Alto recorders by Bressan: bore profiles

This is the fourth article in a series about the alto recorders of Peter Bressan, the famous woodwind maker who worked 300 years ago in London. In this article I give not only information about the bore profiles of Bressan's alto recorders, but also some tips about making and adjusting bores and about the use of reamers.
The first article in this series (in *Q.* No. 113, comm. 1880) was an introduction, concerning the difficulty of measuring windways, the second article (*Q.* No. 115, comm. 1898), about the windway design of five alto recorders by Bressan. In *Q.* No. 116, comm. 1910, I wrote about the pitch and sound of these instruments, and about the difficulties to measure and describe these qualities in words.
One of the conclusions in Comm. 1898 was that the quality of finishing of the windways (and block, and labia) was probably more important for the quality of the recorders by Bressan than their design (shape, dimensions). I could not discover details or aspects which were special or typical for Bressan. The question is: which information can we get from the bore profiles of the instruments? The bores of the joints were made with one of more reamers, resulting in profiles with the same shape as these reamers. These profiles give us a characteristic signature of a woodwind maker (or of his tools), much more than for instance the exterior details of the recorders, which are the result of free-hand turning. As a woodwind maker and researcher, I want to know the relation between the bore profiles and the sound and other playing characteristics of the instruments. It is also interesting to see where Bressan might have made variations in the design of his instruments; I can already disclose one aspect, i.e. the variation in length and bore profiles of the feet of the altos.

Some remarks about bore profiles and the acoustical properties of a recorder
The quality of the sound of a recorder depends on several things. The sound is made by blowing air through the windway against the sharp edge of the labium (or, more correctly: most of the air is blown just over that edge). The design and finishing of the windway, window and upper and lower side of the labium are indeed very important for the quality of the sound and other playing characteristics of the recorder. But the sound begins earlier, in the lungs (supported by the diaphragma) or even lower - some players say - in your toes: it is all about support and control, relaxing the airways and making our body cavities free and able to resonate the sound of the instrument. I have heard some professionally educated musicians who produced a disastrous noise on well made recorders, whereas other players - who were much more able to listen to the instrument - produced a heavenly sound.
At the other side of the window and labium lies the cavity of the recorder itself, that is what we call the bore of the instrument. The profile of this bore determines - together with the position, size and shape of the fingerholes - the position of the nodes and antinodes of the vibrations of the tones. And that is all important for the pitch and sound (harmonics) of these tones.
The profile of that bore is in baroque recorders irregular: slightly narrowing or even cylindrical in diameter in the head, narrowing in the middle joint (more strongly in the lower section, and often most strongly after fingerhole 5 or 6), narrowing further in the bore of the foot (and sometimes cylindrical or even widening over a short distance at the lower end). We find this type of profile with small variations in all baroque recorders. The generally narrowing shape of the bore makes that the fingerholes can

be drilled in positions which are in easy reach for the player and that they are smaller - and easier to cover - than on instruments with a cylindrical or much less tapering bore. The bore profile has also effect on the sound levels: on baroque recorders is the sound generally more refined and less loud than on renaissance types with their less tapered bores. For a given bore profile and wall thickness, the position and the size of most of the fingerholes is fixed. Tuning a recorder means that you must drill and undercut the holes to their right position and size, but sometimes also that you must make some small corrections to the bore profile. And don't forget: the tuning has some influence on the voicing: widening the fingerholes causes also a change in the sound quality of the tones.

Measuring bore profiles

Measuring bore diameters is generally easier than assessing the windways. There are two combined data which must be obtained: the diameter at a point in the bore, and the distance of that point to a reference point (which can be the top or lower end of the instrument section). There are two options to present the results: giving the diameters at preset length positions, or giving the lengths at preset diameters. For instance: Fred Morgan gave on most of his drawings bore diameters (accurate to 0.1 mm) at length intervals of 10 mm (or smaller). Other people measure the lengths (accurate to 1 mm) at diameter intervals of 0.1 or 0.2 mm.
There are some complications in case of crooked recorder parts, and/or where the bore is warped in cross section. That's why I like to know how the measurements are obtained. *Despite the importance to measure as accurate as possible, we must not forget to put the results in perspective, not making them too absolute!*

Sound and soul of Bressan's recorder

I mentioned in the previous articles a major problem: we must nowadays use existing data of original recorders, because of the restrictions in most collections of measuring and playing these instruments. But how must we get closer to the 'soul' of the recorders, and about the ideas of Bressan? What was his way of playing, what was - or is - the typical Bressan sound?
I have managed to find some recordings on original Bressan instruments, such as by Frans Brüggen, but found it difficult to combine the information of listening to these recorderings with my memories of playing the same or other Bressan recorders (unfortunately a long time ago, and each instrument only for a very short time). I have recently also played several copies of recorders by Bressan and the Stanesby's, built by various makers and factories. But the information of these playing sessions was also rather confusing and didn't bring me much nearer the secrets of Bressan.
What remains in order to get more insight is making one or more copies of his recorders. That is what I did in the past months, stimulated by Ben Nieuwhof, one of my fellow members of the 'Bouwerskontakt', who has made a set of reamers based on the Bressan alto recorder in Berlin. On my firsty copy I put the lowest reamer for the middle joint not far enough, resulting in a bore which became some tenths of a millimeter too narrow in that section. Because I made my first copy in Indian palissander (*Dalbergia latifolia*), which wood appeared to be 'very quick in reacting' to my tools, I removed a little bit too much wood when I turned it. The result was that the fingerholes of the middle joint had to be made a bit smaller than on the example from Berlin (see table 4). That happened not to be a problem: tuning was easy, the smaller size of the holes had an advantage for some of the fingerings. But I came of course further away from the idea of an exact copy of a Bressan recorder.

