più delli sei costumati siano li bordoni fermi, et sonori d’una corda per ciascuno, et non di due, et infine che l’leuto sia armonioso et argentino, cioè con suono chiaro et sonoro, et che i bassi rimbombino il più che si può

[The other thing is that being able to find an eight-course lute, as a German master who is in Padua is accustomed to do, named Master Venere Alberti, it would please his Highness to present it to him, which lute having then to serve for me, I desire that it should be ordinary as to size, and that the two bass courses, more than the accustomed six, should be solid and powerful bourdons, of [only] one string, and not of two, and finally that the lute should be harmonious and silvery, that is with a clear and sonorous sound, and that the basses should resound [/thunder] as much as possible]

(quoted in M. Bizzarini, Marenzio. ‘La carriera di un musicista tra Rinascimento e Controriforma’, 1998, p. 40)
Francis Bacon (1629) wrote:

For we see, that in one of the lower strings of a lute, there soundeth not the sound of the treble, nor any mixt sound, but onely the sound of the base.

Edward Benlowes, (1603–76):

still torturing the deep mouth'd Catlines till hoarse thundering diapason should the whole room fill.

Mersenne in *Harmonie Universelle* (Paris, 1636) wrote that the sound/vibration of the thicker lute bass string (the 11th) was of 20 seconds almost: I have never heard, honestly, this acoustic quality on a modern bumped/smooth roped string (but even with modern nylon wound strings! I think that this affirmation was exaggerated or not real)

Conclusion: a modern unloaded gut string on the bass side does not have such a powerful performance as that described by the sources of the 17th century, in comparison with the upper strings.

3) Equal tension/equal feel: general implication for string thicknesses

Several early sources say that the tension of the strings should feel the same across the different courses, and there has been much debate as to whether this means literally the same measured tension (there is some evidence that this is the case for violins) or, as I believe, equal feel of tension, which is not quite the same thing.

But at all events, considering the equal tension/equal feel profile (as suggested by J. Dowland, the Burwell Lute Tutor, Thomas Mace), if the basses actually worked at those very low tensions (0.9–1.5 kg, as calculated by Ephraim Segerman and modified by me), and being non-loaded natural gut—i.e. a whole set-up of thin strings at low tensions—the first string would have to be from 0.26 to 0.32 mm gauge; the second course around 0.36-0.38 mm and the third around 0.48-0.50 mm. I have never seen such a thin first gut string in all my life: in my experience, such a thin lamb intestine does not exist in nature.

In practice, it is not possible to produce them at all: the very minimum gauge I have been able to make was around 0.42 mm (after a light polishing) which I obtained from a single whole unsplit gut of a lamb of an age of about 1 month (see A. Kircher, Rome, 1650 below, concerning the Roman stringmakers: the first lute string is made using one gut only).11, 12

Actually, the range I have obtained from different samples of single, whole lamb guts of different provenance had a minimum gauge of 0.40 minimum and a maximum of 0.48.
Conclusion: there does not exist in nature any lamb intestine thin enough to produce strings thinner than 0.38-0.40 mm about so it is not possible to reach an equal feel profile of tension on all the strings as indicated by the early sources.

4) The colour of gut bass strings

People commonly think that the question of colour is the ‘primordial’ evidence in support of the loaded gut theory. This is a misunderstanding: colour actually is just the last point in the scale of things that tell us that these old basses had something interesting in their technology.

The aesthetically pleasing colours for trebles and means mentioned by the old sources were light blue, light green, yellow, light red. On old paintings one can sometime see such strings put on the first to fifth courses; on both the strings of the course or just on one only; coloured strings are also sometimes visible on the octaves of the basses. (Dowland op. cit. fn. 5) (Mace op. cit. fn. 10)

Instead, on these gut basses in the paintings, when they are colored, we can see only deep red, deep orange, all gradations of brown, grey, blackish. There is one more thing to see: starting from the sixth bass course down till to the last one, one can see that the colour of the bass series is exactly the same on all of them and it is, generally speaking, in the same position where today we put our modern nylon wound strings, roped gut strings, or even fluorocarbon strings. They even look ‘thin’, not thick:

Anonymous, second half of the 16th century
Rutilio Manetti, Siena, 1624

Anonymous, second half of the 17th century
Nicolas Henri Jeaurat de Bertry, second half of the 17th century

Eglon van der Neer, c.1677
F. De Troy: portrait of Charles Mouton, c.1690

F. De Troy: portrait of Charles Mouton, c.1690 detail
In order to reach a density that is twice that of natural gut (later I will explain why it should be twice) it is indispensable to employ something that has a very high density and is insoluble.

I observe that the denser, insoluble substances widely in use in the 16th and 17th centuries, whose densities are above 8-9 gr/cm³ (mineral pigments such as oxides, sulphides, copper powder etc), are of colours ranging exactly from deep red, all the gradations of brown, dark grey and finally blackish: the same colours we have found on the bass lute strings in old paintings or in written descriptions and lute treatises—a pure coincidence?

There is no trace at all in late 16th to 17th-century paintings of similar gradations in light blue or light green colours anywhere on lute bass strings below the sixth courses; and no mention of light blue or light green in the 17th-century lute basses described in the old lute treatises.

These very heavy and insoluble substances commonly in use in the 16 and 17th centuries were lead and mercury oxides and sulphides, and also fine brown metallic copper powder. There are some mid 16th century recipes that explain how to obtain this.

There is an important point to clarify: it is possible to charge a fresh gut with yellow litharge, brown lead oxide, brown lead dioxide or light brown mercury oxide, so a 17th century painter might have painted the basses with the same colour as the upper strings if these were used, because the colour would not differ much from plain gut.
In other words, it is not true that a gut string that was made denser would automatically have a different colour than the upper strings. Actually, a gut string can be made denser and, at the same time, have a similar colour as the upper gut strings (whose colours, in the old paintings, range from a light yellow down to every gradation of brown: we should be aware that most of these heavy substances I have mentioned have exactly these kinds of colours).

There is an additional option: the ‘deep dark red colour’ mentioned by Mace for the Pistoys can be intentionally obtained adding some traditional red colours employed by painters to the fresh strings just after the loading process with a heavy agent that might have a different colour (for example orange; light brown etc.) with the intention of characterising the provenance of the string and the manufacturer.

Conclusion: the colour actually is just the last point in the scale of things that tell us that these old basses had something of interest in their technology. Incidentally, the colour of the basses in several 17th century paintings is the same as that of the heaviest insoluble thin pigments/oxides/sulphides/copper powder in use in the 17th century (dark red, dark orange, brown, blackish); no mention in the old written sources of blue, green etc. gut basses. It is possible to have a loaded gut string with a colour similar to natural gut strings (the upper ones).

5) The period when roped gut strings were introduced

Some scholars, even today, still think that ‘roped’ gut bass strings (i.e. catlines, in Segerman’s writings) were introduced around the years 1565–70, when the lute was expanded in the bass register. This thinking should be updated: a few years ago Patrizio Barbieri discovered some sources from the second half of the 15th century where it is very clear that the roped strings, on musical instruments, were already in use.13

Actually, roped (gut?) strings were already in use in the late Roman imperial period:
Barbieri also demonstrated the presence of special machines called in Italian ‘orditori’ (ropewalks), a technical term for a special manual machines employed for making ropes, hems etc) in mid 16th-century Roman stringmakers’ workshops (Barbieri op. cit, fn. 13).

Considering these new sources, my opinion is that the (smooth?) roped bass strings mentioned in the 15th-century sources, thanks to their better elasticity compared to a traditional high-twist gut strings, could well have opened the door to the addition of the sixth bass course to 5-course lutes, giving the lute a new acoustic limit or open range of a full two octaves.

By the way: the greater elasticity of a roped string makes the so-called fret sharpness (a problem that happens when a thick high or low-twist string is pushed down on the fret, slightly increasing its tension and therefore raising its pitch) much less evident: actually, no one in lute treatises from the first half of the 16th century complains about it (instead, they mention the tapering/conicity of the lute gut strings as a real concern (Capirola c. 1517 and Vincenzo Galilei, 1568). Could this be indirect evidence of the use of bass roped strings?

In conclusion, considering the historical evidence that roped strings (bumped or smooth: we do not know which) were already in use from the late 15th century, we may ask what really happened around 1565–70, when, in the space of a very few years, more basses were added to the lute as normal practice, something only rarely tried or referred to before. The new open range was enlarged to two octaves, adding a fourth or fifth on the bass side, and at the same time the performance of these all-gut basses became magically so good and powerful and loud. This question is a crucial one: what was that innovative technology?

Conclusion: there is historical evidence that roped strings were already in use from the late 15th century, as a consequence a roped string cannot be considered, as the novelty that permitted the expansion of the lute in the second half of the 16th century,

6) Lute basses: smooth finish or bumped construction?

Only today do we find ‘bumped’ strings described as historic; all the 17th-century lute sources mentioning lute strings in general, there is no kind of evidence to indicate they were anything but smooth. This is part of the historical evidence one can put forward in answer to Charles Besnainou, the French scholar who considers as historic his hand-made twine bumped rope basses. These he makes starting with a very long, twisted, two-strand string folded in two and then twisted again together in the opposite direction. The two ends of the folded string are left untwisted but only one of these goes through the narrow bridge hole and then is knotted with the other free end on top of the bridge. This would be, in his opinion, the way gut basses were made in past times, presumably by the player directly on the instrument.14
Here is the evidence we have found about the surface finish of the strings. Mersenne affirms that gut strings were well polished cylinders, finished with the use of a grass with an abrasive property (equisetum or shave grass), but he did not say anything that leads us to believe that this procedure was given only to thin-strings.\textsuperscript{15}

Thomas Mace states clearly that the deep dark red Pistoys (for him the best lute basses) were smooth: “They are indeed the very best, for the basses, being smooth and well-twisted strings. . . ”. This does not imply, automatically, that Lyons were not. Actually, nothing at all is said about the surface of the Lyon bass strings. (Mace op. cit. fn. 10)

James Talbot says that Violin-Lyons were smooth: ‘Best strings are Roman 1st & 2nd of Venice catlins: 3rd & 4th best be finest & smoothest Lyons, all 4 differ in size. . . ‘.\textsuperscript{16}

The Mary Burwell Lute Tutor, describing the best strings for the lute (‘Romans’ for trebles, and ‘Lyons’ for basses and respective octaves) explains that an important feature of almost all of the strings is exactly that the surface should be well smooth and free from ‘knotte’ and ‘rugged’; Lyons basses were clearly included. (Burwell op. cit. fn. 9)

Mace, in addition, states that the Venice-Catlins for the ‘Meanes’ were smooth, so when he also states that ‘Pistoys’ were but thicker Venice-Catlins we must infer that they, too were smooth. (Mace op. cit. fn. 10).

