

# 'Matière et Musique'

## *The Cluny Encounter*

*Proceedings of the European Encounter on Instrument Making and Restoration*

*Actes de la rencontre européenne autour de la facture instrumentale*

*Akten van het Europees Congres over instrumentenbouw en -restauratie*

(Cluny 1999)

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*Labo 79*

2000

# The late Cristofori

## Creativity with a common base

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I worked for seven years as a restorer of musical instruments at the Händel-Haus in Halle in Germany, and during the last years there from 1993 to 1996 I worked on a project on Cristofori in collaboration with the *Musikinstrumenten-Museum Leipzig*, which owns five instruments by Bartolomeo Cristofori.

In 1997, I finished the copy of the Leipzig Cristofori piano presented in concert<sup>1</sup>. Since then, I have been living in Italy north of Florence, working as an independent instrument maker.

Bartolomeo Cristofori worked from 1688 onwards in Florence at the court of the Medici. The only signed instrument of his early period is the beautiful oval shaped spinet from 1693, today in the *Musikinstrumenten-Museum* in Leipzig. An ebony harpsichord, which can quite certainly be attributed to Cristofori, also belongs to his early period. This instrument is now on display in the *Accademia delle Belle Arti* in Florence.

From his late period (Cristofori died in 1732) five signed instruments survive: a piano from 1720, a harpsichord and a piano from 1722, a harpsichord and a piano from 1726.

The 1720 piano is today in the *Metropolitan Museum in New York*. The 1722 piano belongs to the *Museo degli strumenti musicali* in Rome. Both harpsichords and the piano from 1726 are conserved in the *Musikinstrumenten-Museum*, Leipzig and they will be on display together in a newly arranged exhibition from the year 2000 onwards.

These few surviving instruments by Cristofori exemplify three different types of keyboard instruments: the spinet, the harpsichord and the piano. The variety of instruments is increased when we add the instruments attributed to Cristofori, like the *spinettone* (*Musikinstrumenten-Museum Leipzig*) and the clavi-chord (private ownership in Hamburg). Looking more closely at these instru-

<sup>1</sup> See the article by Antonello Palazzolo.

ments we find all sorts of special features: 1. The spinet is not an ordinary one but an oval shaped instrument, unique in both its geometrical construction and artistic layout; 2. The *spinettone* is a mixture of a harpsichord and a spinet; 3. One of the three harpsichords is made in ebony, a wood rarely used for harpsichord cases. There is also an unusual disposition of the registers in one of his harpsichords; the 1726 harpsichord has one 8', one 4' and one 2' register with numerous possibilities for combining them; 4. The clavichord has an inverted stringband with the shorter keylevers in the treble and fretting only in the bass notes; 5. The two harpsichords and the three pianos from his later life have a very unusual case and inner construction; 6. The piano action is the invention of a genius, already displaying all the fundamental elements of our highly developed modern piano action.

This short overview gives an idea of Cristofori's enormous creativity.

There are several articles already published on archival documents<sup>2</sup> relating to Cristofori, one article especially about Cristofori's activities as a harpsichord maker<sup>3</sup>, and also two recently published books<sup>4</sup> on the invention of the piano.

The work I have done fills, I think, a gap in the research done on Cristofori. I have looked at his surviving pianos and harpsichords as a group, as if they were a single type of instrument. Concentrating research on his late instruments from the period 1720 to 1726 helps us to understand to what extent Cristofori's pianos were still harpsichords and how far they already had their own special features. I should also say that I was lucky to be the first person to gain access to the inner construction of the Cristofori harpsichords from 1722 and 1726, which gave me the opportunity of being the first to compare the case construction of Cristofori's late pianos and harpsichords.

<sup>2</sup> G. MONTANARI, *Bartolomeo Cristofori. A list and historical survey of his instruments*. In: *Early Music* 19 (1991), p. 383-396. - F. CASAGLIA, *Per le onoranze a Bartolomeo Cristofori che avranno luogo in Firenze il 7 di maggio 1876*. In: *Tipografia della Gazzetta d'Italia*, Firenze 1876, p. 3-32. - V. GAL, *Gli Strumenti Musicali della corte Medicea e il Museo del Conservatorio 'Luigi Cherubini' di Firenze*. Firenze, 1969, p. 6-21.

<sup>3</sup> H. HENKEL, *Bartolomeo Cristofori as Harpsichord Maker*. In: *The Historical Harpsichord. A Monograph Series in Honor of Frank Hubbard*. General Editor Howard Schott. Volume 3. Stuyvesant, New York 1992, p. 1-42.

<sup>4</sup> S. POLLENS, *The Early Pianoforte*. Cambridge Musical Texts and Monographs. Cambridge 1995. - K. RESTLE, *Bartolomeo Cristofori und die Anfänge des Hammerclaviers*. Munich 1991.

For reasons of space I will only present here a summary of the results of a careful investigation into the restoration history and the original state of each of the instruments.

In Table 1 are listed the five instruments that will be discussed here. Illustrations 1 to 3 show the Cristofori harpsichord of 1722, the Cristofori harpsichord of 1726 and the Cristofori piano of 1726.

### Case construction

Despite the many years of discussion about the singular construction of Cristofori's pianos, in particular concerning the special feature of the double bentside, and the debate about a much heavier stringing for these instruments, it is very important to note that the three surviving pianos and the two harpsichords by Cristofori from the 20's of the 18th century are built following the same principle.

The most important features of the construction of the five instruments are:

1. the 10-15mm thick poplar bottom and case sides, reinforced on the outside by vertical battens set at intervals around the entire case; 2. the bracing system, consisting of a combination of glued and nailed square braces with oblique long braces inserted between them (ill. 4, 6, 8, 10, 12); 3. the wooden gap spacers between bellyrail and wrestplank: 3a. The harpsichord of 1722 has upper and lower guides for the registers and sixteen 5mm chestnut gap spacers. The lower register guide has been glued underneath the T-stiffener of the bellyrail (ill. 13, 14); 3b. The harpsichord of 1726 has a special register construction, which is shown in ill. 15 (see also ill. 8); 3c. The pianos of 1722 and 1726 are made with an inverted wrestplank, where the strings are fixed underneath the wrestplank. Six gap spacers go from the wrestplank through the bellyrail into the bottom (ill. 16); 3d. The 1720 piano has no inverted wrestplank. The gap spacers consist of 5mm-thick strips rebated into the wrestplank.<sup>5</sup> The wrestplank itself is only 15mm thick, but it has been stiffened by a 52mm-thick block which serves as a yoke, as in the system found later in many Viennese pianos; 3e. In Table 2 one can see that by using an inverted wrestplank Cristofori could double its thickness in comparison to that of the piano of 1720 which was not yet made in this

<sup>5</sup> See S. POLLENS, *The Early Pianoforte*. Cambridge Musical Texts and Monographs. Cambridge 1995, p.76, fig. 3.20.

way. The measurements also show that the wrestplanks of the harpsichords are thicker and that the bellyrail thicknesses of the harpsichords and pianos are not very different; 4. The next important feature of the Cristofori construction is the so-called double bentside which is actually a triple- to quadruple- bentside extending around the tail (ill. 17, 18); (4a) The higher hitchpin rail is related to the special bentside construction; 4b. The hitchpin rail lies approximately 2mm above the soundboard and in conjunction with the low bridge height results in a small down-bearing angle to the strings.

