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Denzil Wraight

THE ORGAN BUILDER AS HARPSICHORD MAKER IN VENICE: A CONSTRUCTION PRINCIPLE REVEALED

The subject of this discussion is two of the dimensions in the design and construction of harpsichords made in Venice in the 16th century: the width of the instrument and its length.

There has been a great deal of work done over the years by many authors to determine how the old makers designed and constructed their instruments, but I do not intend to review all this work here. I would however like to mention one article published by Stephen Birkett and William Jurgenson aptly entitled «Why didn't historical makers need drawings?» since it contains a lucid and critical review of the different types of methods the organological community has used over the years to analyse the construction of instruments.[1] They introduced a terminology which is appropriate for my purposes here. The question is: were instruments designed from the «outside in», or from the «inside out»? That is, did the Italian makers *start* with case dimensions, perhaps using modular design, proportional design, or geometric construction, and then fit the keyboard and strings to the case, or did they start with the keyboard and strings, then build the case around them?

It will be my contention here that several Venetian harpsichords were designed from the «inside out». Furthermore, I infer a design principle which related the case size of certain harpsichords to their string scaling, which was previously unknown. If I am correct in my

[1] See Stephen Birkett, William Jurgenson, *Why Didn't Historical Makers Need Drawings? Part II - Modular Dimensions and the Builder's Werkzoll*, «Galpin Society Journal», LV (2002), pp. 183-239. The authors argue how the case width depended on the dimensions of the keyboard used.

interpretation that the spine length was derived from other factors, then it follows that we would be mistaken if we tried to understand the genesis of such a harpsichord from the «outside in». This means that a description of the *case length* in terms of inches, modular dimensions, or proportions would, for some instruments, be an inapplicable procedure.

The problem is, in analysing old instruments, that one can usually find measurements or proportions which fit some dimensions, even after a case has had its original size changed! However, rather than analyse the organological thinking on these matters I shall lead you more directly to the observations I have to offer, although this essay is not intended as a complete or final contribution on the subject.[2] These observations have grown from the examination of Italian harpsichords so the approach has been empirical, but it has required a long process of data collection, reflection, and the testing several types of explanation. The final impulse in the direction my thoughts have taken, did not come until I was «forced», one might say, to think as an organ maker and not simply as a harpsichord maker. This came about through the project to make a small chamber organ based on the instrument by Lorenzo da Pavia of 1494, which was produced in Venice. There has long been a division of trades between organ and harpsichord making, but in the 16th century in Italy there was not such a clear-cut demarcation. In Venice this may have had to do with the guild system where the *corporazione* were less restrictive than the German *Zünfte*. We know that two members of the Trasuntini workshop, Alessandro and Vito, worked on organs. Domenico da Pesaro, whose surviving oeuvre is the largest of any 16th-century string keyboard instrument maker, also produced at least one chamber organ with paper pipes. For these makers the ancient Pythagorean principles of string length being proportional to pitch applied equally to strings and pipes.

However, I need to start the description at a different place in order to guide you through the steps I have taken. When I started exam-

[2] The reader is referred to Grant O'Brien's discussion on the construction of instruments in *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments: an aid to attribution and to organological analysis*, «Galpin Society Journal», LII (1999), pp. 108-171.

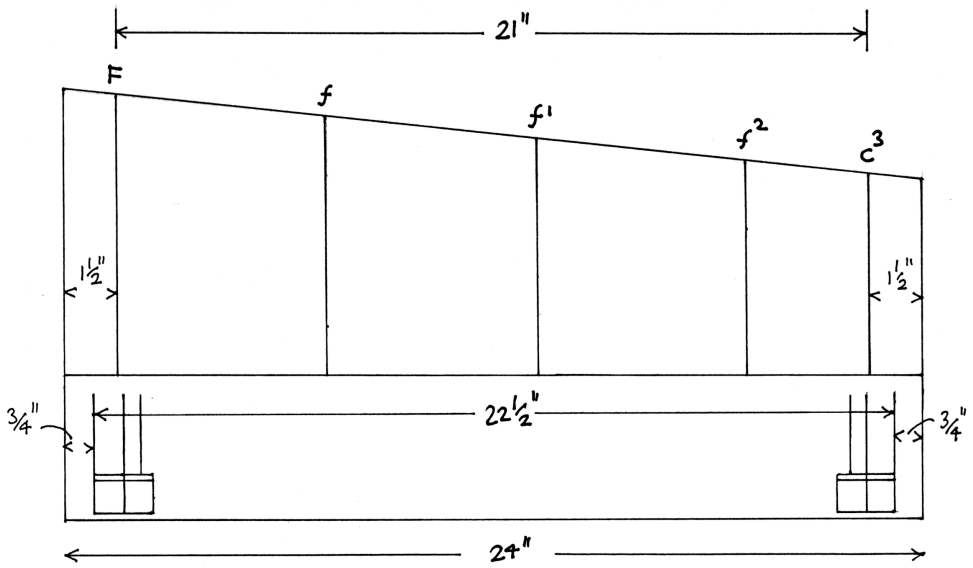
ining Italian instruments I became aware of the use of positioning pins at the bridges of harpsichords and virginals. These are usually now only visible as plugged pin holes beside the bridges, and from studying unaltered instruments it became clear that such positioning aids in the layout were used at the *f notes* of an instrument, not at the c strings which we nowadays usually measure. This feature was found with such regularity and even on instruments with a compass of C/E-c_3, so that I can state that this «f-orientation» was the dominant feature of Italian, 16th-century instrument making, most of which is documented by Venetian instruments. At a later date we find that the larger C/E-f_3 compasses were no longer used, but instead C/E-c_3 and it is normal in 18th-century instruments to find positioning pins at the c notes.

