Harpsichord tuning
Course outline

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1. A harpsichord, like all other stringed instruments, has to be tuned now and then. It goes out of tune mainly because of changes in humidity, which cause swelling or shrinking of the wood, especially the soundboard. In a new instrument, stretching strings and wood that is not yet „worked out" have their effect.
Every harpsichordist should know how to tune his instrument, not only because it is so frequently necessary, but also because of the importance of different tuning systems for music of different styles and periods (see 9). Tuning has long been part of a harpsichordist's study; teaching methods of the seventeenth and eighteenth centuries usually contain a scheme for tuning.

The tuning process can be divided into two parts:

— determination of the size of all the intervals within one octave, called „setting the temperament" (the various ways of doing this are the most important subject of this course);
— using the „tempered" octave as a basis, the tuning of the rest of the register, chromaticly and in parallel octaves. Other registers can now be easily tuned, note for note, to the first. The real difficulty is in setting the temperament.

2. The present „standard pitch" is a' = 440 Hz. One can start setting a temperament by taking this tone from a tuning fork. In the baroque period, instruments were often about a half-tone lower, but in this and earlier periods there was no clearly defined diapaison (see 11).
It is wise to keep an instrument at one pitch, because of the time it takes an instrument to adapt to a new tension. Several tunings are necessary to stabilize it at a new pitch.

3. Hints for a stable tuning-job:

— keep a harpsichord away from drafts and direct sunlight;
— hold a tuning hammer loosely, overhand (with a gooseneck hammer, the thumb close to the tuning pins). Support the elbow, avoid leaning on the hammer; the pin should be turned, not bent;

- turn the pin as little as possible, not wildly back and forth; listen carefully as you turn the pin.
- keep the instrument well in tune.

4. The tuning process, step by step:

- remove music desk and jackrail for good visibility;
- disengage all registers, and see that every quill passes its string noiselessly;
- engage front 8';
- take the „A" below middle C from tuning fork;
- set your temperament within one octave;
- tune the rest of the register in parallel pure octaves;
- add the back 8' and tune pure unisons with the front 8';
- disengage back 8', engage 4', tune pure octaves to front 8';
- check your work by playing octaves in both hands throughout the keyboard, all registers engaged; the multiple octaves and unisons should be pure.

5. Before embarking on the subject of temperament, we should discuss the method of tuning two notes to each other, whereby use is made of the apperance of *beats* in an impure interval.

If an interval is close to being pure, one can hear a periodic waxing and waning of the combined sound. This is a result of the sound waves of two different frequencies passing in and out of phase with each other; the sound is alternately strengthened by the synchronized waves, and weakened by waves whose crests arrive at different moments.

You can observe this phenomenon by playing, for example, the octave a-a' on a single 8' register; if the octave is pure, you will hear a single

straight tone. Tune the a' sligthly lower, and you will still hear one pitch, but with beats. The lower you tune the a', the faster the beats will become. Eventually you will recognize two distinct pitches. As you tune the a' upwards again, the beats become gradually slower, until they stop. At this point the octave is pure. Tune higher, and the beats will slowly begin again.

So we see that there is one point only where the pure octave is heard; the farther from this point we go, the faster the beats come.

In setting a temperament we often must tune impure fifths, fourths, and thirds. Two things must be taken into account in doing this: the degree of impurity, which, as we just saw, is reflected in the speed of the beats; and whether the interval is to be wider or narrower than the pure interval.

This technique of listening to and manipulating beats can only be mastered with practice; once you understand it, however, tuning is no longer a problem.

When tuning a unison, the beats are generated by the fundamentals of the two tones; in an octave, by the fundamental of the higher pitch and the first harmonic of the lower; in a fifth, by the second and third harmonic respectively; in a fourth, by the third and fourth harmonic; and in a third, by the fourth and fifth harmonic. The „tempo" of the beats represents the difference in frequency (number of waves per second) between the pitches generating the beats.

For this reason, an interval with a given degree of impurity will beat faster, the higher in range it is tuned; the beats will double in speed with each octave transposition.

6. SETTING THE TEMPERAMENT

The problem we meet in setting a temperament is: the impossibility of tuning all intervals in our twelve-tone octave pure. (Keyboards with „extra" keys in the octave have never provided a widely-accepted resolution of this dilemma, and will not be considered here.)

This may seem strange at first, but it can be proven with a little arithmetic.

An interval can be expressed as the ratio of the frequencies of the two pitches.

For a note to its octave, this ratio is 1 : 2
to its fifth, 2 : 3
to its fourth, 3 : 4
to its third, 4 : 5, etc

Three consecutive major thirds give, therefore, an interval ratio 5/4 x 5/4 x 5/4 = 125/64. This interval is smaller than an octave (2/1 = 128/64) by an interval with ratio 128/125 (about 2/5 of a half-tone!), called a *diësis*.

Four consecutive fifths give an interval ratio $(3/2)^4$ = 81/16. Two octaves and a major third, however, result only in 2 x 2 x 5/4 = 20/4 = 80/16. The interval of the difference (81/80) is called a *syntonic comma*.