This whole case construction is glued and nailed together without any joints.

Cristofori's instruments do not imitate an instrument in an outer case. There are no mouldings on the upper edges of the case above the soundboard. The inner bentside veneer above the hitchpin rail, which at 6mm thick is really too thick to be called a veneer, forms an important constructional element. The spine and the cheek are simply veneered with cypress in the piano of 1720, and the harpsichord and piano of 1726, the piano and harpsichord of 1722 all have bare poplar wood above the soundboard.

So much for the case construction. I will now talk about the soundboard, the ribbing system and the string layout.

The soundboard thicknesses (ill. 19, 20) of the piano and the harpsichord of 1726, the only ones that I was able to measure carefully, show that in both instruments the soundboard is at its thickest at its centre on the left hand of the bridge (3.6mm C1726, 4mm Pf1726). From this point down to the edges the soundboard has been thinned out, in the 1726 harpsichord down to 2.5mm and in the piano down to 2.9mm.

The piano soundboard is slightly thicker than that of the harpsichord.

The characteristics of the ribbing system (ill. 5, 7, 9, 11) are a curved diagonal rib parallel to the bentside and ribs running perpendicularly from the diagonal rib to the spine.

In the 1726 harpsichord the hitchpin rails for the 4' and 2' take the place of the perpendicular ribs.

We have to bear in mind that unlike the normal Italian harpsichord with a cross-ribbed soundboard, Cristofori's soundboards in the 4 late instruments have no structural function anymore because the inner bentside to which they are fixed effectively isolates them from the compressive effect of the string tension.



The string lengths (Table 3) of Cristofori's instruments all correspond for the three octaves from the treble down to c. Down to this point the scaling is Pythagorean; the string lengths of the octaves have a ratio of exactly 1:2. The c2 equivalent lengths show clearly the different methods of shortening the last bass octave. The harpsichord of 1722 has the longest bass length (C of 1982mm) and the least foreshortening, of approximately one tone. With a case length of 2.40m, it is also the longest instrument. The piano of 1722 has the shortest bass strings (C of 1814mm) and the largest foreshortening of around two whole tones; with a case length of 2.22m, it is the shortest instrument.

The two harpsichords and two pianos from 1722 and 1726 have a fairly similar keyboard layout with the consequence that the position and direction of strings are the same, only the last bass octave strings are more angled in the pianos. The bridges are placed parallel to the bentside at a distance of 10cm.

A fundamental difference between the harpsichords and pianos is the different plucking points (Table 4). The strings of the harpsichords are plucked further from the nuts than the striking point of the pianos. In the 1722 and 1726 pianos, the hammer strike points form a straight line perpendicular to the spine; in the 1720 piano the line is slightly angled. The nut of the pianos is very curved.

Another important difference between Cristofori's pianos and harpsichords is how the strings continue after the bridge pins. The strings of the harpsichords are as usual angled at the bridge pins, only the last bass octave in C1726 has double pinning and the strings are fixed at the front edge of the wider hitch pin rail. The pianos have double pinning throughout. They also have a continuously widened hitch pin rail and the strings go around a second set of pins fixed at the inside edge of the hitchpin rail. I suppose this is to spread the string tension more evenly along the bentside rather than being concentrated at the tail end of the pianos, which would be the case with the straight strings resulting from double pinning.

As a preliminary conclusion one can say that:

Cristofori's pianos and harpsichords from the 1720's are made following the same principles. They have a similar inner construction, the same kind of ribbing, the same string length (only the last bass octave is different), the same stringband position and the same key dimensions. The construction itself does not give an indication for heavier strings for the piano.

### **The double bentside**

The system of the double bentside has been thought for some time to be a particular feature of the Cristofori pianos. The mention of a stronger stringing for the new invention in the most important document of Cristofori's time, the article by Scipione Maffei, has been taken as a proof of their use by Cristofori, and the special inner construction has been explained as his way of preparing the new invention for the increased tension caused by much thicker strings.

The fact that not only the pianos but also the harpsichords are made with the double bentside, and the fact that his late harpsichords are made with the same construction principles as the pianos, puts the question in another light.

A summary follows of the analysis of the three documents (Table 5) from Cristofori's time which describe the new invention:

Maffei (1711), who describes the new invention, especially the action, in detail mentions the fact of the higher hitchpin rail and a heavier stringing for the piano.

Interestingly the notes on which Maffei based his article have survived, and these notes do not mention the inverted wrestplank, the higher hitch pinrail and the heavier stringing. In these notes one can, on the other hand, find a sentence which points out that for Cristofori the perfection of an instrument depended on right measurements, on a soundboard which is not too thin, and on the bents (that means bentside and bridge) whose elasticity should not put too much pressure on the soundboard. Also in Maffei's article we find similar references about the elasticity of the bentside. In both documents, the notes of Maffei's interview and his later article, the problem of the bentside elasticity is described as being a preoccupation of Cristofori, especially as being bad for the sound and something he had not noticed in old instruments. (Here I should mention that Cristofori was curator of the Medici collection of musical instruments, and the restoration of historical keyboard instruments was normal work for him, so he was in direct contact with the work of the old masters.)

In the third document, the anonymous dictionary of the 18th century, the owner of a Cristofori piano describes the construction of the instrument as having a special inner construction which produces a different sound quality but which is not visible from outside.

To sum up, I would like to emphasise that it was probably much more the search for a certain sound than a search for a stronger construction system that led Cristofori to the special construction of the double bentside. This construction with all its braces seems to be very stable but because of the separation of

soundboard and bentside, the inner framework has to support all the tension from the strings alone, a function which is normally shared between soundboard and bentside. As a consequence of the highly flexible 4mm inner bentside to which the soundboard is glued, Cristofori had to minimise the pressure of the bridge on the soundboard. In consequence, he located the hitchpin rail higher, and, in his pianos, double-pinned the bridges. Seeing the late Cristoforis with their lightweight poplar cases, their thin bellyrails and their thin wrestplanks (especially so in the pianos in comparison to a similar long-scaled Italian harpsichord with normal inner-outer construction) one has to assume that Cristofori made his late instruments as heavy as necessary for the string tension but as light and flexible as possible for the sound.

### The stringing

The consequence of the above analysis in respect to the stringing of Cristofori's harpsichords and pianos is that we cannot infer a heavier stringing from the special case and inner construction compared to that of a normal inner-outer Italian harpsichord.

Taking the gauge numbers (Table 6) which are written in ink on the wrestplanks of both Cristofori harpsichords as possible indications for the string thicknesses, the above assertion is further confirmed. The gauge numbers of both Cristofori harpsichords begin in the treble with no. 10 and go down to no. 5 in the bass. This kind of system can be found in many other Italian harpsichords of the 17th and 18th centuries. Trying to interpret these gauge numbers of Italian harpsichords invites a contradiction between almost half a century of experience in stringing copies of historical keyboard instruments and the research done into historical Nuremberg wire making.