In some Venetian harpsichords we find lines scribed on the baseboard underneath the wrestplank, occasionally extending back through the instrument to the bentside and tail. The 1538 Alessandro Trasuntini harpsichord in the Royal Conservatoire in Brussels has a full «drawing», one might call it, on the baseboard. An unsigned harpsichord (W366 in my catalogue), originally made with split sharps and now in Schloß Köpenick, Berlin, also has a full drawing.[3] The 1579 Baffo harpsichord in Paris also has lines extending deep into the instrument, which are partly visible through holes in the baseboard. These scribed lines are also at the f notes and represent more or less accurately the position of the f-strings. Since such «drawings» are not always present in harpsichords; one might surmise that they were only used when a new or variant design was constructed, a design for which patterns or jigs were not available. Virginals rarely had such construction lines.

When we consider the spacing of these f lines on the baseboard, the question arises how they were positioned and what was the order of construction of case, keyboard, and jackslides? We are fortunate that several instruments by Domenico da Pesaro have such lines on the baseboard and therefore permit a comparison of his working method. Although no two of Domenico's instruments are identical, and even

[3] See Denzil WRAIGHT, *The stringing of Italian keyboard instruments c. 1500 - c. 1650*, Ph. D. dissertation, Queen's University of Belfast, 1997 (UMI order no. 9735109), Part 2, pp. 334-335.

ostensibly similar instruments such as the 1543 and 1546 octave harpsichords have slightly different case dimensions, we nevertheless find a consistent method in four harpsichords from Domenico's workshop of laying out the baseboard. The following sketch the baseboard of the 1554 harpsichord from the front of the baseboard back to the bellyrail, which is as much as is visible. (The top and bottom keylevers have been added for this drawing to clarify their position; they are not marked on the baseboard)



1. Domenico da Pesaro, 1554 baseboard level

These harpsichords show that the top and bottom lines drawn on the baseboard were placed 3/4 Venetian inch inside the edge of the keyboard and 1 1/2 Venetian inches from the edge of the baseboard.[4] The space of 3/4» either side of the keyboard was occupied by a keyboard block. Thus, we can infer a simple formula for determining the width of the case, which was:

case width = intended keyboard width + 2 x (keyboard block width)

[4] The Venetian foot is often given in the literature as about 347.7 mm, in which case the inch is 28.975 mm. See Herbert Heyde, *Musikinstrumentenbau*, Wiesbaden, 1986, pp. 76-77 for a list of sources. An extensive list of Italian foot measures is given by G. O'Brien, *The use of simple geometry*, see note 2, pp. 164-171.

In a fifth harpschord, made by Domenico in 1533, there is no baseboard drawing and the keyblocks are 1" wide.[5] Thus, the formula is valid, although the keyblock width was greater than in the other four examples.

It is interesting to note that in all of these examples mentioned, the width of the keyboard is not drawn on the baseboard, although its dimension must have been known, at least as an *intention*. In fact, one of Domenico's harpsichords, made in 1570, suggests that the keyboard had already been made before the baseboard lines were drawn. The keyboard is obviously wider than the nominal 24" and the baseboard lines are correspondingly more widely spaced, apparently to match the pre-existing keyboard. However, the baseboard is 26" wide, indicating that the slightly-oversize keyboard did not lead to an oversize baseboard.

So what would the nominal keyboard width have been in a Venetian harpsichord? It turns out that the width of the keyboard at the natural covers is *often* the number of notes divided by two, and expressed in Venetian inches. Thus, a C/E-f_3 compass, which has 50 notes is often 25 Venetian inches wide, a fact which has not escaped the attention of other researchers.[6] Although it seemed to me at an earlier stage of my investigations that this might provide a formula for constructing the size of an instrument, my recent detailed analysis has shown a wider variety of sizes used by Venetian makers.[7] We can infer from this that the size of keyboard varied, depending on factors which we cannot clearly identify, but probably based on the requirements of customers. Thus, the main part of the case width was determined by the width of the keyboard chosen, the remaining part being the width of the keyblocks adopted.

The resulting value is always expressible in Venetian inches, although sometimes the baseboard width (between the case sides) includes half an inch, as a result of the compound method. Domenico da Pesaro made his W112 (undated) harpsichord with $^3/_4$" keyblocks

[5] Musical Instrument Museum, Leipzig University, No. 67.

[6] See G. O'Brien, *The use of simple geometry*, see note 2, p. 145.

[7] My findings were reported in *A contribution to the analysis of local units of measurement in Italian keyboards*, a paper presented at the symposium in Herne in 2010, *Cembalo, Clavecin, Harpsichord - Regionale Traditionen des Cembalobaus*, in press.

and a 24" keyboard, but for the 1533 harpsichord, which has the same compass, 1" keyblocks and a 25" keyboard were preferred. The harpsichords are therefore (respectively) 25 $^1/_2$" and 27" wide.

A second conclusion from my study of keyboards was that the inch measure was *not* used as a convenient way of constructing the string spacing. For example, the stringband was not necessarily 25 Venetian inches wide for 50 notes, i.e. half an inch per note. The actual method used was more practical, as will be described briefly later.

Thus far we have seen that the layout of the instrument proceeded at least from *knowing* the width of the keyboard, if not indeed from the keyboard itself. The instrument maker could have distributed his strings for the bottom F and subsequent octaves by measurement, but he might also have worked empirically from the jackslide intended for the instrument. The 1579 Baffo harpsichord, I mentioned earlier, appears to indicate this procedure. Beside the string lines on the baseboard there are indentations on the baseboard of what is in all likelihood the mark of a jack which has been placed in the jackslide and then hit with a hammer to leave these marks. At the position where the plectrum of a jack would touch the string there is a clear point mark.

When one considers how such jackslides were made it is obvious what order of construction could have been used. The jackslide consists of small blocks glued between two thin strips of wood. The blocks would be positioned to leave the necessary amount of play for each actual jack. Our method today is to work with standard sizes, and with modern machinery jacks can be produced with high accuracy. Nevertheless, we can readily appreciate that the cumulative error of only 0,1mm would yield a total error of 5mm across the width of a 50-note keyboard. The Venetian harpsichords we are considering here typically had a 50-note C/E-f_3 compass. In practice you will find that the octave width of these string lines varies slightly, suggesting that they were laid out empirically and not according to a theoretical octave width. If you were to saw up the keylevers from the keyblank *before* making the jackslide, alignment problems of the jacks with the keylevers would probably result. Thus, starting with the jackslide and aiming for the nominal width of the keyboard enables the jackslide to be trimmed in construction to come within tolerance and the keylevers to be cut to fit *exactly* the slot positions, a simple «low tech» solution.