Twelve consecutive fifths: $(3/2)^{12}$ form an interval somewhat wider than seven octaves, 2^7. The interval of the difference is called a *Pythagorean comma*.

Work out these formulas on your harpsichord; hearing a real live diësis or comma gives a special insight into the subject.

7. FOR THE SAKE OF SIMPLICITY, WE WILL CONSIDER THESE TWO COMMAS AS ONE AND THE SAME, AND A DIESIS BEING EQUAL TO TWO COMMAS.

8. There being thus no way of tuning all the intervals pure, we can exclude the possibility of a „pure" temperament. All temperaments are compromises, and the Latin „temperamentum" means, in fact, „the proper balance in a mixture".

This compromise can be reached in an infinite number of ways, and quite a number of them have been tried through the ages. We will consider a number of „textbook cases".

The octave has always been tuned pure. Our arithmetic showed that pure fifths are too large to come out to a pure octave, and pure major thirds much too small. Moreover, pure fifths and thirds make op-

posing demands on a temperament: pure fifths give very wide thirds, and pure thirds result in narrow fifths.

A clear comparison of various temperaments can be gotten by showing the size of the twelve consecutive fifths of each system; from such a „circle of fifths" one can also deduce the size of the thirds (see 10).

In the middle ages these fifths were kept pure, and the thirds suffered: Pythagorean temperament (see 13). Renaissance polyphony brought a desire for better thirds. „Meantone temperament", first used around the beginning of the sixteenth century, used a maximum number of pure thirds, at the expense of the fifths, of course.

A player could not modulate freely, however, and musicians of the Baroque period found this an unacceptable limitation. The resulting tampering with intervals, which might have gone on endlessly, has left us with a large number of „temperaments" from that time. They mostly boil down to an allotment of the best thirds to the keys with the fewest accidentals, and gave rise to the phenomenon that each key had its special character. Later, the keys lost their personality again with the oncoming of so-called „equal temperament", the system still in general use, whereby all fifths are equally narrowed, and all major thirds equally widened.

9. Temperament is a factor to be considered in interpreting a piece of music - a tool for the creation of harmonic and melodic tensions that was often, if not always, used by composers before the acceptance of „equal temperament". The decision which temperament to use for a given piece cannot always be made with certainty. Generally speaking, one could assume Pythagorean temperament for medieval music, meantone for Renaissance music. During the seventeenth century, modified meantone systems were used (see 16). At the end of that century in Germany, Baroque temperaments came into use; a good example is Werckmeister III (see 17). At about the same time we find similar temperaments in Italian sources (see 18). Incidentally, meantone temperament did service long after it had fallen from general use. There are clear indications of its practical application in Italy, Spain, Portugal, and also in England until around 1900!

Equal temperament is a very old idea, but it was not the generally accepted keyboard temperament until about 1800 in Germany; in England and France not until some decades later, and in Spain probably still later. Since 1900 it has been in general use.

10. To give a quick idea how a temperament is organized, one can indicate by means of a „circle of fifths" the size of all the fifths (see diagrams). For example, — 1/4 means that the fifth concerned is tuned one-quarter comma narrower than pure. To keep the octaves pure, the twelve fifths will have to be „corrected" a total of — 1 comma. One can also read the major thirds from such a table, as they are determined by four consecutive fifth-tunings (minus two octaves, which are not considered). (See 6)
If these four fifths are tempered a total of — 1 comma, then the third is pure. If the fifths are pure, as indicated by 0, then the third is one comma wider than pure.
For a number of tuning systems we have given a table of thirds; this is a good way of comparing temperaments.
Minor thirds can also be deduced from the circle of fifths, since a pure fifth is composed of a pure minor third and a pure major third.
In this way we can conclude, for example, that meantone minor thirds are one whole comma narrower than pure.

11. To set a temperament, we now need a tuning scheme, made up again from the circle of fifths. The „corrections" in commas are here translated into a beat-„tempo" for the interval concerned. Tuning schemes for various temperaments are given below.

- Begin by taking the given a from the tuning fork. Hold it between your teeth, as you need both hands free. The pitch you use is of no influence on the temperament, or relationships among the tones of the octave. The term „old tuning" is often misused by people referring to the use of a pitch other than a' = 440 in an equally-tempered instrument.
- From here, tune the lower fifth (d); then the upper fourth of the d, and so forth, following a descending circle of fifths. Each note is first tuned to the pure interval, then raised until the beats reach the indicated tempo. „O" indicates the pure interval.
- Notes already tuned are notated black.
- The numbers indicate, unless otherwise noted, the number of beats per minute. If you don't trust your guess for this „tempo", use a metronome. Save the trouble of attempting a precise realization of the numbers; you will not succeed, and an approximation is satisfactory. A good routine gives the best results. If a metronome is unavailable, base your estimates on your pulse (70 - 75) or, for quick tempi for thirds, on a wristwatch (5 per second).
- If you have difficulty tuning fourths, tune them in two steps: first a (pure) upper octave, then a lower fifth, tempered to the same beat-tempo as indicated for the fourth.
- Be sure to set the temperament in the octave indicated, as the beat-tempi depend on the pitch.
- To keep you from carrying an early mistake through to the end and ruining the job, there are checkpoints after every four fifths, where the last fifth is checked against a major third. Tempered thirds sometimes beat so fast that their tempo must be indicated in beats-per-second, instead of per minute, as with fifths. If the check-third is unsatisfactory, begin again at the last checkpoint. The checkpoints are indicated by two black notes.