Bressan alto recorders: length and bore measurements of head joints

More information about the descriptions and measurements of the altos a- to e- in Comm. 1898 and 1910 (*FoMRHI-Q* 115 and 116).

All measurements in millimeters; *in italics: measurements after repair of (this part of) the recorder*
L = length; SL = 'sounding length' (head: SL = L from lower end to block line; middle joint: SL = L between tenons, foot: L = SL)

Table 1	alto-a Bate Coll, ex-Hunt Oxford	alto b- Ueno Gakuen Tokyo	alto c- Brüggen-XI Amsterdam	alto d- Brüggen-X Amsterdam	alto e- Berlin
Head					
L-total	194.2	194.1	193.2	192.5	191.55
SL	133.3	133.3	132.9	131.0	132.55
L windway	60.9	60.8	60.3	61.5	59.0
Middle joint					
L-total	252.9	252.95	*254.9*	251.9	254.35
L upper tenon	27.8	28.0	*28.2*	26.7	27.85
SL middle section	209.3	209.0	*210.8*	209.2	210.5
L lower tenon	15.8	25.95	15.9	16.0	16.0
SL head + middle j.	342.6	342.3	343.7	340.2	343.05
Foot					
L/SL-total	102.1	101.95	106.5	110.3	102.7

Thomas Lerch gives in his dissertation 'Vergleichende Untersuchung von Bohrungsprofilen historischer Blockflöten des Barock' (Berlin, 1996; see my review of this book in *FoMRHI-Q* No. 87) the measurements of some other Bressan-recorders.

	SL head - middle joint - foot;	SL head + middle joint:
TL-01 - Bressan-Paris	131.4 - 209.0 - 110.7	340.4
TL-02 - Bressan-London-Horniman	132.4 - 208.0 - 101.0	340.4
TL-03 - Bressan- private collection MB	132.3 - 209.5 - 110.0	341.8
TL-08 - Bressan-Chester (507)	132.2 - 208.0 - 106.2	340.2

A first conclusion is that there is not much difference in the (sounding) lengths of the heads and middle joints: added up we see the biggest difference in the two altos in the Brüggen collection: only 3.5 mm. Some of these differences can be caused by shrinking of the wood, or by rounding off. But there is much more difference in foot length. The shorter feet are 101 to 102 mm, the longest about 110 mm, two have intermediate lengths of about 106 mm. Why varied Bressan so much the feet of his alto recorders?

Table 2 Head joint bores (Ø-max in mm)

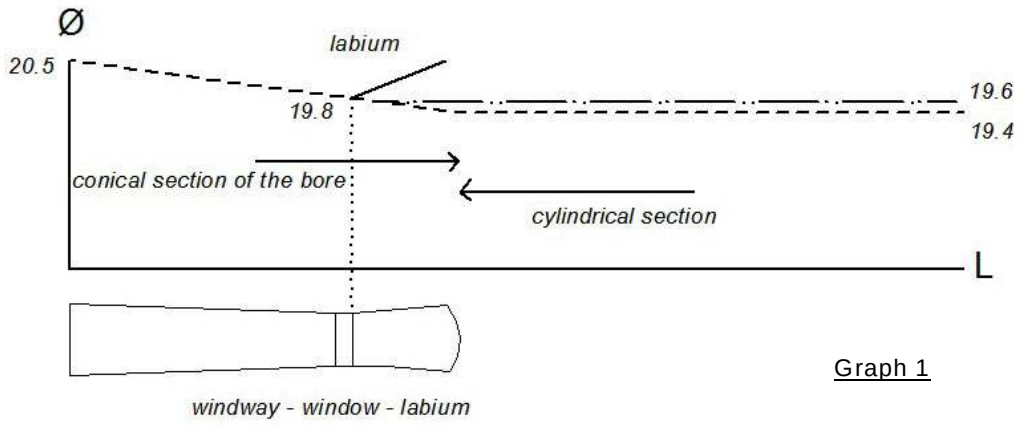
	at blockline	- at	L 80,	100,	120,	140	and 160 mm from upper end
alto a-	19.7		19.6	19.5	19.4	19.4	19.6 (min.19.2)*
alto b-	19.8		19.8	19.7	19.5	19.5	19.5 (min. 19.1)*
alto c-	19.8		19.75	19.7	19.6	19.6	19.45
alto d-	19.8		19.65	19.6	19.65	19.6	19.55 (min. 19.4)*
alto e-	19.7		19.45	19.5	19.55	19.7	19.54 (min. 19.37)*
TL-01**	19.8		19.5	19.5	19.5	19.6	19.6
TL-02	19.8		19.4	19.5	19.5	19.5	19.6
TL-03	20.0		19.9	19.7	19.7	19.7	19.6
TL-08***	20.0		19.7			20.0	19.9