This discussion of the layout procedure assumes that the position of jackslide was known. How this was normally derived I cannot say with certainty since the «drawings» we find on the baseboards vary. The front edge of the wrestplank, i.e. at the player's side, appears to have been an important datum line on the baseboard drawing and the bellyrail position is also usually marked. Once these positions have been established, the line of the jackslide is decided. Obviously practical experience enters into the design, that is knowing how long the keylevers need to be and what slope of the jackslide is acceptable or desirable. In all Venetian harpsichords I can recall, the jackslide is not at 90° to the spine, but slopes forward, towards the player.

With these string lines in place it was possible for the maker to lay out a bridge position on the baseboard and then derive a curve for the bentside from it. Of course, in order to complete the curve it would be necessary for him to decide how long the instrument should be, and this brings me to the second topic I wish to discuss

It appears to me that the string lengths were measured in Venetian inches, using the normal commercial measurement where the foot is about 347.7 mm, yielding an inch of 28.98 mm.[8] The sizes of Venetian keyboards I have examined conform to this dimension, so it is adequately confirmed in practice.[9] Regarding the string lengths, I have been able to measure a large number of lengths between the nut and bridge pins,and also find the positions on the soundboard when bridges have been moved, thus the data is based on many instruments. Certain string lengths occur with such regularity than we can be sure we are not observing an isolated phenomenon.

For many years I have considered the possibility that there might have been a special «organ makers'» foot which was also used by string keyboard instrument makers. Gastone Vio published a document which showed a drawing from 1707 including the measurement of *piedi organici* (as they are called in Vio's document) of 265 mm, as was inferred by comparison with the Venetian foot also illustrated.[10] This possibility was especially interesting because this is the measurement

[8] See note 4 above.

[9] See my article: *A contribution to the analysis*, see note 7.

[10] See Gastone Vio, *Documenti di storia organaria veneziana*, «L'Organo», XIV (1976), pp. 33-131; dis. S. Margherita.

(within a few mm) used at f_2 in a number of the 50-note Venetian harpsichords I have examined, such as the 1531 Alessandro Trasuntini harpsichord in the Royal College of Music, London. Thus, such an instrument might have been thought of as an «eight foot» instrument, the bottom F being theoretically eight *piedi organici*. Whether this was a widely-used reference standard, or a method of measurement existing alongside the Venetian inch is still an open question, but I will return to the subject again later.

Continuing the description of the string layout on the baseboard, it may have been that the nut position was laid out as a measurement from the front edge of the wrestplank and that the string band was developed from this. In the 1538 Alessandro Trasuntini harpsichord however, there is not even a nut line; the strings have been measured backwards from the front edge of the soundboard (or belly rail) and end at a curved bridge line. Obviously this was used to develop the case outline, which in Venetian harpsichords is often parallel to the bridge line.

Since I only know of two baseboard drawings which are (or were at some time) completely accessible, the information on this subject is limited; the second harpsichord is the one I referred to earlier, in the collection at Schloß Köpenick, and was originally made for the court at Ferrara, possibly by the Trasuntini workshop. The 1531 and 1538 Alessandro Trasuntini harpsichords, although similar in size, are not identical and this complicates the interpretation.

However, what has gradually been distilled from several sources is the following scheme, which I present here as a drawing (*fig. 2*). It represents the string band in the case of a Venetian harpsichord. What is evident is that the string scale usually doubles at the octave only down to f_1. Since f_1 is also the string in the middle of the instrument it may have been his central datum line and had the significance for the Venetian maker which we now tend to accord to c_2 measurements. Indeed, in the 1531 and 1538 Trasuntini harpsichords f_1 at the bridge, or the apparent bridge line, is 24" from the front edge of the case, and this may have been intended as part of the working procedure.[11]