It is obvious that the same results can be reached following different schemes, and those given here are just examples.

12. A few more guidelines:
- Learning to hear beats takes practice — even the best musical ears have difficulty with it at first.
- It may help sometimes to use a rolled-up sheet of paper as an ear-trumpet.
- Often you will hear more than one beat-system in a single interval. Listen to the slowest; the others are caused by higher harmonics.

- Sometimes a string has its own „vibrato", which makes tuning difficult. Usually, the best remedy is a new string of the proper guage, but with practice you can distinguish the beats from the false string from those generated by two strings sounding together.
- A third, softly-sounding string can also annoy in the same way. Move the offending quill farther from the string.
- An experienced tuner uses more checkpoints than we have indicated in our schemes, but to have included them might have clouded the picture. If we have succeded in giving real insight into tuning, you will discover them yourself.
- Don't feel obliged to stay faithful to the textbook-temperaments given here. This is good in the beginning, but later a certain piece may require a little liberty-taking. Certainly harpsichord tuners have done it in ages past.

13. Pythagorean temperament.
This tuning demands the largest possible number of pure fifths: eleven. Begin at a and tune pure fifths a-d, d-g, and so forth to e-flat; begin again at a and tune pure fifths a-e, e-b, and so forth to g-sharp. The remaining „fifth" g-sharp - e-flat is a comma narrower than pure (see 6), and is called the „wolf" because it is so howlingly false.
The thirds are very poor, a comma too wide (see 6).
This tuning was very probably in general use for keyboard instruments until the end of the sixteenth century.

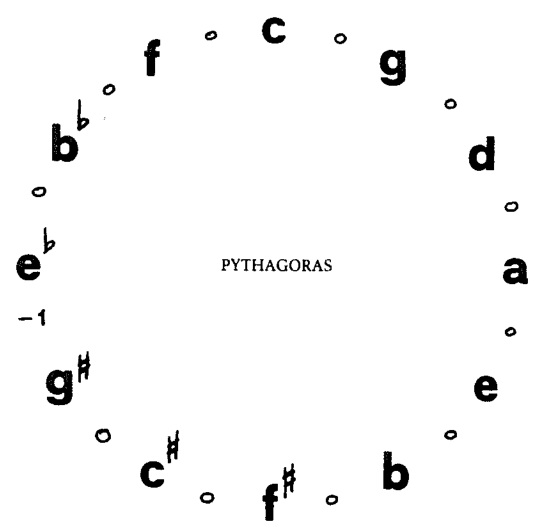

fig. 1

14. Pythagorean temperament does produce four pure major thirds (b - d-sharp, f-sharp - a-sharp, d-flat - f, and a-flat - c), but they were virtually never used. ARNOUT van ZWOLLE (± 1400 - 1466) suggests an interesting variant: he makes the fifth b - f-sharp the wolf, clearly to enable the use of the four pure thirds that are thus moved to d, a, e and b. Even the useful major triads on d, a and e are completely pure.

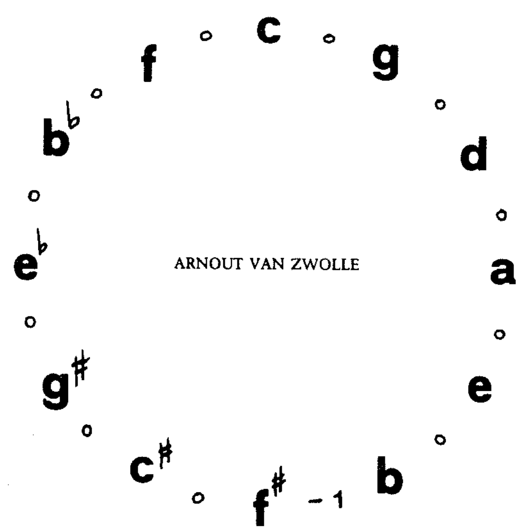

fig. 2

15. Meantone.
Here the thirds, and not the fifths, are tuned pure. The fifths are narrowed 1/4 comma (see 6).
Of all the systems we are considering, this one sounds best on the harpsichord.

Because eleven fifths are narrowed 1/4 comma, the circle cannot be closed; the last „fifth" would be one and three-quarters comma to wide! This makes enharmonization impossible. The accidentals are tuned c-sharp, e-flat, f-sharp, g-sharp, and b-flat, and keys with more than three accidentals are therefore unusable.
If the need arises, the g-sharp can be retuned to a-flat (major third below c), and the e-flat retuned to d-sharp (major third above b). Instruments have also been built with keyboards where these two accidentals, which are usually the troublemakers, were split in two and each part provided with its own string, making both notes available.