A very accurate painting by Rutilio Manetti (Siena, 1624) clearly contrasts smooth lute basses and the roped metal cittern bass strings.
If the lute basses had actually been bumpy, like the cittern strings, the painter would have done them in a similar way (Mersenne describes roped metal cittern strings: ‘... the thickest string of the third or fourth is twisted, and made from a string doubled and bent in two, so as to make fuller tones...’).

Conclusion: all our historical evidence points to the fact that the strings, basses included, were smooth, not bumped.

7) Paintings attesting to the pliability and the smoothness of lute gut bass strings

On many of the 17th century paintings (and even later) the lute basses are often represented by the painter as very much thinner than they should be if they were made with plain unloaded gut, and always smooth, not roped (in fact to this day I have not yet found a painting clearly showing roped bass strings):

Jan de Baen, painting of Johanna le Gillon, c.1670, detail

Maybe in this painting there is the evidence of silver-wound bass strings: bass strings are apparently very ‘thin’ and ‘white’ in comparison with the paired clear brown/dark yellow paired octaves. Admittedly in spite of its excellent finish the painter had not quite understood his subject: the bass rider plainly has two strings running to one peg! But presumably he painted the colours, and fall of the strings as he saw them.
In some cases, it is possible to see just how flexible they were (by the way they were knotted at the bridge for example, or even the kind of ‘soft’ bundle):

Rutilio Manetti, Siena, 1624: detail on smooth bass strings
Anonymous 17th century: detail

Conclusion: the old 17th-century paintings shows that lute gut bass strings were pliable, smooth and thinner than what one can expect with unloaded gut strings.

**Final conclusion**

In order to satisfy all these 7 criteria I was able to find only one explanation: a loaded/weighted smooth roped gut string: the combination between high density and high elasticity is the best way of guaranteeing the best performance in the lower range of Lutes.

There is nothing strange in considering that a gut string can be made denser: we know that the ancients were aware that the density / gravity parameter was an important thing in relation to frequency. Here is Serafino di Colco:

Coming back to the three parameters that can change the frequency and so, able to produce a change in the sound of the string (and they are the length; the thickness; the tension) I would like to count,
indeed, still a fourth (and not just to three) that is the weight, in other words, the density of the material . . . ’ (author’s translation)

And Vincenzo Galilei explains:

. . . having the same string whose weight is four time more and the thickness the same, you can easily think that it is the thickness and not the weight that makes the frequency lower. The conclusion is that it is the gravity and not the thickness that makes the frequency lower, deeper . . . (my translation)

But by how much were the old bass gut strings loaded or made denser? I have a hypothesis: thanks to Virdung, Galilei etc we know that the gauge of an unloaded sixth (roped?) gut string was, more or less, the acoustic lower limit for the sixth course of the lute (i.e., the minimum for inharmonicity). Then we assume that the same gauge should be, again, the limit of the last bass string on renaissance lutes of 7 or 8 or 10 courses (as well as for the 11-course D-minor lutes). This means that there should be an interval of a fourth or fifth down from the sixth course.

Having the same string length, tension, and gauge, and tuned down a fourth, we can calculate that the density of the string should be twice that of natural gut (2.6 gr/cm³ instead 1.3). This fits quite well even with the bridge hole sizes.

It is interesting to see how the open range of two octaves and a fourth becomes, after the second half of the 16th century, the new limit for lutes as well as for a new kind of bowed instrument: the viola bastarda or ‘alla bastarda’.

I have made some practical tests in this matter just to verify what is the upper limit for loading a gut string: I have seen that, actually, it is around twice (or a bit more) that of natural gut. In my tests, I have employed heavy pigments such as red lead, litharge and, finally, fine copper powder: in fact some time ago, I found some recipes of the mid 16th century that explain how to make it and even how to produce fine silver and gold powders. Here are the recipes from Don Alessio Piemontese I secreti (Venice 1555).
Any hypotheses that try to explain how the old gut lute basses were made should respect all the seven criteria mentioned above. Any criticism is always welcome but, on the condition, that the alternatives one place on the table can actually cover all of the criteria, not just two or three because all of them come from historical sources.

**Objections to the theory of loaded strings, and counter-arguments**

Having said that, here are the most common arguments against gut loading theory.

1) **Home-made roped strings, or ‘split ends’ as an alternative, to fit narrow bridge holes**

Charles Besnainou (‘La fabrication des cordes et en particulier comment répondre aux questions posées par les cordes anciennes’, lecture at Corde Factum, Puurs, May 2008) presented the idea of using an ordinary gut string, of sufficient length, of a diameter to pass through a small bridge hole, ‘fold’ it in half, and then twist it into a roped string directly on the instrument. An alternative would be for the string maker to make the roped string and leave one end open and untwisted, enabling it to be tied with that end on the bridge using some complex type of knot (the string must stay perfectly centred on the bridge in relation to the octave). The resulting string is bumped.

**Counter-arguments**

This hypothesis simply discards the technically easier solution: why not simply drill slightly bigger holes in the bridge as many lute players who like to play with all-gut basses do today?

Twisting two strings into some sort of D-I-Y rope still requires the strings to be wetted beforehand and then carefully twisted with some tool in a perfectly regular manner: no treatise of the time ever mentions a lutenist needing such a complex know-how, nor that he should employ a long thin string and rope it himself, nor that he should sit still for an hour holding the string’s end securely between his fingers waiting for it to be perfectly dry.
Besnainou’s theory, if we compare it with the seven criteria, lacks supporting evidence, as does Ephraim Segerman’s theory concerning the bumped roped strings: it is interesting enough to remember that the etymological connection between the name ‘catline’ and a possible nautical term was actually never supported by documents, and then in the 1990s it was refuted by Segerman himself who switched to considering ‘Catalugna’ as the origin of this name but without any direct evidence.\(^{27}\)

This means in consequence that the connection between a roped structure and the name catlin or catlin is no longer supported. Actually, these kinds of strings were made in northern Italy (in the Bologna area) and they are mentioned mostly in old English sources; Unfortunately, we do not know what the Italian stringmakers and players called them or how they were made.

Here is a list of what I consider to be a lack of practical and historical evidence.

a) Can a lute working at 1.0-1.5 kg tension actually work? No. (Try for yourself).
b) Did a top string of a gauge of 0.26 mm exist? There is no evidence for this at all, for reasons already explained.
c) Were bumped bass strings ever mentioned in old sources? There is no evidence at all. Whenever this technique actually existed, it was expressly mentioned: Mersenne mentions that the cittern’s thicker metal strings were obtained using a long wire, then doubled, bent in two and the two portions twisted together in order to obtain a fuller and better sound—while in the case of gut strings, he wrote that they were made smooth by means of an abrasive grass.

There is a very interesting piece of evidence against the bumped strings hypothesis: Mersenne was clearly aware that a roped string makes a better and fuller sound than a plain string; despite this, he did not mention this practice (i.e. the roped structure) in the section concerning gut strings.

e) Are modern bumped or indeed ‘wet-rope’ smooth gut strings are powerful enough to cover the sound of the upper strings? There is no evidence for this at all. Try yourself by comparison with the sound of upper strings, as is mentioned in the old sources.

f) Were lute gut bass strings bumped roped gut strings made by the player himself or herself using a long ‘meane’ string, then doubled, bent in two and then the two strings twisted together? There is no evidence for this at all: the sources of the 17th century mention three sorts of strings and all were made directly by the stringmaker: trebles, meanes and basses. This includes all basses. They were called: Lyons, Venice Catlines, Nuremberg basses, ‘deep red’ Pistoys. (Dowland op. cit. fn. 5; Burwell, op. cit. fn. 9; Mace op. cit. fn.10).

For this theory to be valid, one should expect that only the trebles and mean types would be mentioned. Also one should expect no particular name for the basses, and perhaps even a few explanations on how to make these home-made basses might have survived (maybe with a short description concerning the special tool able to twist the two portions of the string together).

g) Do any old paintings and/or old documents show or explain this strange method described by Charles Besnainou of fitting the strings into the bridge hole? Again, no evidence at all.

Here is what we can actually see on these few examples—which incidentally show a fine array of coloured strings.

Laurent de La Hyre (1606–1656): detail
Eglon van der Neer, mid 18th century: detail
h) Do the old treatises mention anything about the existence of some special tool for making these home-made roped bass lute strings using very long means drawn into two halves over a hook whose two returning halves are twisted together? No.
i) Is there any historical source that clearly mentions that the Venice Catlines were made roped or even that there is a link with a nautical term or to a Catalan origin? Not at all.

To continue points used against loading theory:

2) No direct evidence or recipes exist from the stringmakers of the past relating to the loading of gut

Counter-arguments

It is true that at present there is no direct evidence related to a process of the loading of gut (a string-maker’s recipe; a document that mentioned that the gut of the basses was treated in some way to make it denser, for example).
Actually, no direct information exists at all from the 16 and 17th century string makers concerning their art in general; this is not just true for the bass gut string technology. For example, we do not even have a clear, direct description concerning how roped strings were made by string makers; we just have just proof of the presence of the ‘orditori’ or ropewalk machines in some 16th and 17th string maker’s workshops. The string makers’ art was always closely guarded; they did not explain their secrets in books or even in some handwritten documents—or in any form—that would have been available to everybody. There are rather indirect clues and evidence that can give a clear vision of how things probably were done at the time.

In theoretical terms, here is an example of the importance of indirect evidence: the planet Pluto was known about but not seen directly by a telescope for almost 50 years or more. Despite that, people knew well that it existed through their knowledge of the force of its gravitational effects on the planet Uranus; this is a case of indirect evidence that became direct evidence through calculations, like some of the arguments here, I believe.

Having said that, I would like to point out the very interesting presence of barrels of hide glue in some stringmaking workshops of the 17th century: ‘Un barilozzo con dentro libbre 30 in circa di colla cerviona’ (a small barrel containing about 30 pounds of hide glue). Containers with red-dye are also mentioned: of course, we cannot know whether that was employed for dye, or loading the gut. (see Patrizio Barbieri; op. cit 13 p. 97).