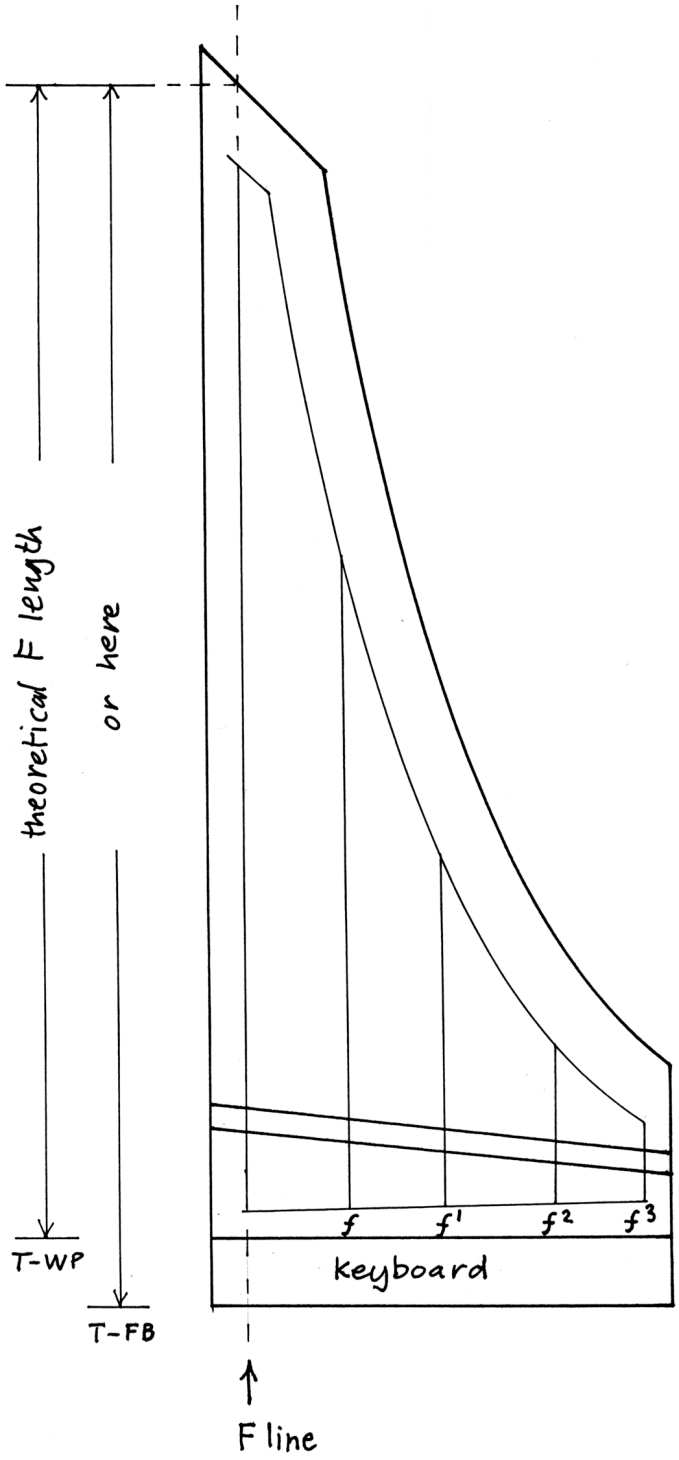
[11] This can be compared with the 49 cm rule (or 19 duimen) which Grant O'Brien found in the construction of Ruckers harpsichords. See G. O'Brien, *Ruckers: a harpsichord and virginal building tradition*, Cambridge, 1990, p. 175, adetail of which I was reminded by John Koster.

Thereafter, towards the bass we encounter the well-known problem that the harpsichord maker after starting with a scale of 9 $^1/_4$" at f_2, then using 18 $^1/_2$" at f_1 cannot double the strings at the octaves f and F otherwise he would have a string length of 74 Venetian inches, or about 2140 mm at F. Since the case lengths used did not permit a bottom C of more than about 1800 mm, roughly a whole Venetian foot shorter, it is clear that that the Pythagorean scaling, as we now call it, of doubling at each octave had to be abandoned at some point. The Venetian organ maker of course would be *obliged* to make his open-flued F pipe nominally 74" long since air does not permit otherwise.[12] In the harpsichord we just use thicker strings. This is the fundamental difference between the organ maker and the harpsichord maker in treating the bass pipe and string lengths, but there is an interesting design rule for the harpsichord maker which derives from organ building practice, or one could say, the ancient Pythagorean theory of string lengths behind all musical instrument making.

What we find in this type of Venetian harpsichord design I am considering is that the *theoretical* length of the F string of 74" is incorporated into the dimensions of the baseboard, even though the *actual* string length is shorter. Alessandro Trasuntini made the case length of the 1531 harpsichord, as measured *along* the F string line on the baseboard, 74" from the tail to the front edge of the baseboard (abbreviated as T-FB). In the 1538 harpsichord, which had slightly shorter strings, probably 9" at f_2, we find that he used 72" for the same dimension. So in either instrument we find the theoretical relationship preserved of f_2 x 8 = F, which suggests we have a design rule and not a coincidence. The 1531 Alessandro harpsichord is the second oldest Venetian instrument known, so the principle was obviously developed at least at the beginning of the 16th century, if not earlier.[13]

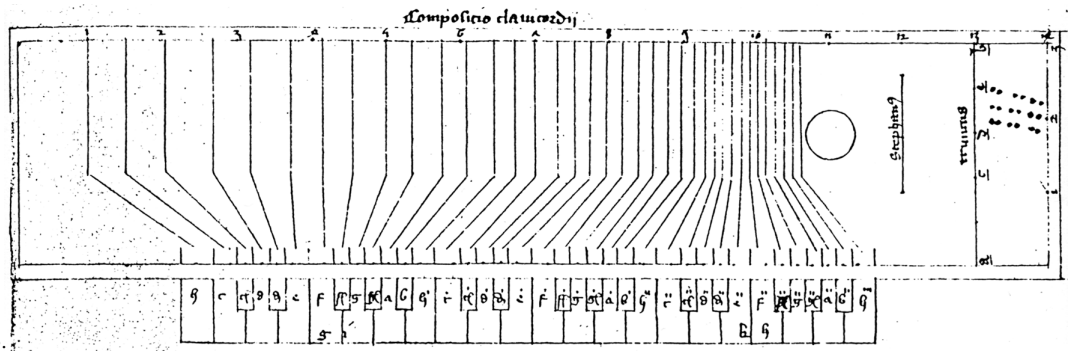
[12] I am neglecting the issue of end correction, which means that in practice organ pipes do not double exactly at the octave.

[13] The reader may wish to consult: John KOSTER, *Some Remarks on the Relationship Between Organ and Stringed-Keyboard Instrument Making*, «Early Keyboard Journal», XVIII (2000), pp. 95-137, as further background to this subject. See also my *Pythagoras and the Scale Design of Early Harpsichords in France, Germany, and Italy*, British Harpsichord Society: http://www.harpsichord.org.uk/guests/dw/wraight.htm.


theoretical F length
or here
T-WP
T-FB
f
f1
f2
f3
keyboard
F line

2.

When we recall that Arnaut de Zwolle's manuscript clavichord design of c.1440 (see *fig. 3*), showed a clear relationship between the length of the longest string and the case length of 11 modules to 14 modules,[14] it should perhaps not surprise us to find Alessandro Trasuntini's principle in a harpsichord. It shows us that the length, and thereby the essential shape of an early Italian harpsichord was determined using somewhat abstract principles so that the case length expressed a certain relationship to the pitch of the instrument.



3.