Begin by tuning the fifths a-d, d-g, g-c, and c-f just narrow enough (all narrowed to the same degree) to form a pure major third f-a. Using these notes, tune further in pure major thirds, using fifths as checkpoints.
In transposing the temperament to the other octaves, you can avoid minor deviations (especially in higher ranges) by constantly checking the purity of the thirds.
All the whole tones are equal: precisely half a major third, hence the name meantone. The half-tones, however, are anything but equal, which can create special effects, especially in chromatic passages.

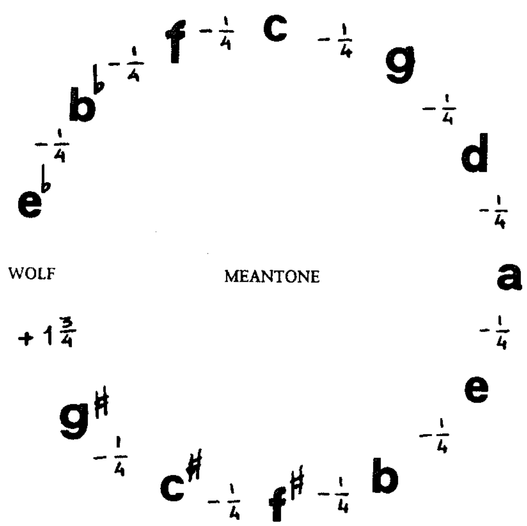

fig. 3

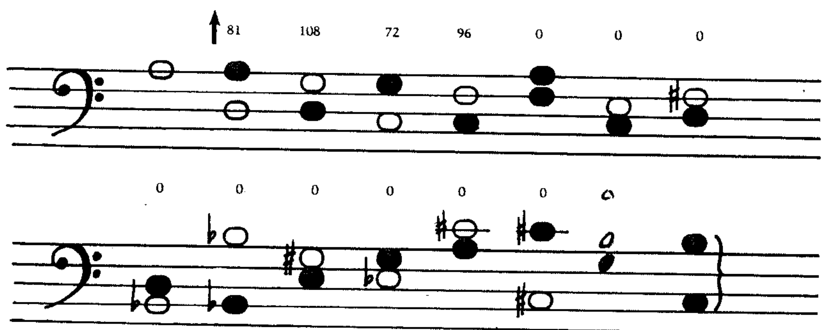

fig. 4

16. It is hard to say when and where meantone temperament was in use.

Tuning instructions from the period are usally vague and sometimes even contradictory. It was, naturally, a question of gradual development and co-existence of many systems and variants. For example, the fifths were sometimes narrowed somewhat less than was necessary for completely pure thirds. Schlick (Spiegel der Orgelmacher und Organisten, Mainz 1511) gives a system with 10 fifths tuned one-sixth comma narrower than pure, resulting in thirds that are one-third comma wider than pure. He accepts the remaining two wide fifths, and arrives thus at a closed system wherein all keys are more or less usable.

Lanfranco (Scintille di Musica, Brescia 1533) suggests, somewhat unclearly, a one-fifth comma meantone temperament. The major thirds become one-fifth comma wider than pure (giving the same deviation from pure for both fifths and thirds), and the wolf is reduced to 6/5 comma.

Descriptions of 2/9 comma and 2/7 comma systems are given by Zarlino (Istitutioni harmoniche, Venice 1588) and others, but he also says, „There is another way of tuning which sounds much better", and goes on to describe the usual 1/4 comma meantone temperament.

He calls it a new system, but Aaron (Toscanello in Musica, 1523) had already given a tuning scheme, albeit not unambiguously, that matches the 1/4 comma meantone system. „New" may mean: „another one".

Praetorius (Syntagma Musicum, 1619) offers it as his only suggestion. There are many other such indications that meantone temperament was very widely used around 1600. Galilei (Dialogo della Musica, ± 1581) asks why harpsichords were tuned in meantone and not equally tempered, as were lutes and related instruments. He thinks the reason is probably that the sharp thirds are more irritating on the harpsichord.

Mersenne (Harmonie Universelle, Paris 1636) also gives the 1/4 comma meantone system (probably misinterpreted by Barbour).

It is easy to find examples of music around 1600 that crosses the bounds of meantone tuning. Byrd and Bull (ut re mi fa sol) which goes as far as c-flat to d-sharp; Sweelinck (chromatic fantasy) e-flat to d-sharp. Frescobaldi often uses c-sharp and d-flat, d-sharp and e-flat, a-sharp and b-flat in one piece.

Possible explinations are:

— instrument with divided accidentals (see 15)

— intentional use of the harsh dissonant

— the use of a variant of meantone temperament.

Many attempts were made at a closed-system meantone temperament by narrowing the wolf and thereby making all keys available. Silbermann, for example, gives a one-sixth comma system, with a wolf five-sixths comma wider than a pure fifth. He also suggests a variant whereby the e-flat is lowered still further to function better as d-sharp (see schemes).