The published results of that research<sup>6</sup> propose that because of the export of

<sup>6</sup> R. GUG, *Die Nürnberger historischen Saitendrahtnumerierungsarten*. In: *Das Musikinstrument* 7 (1986), p. 19-24 (short version of the article *En remontant la filière de Thoiry à Nuremberg*. In: *Musique Ancienne*, 18 (1984), p. 4-76. - A. HUBER, *Mensurierung, Besaitung und Stimmtonhöhen bei Hammerklavieren des 18. Jahrhunderts* (Teil I/II). In: *Das Musikinstrument* 7 (1986), p. 58-63 and 9 (1986), p. 24-29. - S. KLAUS, *Ein Beitrag zur Geschichte des Saitendraht herstellenden Handwerks in Nürnberg bis zum Beginn des 19. Jahrhunderts*. In: *Der "schöne" Klang. Studien zum historischen Musikinstrumentenbau in Deutschland und Japan unter besonderer Berücksichtigung des alten Nürnberg*. Germanisches Nationalmuseum Nuremberg 1996, p. 112-142.



Nuremberg wire all over Europe in the 17th and 18th century, one should interpret the gauge numbers of Italian harpsichords according to the known diameters from the Nuremberg gauge number system. But that would mean string thicknesses of 0.19mm in the treble (for no.10) down to 0.34mm (no.5) in the bass, which is incredibly thin.

If one takes the thicknesses that Grant O'Brien<sup>7</sup> measured on an Italian harpsichord with probably original strings as a possible interpretation for the Italian gauge numbers, we come to diameters of 0.21mm in the treble and 0.46mm in the bass, but of course one instrument alone is far too little to use as a reference point for the gauge numbers on Italian harpsichords. We have to admit to knowing almost nothing about Italian wire making. We neither know whether the Italians made their own wire nor if they bought wire from Nuremberg and drew it to their own sizes.

When stringing my copy of the Leipzig Cristofori piano I began with the thin diameters the Nuremberg system suggests and used them for the first concert in Florence. The sound was much closer to a harp or a lute than to a piano but nevertheless the sound was clear and singing. Curiosity led me twice to change the strings to thicker diameters. Now the piano is strung with 0.27mm in the treble down to 0.52mm in the bass.

Interestingly, these last diameters correspond very well to the 1746 harpsichord/pianoforte instrument of Ferrini, Cristofori's pupil, always taking the Nuremberg wire system as reference. The gauge numbers on this instrument indicate much thicker strings than the Cristofori instruments. This is even more interesting if one considers that it has the same double bentstide and bracing system and the same soundboard ribbing.

Concerning the hypothesis of brass stringing for Cristofori's harpsichords and pianos, I only need to remember that the c2 string lengths are around 280mm long. Our knowledge of stringing practice for historical keyboard instruments has today reached the point that one can generally say that string lengths up to 280mm for c2 were strung in brass, longer scaling with c2 lengths of more than 300mm mostly with iron.

Furthermore we find in Cristofori's harpsichord of 1726 between f<sup>1</sup> and f#<sup>1</sup>

<sup>7</sup> G. O'BRIEN, *Some principles of eighteenth century harpsichord stringing and their application*. In: *The Organ Yearbook*, Vol. 12 (1981), p. 160-176.

in the 2' register a bridge step, in the *spinettone* between  $b^1$  and  $c2$  in the 8' and 4' register. The  $c2$  after the step in the 8' register of the *spinettone* is 335mm. This is a quite clear indication for a change of material. Therefore one can say Cristofori used for his instruments with  $c2$  string length of 280-287mm brass, for a  $c2$  of 335mm iron.<sup>8</sup>

A recently published dissertation<sup>9</sup> on European pitch standards in the Baroque and Classical periods describes the pitches in 18th century Italy as being very low in the south, in Naples and Rome at around 395Hz, and very high in Lombardy and in Venice, at around 443Hz or even 470Hz. Florence probably had a pitch in between, at around 418Hz.

The anonymous dictionary of the 18th century, a document I have already mentioned while talking about the double bentside mentions a low pitch but interpretation is quite difficult since we have no reference point.

The copy of the 1726 piano I made is tuned to 415Hz.

Before concluding, I would like to add some comments about other possible stringing schemes for the Cristofori pianos.

It is true that the percussion action allowed for a potential increase in string tension through increasing string diameters, but the Cristofori hammers, made of hollow paper rolls with only one layer of leather, are so light and elastic that they do not exert enough pressure on the strings to make use of this potential. This is also important for the question of scaling. Later piano builders shortened their scaling somewhat to increase the safety margin before breaking tension, as hammers became heavier and the pressure they exerted on the string increased. In the case of Cristofori there is not yet a difference between harpsichord and piano. The strings of the Cristofori piano can be put under the same tension as a harpsichord.

The idea of hitting the strings with heavier hammers to produce a louder sound was not yet born.

<sup>8</sup> Alfons Huber pointed out this connection already in 1986. A. HUBER, *Mensurierung, Besaitung und Stimmtonhöhen bei Hammerklavieren des 18. Jahrhunderts* (Teil I). In: *Das Musikinstrument* 7 (1986), p. 61.

<sup>9</sup> B. HAYNES, *Pitch Standards in the Baroque and Classical periods*. Dissertation 1995. University of Michigan, Ann Arbor, ed. UMI 1999.

## Conclusion

With Cristofori's development of a fully-functional hammer action a new sound for the harpsichord was born, enormously rich in dynamic nuance. In the fundamental principles of their construction, Cristofori's pianos were not different from his harpsichords of the same period. Apart from the hammer action which set the pattern for the piano industry of the next centuries we find in Cristofori's pianos details like the choice of the position of the striking point close to the nut, the double-pinning in conjunction with the parallel direction of the strings behind the bridge, and the wider hitchpin rail, all of which have proved to be fundamental features of piano-making up to the present time.

**Table 1. Signed Cristofori instruments from his later life.**

**Tabel 1. Door Cristofori gesigeneerde instrumenten uit zijn latere periode.**

<b>Instrument</b>	<b>Museum</b>
Pianoforte 1720	New York, Metropolitan Museum of Art, inventory no. 89.4.1219
Harpsichord 1722	Leipzig, Musikinstrumenten-Museum der Universität, inventory no. 84
Pianoforte 1722	Rome, Museo Nazionale degli Strumenti Musicali, inventory no. 918
Harpsichord 1726	Leipzig, Musikinstrumenten-Museum der Universität, inventory no. 85
Pianoforte 1726	Leipzig, Musikinstrumenten-Museum der Universität, inventory no. 170

**Table 2. Bellyrail / Wrestplank thicknesses.**

**Tabel 2. Diktes van dam en stemblok.**

	<b>pf1720</b>	<b>h1722</b>	<b>pf1722</b>	<b>h1726</b>	<b>pf1726</b>
thickness					
wrestplank	15	46	30	46	27
thickness					
reinforcing block	52				
(yoke)					
thickness					
belly rail +	15	14	14	12	11
stiffening rail	+20	+11			



Table 3. String length and c2 equivalent length.