Now the implication of what I have described here for the case measurement should be clear: if only the distance of the tail to the front of the instrument was measured, then the *actual* spine length was a result of the tail angle used, and may not have been measured. Thus, an interpretation of case dimensions based on the length of the spine, as measured at the baseboard, *could* be wrong.

Until now I think it is only the entire spine length which has been considered in analyses of case layout. This has significant consequences for any type of layout analysis which attempts to incorporate the spine length, be it through modular measurement, as a proportion to other case sides, or through simple measurement with local foot measures.

What is interesting about this construction principle is that it can be used to investigate the design of other sizes of harpsichord. I have discussed until now only instruments which were of the lower-pitched variety, i.e. where the the f_2 is 9 $^1/_4$ Venetian inches (268 mm) and the

[14] The back edge of the case is divided into 14 modules. The beginning of the longest string is at module 1 and ends at module 13.

c_2 string is nominally 357 mm long, in order to translate this into values with which many will be more familar. The Venetian maker might have understood the instrument as having a 74" F, or *if* he used the *piedi organici* it would have been seen as an 8 foot instrument. Strung in iron wire, such scales would probably have stood around 400-415 Hz at a_1, although my discussion here does not take us further into this area of pitch.

One exceptionally long harpsichord is the 1579 Baffo I mentioned earlier. Although this endured changes resulting in three different keyboard compasses during its history, all the original keylevers have survived and the original compass can be seen as C/E-c_4, or if you prefer CC/EE-c_3. The scale is long and apparently 10 $^1/_2$ Venetian inches at f_2 which would yield an F length of 84" or 2432 mm; we find a length of 2436 mm from the tail to the front edge of the baseboard along the line of the F string, which is surprisingly close, and clearly conforms to the design principle.

I have been able to find six Venetian harpsichords which *clearly* show the expected theoretical F string length as a dimension on the baseboard, *along* the F string line. See Table 1 in the Appendix. In two of these instruments (Domenico da Pesaro 1570 and unsigned W112) this theoretical F string length is not from the tail to the front edge of the baseboard (abbreviated T-FB), but to the front edge of the *wrestplank* (abbreviated T-WP). This makes the instrument slightly longer than if the front edge of the baseboard had been used, in practice nearly 4 Venetian inches longer.

It might seem strange to use the wrestplank as a datum line, but if we recall the drawing of Arnaut de Zwolle's *clavisimbalum*, the length of the case (13 modules) extends only to the front edge of the wrestplank, so the player's part of the keyboard is nominally *outside* the case outline. There is also a passage in Vicentino's description of making the Archicembalo, where he speaks of the keyboard as being *fuore dell strumento*, outside the instrument, so it may have been common to think of the instrument proper as ending at the nameboard.[15] The frequent occurrence of a scribed line on the baseboard corresponding to the

[15] Nicola Vicentino, *L'Antica Musica Ridotta Alla Moderna Prattica*, Roma, 1555, ed. Edward E. Lowinsky, *Documenta Musicologica*, 1st, 17, Kassel, R/1959, fol. 100v.

front edge of the wrestplank, even where there are no baseboard markings, suggests the significance of this datum line for the maker.

It is apparent that the longer-scaled instruments used the front edge of the *baseboard* as the datum line, which tends to shorten the overall size, whereas the higher-pitched ones used the front of the *wrestplank*. Thus, the the spine lengths, which is how we normally regard the case size, are not in exact proportion to their pitches; the higher-pitched instruments are a little longer. This can also be seen as a practical way of lengthening the bass strings slightly, without making the instrument unduly long.

If we look at much shorter instruments, such as the 1543 and 1546 octave harpsichords made by Domenico da Pesaro in Table 1 then we find that the dimension along the F string is in *excess* of the theoretical length. In other words, the maker, in creating instruments smaller than the 62" to 64" F size, took advantage of the available space in order to create proportionately-longer instruments.

It seems to me that we are dealing with a construction principle (T-FB or T-WP) which was probably widely used in Venice, although the exact extent will probably not be determined. In several instruments the evidence is missing about original string lengths in order to be able to test whether they conform to the design principle. In others, such as the Domenico da Pesaro 1533, the order of magnitude is correct, but the measurable dimensions are not exact, leaving doubt as to whether the principle was followed. Two harpsichords by Vito Trasuntini are of similar size to the 74" design, but the case dimensions clearly do not correspond to the T-FB or T-WP design principle. Thus, it would not be correct to infer that this design principle was always applied in Venice, and apparently not even in the same workshop, since Vito was the business successor to Alessandro, although not actually related to him.

Another well-known instrument presents a particular puzzle. Vito Trasuntini's *clavemusicum omnitonum* of 1606 with its multiple-keys has dimensions which show that the F string line principle might have been adopted for the tail to wrestplank dimension; at least the error involved is not so large as to be implausible. However, the string length used for the *Trectacordo* (a calibrated monochord for the notes c-e_1, which was intended to set the temperament), is 532 mm, as in the

harpsichord itself. This is a curious value which is not easily expressed in Venetian inches, being neither 18 $^{1}/_{4}$ nor 18 $^{1}/_{2}$". Since the special monochord required a high degree of accuracy for its correct function, it is surprising that Vito's workshop should have been so inaccurate with the open string length, but it *could* be seen as 2 *piedi organici*. Vito is one of the few Venetian instrument makers who is known to have worked on both organs and harpschords. Alternatively, perhaps the actual string lengths at the bridges resulted from some inaccuracy in layout?

Although I have found that this theoretical F string length was laid symbolically along the line of the F string, some makers appear to have *intentionally* placed the symbolic F string length at the spine. Two harpsichords by Domenico da Pesaro, the 1570 und undated W112, made with the same compass and scale exhibit both procedures (see Table 1). A third harpsichord by Domenico (undated W437) is slightly lower pitched and uses the spine length, albeit not the *entire* spine length but only the portion from the tail to the wrestplank (abbreviated S-WP in Table 1). In this respect we again see the use of the wrestplank edge as a datum line. The Schloß Köpenick harpsichord also uses the S-WP design principle, which gives us a total of three instruments with this construction principle.[16] Domenico's 1533 harpsichord has dimensions which might also reflect this S-WP principle; the problem is of knowing exactly what scale Domenico intended. Lastly, two harpsichords by (or attributed to) Vito Trasuntino (VT 1572 and «VT 1571», see Table 1) may also have been designed with the S-WP principle. To assist the reader in understanding the possible interpretations in any instrument, I have given spine lengths as well as those from tail to wrestplank or baseboard in Table 1.