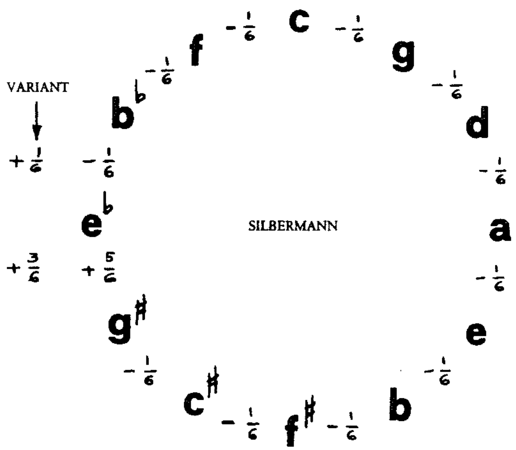

fig. 5

	$d^\flat$	$1\frac{1}{3}$	f	$\frac{1}{3}$	a	$\frac{1}{3}$	$c^\sharp$
	$a^\flat$	$1\frac{1}{3}$	c	$\frac{1}{3}$	e	$\frac{1}{3}$	$g^\sharp$
var.	$e^\flat$	$\frac{1/3}{2/3}$	g	$\frac{1}{3}$	b	$\frac{1\frac{1}{3}}{1}$	$d^\sharp$
	$b^\flat$	$\frac{1}{3}$	d	$\frac{1}{3}$	$f^\sharp$	$1\frac{1}{3}$	$a^\sharp$

fig. 6

Rameau modifies the $\frac{1}{4}$ comma meantone temperament with three pure fifths and two fifths one-third comma too wide, which results in the almost complete disappearance of the wolf (see schemes).
We can assume that meantone temperament was still being applied at much later periods, contemporaneously with other systems. Asioli (Osservagioni sul Temperamento, Milan 1866) writes that the organ builders of his day tuned mostly meantone, and William Pole (The Philosophy of Music, 1879) calls the „modern" equal temperament greatly inferior to the „old" (meantone) tuning.

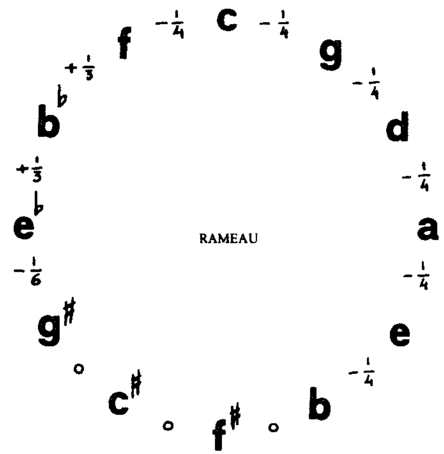

fig. 7

$d^\flat$	$1\frac{1}{2}$	f	0	a	$\frac{1}{2}$	$c^\sharp$
$a^\flat$	$1\frac{1}{4}$	c	0	e	$\frac{3}{4}$	$g^\sharp$
$e^\flat$	$1\frac{1}{6}$	g	0	b	$\frac{5}{6}$	$d^\sharp$
$b^\flat$	$\frac{7}{12}$	d	$\frac{1}{4}$	$f^\sharp$	$1\frac{1}{6}$	$a^\sharp$

fig. 8

17. Baroque temperaments.

The attempts to keep the beautiful meantone thirds on one hand and still have all the keys available on the other, led in a natural way to hybrid Pythagorean-meantone temperaments. An obvious way to begin was to tune 4 „meantone" fifths, 1/4 comma narrow, so that the rest could remain pure and there was no wolf. The „meantone" thirds were good, the „Pythagorean" ones, of course, a comma wide. In between are compromise thirds.

Andreas Werckmeister gave in 1691 a number of such temperaments, of which number three the best, and the best-known is. The meantone fifths are here tuned at c-g, g-d, d-a, and b - f-sharp. The rest of the fifths are pure (see scheme). As can also be read from the scheme, the thirds vary from very good to Pythagorean (see table). This is a characteristic of Baroque temperaments and gives rise to the different „qualities" of the keys.

In general, the keys with few accidentals get the best thirds and therefore sound „natural, perfect, agreeable". Slightly wider thirds give a „sparkling" sound (G, D, B-flat). Still wider thirds are characterized by contemporaries as „smarting, cutting", while keys with Pythagorean thirds sound „raw and brutal" (f minor, 2 major). See, among others, Mattheson, Neu Eröffnetes Orkester, 1713.

This kind of temperament, with which it was possible (unlike with meantone) to play in all the keys, was called „wohl temperirt". It is highly probable that Bach wrote his famous work of that name for such a tuning, with a purpose to demonstrate the characteristics of the keys.

Temperament was thus a tool of the composers of the period; to disregard it is to impoverish their music.

Setting the temperament Werckmeister III is very simple, as only four impure fifths are involved. The cunning placement of the fourth tempered fifth (b - f-sharp) assures the occurence of Pythagorean major thirds only in keys in which, accordi[illegible] Werckmeister, „the ordinary organist can't play anyway."