Tabel 3. Snaarlengte en de equivalente lengte bij c2.

	string lenth (longer 8')					c2 - equivalent length				
	P1720	H1722	P1722	H1726	P1726	P1720	H722	P1722	H1726	P1726
<b>C</b>	<b>1885</b>	<b>1982</b>	<b>1814</b>	<b>1857</b>	<b>1960</b>	<b>236</b>	<b>248</b>	<b>227</b>	<b>232</b>	<b>245</b>
C#	1884	1950	1741	1779	1906	250	258	231	236	252
D	1883	1869	1810	1859	1831	264	262	254	261	257
D#	1882	1785	1736	1779	1756	280	265	258	264	261
E	1881	1704	1658	1700	1679	296	268	261	268	264
<b>F</b>	<b>1880</b>	<b>1621</b>	<b>1587</b>	<b>1621</b>	<b>1606</b>	<b>314</b>	<b>270</b>	<b>265</b>	<b>270</b>	<b>268</b>
F#	1852	1545	1514	1544	1533	327	273	268	273	271
G	1735	1470	1440	1466	1462	325	275	270	275	174
G#	1576	1395	1367	1396	1393	313	277	271	277	276
A	1378	1325	1305	1328	1323	290	279	274	279	278
A#	1258	1257	1239	1257	1253	280	280	276	280	279
B	1173	1192	1180	1194	1190	277	281	278	282	281
<b>c</b>	<b>1100</b>	<b>1132</b>	<b>1120</b>	<b>1130</b>	<b>1127</b>	<b>275</b>	<b>283</b>	<b>280</b>	<b>283</b>	<b>282</b>
c#	1036	1071	1060	1074	1064	274	284	281	284	282
d	976	1013	999	1017	1002	274	284	280	285	281
d#	926	956	949	964	943	275	284	282	287	280
e	880	901	898	909	889	277	284	283	286	280
<b>f</b>	<b>838</b>	<b>850</b>	<b>849</b>	<b>857</b>	<b>840</b>	<b>280</b>	<b>284</b>	<b>283</b>	<b>286</b>	<b>280</b>
f#	794	804	801	808	793	281	284	283	286	280
g	749	758	759	762	751	281	284	284	285	281
g#	706	716	716	720	710	280	284	284	286	282
a	672	677	670	680	672	283	285	282	286	283
a#	638	639	636	643	636	284	285	283	286	283
b	601	604	599	607	602	284	285	283	286	284
<b>c1</b>	<b>566</b>	<b>569</b>	<b>566</b>	<b>571</b>	<b>569</b>	<b>283</b>	<b>285</b>	<b>283</b>	<b>286</b>	<b>285</b>
c#1	538	540	533	541	535	285	286	282	287	283
d1	511	509	520	511	504	287	286	292	287	283
d#1	485	481	475	482	475	288	286	282	287	282
e1	458	454	444	454	447	289	286	280	286	282
<b>f1</b>	<b>430</b>	<b>427</b>	<b>420</b>	<b>428</b>	<b>420</b>	<b>287</b>	<b>285</b>	<b>280</b>	<b>286</b>	<b>280</b>
f#1	406	404	396	404	399	287	286	280	286	282
g1	381	382	374	381	375	285	286	280	285	281
g#1	361	361	352	360	353	287	287	279	286	280
a1	342	340	333	341	333	288	286	280	287	280
a#1	323	321	307	321	315	288	286	274	286	281
b1	304	303	295	304	298	287	286	278	287	281

<b>c2</b>	<b>286</b>	<b>285</b>	<b>280</b>	<b>287</b>	<b>281</b>	<b>286</b>	<b>285</b>	<b>280</b>	<b>287</b>	<b>281</b>
c#2	269	271	265	271	267	285	287	281	287	283
d2	254	256	250	256	251	285	287	281	287	282
d#2	239	242	236	241	238	284	288	281	287	283
e2	224	229	223	228	225	282	289	281	287	283
<b>f2</b>	<b>214</b>	<b>214</b>	<b>211</b>	<b>215</b>	<b>215</b>	<b>286</b>	<b>286</b>	<b>282</b>	<b>287</b>	<b>287</b>
f#2	201	203	198	204	201	284	287	280	288	284
g2	191	192	187	192	189	286	288	280	288	283
g#2	174	182	177	181	180	276	289	281	287	286
a2	171	172	167	171	169	288	289	281	288	284
a#2	164	162	160	160	159	292	289	285	285	283
b2	157	152	150	150	150	296	287	283	283	283
<b>c3</b>	<b>151</b>	<b>143</b>	<b>142</b>	<b>144</b>	<b>142</b>	<b>302</b>	<b>286</b>	<b>284</b>	<b>288</b>	<b>284</b>
c#3	142					301				
d3	118					265				
d#3	131					312				
e3	126					318				
f3	121					323				

Table 4. Plucking points.

Tabel 4. Aantokkel- en aanslagpunten.

	harpsichords		pianos		
	H1722	H1726	Pf1720	Pf1722	Pf1726
			changed		
			bridge position		
	left 8'	8'			
C	165	168	164	121	133
F	156	159	152	110	108
c	145	146	135	89	73
f	134	136	119	71	57
c1	120	123	92	43	38
f1	109	112	73	31	29
c2	93	94	51	21	17
f2	81	84	39	14	13
c3	65	68	26	8	7
f3			19		

**Table 5. Documents which describe the new invention.**

**Tabel 5. Dokumenten waarin de nieuwe uitvinding beschreven wordt.**

1. Notes of Scipione Maffei from the interview of 1709 with Cristofori  
Aantekeningen van Scipione Maffei naar aanleiding van zijn gesprek met Cristofori in 1709

Biblioteca Capitolare Verona: Busta DCCCLVI, fasc. VII. - Laura Och: Bartolomeo Cristofori, Scipione Maffei e la prima descrizione del' gravecembalo col piano e forte'. In: *Flauto dolce* 14-15 (April-October 1986), p. 21-22

2. Article of Maffei, two years later published in the *Giornale de'letterati*  
Artikel van Maffei, 2 jaar later, verschenen in het *Giornale de'letterati*

Scipione Maffei: Nuova Invenzione d'un gravecembalo col piano e forte aggiunte alcune considerazioni sopra gli strumenti musicali. In: *Giornale de'letterati d'Italia* 5. Venice 1711, p. 144-159

3. Short description of the new invention in an anonymous dictionary of the 18th century  
Korte beschrijving van de nieuwe uitvinding in een anonieme dictionaire uit de 18de eeuw

Dictionary from the ownership of Padre Martini, Museo Civico Bologna: Manuscript H 62. Entry Cristofori Bartolomeo, p. 114

**Summary/samenvatting**

Notes/aantekeningen Maffei	Article/artikel Maffei	anonymous dictionary/ anonieme dictionaire
1709	1711	middle 18th century/ midden 18de eeuw
	<p>-higher hitchpin/hogere aanhanglijst</p> <p>-heavier strings/zwaardere besnaring</p> <p>-worrying about the pressure of the bentside movements and the bridge on the soundboard which Cristofori thought must have had a bad influence on the sound/ bezorgd om het probleem van de druk door de vervorming van de gebogen wand en van de druk van de zangbodemkam op de zangbodem, omdat hij vermoedde dat die druk kwalijke gevolgen had voor de klank</p>	<p>-another tone quality/ andere klankkwaliteit</p> <p>-special inner construction/ eigenaardige binnenconstructie</p>

Table 6. Gauge numbers.