Thus, when searching for a symbolic F string length in an instrument I would not limit my search to the position of the F string, and the spine position might have been used from tail to wrestplank. One should also not neglect the possibility that the entire spine length might correspond to the symbolic F string length (i.e. T-FB at the spine).

[16] In a paper delivered on this subject at the Early Keyboard Symposium, October 2008, in Edinburgh in the Russell Collection, I had incorrectly computed the length of the F string and therefore incorrectly identified the design principle as T-WP. This error is herewith corrected.

The usual range of F string length for the design rule of T-FB or T-WP was between 84" and 62"; below 62" the maker abandoned the design principle in favour of a longer instrument. The fact that the design principle can found expressed in this range of sizes speaks for the correctness of this interpretation. With such a small sample of data, statistical methods of testing the hypothesis are hardly useful, but one must consider alternative hypotheses. Were we only to examine case sizes by means of the spine length, expressed in Venetian inches, then we would find reasonably convincing dimensions for most instruments, although the occasional half inch in the figure would seem strange. However, even after such a study we would not have *explained* how the size was chosen. This is the interesting feature of the design rule I have inferred: that it relates string scale to case size and thereby gives a coherence to the dimensions used.

I will now draw together the two topics in this essay and return to the dimension of the case width and combine this with the case length, which has just been examined. Was there any special relationship between the case width and the length, as defined by the Venetian T-FB or T-WP rule? The two instruments by Alessandro Trasuntini give an answer on this matter. As we have seen, the 1531 harpsichord was designed for an F of 74", the 1538 instrument for an F of 72". Although the case lengths were related to the scale through the T-FB rule, in both instruments the width is 26 Venetian inches. Thus, we may infer that no attempt was made to retain a proportional relationship between length and width in the harpsichord design. Furthermore, it follows that these designs are not based on modules, such as we find in Arnaut's *clavisimbalum*.

The argument has been made here not only that the case was *designed* from the «inside out», but also that the order of construction was probably such that jacks and jackslide preceded the keyboard and that only after these had been made was the baseboard laid out. With the Trasuntini case design principle of placing the theoretical F string length between the tail and front edge of the baseboard (T-FB) we have a convincing example of how the internal design of the instrument must have been known before the baseboard could be laid out. Thus, the baseboard was not the first part of the design, but a consequence of the internal parts.

To what extent the T-FB or T-WP (or S-WP) construction principle was used outside the lagoon city, on *terra firma*, is something I have not yet been able to examine in detail. All but one of the instruments described above were produced by makers resident in Venice.[17] Instruments made in Padova and Verona, cities in the Venetian Republic are often sytlistically indistinguishable from those made in venice, so we may be justified in including them as «Venetian», although it is probable that Veronese harpsichords were made using the local Veronese foot. It appears as if we can understand Cristofori's long harpsichord designs as approximating to this rule. Although Cristofori is best known as having worked in Florence, but he came from Padova in the Venetian Republic.

I think it will take much more analysis of harpsichords from different areas in Italy before we are able to be more confident about the probable construction principles for the case length. This is especially true when one is confronted with only a single instrument and one attempts to determine the area in which it was made simply by analysis of the units of measure. In any event, we must consider the possibility that the harpsichord case was not designed using the spine as one of the essential measurements, which has been the normal approach until now.

What I have presented here is the result of many years of enquiry. I did not proceed by arguing how the old makers *must* have thought and then applying this analysis to instruments. Of course Palladio used modules on his architectural drawings and Arnaut de Zwolle constructed his instrument drawings with them, but what has eventually emerged after much sifting of data is that a guiding principle was provided by the theory of string lengths: where a string would have been impractically long, its theoretical length was incorporated in the design in a symbolic fashion. Although the oldest known proponent of this principle, Alessandro Trasunini, was both organ maker and harpsi-

[17] It is not known by whom W366 was made, but the compatibility of the dimensions with the Venetian inch and the stylistic conformity with Venetian harpsichords suggests that the workshop was in Venice. Martin-Christian Schmidt (personal communication) has suggested the Trasuntini workshop for its origin. Franciscus Bonafinis had his workshop in the *sestiere* of S. Marco: see Stefano Toffolo, *Antichi strumenti veneziani*, Venezia, 1987, p. 157.

chord maker, this combination of trades is not a necessary condition for understanding and applying the principle. Firstly, the foundations can be found in the Pythagorean theory of string lengths, known since the ancients. That the old makers should have thought it worthwhile, significant, or even necessary, to incorporate the theoretical F string length as a *symbol* in an instrument reflects the difference between their age and ours. Our problem is to find our way back into an old and discarded way of thinking in order to understand the motivating ideas.

The principle described here of deriving the case length from the scale of the instrument will provide an interesting impetus to reconsider the methods of working by which Italian instrument makers laid out their instruments.

SUMMARY

Two dimensions in a harpsichord which define the essential shape are the width and length of the instrument. 16th-century Venetian harpsichord makers occasionally left construction marks on the baseboards of their instruments, which show us some of their design procedure. The width of the keyboard was measured in Venetian inches (1" = 28.98 mm) and allowance made for keyblocks either side. Thus, the case width was determined from these two components, which occasionally varied so that instruments by the same maker with the same compass sometimes had different widths. Lines for the f strings were marked on the baseboard, possibly using the jackslide intended for the instrument. From these string lines the bridge position was found and the bentside curve determined.