Generally speaking I can say that glue was never used in the traditional or even in the modern gut stringmaker’s art; instead, it is absolutely necessary, for many good reasons, when one is making loaded gut strings today.

The incorporation of insoluble, mineral pigments into wax, silk, wood, cloth, ink, hair etc may be perceived as very strange today, even though it was a very common practice in those times. So an addition of insoluble thin pigments/thin copper powder on fresh gut ribbons was surely nothing strange for people of the 16th and 17th centuries. To some extent, it is a procedure that was very similar to many of the silk-dyeing processes of those times where they sometimes used to charge this material with heavy insoluble substances.

There are many surviving 16th and 17th-century books and manuscripts, for example, that explain how to incorporate cinnabar or litharge or similar substances into several different materials, such as silk, hair, wood, paper, wax, etc.19

Recipes from Giovanventura Rossetti’s Plichto . . (Venezia, 1568) book of dyeing recipes
I have said that there is no direct evidence—in the West—related to a process of the loading of gut. However, we have recently discovered a Chinese source that seems to confirm that copper, gold, silver as well as ceramics (etc.) as powders were employed by the old Chinese stringmakers to charge silk strings for the Guqin: this is a direct evidence that heavy substances were employed to charge musical strings; see: http://www.silkqin.com/02qnpu/05tydq/ty1b.htm#yongyao

3) Modern loaded strings (and so also those of the 16/17th century) are not transparent or translucent

Some scholars believe that the loading of gut cannot be a real historical option because it would have made the bass strings opaque and not transparent or translucent as mentioned by John Dowland. (op. cit. fn. 5).

Counter-arguments

Any possible mention of transparency/translucence related to bass strings is limited exclusively to the Varietie of Lute Lessons. In fact, in the Burwell Lute Tutor and treatises of Thomas Mace and Marin Mersenne there is nothing on that subject. In other words, to extend this to include as well the mid17th century bass gut strings such as ‘Lyons’ and ‘Pistoys’ (which Dowland never described), seems to be placing too much weight on one piece of evidence. These are the salient passages:

Now because Trebles are the principall strings we need to get, choose them of a faire and cleere whitish gray, or ash-colour, and take one of the knots . . .

Dowland here says that Trebles are good when they look clear or clear ash-grey but always transparent. Then:

This choosing of strings is not alone for Trebles [first course], but also for small and great Meanes [second and third courses]: greater strings though they be ould are better to be borne withall, so the colour be good, but if they be fresh and new they will be cleere against the light, though their colour be blackish.

Here Dowland says that the same criteria employed to check the quality of the Trebles must be applied also to the small and medium Meanes (strings for the second and third courses) that are fatter strings than the Trebles just mentioned before. Then he starts to describe the coloured strings and all the related commercial names, behaviours etc: it is clear that he is still speaking of small and medium Meanes and Trebles:

Some strings there are which are coloured, out of which choose the lightest colours, viz. Among Green choose the Sea-water, of Red the Carnation, and of Blew the Watchet. Now these strings as they are of two sorts, viz. Great and Small: so either sort is pact up in sundry kindes, to wit, the one sort of smaller strings (which come from Rome and other parts of Italy) are bound up by certaine Dozens in bundels; these are very good if they be new, if not, their strength doth soone decay: the other sort are pact up in Boxes, and come out of Germany: of these, those strings which come from Monnekin and Mildorpe, are and continue the best. Likewise there is a kinde of strings of a more fuller and larger sort then ordinary (which we call Gansars). These strings for the sizes of the great and small Meanes, are very good, but the Trebles are not strong. Yet also there is another sort of the smaller strings, which are made at Livornio in Tuscanio: these strings are rolled up round together, as if they were a companie of horse hayres. These are good if they be new, but they are but halfe Knots. Note there is some store of these come hither lately, and are here made up, and passe for whole Knots.
Then, after a full stop he starts to speak about the basses:

For the greater sorts or Base strings, some are made at Nurenburge, and also at Straesburge, and bound up onely in knots like other strings. These strings are excellent, if they be new, if not, they fall out starke false. The best strings of this kinde are double knots joyned together, and are made at Bologna in Lumbardie, and from thence are sent to Venice: from which place they are transported to the Martes, and therefore commonly called Venice Catlines.

Having said that, here are my observations:

1) When he introduces the description of the bass strings, there is a clear separation of this from the Meanes, by way of a full stop. There is no description of how these bass strings look. So, any transparency / translucence is related to the Meanes & Trebles only.
2) We should not overlook the fact that when he describes a given sort of string, he (like Mace) always uses a capital letter (i.e. Trebles, Meanes, Basses). This is not the case when he mentions 'greater strings', in the above passage, where he is referring to what comes just before the colon (and the colon, when it does not open a list of items, is explanatory, to make clear a concept that has just been exposed), i.e. the Meanes.
3) It is worth noting that even an unloaded roped string (the only suggested alternative to the loading of gut), thanks to the high double twisting of the paired strings (which do not have their fibres completely glued to each other so there is always some air enclosed), is in fact opaque and not translucent to light, especially if it is dyed. Actually, the only string that is truly transparent (but only if it is not too thick) is a low twist gut string.

Conclusions

My serious, clear questions are still there: why were all these bridge holes not made bigger? It is not necessary to be a graduate from a university to be able to do this easy job. The most important lute sources wrote that the lute must have the same feel of tension on all the strings: with such narrow holes for the bass strings how is it possible to achieve that (when for Treble, the thinnest whole gut gauge is 0.38–0.40 mm)?

The second question: How is it possible that the old gut lute basses were so loud while ours (roped guts) are so weak?

It is rather hard to understand why some scholars introduce complicated and to some extent illogical explanations in order to avoid confronting such clear and plain evidence: the narrow holes found on all these original lutes and the impossibility of playing at 1 kg (or less) tension; the technical impossibility of producing first strings thinner than 0.40 mm gauge; the very good performance of 17th-century gut basses that are described in comparison with the upper strings etc.

Some explanations, avoiding the loaded gut theory, seem unnecessarily complex or contrived: the hypothesis of the self-made roped strings using one very long Meanes string, twisted in the middle by way of a special tool to obtain a thicker roped string, to me does seem an example of this, unless I have misunderstood something.

A second example of a contrived argument to find an explanation for those narrow bass bridge holes, is the introduction by some scholars of the idea that lutes of the past worked with two different degrees of tension on the same instrument: one very low, for the Basses, and another higher for Trebles and Meanes. This is despite the fact that almost all of the lute treatises of those times wrote that the right set-up is for all the strings have the same feel of tension and that the biggest mistake on lutes is when some strings are stiff and some are slack, for instance Thomas Mace (Musick's Monument, London 1676):

The very principal observation in the stringing of a lute. Another general observation must be this, which indeed is the chiefest; viz. that what siz'd lute soever, you are to string, you must so suit your strings, as
(in the tuning you intend to set it at) the strings may all stand, at a proportionable, and even stiffness, otherwise there will arise two great inconveniences; the one to the performer, the other to the auditor. And here note, that when we say, a lute is not equally strung, it is, when some strings are stiff, and some slack. (Mace op. cit. fn. 10)

The Mary Burwell lute tutor (c.1670):

When you stroke all the stringes with your thumbe you must feel an even stiffnes which proceeds from the size of the stringes. (Burwell. op. cit. fn. 9)

John Dowland (Varietie of Lute Lessons, ed. Robert Dowland, 1610):

But to our purpose: these double bases likewise must neither be stretched too hard, nor too weake, but that they may according to your feeling in striking with your thombe and finger equally counterpoyse the trebles. (Dowland op. cit. 5)

Most performers start to perceive a different feel of tension when the difference starts to exceed a semitone of tension. Within that limit they do not perceive any difference; we are in the region of the equal feel of tension. Some players are even more sensitive but they are an exception. The conclusion is that if the bass strings are working at very low tensions, they are clearly perceived by most players as ‘slack’, uneven with the upper strings: we are far from the so called even feel of tension mentioned by all the 17th-century lute treatises.

In conclusion, the hypothesis that lutes of the past worked with two degrees of tension is not historically sustainable.

What can be an historical alternative to the to the loading of lute bass gut strings? Well, I have often tried to find any other logical explanation but I have always failed: if the bass gut strings are not made denser in some way, the tension becomes dramatically too low to be managed (with a strong increase in pitch and fret distortion); the string becomes weak (while in the historical past they were rather loud); as a further consequence, the first, second strings (within the condition on the equal feel of tension) would need to become too thin for the biology of the sheep. Vivi felice!

Appendix 1

Lute strings and their names

Lute strings produced in the 16th, 17th and 18th centuries, unlike today, were identified by names that immediately pointed to the place of provenance, as a clear sign of quality. This particular aspect, in a historical period where copyright did not exist, explains the severity with which the corporations of string makers prosecuted commercial frauds, including string makers within the same corporation if they were caught cheating. Giving the client absolute guarantee that Munich strings were actually produced in Munich remained the highest priority throughout centuries of lute history.

Another point to underline is the manufacturing specialisation typical of different geographical areas: in some regions, for instance, string makers would devote themselves to bass strings, in other regions to treble strings, with astonishing commercial success. Florence (bass strings) and Rome (trebles) are emblematic examples.

This does not mean that Florence produced no treble strings at all, we simply wish to point out that if certain areas gradually specialised in a specific product, it was because they must have found a way to excel in it—be it through the high quality standards, or through new products and more rational and improved methods of production.

Sources from the 16th, 17th and 18th centuries specifically describing the production of strings for plucked and bowed instruments are scanty, particularly concerning the lute, which was the most difficult instrument to string.
Regarding the Age of Enlightenment we have an interesting paradox: at a time when the Encyclopaedists started for the first time to describe in detail the string makers’ art (together with some important aspects of stringing for bowed instruments, mandolin and especially 5-course guitar) we know virtually nothing about the lute in S. L. Weiss’s time: our instrument had already fallen in a dark corner of history which no Light of Reason could illuminate any more.

**Historical sources**

**15th century**

We have no commercial denomination whatsoever for lute strings.