Tabel 6. Nummering snaardikte.

	H1722 C - c3	H1726 C - c3			HP1746 Ferrini GGAA-c3	gauge numbers	diameters Nurem- berg system	Grant O'Brien
	8"	8"	4"	2"	8"	1	0.50	0.68
G1						1	0.46	0.59
A1						3	0.41	0.52
A#1						4	0.38	0.46
H1						5	0.34	0.40
C						6	0.30	0.36
C#						7	0.27	0.31
D	5	5			2	8	0.24	0.27
D#				8		9	0.21	0.24
E						10	0.19	0.21
F						11	0.17	0.19
F#						12	0.16	
G								
G#	6	6			3			
A								
A#				9				
H			8					
c								
c#								
d								
d#		7						
e				10	4			
f								
f#	7							
g			9					
g#								
a								
a#	8	8						
h								
cl				11	5			
c#1								
d1								
d#1								
e1			10					
f1								
f#1	9	9						
g1								
g#1					6			
a1								
a#1								
h1								
c2								
c#2								
d2								
d#2	10	10	11					
e2								
f2					7			
f#2								
g2								
g#2								
a2								
a#2								
h2								
c3					8			
c#3								
d3								
d#3								
e3								





1. Harpsichord 1722 (photo by Kranich, Musikinstrumenten-Museum Leipzig).  
Klavecimbel 1722 (foto Kranich, Musikinstrumenten-Museum Leipzig).

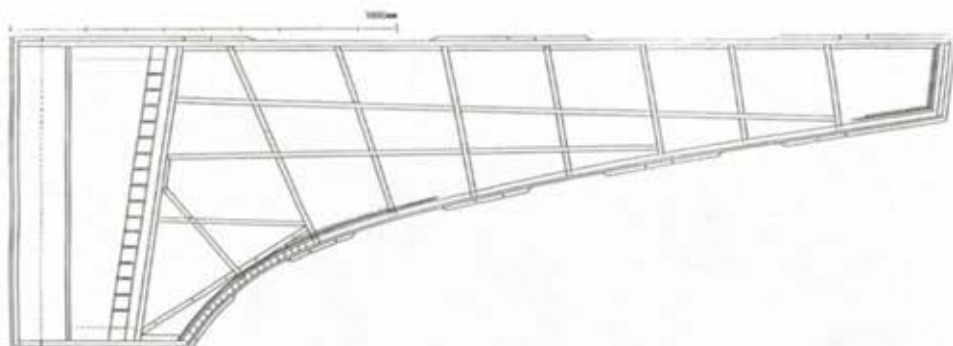


2. Harpsichord 1726 (photo by Kranich, Musikinstrumenten-Museum Leipzig).  
Klavecimbel 1726 (foto Kranich, Musikinstrumenten-Museum Leipzig).



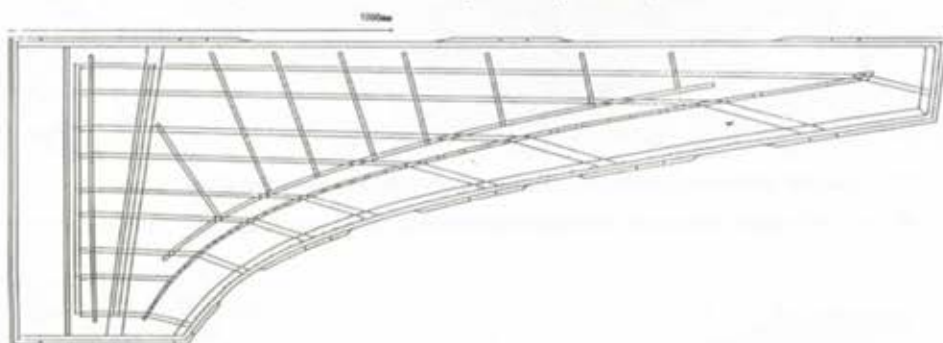
3. Piano 1726 (photo by Kranich, Musikinstrumenten-Museum Leipzig).

*Piano 1726 (foto Kranich, Musikinstrumenten-Museum Leipzig).*



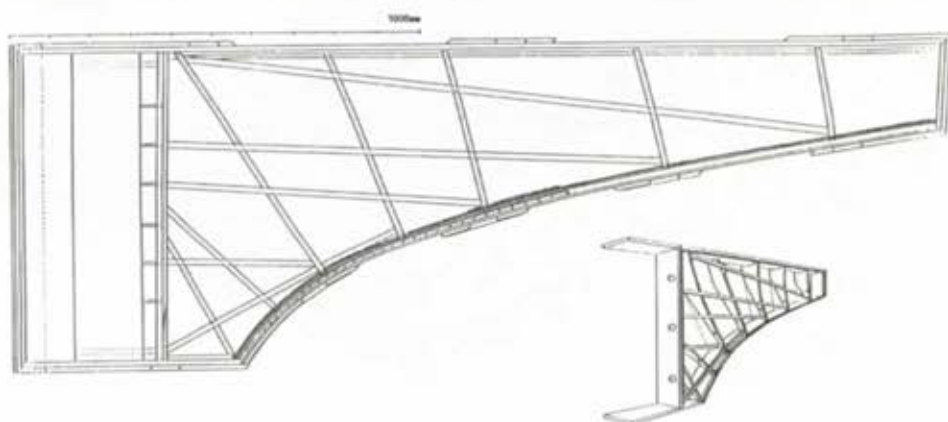
4. Inner construction, harpsichord 1722 (drawing by the author).

*Binnenconstructie, klavecimbel 1722 (tekening auteur).*



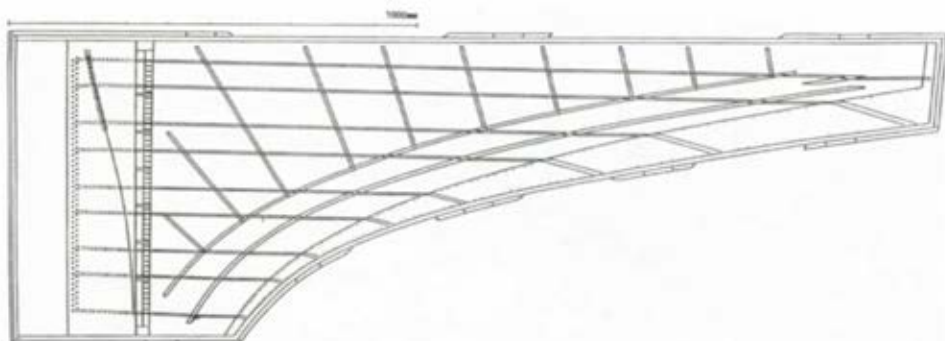
5. Bridge, string layout, ribbing, harpsichord 1722 (drawing by the author).