Whereas the organ maker is obliged by the Laws of Physics to give pipes a length in proportion to their pitch, the Venetian harpsichord maker designed the bass string at F to be almost a foot shorter than its full length. The length of the instrument has been found to be related to the theoretical length of the F string, which was previously unknown. In six Venetian harpsichords the theoretical F length was used to define the length of the baseboard, either from the tail to the front edge of the baseboard, or, in shorter (higher-pitched) instruments to the front edge of the wrestplank. This procedure gave the theoretical F string length a significant but symbolic position in the design. Two of the oldest harpsichords from 1531 and 1538 by Alessandro Trasuntini, who was both organ builder and harpsichord maker, demonstrate this procedure. Case width and case length were not related to each other by a proportional (or modular) proce-

dure, rather each dimension was determined by the particular method described. Thus, case design was determined by a mixture of practical and symbolic design procedures, but which also respected the ancient theoretical teaching that string lengths would be proportional to pitch.

Riassunto

Due sono le dimensioni che definiscono la forma di un cembalo: larghezza e lunghezza. I cembalari veneziani del '500 talvolta hanno lasciato i segni di tracciature di costruzione sul fondo dello strumento: ciò ci permette di capire, almeno in parte, i loro principî progettuali. La larghezza della tastiera era misurata in pollici (*onze*) di Venezia (1 *onza* = 28,98 mm) alla quale andava aggiunta la larghezza dei blocchetti laterali. In questo modo la larghezza della cassa derivava da tali componenti, che a volte potevano anche variare, per cui, strumenti dello stesso costruttore e aventi lo stesso ambito, risultavano, alle volte, di larghezza diversa. Linee rappresentanti le corde della nota Fa (nelle varie ottave) venivano segnate sul fondo della cassa, forse facendo uso della guida dei saltarelli destinata allo strumento. Da queste linee, che rappresentavano le corde, veniva stabilita la posizione del ponticello e, quindi, determinato il contorno della banda (o fascia) curva.

Mentre l' organaro è obbligato dalle leggi della fisica a stabilire la lunghezza delle canne in funzione della frequenza del suono che dovranno produrre, il cembalaro veneziano stabiliva che la lunghezza della corda del Fa grave fosse di quasi un piede (c. 347.7 mm) più corta della lunghezza teorica. Si è così scoperto che la lunghezza dello strumento è correlata alla lunghezza teorica della corda del Fa grave, fatto finora sconosciuto. In sei cembali veneziani la lunghezza teorica della corda del Fa grave fu usata per stabilire la lunghezza del fondo, dalla coda al lato anteriore del fondo o, in strumenti più corti (a corista più acuto), al lato frontale del somiere. Tale procedimento conferiva alla lunghezza della corda del Fa grave un ruolo significativo, ma anche simbolico, nella progettazione dello strumento. Due tra i più antichi cembali esistenti, uno del 1531, e l'altro del 1538, entrambi dell'organaro e cembalaro Alessandro Trasuntini, illustrano il ricorso a tale prassi progettuale. La larghezza della cassa e la sua lunghezza non erano vincolate tra loro da un sistema proporzionale (o modulare): tali dimensioni erano invece stabilite secondo il metodo sopra descritto, un incrocio tra riferimenti pratici e simbolici che, tuttavia, rispettava l'antico insegnamento teorico secondo cui la lunghezza vibrante delle corde era legata in maniera proporzionale al corista.

(*traduzione:* Riccardo Pergolis)

APPENDIX

Table 1. A list of Venetian harpsichords (measures in mm).

Instrument	Spine	= VE"	S-WP	= VE"	T-WP	= VE"	T-FB	= VE"	Inferred F in VE"
AT 1531	2208	76 1/4 (+ 5.5)			2035	70 1/4 (- 0.8)	2149	**74** (+ 4.5)	74
AT 1538	2117	73 (+ 1.5)	2003	69 (+ 3.4)	1969	68 (- 1.6)	2083	**72** (- 3.6)	71-72[18]
DP 1543	1132	39 (+1.7)			997	34 1/2 (- 2.9)	1108	38 (+ 6.7)	32-32 1/2
DP 1546	1146	39 1/2 (+ 1.1)			1009	34 3/4 (+ 1.7)	1132	39 (+ 1.7)	
DP 1554	1791	61 3/4 (-1.4)	1676	57 3/4 (+ 2.3)	1657	**57** (+ 5)	1772	61 (+ 4)	56.5-58[19]
DP 1533	1823	63 (- 2.9)	1712	59 (+ 2)	1674	57 3/4	1785	61 1/2 (+ 2.6)	62-63[20]
DP 1570	1896	65 1/2 (- 2.3)	1791	**62** (- 5.7)	1740	60 (+ 1.2)	1845	63 1/2" - 63 3/4 (+ 4.6) - (- 2.6)	62[21]
DP W112	1916	66 (+3.2)	1813	62 1/2 (+ 1.7)	1799	**62** (+ 2.3)	1902	65 1/2 (+3.8)	62[22]
DP W437	1962	67 3/4 (- 1.4)	1858	**64** (+ 3.2)	1839	63 1/2 (- 1.2)	1943	67 (+1.4)	64-65[23]
W40 Bonafinis[24]	2189	75 1/2 (+ 1.1)	2063	71 1/4 (+ 1.8)	2035	70 1/4	2153	74 1/4 - **74** (+ 1.3) - (+ 8.5)	74
VT 1572 W458	2231	77	2108	72 3/4	2083	72 (- 3.6)	2206	76 (+ 3.5)	74[25]
«VT 1571» W269[26]	2236	77 (+ 4.5)	2116	73	2069	71 1/2 (- 3)	2194	75 3/4 (+ 1.2)	74[27]
VT 1606	2377	82	2215	76 1/2 (- 1.9)	2160	74 1/2	2326	80 1/4	74[28] (for C)
W366	2078	71 3/4" (- 1.3)	1971	**68**	1853	64 (- 1.7)	2029	70	68
1579 Baffo	2462	85 (- 1.3)	2339	80 3/4 (- 1)	2313	80 (- 5.4)	2436	**84** (+ 1.7)	84