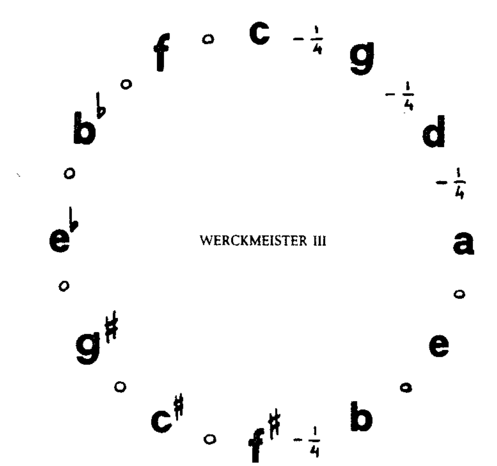

fig. 9

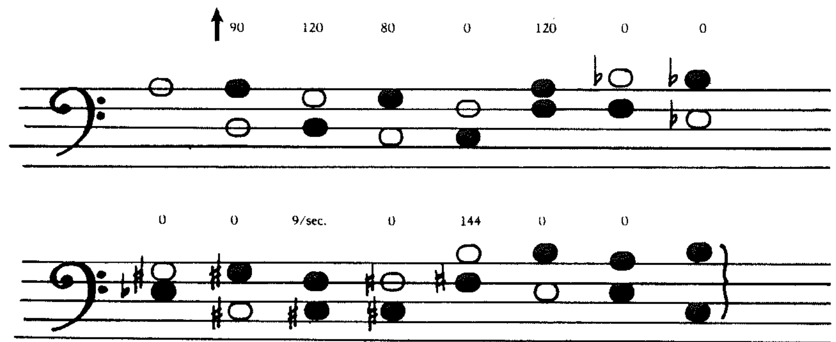

fig. 10

d♭	1	f	¼	a	¾	c#	
a♭	1	c	¼	e	¾	g#	
e♭	¾	g	½	b	¾	d#	
b♭	½	d	½	f#	1	a#	

fig. 11

We give below a few more Werckmeister temperaments. Also later in the 18 th century, especially in Germany, many different temperaments were published and passionately defended. They vary from the very simple to the complex, but always give the best thirds to the keys with the fewest accidentals.
Among the best known in this field are Neidhardt and Marpurg.

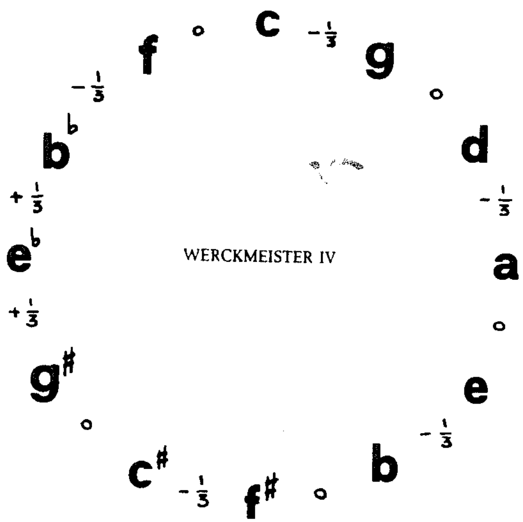

fig. 12

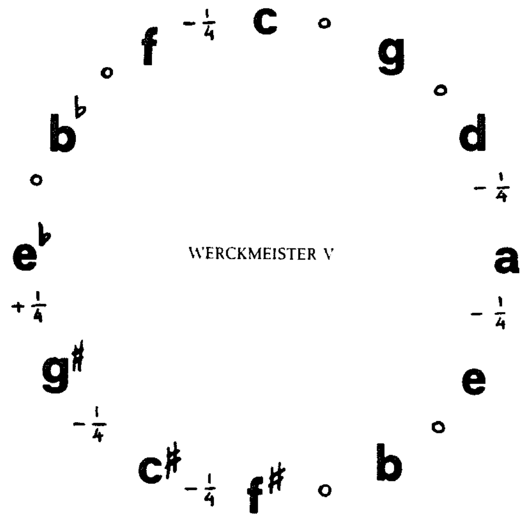

fig. 13

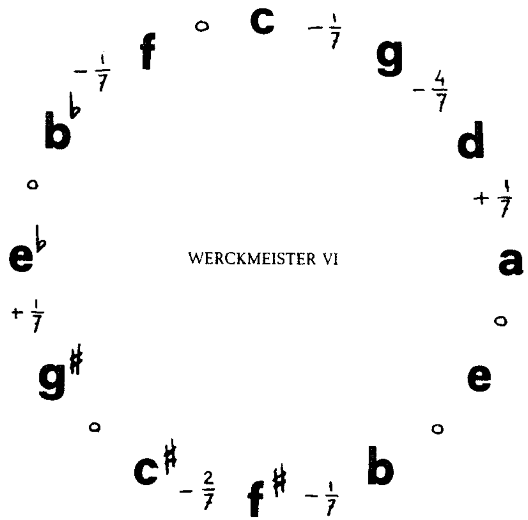

fig. 14

18. Kirnberger published another easy-to-set temperament (Die Kunst des reinen Satzes, Berlin 1779), (see scheme Kirnberger II). Almost all fifths are tuned pure, and the comma is divided between the fifths d-a and a-e. The thirds c-e, g-b, and d - f-sharp are pure. But fifths narrowed 1/2 comma proved more than the Baroque ear could bear, and Kirnberger later offered a „corrected" temperament with the comma divided over four fifths (see scheme Kirnberger III). Kirnberger was a pupil of Bach's, and this has been called THE Bach-temperament on those grounds.