**16th century**

The earliest mention of different types of strings come from the manuscript of the Venetian nobleman *Vincenzo Capirola* (c.1517): for the first time we have a description of strings of superior quality from Munich (Bavaria); a type of string called ‘Ganzer’ is also mentioned, whose origin is not quite clear, although it might hint at a roped structure (see below). Unfortunately, Capirola does not specify where on the instrument the strings he mentions were employed.

Another known source is *Adrian Le Roy* (*A Briefe and plaine instruction* . . . London 1574). Le Roy writes that the best strings are those manufactured in Munich (or near it), or in the town of L’Aquila, in Italy: ‘. . . the best come to us of Almaigne, on this side the toune of Munic, and from Aquila in Italie. . . ‘ After this interesting start he goes on to describing how to tell a good string from a false one. He, too, gives no further information about where on the instrument the strings he mentions were employed. This scanty information is all we have from the 16th century concerning the names and qualities of lute strings.

**17th century**

The first author who finally throws a bit of light on the question of lute strings is *John Dowland*, in his essay in the *Varietie . . .* of 1610. He divides strings as follows:

—‘Trebles’: ‘from Rome and other parts of Italy’; ‘from Monnekin and Mildorpe’ (most probably Munich and Meldorf, both in Germany); besides, he mentions other thin strings, ‘which &c’.

—Small and Great Meanes: Gansars

—Base: Nurembrurge &c. (the best Basses, according to Dowland, are made in Bologna, in ‘Lombardy’)

In Dowland’s work we can see a certain tendency to confusion when describing the Meanes as string typology: it is not quite clear, for instance, whether the smaller strings made in Livorno are Trebles or Meanes, just as it is not clear whether the coloured strings he mentions belong to the Trebles or to the Meanes (or both). Echoing Capirola, he also mentions Gansars.

Next comes *Michelangelo Galilei* who on 6 August 1617, from Munich, wrote to his brother, asking him to get him four thick strings from Florence, for his own and his pupils’ needs. Unfortunately, we do not know the commercial name of those strings.

In the *Mary Burwell lute tutor* (c.1670) we read: ‘The good stringes are made at Rome or about Rome and none that are good are made in any other place except the great strings and octaves that are made in Lyons att Franchise and noe where else’.

Here, too, no particular novelties: it confirms what already stated by *Mersenne* (1636), that the best strings came from Rome. What is new, though, is that bass strings and octaves were made in Lyon. *Thomas Mace* (1676) is definitely our most exhaustive and valuable source. Like Dowland, he describes three typologies of strings:
—Trebles: top three courses and octave sixth: Minikins;
—Meanes: fourth and fifth and all remaining octaves: Venice catlins;
—Basses: Pistoys and Lyons.

Mace, like Dowland, also mentions coloured strings, but is also not clear whether they were used as Trebles or Meanes (or both).

Romans, Venice Catlins and Lyons appear again in James Talbot’s manuscript (c. 1695), as strings for violin and bass violin.

This sums up all the information we have about string typologies in the 17th century.

18th century

We have no specific terminology about Lute strings.

In conclusion, the names given to lute strings in the 17th century always refer to their place of origin, with two exceptions: Catlins (or Catlines) and Gansars. The former were produced, at least in Dowland’s time, in Italy. We do not know what the Italians called them, though. In the 18th century terms like Catlins/Catlines, Lyons, Pistoys etc disappear completely, to give place to a more generic denomination such as: ‘strings made in . . .’

All-gut bass strings made by string makers gave way after the second half of the 17th century to wound basses, which were wound up by the lute maker or even, sometime, by the player himself.

Footnotes and bibliography


4 The density average of a bumped string is less because its structure is less ‘compact’ than those of a standard plain gut string. Inharmonicity is the degree to which the frequencies of the harmonics deviate from being being multiples of the fundamental: ‘a little inharmonicity in the sound changes the timbre in a way that can be considered attractive . . . but increasing inharmonicity reduces the number of audible harmonics (by a phase-cancellation process), which eventually makes the sound too dull and unfocused to be musically useful’ (Ephraim Segerman, Fomhi Quarterly 104, Comm. 1766) https://www.fomrhi.org/uploads/bulletins/Fomrhi-104.pdf. The smooth rather than bumpy texture of a smooth roped string is produced by a ‘wet’ rather than ‘dry’ roping method.

5 John Dowland: ‘Other necessary observations belonging to the lute’, in Robert Dowland: Varietie of lute-lessons [...] (London: Thomas Adams, 1610), paragraph ‘Of setting the right sizes of strings upon the lute’.

6 Johannes Tinctoris: De Inventione et Usu Musicae c.1487 [my translation from Latin]

7 Sebastian Virdung, Musica Getutsch (Basel, 1511).

8 Vincenzo Galilei: Fronimo, Dialogo (Firenze, 1584).
9 Wellesley (Mass.), Wellesley College Library, The Mary Burwell Lute Tutor, manuscript, c.1670, facsimile reprint with introduction by Robert Spencer, (Leeds: Boethius Press, 1973), chapter 16 (the first two quotes) and chapter 4 ‘Of the strings of the lute [...]’.


17 Ephraim Segerman: ‘More on the name ‘Catline’’ *FoMRHi Quarterly* 76, (July 1994), Comm. 1288; pp 85-6.

18 [https://en.wikipedia.org/wiki/Pluto](https://en.wikipedia.org/wiki/Pluto)

19 Giovanventura Rossetti, *Plichto de l'arte de tentori che insegna tenger pani, telle, banbasi et sede si per larthe magiore come per la comune* (Venezia ,1568).


I would like to thank Anthony Hind and Anthony Bailes for their help rereading, commenting, and making some suggestions for the final version of this article.
1. Contents
   1. Introduction
   2. Tools, equipment and experience
   3. Key box
   4. Body
   5. Harpa
   6. Bow
   7. Standard
   8. Case
   9. Testing the harpa

Attachments

A. Time used
B. Nyckelharpa mathematics
2. Introduction

This report provides information on how I built a nyckelharpa, using the instructions found in "Chromatic nyckelharpa - A construction manual (ISBN 91-7910-416-9)’ written by Sören Åhker. This report reflects my personal experiences and approaches and it shows my diversions from the directions of Sören Åhker.

This report does not replace the above construction manual. On the contrary. It is, I think, better understandable by those who know the content of the construction manual.

During the building process I recorded each day what I did and how much time I've spent on it. Information about the time spent can be found in Appendix. The time spent is the net time = time at the workbench. I also have included pictures of the work made.

I hope future nyckelharpa builders will benefit from my experience and tips, and especially from the mistakes I made.

Questions or comments about this report are welcome at my e-mail address.

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Hilversum, The Netherlands, November 2011

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2. Tools, equipment and experience

It will be clear that my approach was partly determined by the workshop and the tools I had. I'm usually using micro tools, such as from Proxxon or Dremel. My workshop is about 15 square meters. It has three workbenches, which allows one to leave unfinished work for a while, and to carry on with something else.

My approach was also determined by my experience with woodworking. It is limited to the use of the common DIY hand tools such as saws, files, planes, chisels and power tools such as drill presses and belt sanders (I had no band saw). I had never made such a complex device as the nyckelharpa. After making it, I am convinced that anyone who masters the basic techniques of woodworking, can build a nyckelharpa, according to the construction manual mentioned earlier.

Tip: Work with the original drawings and not with a copy

Because I was concerned that the drawings attached to the construction manual would be damaged during the building process, I made copies of them. I started working with the copies. When I compared the key guides I had created from the copy, with the original drawing there were unacceptable differences. The measures on the copy were not exactly equal to those of the original.
The construction manual suggests making templates for all parts of the nyckelharpa and using these to create shapes on the wood. I have not done so: I have measured all shapes from the original drawing and have drawn these directly on the wood. I could work that way, I think, because I can draw well.

3. **Key box**

In the construction manual making the body is the first step. Because the key box seemed to me the hardest part of the knucklehead, I started with it. My idea was that, if I could make the key box I could make the other parts too.

*Key Guides*

Because I wondered if the teeth of the key guides were strong enough to withstand lateral forces, I made a test piece. I reinforced a few teeth with copper wire. The others were not reinforced. By exerting pressure on both types of teeth, I could conclude that the non-fortified teeth were strong enough.

I then drew the four key guides on wood, cut them with an electric jigsaw and finished them with key files.
Finally, I covered the inside of the teeth of the key guides with supple leather of 1 mm thickness. (This means that where the keys slide through the key guides; the keys should be 1 mm less thick than is indicated in the construction manual).

**Keys**

I started by drawing the sizes of the keys, and the place of the long holes on the wood.

Tip: Do not use an electric jigsaw without guides

I tried to cut out the long holes with an electric jigsaw. That did not work properly because it was a very difficult to saw straight without guidance. The result was a key with a hole whose edges are not straight and taut.

I thought it would be better to cutter the keys. To do that and I have turned a micro drill into a router table below. That was pretty simple: 1) by turning the micro drill holder upside down and 2) by fitting a custom-made small plateau which the cutter sticking up.
That worked perfectly. So, I could accurately cutter out the holes.

With this tool, I could also cutter the outside of the keys in the desired form.

*Please note:* the picture shows a hole for a tangent. These holes and tangents, however, should be made later in the process.
Placing the keys in the key guides

Because I did not make the harpa body first I had no neck to mount the key box on. Instead of the neck, I used a piece of MDF 10 cm wide, with a length of the neck. I glued graph paper on it, as a guide for parallel and perpendicular placement of the keys in the key guides.

I glued thin leather on the MDF piece under the lower the key guides. The key guides were clamped to the MDF piece. That made little adjustments possible.

Then I precisely fitted each key in the key guides using knife and file. The graph paper was very helpful.

After the bottom row of keys was mounted in position, I fixed the guides with screws instead of clamps. Then the middle and top row keys were fitted and placed in the key guides.
Thus, the key box was built step by step.

The vertical block at the left side of the key box is a temporary replacement for the nut over which the strings will run. It is an easy tool to place on the keys exact marks for placement of the tangent (holes). The holes in the keys at each layer have a different diameter. I drilled them with a drill press.

**Tangents**

The tangents have a different thickness for each key row: 8 mm for the bottom, 8 mm for the middle and 6.5 mm for the top row. For tangents with a certain thickness, I started with a square bar with that thickness. Then I drew the tangent at the top of the bar, the pen of the tangent pointing up. The rest of the bar serves as a handle for holding the workpiece. At the place where the pen stops, I sawed the bar so far in that a pen could be rough cut with a knife and be rounded to the diameter of the pin with a file.
To cut the sloping sides that form the angle which touch the string, I used a sharp knife. After that the tangent is ready and can be cut from the bar. On the bar, the following tangent can be drawn, etc.