Explanation of the table:

Spine mm: the length of the baseboard measured from the tail to the front. N.B. This does not include the case side, which is glued to the baseboard, i.e. it is an internal measurement.
= VE»: previous column expressed in mm is equivalent to Venetian inches. When the actual length is 1mm or more divergent from the theoretical length in Venetian inches, then the divergence is expressed. E.g. the T-FB length for AT 1531 is 2149. 74 venetian inches is theoretically 2144.5 mm, so the difference is + 4.5mm, i.e. the actual measurement is 4.5mm more than the theoretical length.
S-WP: spine to wrestplank (front edge) length
T-WP: tail to wrestplank (front edge) length
T-FB: tail to front edge of baseboard length
Inferred F in VE: The length of the theoretical F string length inferred from the harpsichord string lengths, or baseboard markings, expressed in Venetian inches. 1» VE = 28.98 mm (see note 4 in text).

[18] Although the bridge is original and unmoved, the exact position of the original nut is only known within a few mm. The best estimate for f_2 (8') is 256.5 mm, which implies 8 $^7/_8$" or 71" at F. Since the 8' scale below f is shortened it is not possible to use other string lengths below f_2 to confirm the f_2 length. If 9" (= 261 mm) was the intended f_2 length then an error of about 4,5 mm resulted in the actual string length, which is not implausible.

[19] f_1 is 411 mm implying 14 $^1/_8$" and an F of 56.5". f_2 is 209 mm implying 7 $^1/_4$" and an F of 57".

[20] The original scales were as follows: f_3 = 118.5 mm, f_2 = 225.5 mm, f_1 = 439 mm, f = 846 mm, F = 1519.

[21] The actual scales of f_3 = 112 mm, f_2 = 231 mm, f_1 = 453 mm and f = 899 suggest that F = 62" (F = 1797 mm, f_2 = 225 mm) was intended. The actual F is 1625 mm = 56" (+ 2), which is longer than the F in W112, even though DP 1570 has a shorter case.

[22] The actual scales of f_3 = 113 mm, f_2 = 230 mm, f_1 = 448 mm and f = 883 suggest that F = 62" (F = 1797 mm, f_2 = 225 mm) was intended. The actual F is 1605 mm (±5 mm).

[23] On no account could the theoretical F-scale be longer than 66". Although the f_1-f_2 scales vary slightly in the 8' and 4', they suggest that 64-65" could have been the intended theoretical value: f_2 (8') = 239 mm, f_1 (8') = 467 mm, f (8') = 893, f_1 (4') = 236 mm.

[24] This instrument is better known under the faked inscription which it now carries to ALEXANDER BORTOLOTTI and the date 1585. Under this inscription is an earlier one to Franciscus Bonafinis, as discovered by William Thomas and John Rhodes and communicated to me when I examined the instrument.

[25] The f_2 is clearly defined at 268 mm and confirmed in this order of magnitude by the f_3 (135 mm) and f_1 of the 4' (266 mm). This leads to a theoretical F of 74", but this dimension is not found in the case. Curiously we do find a length of 72" for the T-WP, which was the dimension used in the Trasuntini workshop in 1538, although the 72" there was used for the T-FB length. Whatever the intention, it is clear that this design (W458) uses slightly longer strings than the

Instruments listed

AT 1531: Alessandro Trasuntini, Royal College of Music, London.
AT1538: Alessandro Trasuntini, Musée Instrumental de Bruxelles.
DP 1543: Domenico da Pesaro, Musée de la Musique, Paris.
DP 1546: Domenico da Pesaro, Gesellschaft der Musikfreunde, Vienna.
DP 1554: Domenico da Pesaro, Musée de la Musique, Paris.
DP1533: Domenico da Pesaro, Musikinstrumentenmuseum, University of Leipzig.
DP 1570: Domenico da Pesaro, Private ownership.
DP W112: Domenico da Pesaro, Musée Instrumental de Bruxelles.
DP W437: Domenico da Pesaro, Stiftelsen Musikkulturens Främjande, Stockholm.
W40 Bonafinis: Franciscus Bonafinis, Musée Instrumental de Bruxelles.
VT 1572, W458, Vito Trasuntini, Private ownership.
«VT 1571», W269, Vito Trasuntini, Castello Sforzesco, Milan.
VT 1606, Vito Trasuntini, Museo Civico, Bologna.
W366, Kunst und Gewerbemuseum, Schloß Köpenick, Berlin.
1579 Baffo, Giovanni Baffo, Musée de la Musique, Paris.

Divergences of the actual lengths from the theoretical length have been expressed in brackets inthis table in order to indicate what error is involved (as explained under = VE» above). To put matters in perspective, the width of the 1531 Trasuntini harpsichord baseboard is 758 mm, which is nominally 26 Venetian inches, but the exact value would be 753.5 mm, i.e. an error of +4.5 mm. Thus, lengths of about 62-74 Venetian inches might be expected to have *at least* this amount of error. The 1538 Trasuntini harpsichord measures 754 mm and is therefore without significant error. Only comparison with actual practice will show what we should expect to find.

The design rule which I have interpreted, as expressed in Venetian inches, has been shown in bold type, e.g. 74 inches for AT 1531.

earlier Trasuntini instruments in the bass.

[26] There is some doubt as to whether this instrument is from Vito's workshop since the inscription may have been altered if not faked. See my thesis, part 2, p. 300. However, the design is similar to 1572: see next note.

[27] The «VT 1571» is apparently the same design as the VT 1572 since the dimensions are so close. The S-WP dimension at 73" is very close to the observed f string lengths so that one cannot exclude the possibility that an F of 73" was intended, i.e. f_2 = 264 mm, which would then make these S-WP designs.

[28] The 74 inches is for the note C, as a hypothesis, this being 8x the c_2 value since the instrument has the range C-c_3. In this chromatic design the F strings is more than the usual distance from the case side than in the C/E- short octaves, which are otherwise involved in the instruments considered here.