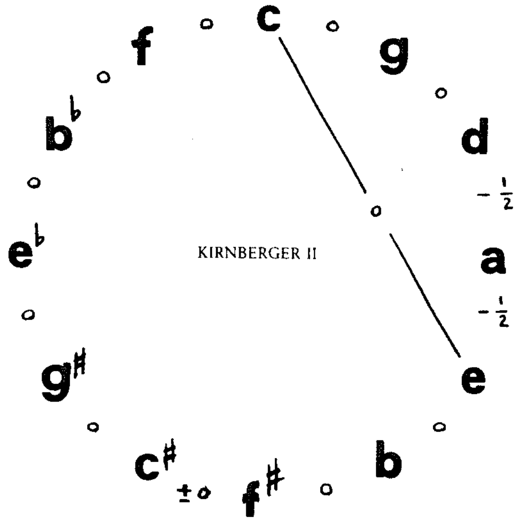

fig. 15

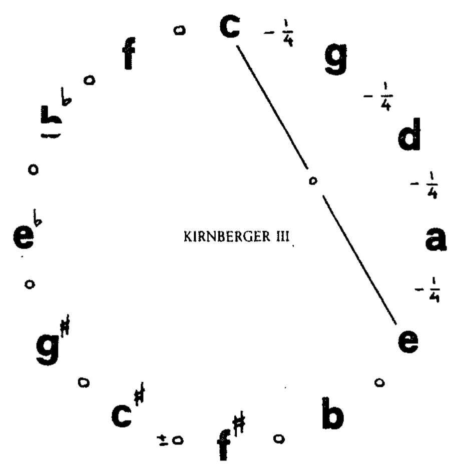

fig. 16

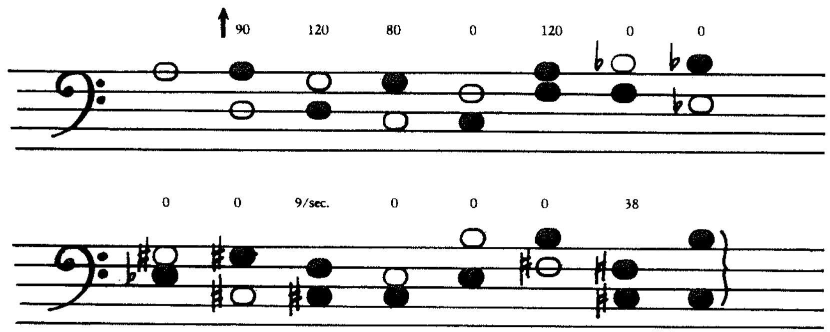

fig. 17

d♭	1	f	1/4	a	3/4	c♯
a♭	1	c	0	e	1	g♯
e♭	3/4	g	1/4	b	1	d♯
b♭	1/2	d	1/2	f♯	1	a♯

fig. 18

19. Comparable systems were used in eighteenth-century Italy. They are often of the Kirnberger III type, but differed in that the fifths e-b, b - f-sharp, f-sharp - c-sharp, and c-sharp - g-sharp were narrowed, and the fifths c-f, f - b-flat and b-flat - e-flat widened, and sometimes by decreasing degrees in that order.
See the scheme for an example. As can be read from the table of thirds, such a system favors the sharp-keys at the expense of the flat-keys, an effect also discernible with „Werckmeister III".

d♭	1 1/6	**f**	1/3	**a**	1/2	**c#**
a♭	1 1/3	**c**	0	**e**	2/3	**g#**
e♭	1	**g**	1/6	**b**	5/6	**d#**
b♭	2/3	**d**	1/3	**f#**	1	**a#**

fig. 19 ~~KIRNBERGER III~~

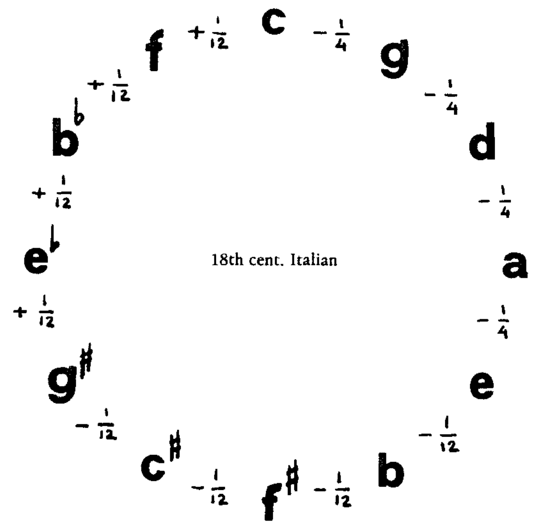

fig. 20

20. A good intermediate „Baroque" temperament is that of Van Biezen, 1970. The commonest keys have the best thirds (see scheme). Pure fifths are tuned above the accidentals, and fifths tempered one-sixth comma above the naturals.
An amusing corollary is that the accidentals obtained correspond to the arrangement of the keyboard: c-sharp lying closer to c than to d, e-flat closer to e, f-sharp closer to f, etc.
This seems to us a practical tuning for organs, which must serve for music of all periods, and one certainly superior to equal temperament.