*Key box finishing*

After placing all the tangents, I have finished the key box.

Because key guides remained not exactly vertical, I made cross connections between the left and right key guides. They consist of threaded rod that runs through the key guides. For show, I caught the rod in a brass tube.

When I was ready, I adjusted the key box to form a self-contained unit, which could later be mounted on the neck. To that end I replaced the MDF piece by a wooden plate of 5 mm thick, 10 cm width, length of the neck. To ensure that this plate is not going to bend due to
temperature or humidity, I made it of plywood. For decoration I finished the short edges with hardwood.

4. Body

Having taken all measures and shapes from the original drawing I drew them on the wood. I checked everything thoroughly. Because I had no band saw, I used the band saw from a shipyard. The width of the blade of the saw did not allow to saw certain curves in one movement.

To solve this some curves were cut out from two sides. It proved difficult to match cuts made from two sides. Then there is a lot of finishing with chisels, files and sandpaper needed to get everything in order.

*Tip: Work with a band saw with a blade width that can saw all curves in one move*

The neck

With a drill press, I drilled left and right a series of holes adjacent to each other. I cut them out with a chisel and file so that elongated holes for the guitar strings were created. The edges of these holes were not nice and tight. That was solved by gluing mahogany strips with an oblong hole. Drilling the holes for the guitar string tuner was simple.
This work was done when the neck was not attached to the harp.

The reinforcement plate and the tuning pegs of the cello strings were made of two types of wood. That is a matter of taste.

I used a peg reamer and peg shaver to fit the pegs in the neck.
The assembly of the harpa

The assembly of the harpa is quite simple.

Here you can see how the parts are glued together and clamped. After this was done, I glued and clamped the back to the harpa.

Bending the top plate

I bought the top plate. It consisted of two parts glued together, 5 mm thick. From the construction manual one can (mathematically) deduce that the top plate should have the shape of a circle segment with a radius of 29 cm.

I have therefore made a mould on which the top plate could be bent and clamped.
The make the top plate easier to bend, I put it one hour in hot tap water. It was held under water with a weight of iron.

Then I clamped the top plate on the mould.
As you can see the glued seam parted in the middle. So, this was not the way to bend the top plate!

To reconstruct the top plate, I let the wood dry, sawed both halves apart, and glued them back together using a specially made mould.

With the template I could exercise horizontal and vertical pressure. I attached adhesive tape to the edges of the top plate to protect the wood against glue. The mould had a notch below the bond line which gave room for the expansion of the glue.

After the top plate was reconstructed, I decided to bend the plate with steam. Therefore I have a steam box made of MDF. The box interior was coated with aluminium foil.
After 15 minutes steaming the top plate could be bent and clamped to the mould that I created earlier.

**Placing the top plate on the body**

The side edges should follow the profile of the now-bent top plate. Where the side edge moves towards the centre line of the harpa, it should be higher. Where it moves outwards it should be lower. It seemed hard to make a perfect fit between edges and top plate, just by hand only.

*Note: apply the Pythagorean theorem to calculate the height of the sides edges*

Then I noticed that the edges should connect to of the circular segment which is formed by the top plate. With the Pythagorean theorem this easily can be resolved, as shown in the figure below. MA is the axis of the harpa. FH is the top of the bottom plate. CF and BG are the outer and the inner edge of the harpa. DCBA is the bottom of the curved top plate with radius \( r = 29 \text{ cm} \). If the outer edge of the side is \( y_2 \) cm from the centre line of the harpa, it is easy to calculate \( x_2 \). At that spot the height of the edge should be reduced by \((r-x_2)\) cm be. In this way all points on the inside and the outside of the edge can be calculated. With a spread sheet with the only variable 'y' are all points can be calculated (the spread sheet formulas and other nyckelharpa mathematics are given in Appendix B).
With the spread sheet calculations in the hand it is simple to mark all points on the inside and the outside edge by pencil.

I checked the formulas, measurements and the pencilled points a few times. I then cuttered away unwanted wood - that was exciting.
I then lightly worked on the edges with a file and sandpaper and verified that the profile fits the top plate everywhere. The next picture shows how I did it.

The result was perfect. We were now ready for the next step: gluing the top plate.

To the glue and clamp the top plate to the harpa, I made a clamping device.
The harpa body can be placed in it and the top plate can be glued and clamped with 25 clamps. Before applying glue I attached adhesive tape on places where glue might damage the wood.

The tail

The tail and the tail holder must resist forces of the stretched strings. I decided for a different solution than is shown in construction manual. In the photo below a prototype of a tail holder is shown. It should be attached to the underside of the harpa. An oblique hole was carved in the tail. The hole fits exactly over the pen of the tail holder.
The holes for the sympathetic strings should run through the middle of the front of the tailpiece to the bottom of the cut that is made for the ends of the strings - a slight angle so. I have solved this by tilting and clamping the tailpiece to the workbench and drilling vertically.

5. Harpa

Subsequently I mounted the tailpiece, the key box and a makeshift bridge. I stringed the harpa with nylon strings (cello strings only) to make sure everything is fitting.
Then I made a permanent bridge, 5 mm higher than described in the construction manual (because of a wood plate of 5 mm under the key box. Placing all the strings is a process of trial and error, partly because the bridge can slide a little under the pressure of the strings.

The picture below gives an impression of the stringed, not stained harpa.

Tightening the cello strings was really heavy going and it was therefore difficult to tune them precisely. Therefore I made a few accessories to tighten the bolts more easily.
I made these before I discovered the existence of a lubricant for pegs which ceased to run smoothly.

6. **Bow**

I have built the bow by gluing a number of layers of two different types of veneer and bending and clamping it with a mould. The result was a rectangular stack of glued veneer with a curve. I planed and sanded it into the proper shape.

For the frog I have made an oblong hole in the bow, by moving a cutter with a mechanical stage over the fixed bow.
At the tip of the bow, I have glued an ebony block with square hole in it. This hole is for fastening the bow hair. The next picture shows how I have drilled a square hole by drilling away the edges of the hole and by filing.

The picture below shows how the ebony block is glued and clamped to the tip.
The picture below the shows the ready bow. The bow hair was fastened by a professional violin maker.

7. Standard

It seemed useful to have a stand on which the harpa could stand stable if not played. There are stands for violin and cello for sale but I did not like them and they did not fit. I decided to make one myself. Any design will do as long as the harpa stands stable.
The picture above shows what I've made. The standard consists of five parts which click together without screws: two round legs that click together, a vertical support for the harpa that clicks around the legs, a back support which is attached to the vertical support with a wedge, and a safety bracket which is clicked on the vertical support. All parts coming into contact with the harpa have been covered with felt (not in this photo) to prevent damage to the harpa.

8. **Case**

The case was made from plywood. I covered the outside with vinyl. On the case bottom I placed a mould fitting the bottom of the harpa. This prevents forwards or sideways movements of the harpa. For the end of the neck, I made a recess. I made clips covered with felt in the lid. They press the harpa tight against the bottom as the lid is closed. The bottom of the box has enough room for the bow and other accessories.

The box is strong but also very heavy. For someone who is small or not strong, this is a disadvantage.

*Tip: Try to build a strong case with lighter materials*
The round legs of the stand I have attached with Velcro to the inside of the box. I have clamped the long supports using a swivel clip.

9. **Testing the harpa**

I started to play the unstained harpa a few weeks tried (I had never played on a violin or harpa). This gave the opportunity for small corrections to the harpa. On my request an experienced harpa player tested the quality of the instrument. Her judgement was that I made an instrument that is acoustically and mechanically completely satisfactory.

The instrument is still unstained.

Appendix A. Time used

<table>
<thead>
<tr>
<th>Part</th>
<th>Hours at the workbench</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key box</td>
<td>130</td>
</tr>
<tr>
<td>Body</td>
<td>130</td>
</tr>
<tr>
<td>Harpa</td>
<td>40</td>
</tr>
<tr>
<td>Bow</td>
<td>15</td>
</tr>
<tr>
<td>Standard</td>
<td>20</td>
</tr>
<tr>
<td>Case</td>
<td>25</td>
</tr>
<tr>
<td>Finishing the harpa</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
</tr>
</tbody>
</table>

In this time several moulds were made, as described in the report. The time does not include time for shopping and pick up wood and tools.
Appendix B. Nyckelharpa mathematics

Fitting the top

Deflection curve or the top

Drawing 1.3 shows a peak deflection of 15.5 mm over a total breadth of 185 mm (90 mm 95 mm). Assuming the form of a deflection is a circle segment, the centre point and radius of the circle can be easily calculated. See figure 1 below.

Figure 1

Curve EDB is the underside of the deflected top. Half of the breadth b is (it is assumed for calculation purposes that both half breadths are equal). The deflection is d. The radius of the circle is r. Now the radius can be calculated using the right triangle ABC the Pythagorean theorem and applying: \( BC^2 = AB^2 + AC^2 \). \( AC = r - d \) and \( AB = b \). Therefore \( r^2 = b^2 + (r-d)^2 \). From this follows: \( r^2 = b^2 + r^2 + d^2 - 2rd \), and thus \( 2rd = b^2 + d^2 \). Finally we conclude the \( r = \frac{(b^2 + d^2)}{2d} \). By filling in the values of b (= 90 mm) and d (= 15.5 mm), we calculate \( r = 295.5 \) mm.

Breadth of the top

The circumference of the circle with centre point C and radius r equals to \( 2 \pi r \). This length corresponds with 360 degrees. To calculate the length or curve EDB (= net breadth of the top) we are determine angle ECB. \( ECB = 2 \times \text{angle ACB} \). \( \text{Tg} \ (ACB) = \frac{b}{(r-d)} \). Therefore angle ACB = \( \text{arctg} \ (b / (r-d)) \) radians. Thus the length of curve EDB = \( 2 \times \text{arctg} \ (b / (r-d)) / 2 \times \pi r \). Add extra millimetres to the breadth to make sure the top sticks out from the sideboard.