** these are minimum values caused by ovally warping of the bore*
*** in his book, Lerch presents the diameters in relation to the distance from the lower end of the instrument*
**** it is difficult to interpret the bore measurements of this head*

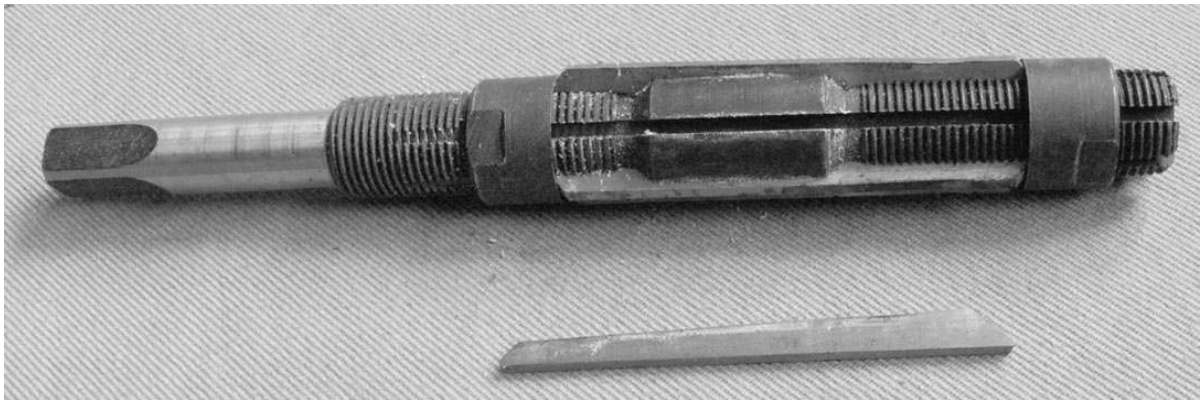
Shrinking of the wood has more influence on the diameters than on the length of the instrument parts. In the table of the head joint bores, the maximum values are given. The minimum values can be 0.2 to 0.4 mm smaller (narrower), resulting in oval-shaped cross sections. In my research into historical recorders, I saw the strongest warping close to the window and labium, but I have never examined myself one of the Bressan recorders thouroughly, and don't know how stable his boxwood was.

Fred Morgan didn't give the minimum bore diameters for the Bressan recorders in the Brüggen collection, nor did Beaudin for the alto in Berlin. That makes it more complicated to assess the bore measurements with those of the playing sessions: narrower bores result generally in higher pitches of most of the tones. A new copy, based on the wider bore dimensions, will sound flatter than the examplary instrument with its oval bore.
Regarding these facts, I can say that the bores of the head joints of the Bressan recorders in the table on the previous page are rather wide (19.4 as miminum value) or even very wide (19.7 mm), compared with other baroque alto recorders of more or less the same pitch. But I must admit that I have no good overview of the instruments of other European makers (except those who worked in Holland). And again: for a useful comparison it is best to have the recorders measured in the same way (and preferably all research done in the same place, together).
Most head joints of the Bressan altos have a bore profile which is conically in the top section (in which the block can be fitted tightly), becoming cylindrical or almost cylindrical up to the socket. Alto e- in Berlin has a head bore which is narrowest in the middle, and from there widening towards the socket. There is always the suspicion that this might be the result of a later bore correction (by Bressan himself, or by somebody else), just because the other instruments do not show this bore profile.

When I make a copy, I ream the bore in the upper section of the head with a conical reamer, diameter between 20.5 and 21.0 mm at the upper end of the head (the beak has not been cut out in that stage), to about 19.8 at the window and going to about 19.2 mm just 20 mm after the labium edge. The rest of the bore I preferably do with an adjustable metal reamer. This tool makes a cylindrical bore, and I can very exactly make a bore with smooth walls with a diameter of 19.4, 19.6 mm, etc, just what I want to have. And I have not to be afraid that my labium edge will be damaged, because on that point is the bore with about 19.8 already wider. Of course you can change these figures, for instance making the bore 20.0 mm wide at the window, and going to 19.7 in the lower section of the head. But it is always good to have this conical section in the top (see graph 1 below).



Graph 1



Adjustable metal reamer; this tool has 5 or 6 blades which can be moved in grooves around the corpus. The grooves are deeper at one side, the surface of the blades is parallel to the axis of the reamer. One of the blades is taken out, showing its shape.
By turning the nuts, the blades move up- or downwards in these grooves. Because of the sloping grooves, the effective diameter which the reamer makes, can be adjusted very accurately. These adjustable reamers can be used in a lathe (preferably in a metal lathe, at a slow speed), or by hand and give in most woods smooth surfaces. The reamer on the photo can be adjusted from 15.5 to about 18 mm.
A conical bore profile can be realized by reaming a set of cylindrical sections (for instance with diameter steps of 0.2 mm). By grinding the ends of the blades over a few millimeters slightly, there will be smooth and hardly visible steps between the reamed sections.