*Kam, snarenplan, zangbodembeëanking, klavecimbel 1722 (tekening auteur).*



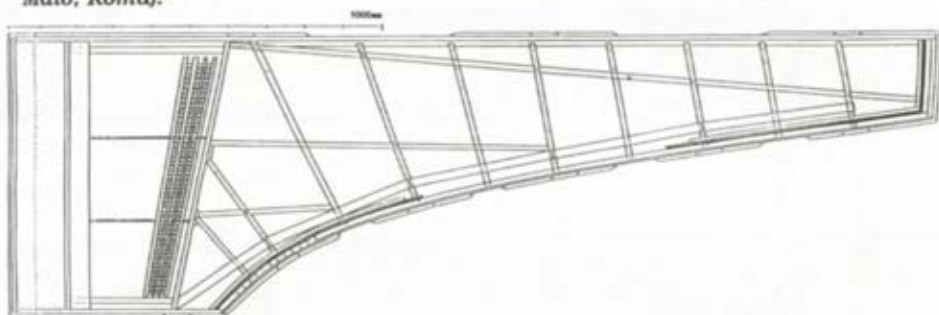
6. Inner construction, piano 1722 (drawing by the author after Di Maio, Roma).

*Binnenconstructie, piano 1722 (tekening auteur naar Di Maio, Roma).*



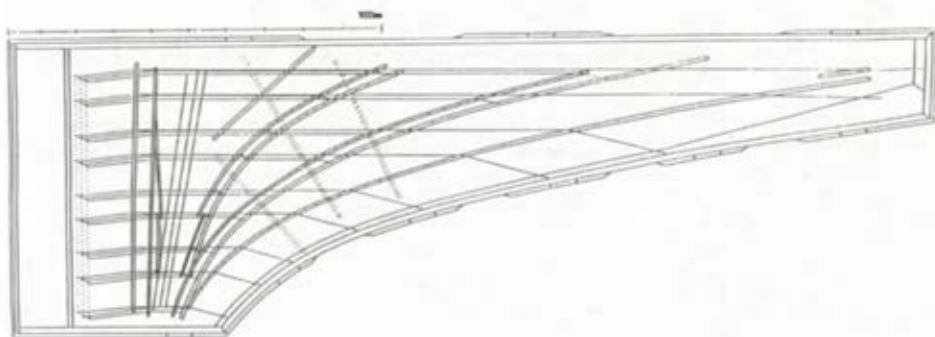
7. Bridge, string layout, ribbing, piano 1722 (drawing by the author after Di Maio, Roma).

Kam, snarenplan, zangbodembekalking, piano 1722 (tekening auteur naar Di Maio, Roma).



8. Inner construction, harpsichord 1726 (drawing by the author).

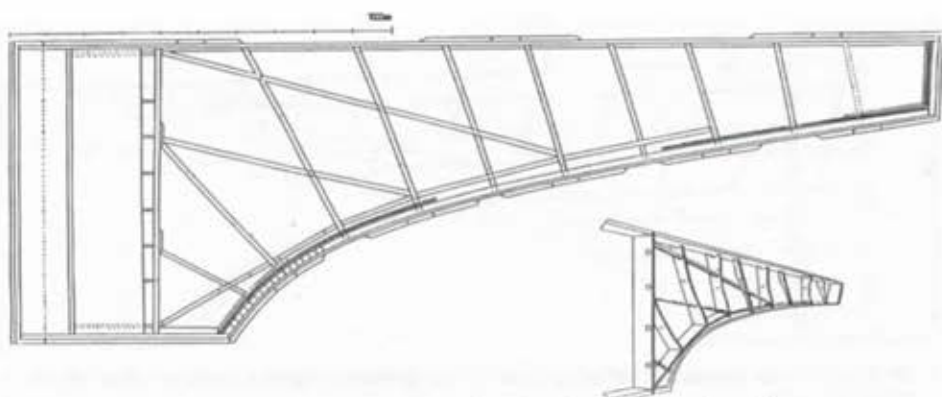
Binnenconstructie, klavecimbel 1726 (tekening auteur).



9. Bridge, string layout, ribbing, harpsichord 1726 (drawing by the author; the dotted lines indicate the position of non-original soundboard ribs).

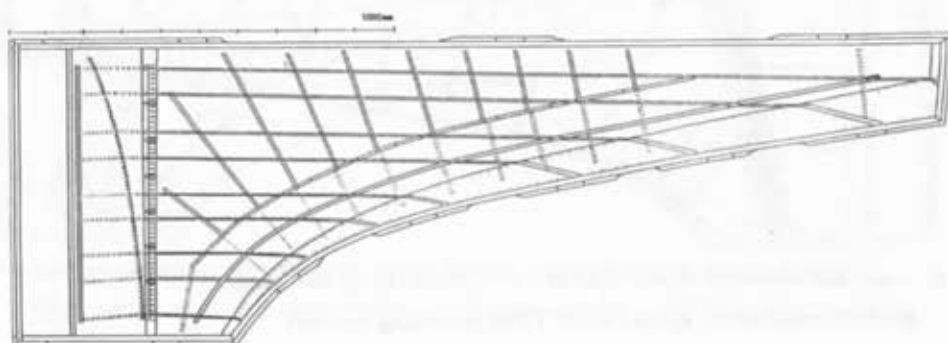
Kam, snarenplan, zangbodembekalking, klavecimbel 1726 (tekening auteur; de stippellijnen geven de positie aan van de niet-originele zangbodembekalking).





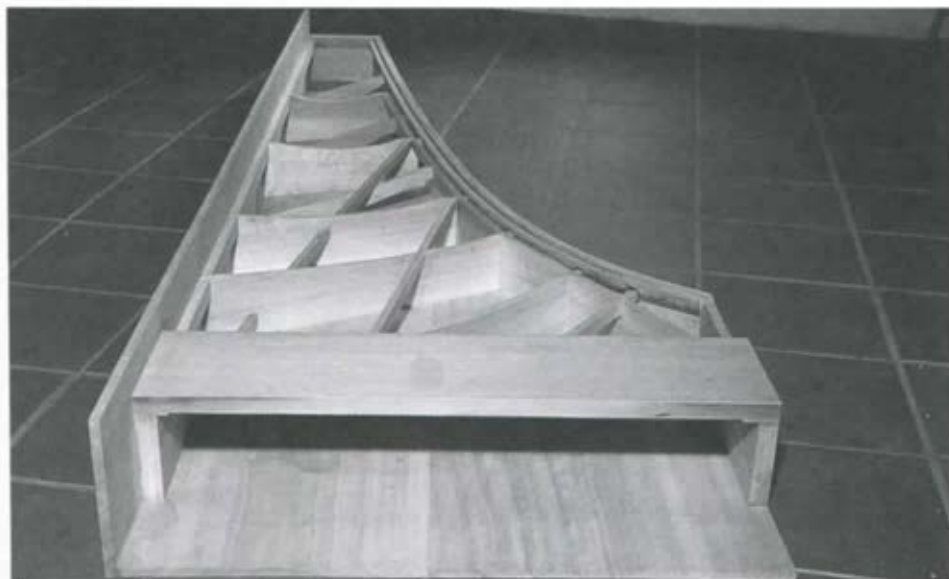
10. Inner construction, piano 1726 (drawing by the author after Singer, Musikinstrumenten-Museum Leipzig).