Calculating the height and angle at peak each position of the sideboards

In the figure 2 below a cross section of the harpa is shown.
The harpa is standing on its side (this picture shows one half of the harpa). FGH is one half of the bottom plate. FGBC is a cross section of the sideboard. FC is the outside of the sideboard, GB is the inside. FG is the thickness of the sideboard at a certain cross section. HA is the maximum height of the sideboard. ABCD is the deflected top of the harpa. MD is the radius of the deflected top. ABCD is the underside of top half of the deflected top. HEA is the middle line of the harpa. The upper side of the (unbowed) sideboard lies in the plane AJI. At a certain vertical cross section of the sideboard, points C and B and curve CB should be positioned to fit exactly the top. This can be done by filing away at a particular cross section, IC at the outside, and JB at the inside of the sideboard. For practical purposes BC is considered to be a straight line.

Calculating the height

That cross section at the outside of the sideboard, FC, the inside is GB. Easily we can measure the distances of these sides to the centre line of the harpa (which corresponds with a line perpendicular to the plane or figure, through point H). Coordinates of point B and point C are (x1, y1) and (x2, y2). Coordinates y1 and y2 are known by measuring the distance of the outside and inside of the sideboard to the bottom centre line of the harpa. Coordinates x1 and x2 now can be calculated.

We apply the Pythagorean theorem we to the triangles BMx1 and CMx2. In general \( r^2 = x^2 - y^2 \) applies for triangles, and therefore \( x = \text{square root} \left( r^2 - y^2 \right) \). For triangle BMx1 applies \( x_1^2 + y_1^2 = r^2 \). For triangle CMx2 applies \( x_2^2 + y_2^2 = r^2 \). Therefore point B lies \( r - \text{square root} \left( r^2 - y_1^2 \right) \) below to the top edge of the sideboard, point C lies \( r - \text{square root} \left( r^2 - y_2^2 \right) \) below the edge. These points can be calculated and marked at the inside and outside of the sideboard. By connecting the marked points at the inside and outside, we shall see the curves of the board that side will fit the top exactly.

Calculating the top angle

The top angle of the sideboard is KCB angle in Figure 2. It is equal to \( \arctg \left( \text{KCB} \right) \). \( \text{Tg} \left( \text{KCB} \right) \) equals to \( \frac{\text{KB}}{\text{KC}} \). KB = \( x_2-x_1 = \left( r - \text{sqrt} \left( r^2 - y_2^2 \right) \right) - \left( r - \text{sqrt} \left( r^2 - y_1^2 \right) \right) \). KC is the thickness of the sideboard = \( y_2 - y_1 \). From this \( \arctg \left( \text{KCB} \right) \) can be calculated.
### Spread sheet to perform calculations

<table>
<thead>
<tr>
<th>item</th>
<th>symbol</th>
<th>formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>** breadth and bend through of top board</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA maximum deflection</td>
<td>d</td>
<td>input data</td>
</tr>
<tr>
<td>AB half breadth</td>
<td>b</td>
<td>input data</td>
</tr>
<tr>
<td>CB=CD=CE radius</td>
<td>r</td>
<td>r=(b<em>b+d</em>d)/2*d</td>
</tr>
<tr>
<td>** bend through at distance y1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GH measured distance from bottom centre line</td>
<td>y1</td>
<td>input data</td>
</tr>
<tr>
<td>BX1 horizontal projection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JB bend thru at y1 distance</td>
<td></td>
<td>r - square root (r<em>r-y1</em>y1)</td>
</tr>
<tr>
<td>** bend through at distance y2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FH measured distance from bottom centre line</td>
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<td>input data</td>
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<tr>
<td>GX2 horizontal projection</td>
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<td></td>
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<tr>
<td>IC bend thru at y2 distance</td>
<td></td>
<td>r - square root (r<em>r-y2</em>y2)</td>
</tr>
<tr>
<td>** angle from (x2,y2 to (x1,y1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KCB angle of the upper edge of the sideboard</td>
<td></td>
<td>arctg (KCB)</td>
</tr>
<tr>
<td>tg(KCB)</td>
<td>KB/KC</td>
<td>KB/KC</td>
</tr>
<tr>
<td>KB x1-x2</td>
<td></td>
<td>(r-sqrt(r<em>r-y2</em>y2)-(r-sqrt(r<em>r-y1</em>y1))</td>
</tr>
<tr>
<td>KC y2-y1</td>
<td></td>
<td>y2-y1</td>
</tr>
</tbody>
</table>
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 \times 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 \times 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 $d_2$ 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 ($c_1$) 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 $g_1$ and (overblown) the $g_2$ 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.

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.

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

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 ‘Über 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
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.

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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.

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.
Making woodwind instruments

10.11 Tuning the baroque oboe

Introduction; fingering tables
Simply because my own practical knowledge was too restricted to answer all questions, I have consulted several people on the subject of making and tuning the baroque oboe. I mentioned them at the end of Comm 2097. In this section I refer several times to the article by Marc Ecochard about Karl F. Golde. See 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_publications/objet.php?reset=1&p_ftype=3). Longer quotations from the Golde article are in italics; I made some adaptations in the notation of the tones and names of the tone holes.

Concerning fingerings, I strongly advise reading the article ‘Oboe Fingering Charts, 1695-1816’ by Bruce Haynes, published in *The Galpin Society Journal*, Vol. 31 (May, 1978), pp. 68-93. I found it also on internet: www.jstor.org/stable/841191. He suggested that most fingering charts were written for amateur players (professionals didn’t need them). Modern fingering charts (published in the last 30 years) for the baroque oboe are surprisingly very rare, I found actually only one, on http:// hautboy.org/fingerings with the fingerings for the ‘Saxon model baroque oboe’. We will see that several fingerings on that chart are different from those which were used before 1750.

About the notation of the fingerings I use here: I give the numbers of the holes which are closed, and for the keys if they are activated. ‘7’ means also that the hole of the small key is opened, but ‘8’ that the hole of the great key is closed. For instance: 1 2 3 4 + 7 means that holes 1 to 4 are closed, and that hole 7 is open. A dot ( . ) means that that fingerhole is open.

For instance: with the fingering 1 2 3 4 . 6 + 7 is hole 5 open between two closed holes (4 and 6), it is a so-called fork-fingering. To avoid confusion, I put the tone names in italics.

Resonance holes
$c1$: 1 2 3 4 5 6 + 8 and $c#2$: . 2 3 4 5 6 + 8
These holes are on the bell, and are also called ‘vent holes’ or ‘tuning holes’. On most oboes there are two of them, drilled at each side of the bell. Oboes d’amore don’t have these holes, but I have seen a tenor oboe (in f) by Robbert Wijne with a bell like an oboe d’amore, but with resonance holes.

The resonance holes on baroque oboes are always open and they are in the first place important for the pitch of the $c1$, the lowest tone on the descant oboe. With (almost) the same fingering, only hole 1 opened as an octave hole, the $c1$ overblows not to the $c2$, but a semitone higher to the $c#2$ (such ‘false - but useful - harmonics’ can also be observed on the lowest tones of baroque recorders).

This $c1$ is on many historical oboes rather sharp; Marc Ecochard writes that on the first generation of (French) oboes this tone even comes close to $c#$. And on some bagpipe chanters (*musette de Poitou*) it was indeed intended as a $c#$. Modern players of the baroque oboe do not like the sharp $c1$ so much. But by making the resonance holes smaller (resulting in a lower $c1$), other problems may arise. The pitch and sound of the $d1$ and $f1$ become worse, $c#2$ and $d2$ becoming too flat, and Piet Dhont told me that $e2$ might become just (and surprisingly) too sharp.
Karl F. Golde says that if the bore of the bell after the resonance holes is too narrow, it will result in the c1 becoming too sharp. And also that the bore in the upper section of the bell (between the socket and the resonance holes) needs to be wide enough. A narrow bore in this section makes the c1 flatter, but then you can’t get the d1 (which is more important tone than the c1) in tune. I suppose that this is the reason that on so many baroque oboes there is a clearly visible leap in the bore from the middle joint to the bell (for instance for the oboe by Haka in the Gemeentemuseum Den Haag: a leap from 17.4 to 20.0 mm). Golde continues: In general, it will be more beneficial for the middle register when the c1 and d1 are sharp than when they are flat. In the latter case the e, f, and g in both octaves will also be too flat, and the d2, d3 and a [I suppose a2] will be too sharp.

Hole 8 (hole of the gret key)

d1: 1 2 3 4 5 6 and d2: . 2 3 4 5 6

Hole 8 is the tuning hole for d1 and d2. Whereas c1 is often a bit (or more than a bit) too sharp, the d1 is more representative as a reference tone for the whole instrument. In other words: here begins the tuning of the oboe, and all other tones are tuned in relation to the d1.

The pitch depends not only on the size of hole 8, but also on the key action. Golde specifies that the pad of the key must have a wide opening angle.

Hole 8 is on most baroque oboes the widest hole, and can be far undercut: Piet Dhont told me that this improves the response of the c3 (with . 2 3 4 5 or . 2 3 4 5 + 7).

In old fingering charts hole 1 is always open for the d2. Bruce Haynes writes: on the modern oboe, hole 1 is covered by an ingenious plate which makes it easy to ‘half-hole’, or open this hole only a fraction, so that it can act as an octave speaker for the c♯2, d2, and eb2. This technique has often been quite naturally taken over on the early oboe for d2 and eb2. The charts, however, indicate that this fingering is rarely used: the earlier charts prefer an entirely closed first hole for d2 and e-flat2, and after c. 1770 the d2 is usually entirely open. The same is true for the c♯3: on all charts, the first hole is left completely open. It is only rarely half-closed for d3. Again, this fact probably has something to say about our present manner of making reeds and blowing them.

Hole 7 (hole of the small key)

d♯1/e-flat1: 1 2 3 4 5 6 + 7 and d♯2/e-flat2: . 2 3 4 5 6 + 7

Just as with hole 8, the action of the flap of the small key affects the pitch of the d♯/e-flat.

It was for Johann Joachim Quantz in his Versuch einer Anweisung die Flöte traversière zu spielen (Berlin, 1752) very important to make a distinction between the pitch of d♯ and e-flat. He even designed (or perhaps made himself) traversos with two keys, the d♯ being a bit (a comma) sharper than the e-flat. But other instrument makers didn’t follow him and as far as I know there have not been experiments with oboes with this system of double small keys.