d♭	1	**f**	1/3	**a**	2/3	**c#**
a♭	5/6	**c**	1/3	**e**	5/6	**g#**
e♭	2/3	**g**	1/3	**b**	1	**d#**
b♭	1/2	**d**	1/2	**f#**	1	**a#**

fig. 21 VAN BIEZEN

fig. 22

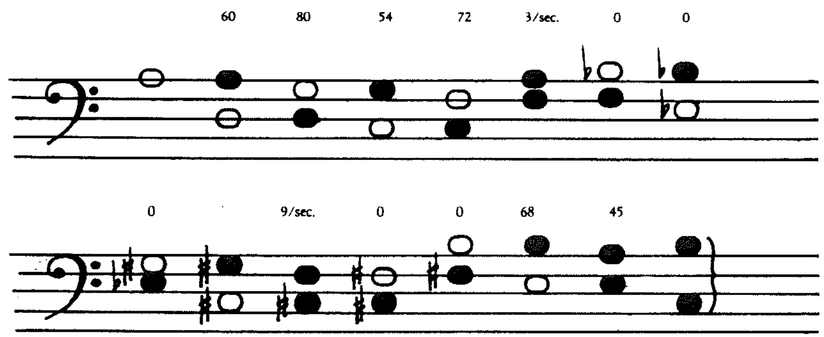

fig. 23

21. Equal Temperament.

Divide the comma equally over the twelve fifths, and you have equal temperament. Each of the fifths is narrowed 1/12 comma. The thirds are equal as well, all two-thirds comma wide. Obviously, all keys are available and the possibilities for enharmonization are unlimited. However, these freedoms are dearly paid:

— there is not a single pure interval;

— the thirds especially are poor, and give the triad an insecure and restless sound;

— there is no differentiation among the keys;

— melodic tensions are reduced;

— the temperament is difficult to set.

Early in the sixteenth century we already find tuning schemes, that result in a virtually equal temperament, in Gafurius, Grammateus, Schlick, and others. Lutes and related instruments were almost or completely equally-tempered, as can be concluded not only from exact depictions of these instruments, but also from Galilei's Dialogo della Musica, ca. 1581 (see 16). Not until the late eighteenth century did this become a common temperament for keyboard instruments; a reluctance to give up the keys' individuality played a definite role here, but the main objection was to the poor thirds. These are more bearable on the piano because of its lack of upper harmonics, and it can hardly be coincidence that equal temperament had no chance until the rise of the piano. It certainly is unfit for the performance of „old" music on the harpsichord, and thus we can drop our discussion of it. Here follows a tuning scheme for those wishing to tune their own piano.

We follow the usual pattern of descending fifths and ascending fourths, the fifths narrowed and the fourths widened; every note is thus tuned higher than pure.

To avoid working in vain because of an early mistake, we first tune three checkpoints by dividing the octave in three equal major thirds.

We use the lower octave, since the thirds of the octave above middle c beat faster than they can be counted. The „third" c-sharp - f beats about as fast as a wristwatch ticks; A - c-sharp slightly slower and f - a slightly faster.

You will come out fine by taking your heartbeat (72) as an average tempo for the beating fourths and fifths. Quite a passable result will be reached by tuning the fourths somewhat „faster" than the fifths, equal temperament is out of reach of even the most obsessive tuner anyway.

Translated by *Glen Wilson*

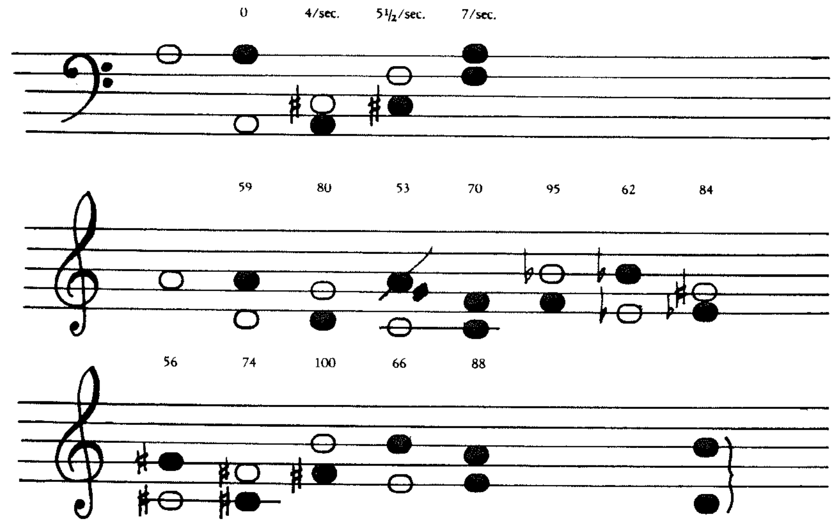

fig. 24

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Garderen, June 1974

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Werkplaats voor Clavecimbelbouw – G. C. Klop – Garderen