*Binnenconstructie, piano 1726 (tekening auteur naar Singer, Musikinstrumenten-Museum Leipzig).*

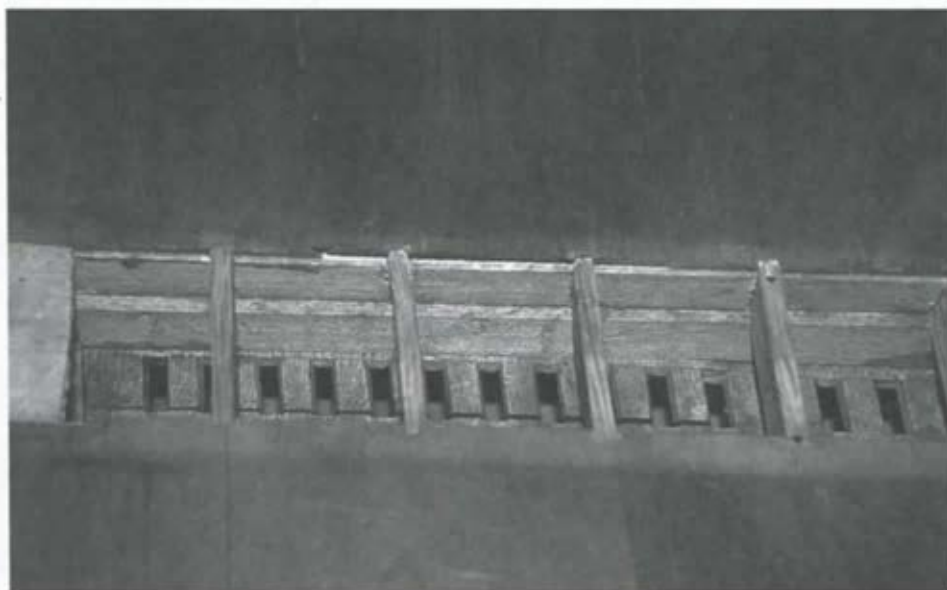


11. Bridge, string layout, ribbing, piano 1726 (drawing by the author after Singer, Musikinstrumenten-Museum Leipzig; the dotted lines indicate the position of non-original soundboard ribs).

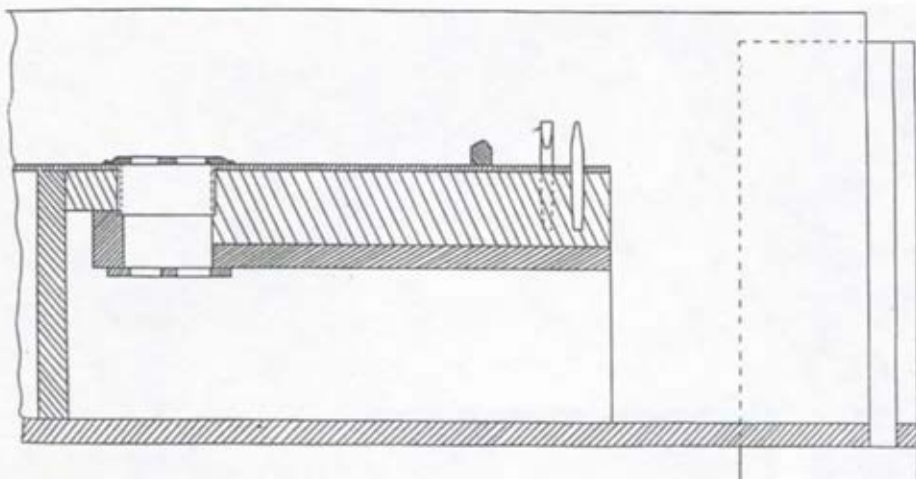
*Kam, snarenplan, bebalking, piano 1726 (tekening auteur naar Singer, Musikinstrumenten-Museum Leipzig; de stippellijnen geven de positie aan van de niet-originele zangbodembebalking).*



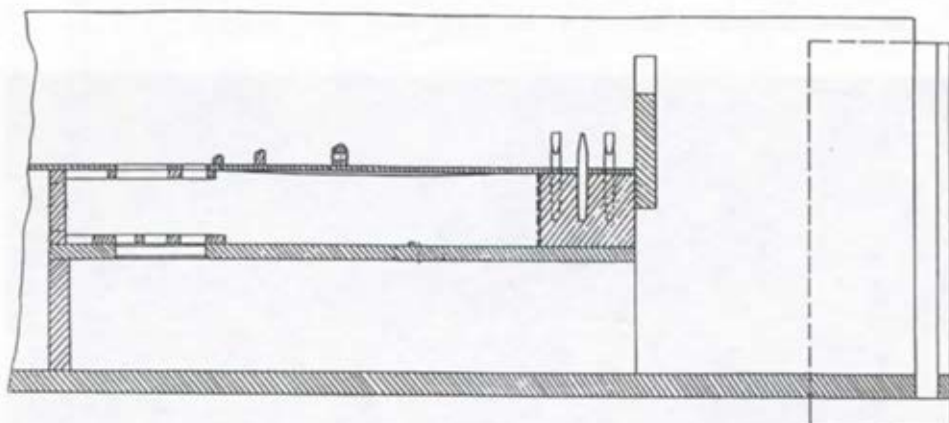
12. *Inner construction Cristofori piano, copy of the author (photo by the author).*  
*Binnenconstructie Cristofori piano, kopie auteur (foto auteur).*



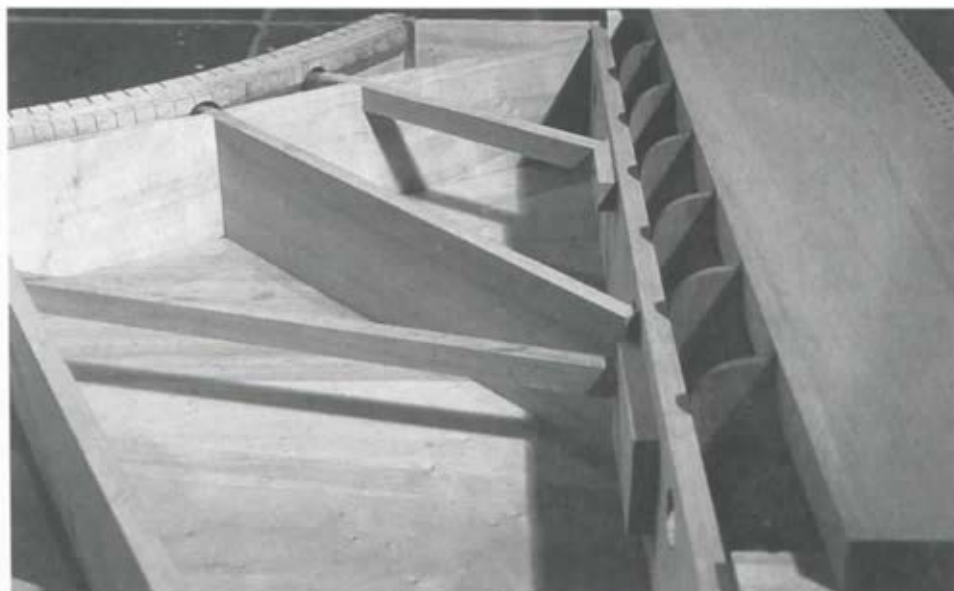
13. *Gap spacers, harpsichord 1722 (photo by the author).*  
*Uithouders, klavecimbel 1722 (foto auteur).*