One could say that this is not important issue, but it surely matters when we look at some Dutch oboes where we found that hole 7 was remarkably small (less than 4 mm), combined with a low key action. The resulting tone was much more suitable as a meantone d♯ than an e-flat. That makes restrictions in the music you can play on these instruments.

It is of course possible to make hole 7 wider, as Mary Kirkpatrick did on her copy after Haka (see Comm. 2055 in FoMRHI Q 135). Golde gives a size of 5.5 to 6 mm for hole 7 on his instruments, and on a ‘romantic oboe’ in my collection this hole is even 7 mm wide. But on most baroque oboes, hole 7 is clearly smaller (< 5 mm). The same pattern can be seen on traversos: on instruments from the late 18th century, hole 7 is much wider than on the longer instruments from the beginning of that century.
I myself prefer baroque oboes where hole 7 is not very small. On my copy after Wijne (private collection) is the diameter 4.8 mm, on the oboe by Van Heerde in Stockholm, c. 5 mm. The b-flat2 with 1 2 4 5 6 + 7 on the baroque oboe is the third harmonic of the e-flat1. The pitch of the b-flat2 is thus related to the size of hole 7. I think that the pitch of the tones of the upper registers depend more on the bore profile. Golde gives no information about this tone.

**Hole 6**

**e1 and e2: 1 2 3 4 5**

At first sight there are no problems for tuning e1 and e2. It is perhaps more difficult to get the sound perfect (just as on a baroque traverso, where the e1 is often the weakest tone). Ecochard gives in his article about Golde the advice is to bore hole 6 downwards, which rectifies a natural instability of the note and a natural tendency for the octave to be too wide. That confirms the observation of Steinkopf that on an oboe you must work downwards to avoid wide octave intervals. The downwards angle of the undercutting means that you can only undercut the hole above (see figure left); that immediately raises the fundamental and the octave. The thickness of the wall plays a role as well in fine tuning. Piet Dhont removed some wood (by sanding) around hole 6 on one of my oboes to improve the e1 and e2.

**Hole 5**

**f1: 1 2 3 4 . 6 (7) and f2: 1 2 3 4 . 6**

**f#/1 and f#/2: with the fingerings 1 2 3 4 . (+ 7)**

For f1 and f2 there is just this one fork-fingering: 1 2 3 4 . 6. Activating the small key (thus opening hole 7) makes the sound of f1 - which is often a bit weak - much better.

Piet Dhont told me that he once used to put a piece of paper for narrowing the bore a little bit just above hole 4 when he had to play pieces with many f’s. That improved the sound of f1, but in later years when he used staples with a narrower bore, he had no problems with this tone. He also told me that he preferred to place hole 5 a bit lower on the middle joint: a bit closer to hole 6 than to hole 5, just as on the oboes by Jacob Denner and that then with the tuning he worked upwards (making the hole wider, undercutting). But he said also: be careful with undercutting at the upside edge of the hole.

This information seems to me different from what I read in Golde/Ecochard: this tone hole (hole 5) is drilled vertically or with a slight downward angle, which permits undercutting on the upside edge and on the sides in order to reinforce the tone of the fork fingering without making the note too sharp. Ecochard continues: a good position and good undercutting of the F tone hole helps the response and intonation of high D (d3), which could have a tendency to be too low if hole 5 hole is lowered in position between hole 4 and 6; this latter position, which permits opening the tone hole more and thus gives a better tone to the cross-fingering, is to be found frequently on some German or Italian hautboys. And he concludes: modern players most often find the cross-fingered F on original instruments to be much too high: this is due partly to the original tuning which favours a rather high F, but mostly to an unsuitable reed setup. The frequent use of too thick a scrape and blades that are too long, together with an unadapted taper of the staple, makes the cross-fingering unavoidably stuffy in tone and too high in intonation.

About the f#: the size (position and shape) of hole 5 is also - or even in the first place - important for the f# fingered with 1 2 3 4 + 7. This fingering is in all old charts mentioned as the first
and main option for f♯, but is - just as on the traverso - always a bit flat. That is, for our modern ears. That’s why most players of the baroque oboe nowadays use the alternative fingering 1 2 3 4a . 6 + 7 for f♯1, thus covering one of the small holes of hole 4. As this fingering is too sharp for f♯ (but useful for g1-flat), hole 6 must be closed as well, adding the small key for the final correction. f♯2 is seldom a problem with the fork-fingered 1 2 3 . 5 6.

Bruce Haynes mentions the question of both fingerings for f♯1. He says that: the unanimity in the charts is startling. Michel Corrette made an interesting distinction between what he called the 'Italian' f♯1, fingered 1 2 3 . 5 6 or 1 2 3 4h in both octaves, and the 'French' 1 2 3 + 7 Most oboists of the time evidently preferred the French version. Intriguingly, Francoeur in 1772 complained that the low f♯ on the oboe is always too low, even when one forces it by blowing, so that it should be used only in passing', and he was not the only one to complain about this note.

Haynes states that: the invention of the double-hole with an indentation or 'dimple' must have been a great help to early woodwind players who needed to close certain holes only partially. Yet long after the invention of the double holes, and often even on oboes whose 3rd hole is doubled, the 4th hole was still made single. ... It should be pointed out that in the 18th century leading tones (i.e. sharpened notes) were played low, which helps explain why a flat f♯ was tolerable or even appreciated. By the 1820s, the leading tone had reversed positions and was played higher than normal, making a low f♯1 unendurable, and required the use of a special key. Although the 1 2 3 4 + 7 fingering is awkward in fast combinations with low c1 and d1', most technical passages are noticeably easier with it. Its appropriateness when playing with the flute (traverso), which uses the same fingering, and which also tends to be low, is self-evident. When playing an oboe with a single 4th hole, if one must choose between 1 2 3 5 6 (too high) and 1 2 3 4 + 7 (too low), the latter would seem preferable in most harmonic situations.

Back to Marc Enochard; he says that: if the octaves of d, e-flat, e and f remain flat after tuning (chambering and undercutting tone holes), it is necessary to expand the upper portion of head joint slightly, between hole 1 and the narrowest point; this explains the particular profile that one sometimes finds in the bore of a hautboy in this region: namely a reamer step just after the narrowest point and a widening of the bore. Octaves of e-flat and f are tuned in the same way, the chambering being carried out a little lower in the bore. Chambering the bore just below the socket of the middle joint facilitates the response and tuning of f.

Is it possible to do something with the bore profile and the fingerholes to optimise the difference in pitch between 1 2 3 4 and 1 2 3 4 . 6? The same question is asked for traversos, where there are indeed instruments where this difference is bigger than on others. My suspicion is that very wide undercutting in combination with a thin wall makes the difference in pitch smaller, but I can’t exactly prove or explain that.

Hole 4 (4a and 4b)
g1 and g2: 1 2 3, f♯1 with 1 2 3 4a . 6 + 7 and d3: 1h 2 3 + 8
Piet Dhont told me a long time ago that some problems, such as g1 too low or the octave g1-g2 too wide (with the nasty additional effect a bad response of f2# with 1 2 3 . 5 6) are hardly to be corrected at hole 4. You have to find a solution in the bore: making the section between holes 2 and 3 a bit wider may result in a better balance between g1, g2 and f♯2. But he warned: don’t go too far with reaming corrections!

Golde says that: the g in both octaves is usually flat and becomes more so when the low notes are too flat. If g1 is too flat its hole can be conically undercut, or the upper end of the lower joint bore can be gently widened from above, or the upper joint can be slightly chambered from its lower end up to just below the hole 3.
Ecochard adds that hole 4 (single or double) is often drilled upwards, to make the octave interval (which is often a bit small) wider.

When both small holes at 4 are of the same size, the fingering 1 2 3 4a produces a tone which is too sharp for f#1. That’s why nowadays oboes are made with a different size of the holes. See the photo (from the website of Marc Ecochard). Disadvantage: you can’t play so well this oboe with the left hand below. At hole 3, Ecochard left both holes at the same size.

See also the small size of the coves of the fingerholes of this copy (after Naust). Mary Kirkpatrick mentioned similar small coves on the Haka oboe. Piet Dhont recommends for the situation that f#2 tends to overblow into the next harmonic (which might happen by going from a2 to f#2), that you can make the cove slightly deeper (but be careful, it is easy to go too far), or - what you also can do - undercut the hole at the lower side. Undercutting helps also to make the sound of the f#1 more clear.

d3 with 1h 2 3 + 8 is the third harmonic of g1: you can’t tune this tone (and others in the third register) so much by manipulating the finger holes, as they have to be optimized for the tones of the lower registers. Small corrections are sometimes possible, see for instance at the description of hole 5 where the position of that hole has influence on the pitch of the d3.

Hole 3 (3a and 3b)

a1: 1 2 and a2: 1 2, and also g#1/a-flat1 and g#2/a-flat2 with 1 2 3a
At first a remark about g#1/a-flat1: in the chart for the Saxon type of oboe there is only this fingering with hole 3 half covered. A fork fingering is not possible in the first register, but does so in the second register voor g#2/a-flat2: with 1 2 . 4 or 1 2 . 4 + 7; the Saxon chart gives also 1 2 3a 4 5 6 + 8, which you can you for pp passages. There is the same situation for a2: in old fingering tables give the ‘short fingering’ with 1 2, but the ‘long fingering’ with 1 2 . 4 5 6 + 8 is more stable and safer. It also depends on the reed and Marc Ecochard says in his article: the modern use of a bocal-and-tube set give the player a steady sound and good balance throughout the whole register of the hautboy, but poor responsiveness of the high register (above A), which prohibits the regular use of natural fingerings (short fingerings) for high notes; this problem is avoided with a one-piece tube, the taper of which is not disturbed as it is by placing a tube on the bocal.

Hole 3 is actually almost always double, even on oboes where hole 4 is single. Piet Dhont recommended to drill the holes in a downwards angle, even if that was not the case on the original oboe. By doing so the volume of the holes become slightly bigger and the diameter of the holes can be enlarged a bit. This prevents that the a1 becomes too soft in relation to the g1.

Golde mentions the same but adds some more information: the double holes for A must be drilled and undercut so that their edges meet at the bore and almost form a single hole. This improves the speech of the A. If these holes are drilled diagonally towards the tenon they must be made larger. This gives the A the same strength as the G. These holes must be significantly smaller if they are drilled perpendicular to the bore as the other holes, since the effectively lower-placed diagonal holes must be wide rather than narrow.