Table 3: fingerhole positions

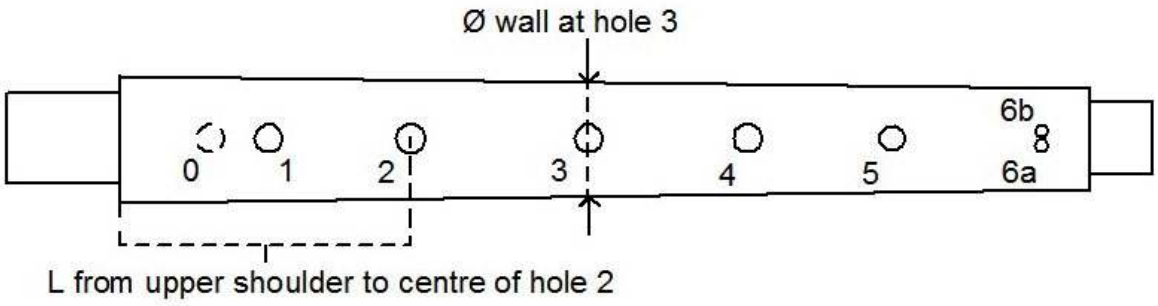
		position from centre of fingerhole to upper shoulder						
	hole	0	1	2	3	4	5	6
alto a-		20.0	35.0	63.8	98.5	138.3	169.5	199.5
alto b-		19.85	34.7	63.55	98.75	137.9	169.15	199.15
alto c-*		*22.4*	*37.45*	*65*	*100.5*	*139.7*	*171.5*	*200.5*
alto d-		21.2	36.0	64.2	99.4	138.5	170.3	199.6
alto e-		21.5	36	65	100.5	139.5	172	201
TL-03		20.5	35.0	64.5	99.5	139	170	201
TL-08**		20.0	34.8	62.8	97	137	168	198/199
copy**		21.5	36.0	65.5	100.5	138.5	172	201/201.5

**: after repair **: hole 6 double*

Table 4: finger hole dimensions and wall thickness

		size of hole (min/max) - Ø of wall						
	hole	0	1	2	3	4	5	6
alto a-		6.4/6.4 - c. 28.0	5.4/5.7-27.8	6.1/6.2-26.7	6.1/6.1-25.7	5.8/5.9-25.4	5.6/5.7-25.0	5.2/5.3-24.9
alto b-		6.2/6.6-27.8	5.6/5.7-26.9	6.1/6.3-25.9	6.1/6.2-25.1	5.6/5.8-24.6	5.5/5.7-24.5	5.2/5.3-24.9
alto c-		6.5/6.5-27.6	5.7/5.9-27.4	6.2/6.3-26.5	6.2/6.3-25.5	5.8/5.8-25.3	5.6/5.8-25.0	5.2/5.2-24.9
alto d-		c. 6.4 - c. 28.2	5.9/6.1-27.9	6.2/6.4-27.3	6.1/6.3-26.5	*5.7/5.9*-26.0	*6.4/6.4*-25.5	5.2/5.5-25.0
alto e-		6.3/6.4 - 28.1	5.7/5.8-27.6	6.3/6.3-26.6	6.4/6.5-25.8	5.8/5.8-25.5	5.7/5.8-25.4	5.1/5.2-25.3
TL-03		6.5/6.5	5.6/5.9	6.2/6.4	6.0/6.4	5.8/5.8	5.5/5.7	4.9/4.9
TL-08**		6.3/6.7	5.8/6.0	6.5/6.6	6.2/6.9	5.9/6.1	5.9/6.1	4.2/4.5 - 3.8/3.9
copy**		6.1/6.3-27.1	5.4/5.5-26.8	5.9/6.2-26.3	5.8/5.8-25.6	4.9/5.1-24.7	5.3/5.3-24.3	3.8/3.9 -3.6/3.7

***: hole 6 double*



The middle joints - how to compare measurements

Table 1 shows us that the lengths of the middle joints are very much the same: differences up to 1.0 mm are negligible. Ask 10 people to measure the length of one particular middle joint of an alto recorder, and compare the results. I should not be surprised when the outcomes vary more than 1.0 mm.

Are the bore profiles identical in the same degree? The best way is to make graphs of the bore profiles on graph paper with millimeter grid. I prefer to use for the graph a relation of 10 to 1 for diameter to length. This gives us a good visual picture of the bore profile. Using graph paper, it is possible to compare bore profiles by putting two sheets of paper on each other and holding against a lamp. Then you can immediately see if these bores are identical, or if sections are identical or parallel: in case the maker put one reamer further in a joint than in another. Using this method, I discovered that some Dutch makers used the same reamers for bore sections of their (soprano) recorders as well - in opposite direction! - as their oboes. It is far more complicated to do the same comparisons working with mathematical formulas and statistics!

A problem: it is difficult to reproduce graphs on millimeter paper. Therefore I have made some graphs with a computer program (see some pages further), but these are less detailed and only usable for a quick survey.