14. Cut section register construction, harpsichord 1722 (drawing by the author).  
*Doorsnede van de registers, klavecimbel 1722 (tekening auteur).*



15. Cut section register construction, harpsichord 1726 (drawing by the author).  
*Doorsnede van de registers, klavecimbel 1726 (tekening auteur).*



16. Gap spacers piano, copy of the 1726 piano (photo by the author).

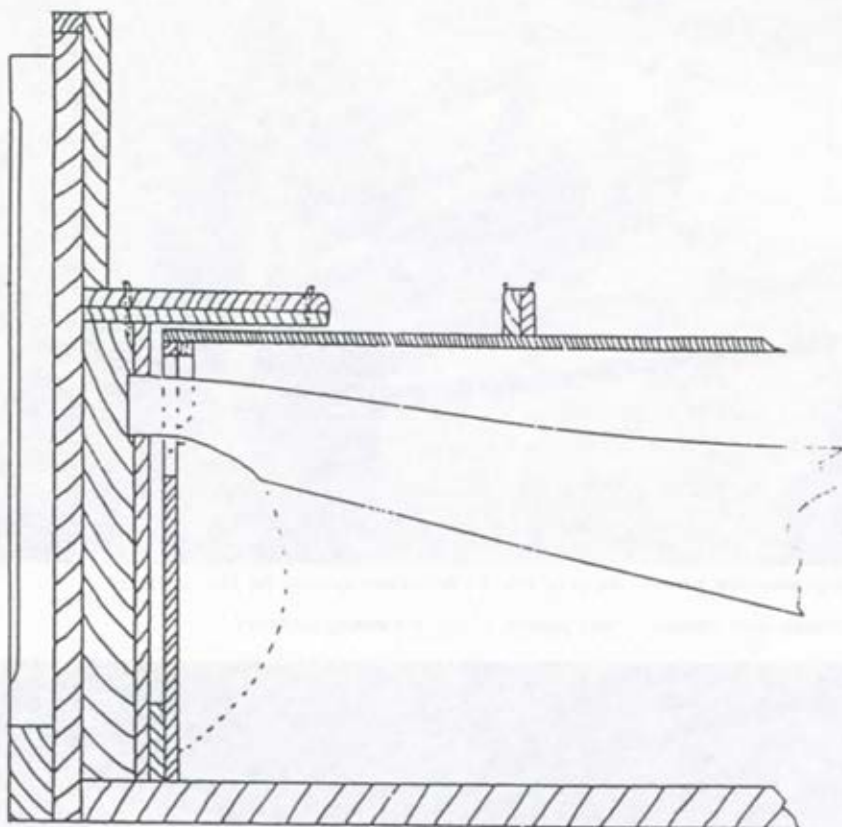
*Uithouders piano, kopie piano 1726 (tekening auteur).*



17. Double bentside, copy of the 1726 piano (photo by the author).

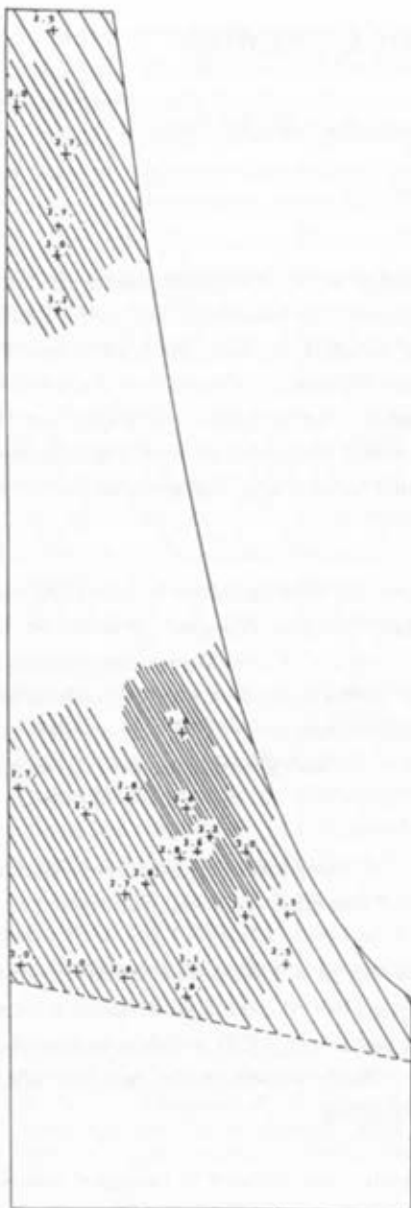
*Dubbele gebogen wand, kopie piano 1726 (foto auteur).*





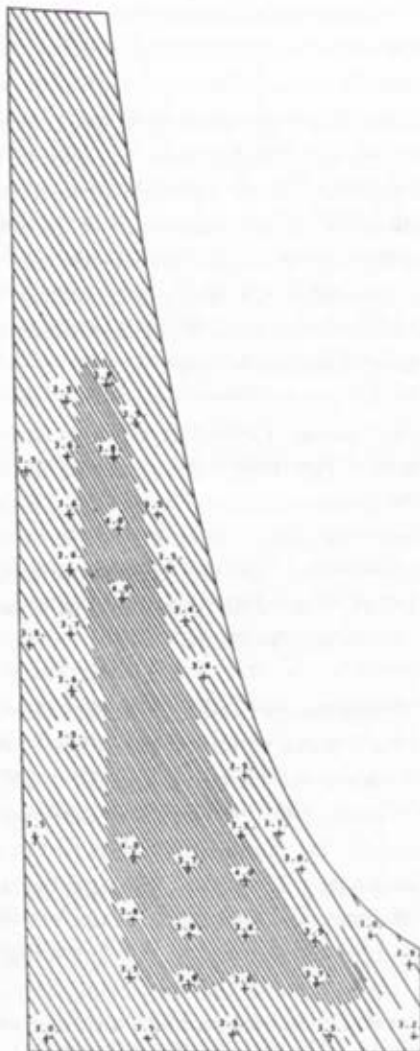
18. Cut section double bentside piano 1722 (from the drawing of Di Maio).

*Doorsnede dubbele gebogen wand, piano 1722 (tekening Di Maio).*



19. Soundboard thickness harpsichord 1726 (drawing by the author).

Dikte zangbodem klavecimbel 1726 (tekening auteur).



20. Soundboard thickness piano 1726 (drawing by the author).

Dikte zangbodem piano 1726 (tekening auteur).