Golde continues: it is preferable to leave the A holes somewhat small and to enlarge them
when tuning, since both the As easily become sharp. If the A remains slightly flat a small
chamber must be made between its hole and the B hole. Also, if the middle C and D are too
flat the narrowest part in the bore can be enlarged through the reed socket with the long
reamer. The clarity of the middle D depends, however, on the lower C and D holes being
adequately enlarged.

Hole 2

\( b\flat_1 \): 1 or 1 , 4 5 6, \( b\flat_2 \): 1 , 3 4 5 6 + 7 or 1 + 7

\( b2 \) is actually always played with the long fingering (1 . 3 4 5 6 + 7); concerning the short
fingering see what is said above for the \( a2 \). On my Wijne copy I can quite easily play the short
fingering when I use the small key (1 + 7), but I don’t know if that works on other oboes.

Also in the first register is \( b\flat_1 \) with 1 . 4 5 6 (or with 1 . . . 5 6) more stable and safe than
with only hole 1 closed. With 1 . . 4 5 is \( b\flat_2 \) a bit sharper.

Hole 2 is on several oboes drilled upwards, or even (as on most bassoons) downwards. This
makes the hole longer and that has an effect on the response and relation between tones which
are tuned on this hole \( b\flat_1 \), \( b\flat_1 \) (1 . 3) and \( b2 \). I discovered that closing more holes down the
fork (1 . 3 4 5 6 or 1 . . . 5 6 + 8) for \( b\flat_1 \) this tone sounds brighter, but also a bit sharper.
It is a matter of tuning and voicing: you can’t do that separately and sometimes you have to
made a compromise, especially for such critical fork fingered tones as \( b\flat_1 \) and \( f1 \).

The table for the Saxon type baroque oboe gives 1 . 3 4a for the \( b\flat_1 \); this fingering makes
on my Wijne copy this tone a little sharper than 1 . 3. Ecochard says that hole 2 is generally
notched with a slight upwards angle and that it needs to be rather undercut on its downside edge
and well opened to get a good response for the \( b\flat_1 \). This tone is on historical oboes often
rather high (giving a mean tone minor third from the \( g1 \)). But making hole 2 smaller makes \( b2 \)
with the short fingering too flat.

Hole 1

\( c2 \): . 2 (only hole 2 closed) and \( c\#2 \) with all holes open

Both notes are more stable when closing some holes in the right hand (4 5 6). For \( c\#2 \) there is
also the fingering . 2 3 4 5 6 + 8, which is tuned together with the \( c1 \).

Piet Dhont told me that on hole 1 we have to deal with a difficult compromise: we want to
have a stable \( e\flat_2 \) (which should be easily playable without half covering hole 1 - despite
the fact that most players do just that) and also a good response for the \( c3 \) (with . 2 3 4 5 + 7). A difficult \( c3 \) is often caused by the \( e\flat_2 \) being too stable. It might help in that case to under-
cut hole 1 a bit at the lower edge.

Golde says: the holes on the upper joint must be rather undercut. Care must be taken, how-
ever, to avoid undercutting hole 1 too much as this will cause the \( c2 \) to be too sharp and sound
poorly. Hole 2 can, in contrast, be more undercut.

Hole 1 and hole 2 are positioned high on the instrument and I think that for the tones which
are tuned at these holes, it matters more than for the lower tones how far the staple with the
reed is sticking out the bore. You can’t tune the tones on an oboe individually (as on a piano),
each on its own and by looking on the display of your tuner. It is always about playing runs
and intervals and finding the ideal position of the staple, how far to push it into the bore.

Other tones

Some more high tones can be played on the baroque oboe (depending on your reed and so on),
but tuning at the fingerholes is not easy or possible. But it is good to know about the relations
between the tones. I give here some tones and their fingerings, with comments which Piet
Dhont has given me.
- c3: .2 3 4 5 (recommended, and useful in connection with b2 with .1 .3 4 5 6 + 7 or with the short fingering for b2 (only hole 1 closed); c3 has with .2 3 4 5 + 7 a bit stronger or piercing sound. With 1h 2 3h 4 5 + 7 you can play it in a more subtle way (for pp attack). With .2 .4 5 might the c3 a bit risky, but with a clear sound, just as with the aforementioned .2 3 4 5.
- c#3: 1h 2 3 4 is the third harmonic of f#1. You can’t do so much with this tone, it is no problem when it is a bit flat as leading tone to d3.
- d3: 1h 2 3 + 8; see the remarks given at hole 4. Other fingerings for d3: 1h 2 3 . 6 or 1h 2 3 + 7 (for combinations with c3 played with .2 3 4 5 + 7 where c3 is the more important tone, or in combination with other tones which are played using the small key.

Finally the fingerings for e-flat3: 1h 2 3h + 7 (hole 1 only a fraction to be opened), e3: 1h 2 3h 4h 5 6 + 7 and f3: 1 2h . 3 5h 6 + 7.

Mary Kirkpatrick discovered that making the bore wider in the narrowest section in the top joint of her Haka copy improved the response of some of the top notes very much (see her Comm. 2055 in Q 135). To me that sounds remarkable, for I had expected - coming from my experience with recorders - just the opposite effect. And that proves again that on oboes many things are just different from what we know about other woodwind instruments. The baroque oboe is a flexible instrument, which means that you have to be flexible as a player as well: there are for several tones more than one fingerings possible, and for intonation problems you must look for more than one cause and solution. But I must add a warning: be careful and even reluctant in applying the suggestions collected in this chapter: it is easier to make things worse than to solve a problem.

Some tips and warnings
- A tone on a musical instrument is never tuned on its own, but always in relation and combination with others. There is also - especially on oboes - a strong relation between pitch and sound: by manipulating a tone hole, you are combining tuning and voicing to get both aspects right. Tuning an oboe means that you have to play intervals and runs: you are always coming from one note and going to another, and you must be sure to apply the right amount of pressure: with your breath, and with your lips on the reed (it is, however, interesting to play the oboe with the reed completely in your mouth, thus not pressed between your lips, and then check the pitch).
- Modern tuning devices are very helpful, as they automatically select the tone for you. Lucas van Helsdingen prefers another approach: he uses what is known as an Orgelpunkt (pedal point, a long sounding tone) as a reference to compare the intervals (for some tones he switches to another pedal point tone).
- If the instrument does not work properly it is well worth trying different reeds and staples before doing permanent damage to the instrument itself. Some reed-makers make staples and reeds for specific old maker's instruments, so it is sensible to start with a reed that someone knows works on a Denner oboe before modifying a new Denner oboe copy. Squawks, burbles, unstable notes, excessively veiled notes and problems with octaves can all sometimes be corrected by a different reed. It is also worth measuring the instrument to be sure that it has come out as intended!
- It is important that every action in the bore profile will affect more than one tone: don’t think that e.g. a quick scrape of the bore below hole 2 will affect the tone A and nothing else! 'Everything affects everything’ to some degree. Try everything with a piece of card or something similar (thin brass sheet, a bit of plasticine, it is not necessary to put it evenly around the wall of the bore) to get the reverse effect before reaching for the reamer.
- The usual way in tuning a new oboe is drilling all tone holes a bit too small, followed by
enlarging and undercutting, beginning with the lowest holes on the instrument. But with these actions you are affecting the bore profile as well. Which means that eg. enlarging hole 2 may have an effect on a tone (pitch or sound) of a tone which was tuned on a lower hole: just because one of the nodes or antinodes of this tone (including its harmonics) are just at that position in the bore. It is very difficult to predict these effects; it is best to pre-drill the holes not too small, and to ream or at least to clean them carefully before you start down on the instrument.

Some final remarks
How were the oboes played in the past, by professionals and amateurs? I mentioned in chapter 10.9 the old and new types of scraping reeds, which has a direct effect on the sound of the instrument. In my dissertation (Par. 9.6.3, p. 454), I wrote about the difficult aspect of the resistance of the oboe: a concept that is not easy to define. When producing a tone on an oboe, the player aims for a precise and well-balanced attack, whether he is playing legato or piano, staccato or louder. For a successful result it helps if the player encounters a certain degree of resistance from the instrument, so that the tone will not go off uncontrolled in all directions. Resistance does not depend solely on the quality of the reed, but also on the oboe's bore and the size and shape of the tone-holes. Generally speaking, a player encounters less resistance from a relatively wide bore and large tone-holes than from a narrower bore and holes. Additional factors are the effective local thickness of the oboe wall at the tone-holes and the angle at which the hole is drilled. Finally, an instrument's condition may also affect its playing. Two instruments (Van Heerde's oboe in Stockholm and Terton's one in Den Haag) show traces [glued cracks, wear of wood] of intensive use in the past; perhaps this accounts for their excellent technical playing qualities.

Back to the fingerings and fingering charts: Bruce Haynes suggested in his article that virtually all of these charts were written for beginners and amateurs and that a study of them therefore gives a rather superficial picture of the real fingerings used on the oboe in the 18th century. I see myself in relation to the hautboy also still also as a relative beginner and amateur, without a very thorough experience in making and tuning this beautiful instrument. I had the privilege to see and measure many fine historical oboes: over 90, by around 20 Dutch makers, which was then a reason for me to make some copies. About those old instruments: I was surprised by their variety and also the quality. Apparently, their makers all seem to have conquered the problems in producing (voicing and tuning) the oboes, without slavishly copying each other bore profiles and other technical aspects. There are so many secrets yet undiscovered. One example: how to interpret the variation in fingerholes sizes (and wall thicknesses) on the oboes (there are over 30 made by them) by Hendrik and Fredrik Richters (see Table 9.9. in my dissertation: Dutch woodwind instruments and their makers, 1660-1760, Utrecht 2005).

At the moment I don’t have plans to go on with the oboe and make new copies; this article about tuning the oboe can be seen more or less as a conclusion of a long and fascinating period. Which means: do not come to me with your questions if you have a problem with your oboe, but you are welcome to ask them and share your experiences on the pages of the FoMRHI Quarterly! And I am always interested to receive information about historical oboes, especially when they are made by Dutch makers.
The Musical Instruments Resource Network (MIRN) promotes understanding of issues surrounding the care and display of musical instruments and collections within the United Kingdom. It disseminates information and expertise in accord with current best practice, and advocates for the wide accessibility of public collections.

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