Assessing bore profiles from the graphs means: see where there are irregularities, such as tenon contractions (often at the upper tenon of the middle joint). Or where is for instance a section where the graph is suddenly steeper or just flat: such changes in the angle of the graph are an indication of successive reamers which were used by the woodwind maker. Longer flat sections indicate the (widest) diameter of a reamer or drill, and might therefore more often occur, and are then characteristic for the instruments of that woodwind maker.

We see often parabolic shapes in a bore profile, that is where the graph becomes gradually steeper, often found in the lower section of the middle joint (for instance in altos a- and e-). These parabolic sections are also characteristic and are useful as reference when we compare bore profiles using the method with two sheets put together. In the recorder feet we find sometimes ‘hyperbolic’ sections, where the tapering diameter of the bore is just decreasing (altos a- and b-), sometimes becoming cylindrical or almost cylindrical. I do not know if Bressan (or any other woodwind maker) used his reamer like ‘stirring in the soup’ (that is with a lateral movement, what you can do over a short distance, for instance in a foot where the wood is thick enough to resist the forces of the reamer), which can result of course in bore profiles with all kinds of shapes.

Table 5: bore measurements of the middle joints and feet

middle joints

L	alto a-	alto b-	alto c-	alto d-	alto e-	TL03	TL08	copy
0	Ø 18.6	18.5	*20.3*	19.4	19.2	19.4	19.5	19.5
10	18.7	18.6	*20.2*	19.3	19.1	19.3	19.3	19.3
20	19.0	18.8	*20.0*	19.2	19.1	19.1	19.1	19.1
30	19.2	18.9	*19.2*	19.0	19.0	19.0	19.0	19.0
40	19.0	19.0	*18.6*	19.0	18.9	18.9	18.8	18.8
50	18.8	18.7	18.4	18.8	18.7	18.8	18.7	18.5
60	18.4	18.4	18.3	18.5	18.4	18.6	18.6	18.2
70	18.3	18.3	18.3	18.1	18.2	18.4	18.4	18.0
80	18.1	18.2	18.2	18.0	18.1	18.2	18.2	17.6
90	17.9	18.1	17.9	17.8	17.9	18.0	18.0	17.5
100	17.8	18.0	17.7	17.6	17.7	17.8	17.8	17.4
110	17.7	17.9	17.6	17.6	17.6	17.8	17.7	17.4
120	17.6	17.8	17.6	17.6	17.5	17.8	17.7	17.4
130	17.6	17.8	17.6	17.5	17.4	17.8	17.7	17.4
140	17.5	17.6	17.5	17.5	17.4	17.7	17.6	17.3
150	17.3	17.5	17.4	17.3	17.4	17.4	17.4	17.2
160	17.2	17.3	17.2	17.0	17.2	17.2	17.2	17.1
170	17.0	17.2	17.0	16.9	16.9	17.0	17.0	16.8
180	16.8	16.9	16.9	16.5	16.7	16.7	16.9	16.6
190	16.7	16.8	16.7	16.2	16.5	16.4	16.6	16.3
200	16.4	16.5	16.4	16.1	16.1	16.2	16.2	15.9
210	16.1	16.3	16.1	15.8	15.9	16.0	15.8	15.5
220	15.9	16.0	15.7	15.4	15.6	15.7	15.4	15.2
230	15.7	15.7	15.0	15.0	15.2	15.2	15.2	14.7
240	15.1	15.1	14.5	14.6	14.6	14.8	14.7	14.0
250	14.3	14.3	14.2	14.3	14.0	14.5	14.5	13.6
end	14.2	14.1	14.1	14.2	13.9	14.4	14.4	13.4

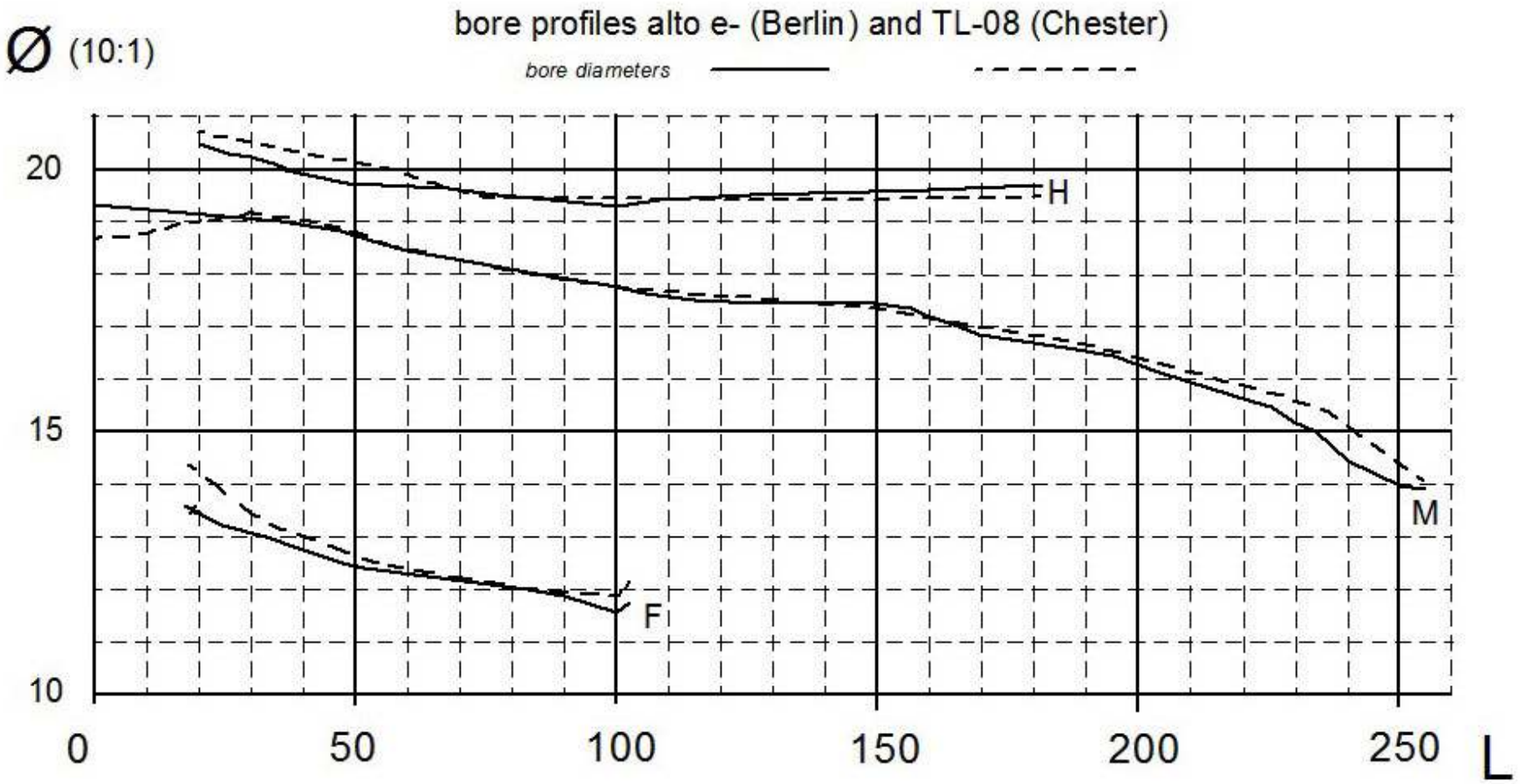
all data are extrapolated and rounded off from other tables and graphs, deviations of +/- 0.1 mm are possible

feet

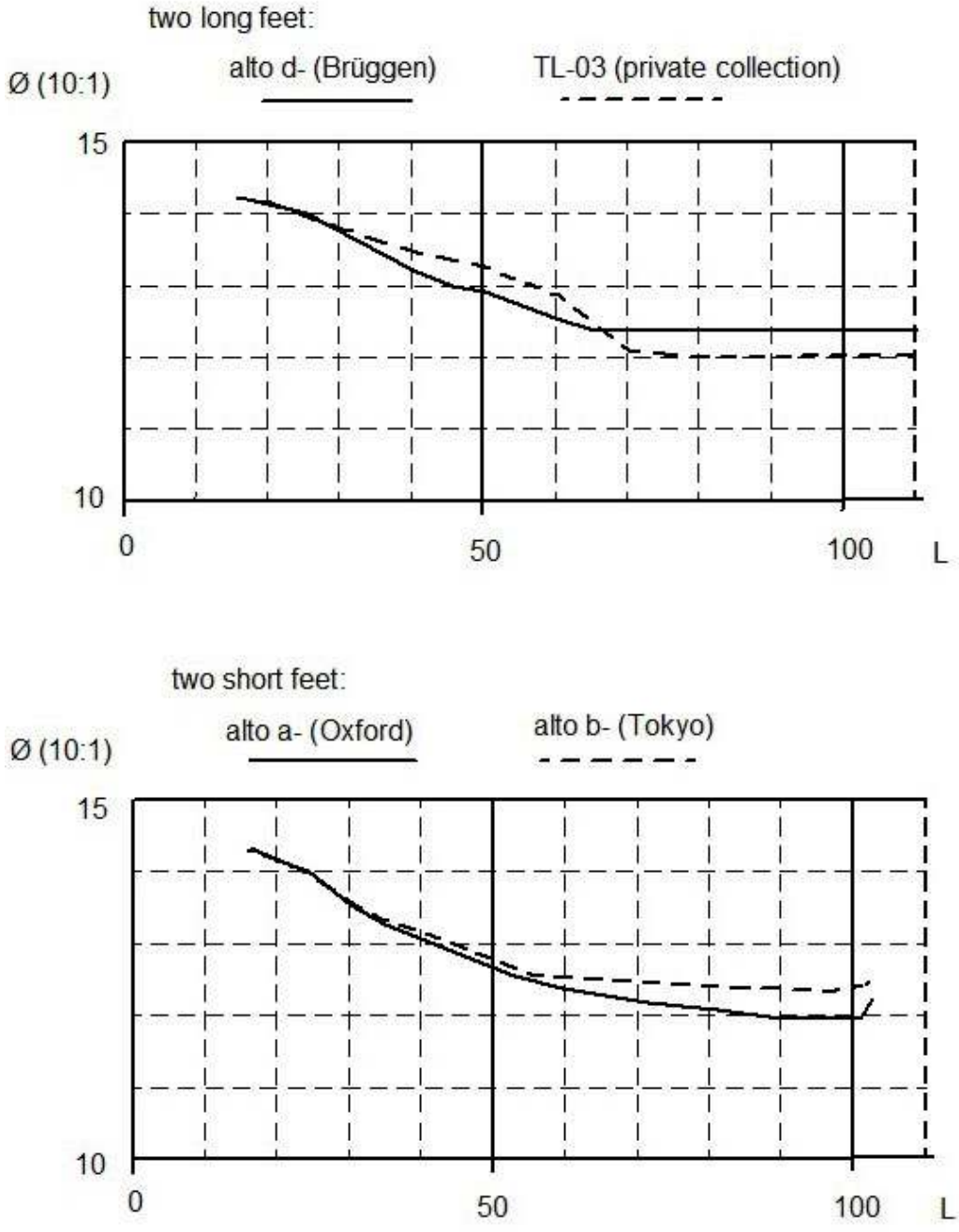
L	alto a-	alto b-	alto c-	alto d-	alto e-	TL03	TL08	copy
16	Ø 14.3	14.4	13.9	14.2	13.5	14.2	14.5	13.6
25	13.8	13.8	13.5	14.0	13.1	14.0	14.2	13.3
35	13.2	13.3	13.2	13.5	12.9	13.6	13.6	13.0
45	12.8	13.0	12.7	13.0	12.7	13.4	13.0	12.2
55	12.5	12.6	12.3	12.7	12.3	13.1	12.3	12.0
65	12.3	12.6	12.1	12.4	12.2	12.5	12.1	11.8
75	12.2	12.5	11.9	12.4	12.1	12.1	12.0	11.8
85	12.0	12.5	11.7	12.4	11.8	12.0	11.9	11.7 min
95	11.9	12.4	11.35	12.4	11.7	12.0	12.0	12.0
100	11.9	12.5	11.5	12.4	11.5	12.0	12.9	12.2
end	12.2	12.6	11.8	12.5	11.6	12.1	13.2	12.5
L	102	102	106.5	111	102.7	110	106.2	104.5

hole 7

Ø min/max	5.3/5.5	5.3/5.4	4.9/5.2	5.0/5.5	5.3/5.4	4.9/4.9	4.3/4.5 3.7/3.8	4.1/4.2 3.5/3.6
Ø wall	31.8	32.2	32.3	32.0	32.2	-	-	31.1


bore profiles alto e- (Berlin) and TL-08 (Chester)
bore diameters
Ø (10:1)
20
15
10
0
50
100
150
200
250
L
H
M
F

Three other middle joints, of alto-d (Brüggen), TL-03 (private collection) and TL-08 (Chester) have even more identical bore profiles, and different from those of the altos a- and b. Only between fingerholes is a short section where TL-08 is slightly wider than alto d-. And the bore of TL-03 is over the whole length from hole 0 to the lower end about 0.2 mm wider. That can be caused by difference in shrinking of the wood, or by using other measuring techniques.
Another interesting aspect of the middle joints of these three altos is that they have both a flat bore section with a length of about 40 mm around hole 3. The diameter of the bore is here 17.5 mm (alto d-) and about 17.6 in TL-08. We see almost identical flat sections in altos c-, e- and (with 17.7 mm slightly wider) in TL-03.



Bore profiles of four feet of Bressan recorders

Left:
my copy (in *Pau ferro*, or *Santos palissander* with mounts of artificial ivory) of the Bressan alto in Berlin, with three middle joints, in a-392, 405 and 440 Hz.

Right:
Bressan copy in a-415 Hz in *rock maple* with the stamp of Hans Coolsma (Aafab, Utrecht).
This copy has a complete difference design, it has (apart from the shorter foot) about the same length as my copy with the a-405 joint, but the distance from hole 1 to 6 (and the size of most of the holes) is much larger.
This copy must be played with Dolmetsch-fingerings; hole 5 is placed much closer to hole 6 than to hole 4, not so pleasant for players who are used for holes which are more evenly spread.

Interpretation of the data

It is not easy to interpret the avalanche of data I have given on the previous pages: and these are only a summarized selection of what I have found in several sources. Some observations and conclusions:

1- There is a remarkable consistency in the length of the middle joints, and also in the position and size of the fingerholes. Alto b- has thinner walls, but not smaller holes, nor a narrower bore. Alto c- was shortened at the upper end of the middle joint, some time in the 20th century, to play the instrument in a higher pitch (but I don't think that the tuning was very goood after that operation). Coolsma restored the joint to about its former length (gave it maybe 1 mm too much), but gave it a bore which was about 1 mm too wide over the first 20 mm. For the other instruments I suspect that there were no shortenings.

2- The bore profiles of the middle joints vary more than their lengths. That might be caused by differences in shrinkage of the wood (which has a greater effect on the wood in tangential than in radial direction): the middle joint of TL-03 is very similar to alto d- but is over a greater part of the length 0.2 mm wider. That can be caused by less shrinkage of TL-03 (or by other rounding off of measurings tools, or by measuring at higher temperatures, etc.), or maybe that Bressan has polished the bore of this middle joint heavily, causing some widening. I should do some tests with my own instruments: measuring the bore before and after polishing (which is by the way seldom necessary in boxwood). Another possibility is that alto d- is much jounger than TL-03, and that Bressan has resharpened his reamers so often that they has become thinner. Whatever is true here, the copy maker must be aware what he is doing: copying a recorder in its present or original state. And it is not so easy to reconstruct that original state; therefore you must compare more instruments of the same maker - and that is just what this article is about.

3- Comparing the altos a- (Oxford) and b- (Tokyo), we see immediately that the bores of their middle joints are very much identical, with only minor differences. Both joints suffer from a contraction at the upper end (over 30 to 35 mm): this is a common problem, caused by the forces over the centuries on the thin section of wood of the tenon. On the lower tenon is this contraction much rarer, or more difficult to see because the profile of the bore is here much stronger tapering. When making a middle joint, I often ream the bore from the upper rim to about hole 0 (thumb hole) not completely, leaving it a bit too narrow. This section of the bore is important for the tuning the octave intervals of a1-a2 to d2-d3: reaming the bore too much, makes these intervals too wide, which is a much greater problem to solve than intervals which are too narrow.

4- From L 180 to the lower end (Ø 17.0 tot 14.0) of altos a- and b- Bressan used the same reamer and put it exactly at the same length in both joints. He used another reamer for the section of the middle joint between Ø 18.3 and 17.0, but put this tool in alto b- about 10 mm further: also from L 70 to L 180 in alto b-, and from L 60 to L 170 in alto a-. The bore profile of the upper sections of both middle joints is unclear, partly because of the aforementioned tenon contractions. Interesting is that Bressan placed the fingerholes on alto a- about 3 to 5 mm lower on the joint. Why he did that, I don't know; and 3 to 5 mm is rather much, I should expect that that gives tuning problems (such as too wide octave intervals) if you don't make necessary bore adjustments.

5- The bore profiles of the feet of the alto recorders by Bressan show a surprising great variation in length and bore profiles. The feet of alto d- and TL-03 are with about 110 mm the longest, there are three with short feet (altos a-, b- and e-); two

other altos (c- and TL-08) have feet of a medium length (about 106 mm). About the question of short foot and long foot recorders I have written in my dissertation (*Dutch woodwind instruments and their makers, 1660-1760*; Utrecht 2005), in chapter 7.8.5 under c-. It is a complicated story. I don't know which are the older instruments: those with a short, or those with a long foot. And as far as I can see, there are not so many makers who made both types of feet. Bressan is here the exception.
The length of the foot is important for the pitch of the fundamental (f1 on an alto), but has also a great influence on the tones of the third and higher registers (e-flat3, e3, f3, g3) - and: good to know for copy makers - hardly on the pitch of the tones of the second register (a2 - d3). If you make the foot longer, you have to make also the bore wider (and/or less tapering). And that is indeed what we can see in Bressan's alto feet: the longest feet have generally the widest bores. And of course, there is the exception here, and that is alto b- with its widely reamed short foot. It is not possible to find a relation with the pitch of the tones of that recorder, because you can't play it so good because of the bad condition of its head.
There is no foot bore profile on the Bressan altos completely identical. The angles of the lines in the graphs vary (see the graphs with the bore profiels of alto e- and TL-08), the shape of the graphs vary (from 'hyperbolical' to a combination of straight conical and cylindrical, or even almost straight conical over the whole length, as on alto c-). Bressan must have used several reamers, or he has used the aforementioned 'stirring techniqe'.
For a copy maker is it good to know not to worry too much about foot bores: it is a good place to do some experiments. I have made the foot of my Bressan copy a few millimeters longer, because the tones of the third register were initially too sharp (just as on the alto e- in Berlin, on which my copy was based). I have then made the bore in the lower section of the foot some tenths of a millimeter wider, also some contra reaming (at the lower end) was needed to get everything in good balance. But Ben Nieuwhof made his copy of the alto in Berlin without changing its dimensions, and had no tuning problems.

Conclusion and a surprise

Did I discover the 'secrets of Bressan'? No, really I didn't. But I came a bit closer to his way of making recorders and more familiar with their design. As a result of concentrating me on his instruments, I succeeded in making a few very fine recorders, with a sound which was different from my other altos - and that was one of the goals of my project.
One of the reasons for that other sound is the low pitch (a1=405 to 408 Hz) of the original instruments. I have than made an extra middle joint, a bit shorter (202 mm between the shoulders) for a combination in a1=415 Hz which has very much the same character. But the surprise came when I made a longer middle joint (227 mm) for playing in a1=392 Hz, the French baroque pitch. That combination is even better, both full and sweet in sound, everthing well balanced, a great joy to play.
It is good to realize what is going on here: with a longer middle joint, the relation between the (average) bore diameter and length (in German: the *Mensur*) changes, becoming smaller. The question is: must I make the bore of my alto recorders in modern pitch (a1=440 Hz, and about which I am on the moment not so satisfied), also narrower, to come closer to that so lovely low-pitch sound?