TUNING AND TEMPERAMENT IN SOUTHERN GERMANY TO THE END OF THE SEVENTEENTH CENTURY.

VOLUME I

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ABSTRACT.

In an age when consistency between the macro and the micro were believed to indicate sure signs of God's eternal truth, the anomalies which crop up as soon as a comprehensive, interdependent theory of consonance and harmony is attempted must have been a source of bewilderment and embarrassment to Renaissance and Baroque theorists and musicians. Composite instruments such as human voices in concert have no difficulty in making pitch adjustments necessary to achieve consonance, but the keyboard with its twelve pre-set notes is inhibited. The history of temperament is an account of the struggle to endow the keyboard with something approaching the versatility of the human voice.

German theorists and musicians were leaders in the recognition of the need to compromise between purity of interval and harmonic freedom. Part 1 of the dissertation traces the development of temperament from Schlick to Werckmeister, but concentrates on the seventeenth century. It attempts to show how temperaments became obsolete as musical vocabulary widened, and how, at least in Werckmeister's case, temperaments were assessed not only for their faithfulness to the accepted standards of consonance, but for their ability to give to certain keys certain affective characteristics.

The music of several southern and central German composers is considered in varying degrees of detail. The most detailed study is of the music of Froberger, an important predecessor of, and influence upon, J.S.Bach. Almost exclusively, Froberger was a composer of keyboard music, and a musician most probably familiar with temperaments used in other musical centres of Europe, because he travelled widely as a celebrated keyboard artist.

As the research progressed, a need to assess in objective terms the qualities of different temperaments when applied to the keyboard music of the time became increasingly insistent. Part 2 of the dissertation shows a method of solving this problem. The psychological effects of musical sound received by the human ear are considered. By dissecting a piece of music into its smallest interacting parts, i.e. its intervals and their duration, objective comparison can be made between the piece played in one temperament and played in another or other temperaments. The complete process is laborious, but is greatly alleviated by transferring data to a suitably programmed computer, which can then process the data in relation to any

temperament applied. Some of the music of Froberger has been examined in this way and conclusions drawn.

The final chapter looks back over the ground covered, outlines some issues which still require investigation, and makes suggestions for further research, using the information, arguments and techniques to be found in this dissertation.

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PREFACE.

The subject of tuning in its general musical meaning has always fascinated me. My experience as a keyboard player, and as a chamber musician and madrigal singer, brought home to me the wide difference of aural result between ready-made and made-to-measure tuning. For many years my interest remained alive in its practical application, but undisciplined.

Redundancy is usually an ill wind. It blew me out of my useful and comfortable profession, and offered me time and opportunity for research which previously I had never dreamed of. I am one of many who have grasped the chance which redundancy has offered them to redirect their talents and expertise. I am grateful to the Department of Education and Science for blowing me some good.

The furrow which a research student ploughs may be a lone one, but he is sustained in two ways; firstly, by the thought that his work may be of benefit to knowledge and scholarship, and secondly, by a host of helpers whose skills, advice and encouragement are essential if the project is to be transformed from possibility to reality. My colleague, Dr. John Meffen, had ploughed a similar furrow a few years earlier than mine. He spoke the language of temperament. He gave me reassurance.

I should like to mention the assistance I have had from the librarians of the universities of both Leeds and London. They have shown great patience and persistence in obtaining for me the source material and books I needed. I am grateful to Penelope Hyslop for vetting my translations.

My supervisors stepped out in faith when they agreed to underwrite me. Francis Mumby held my head above water in the early days, when I was thrashing about wildly in different directions. Dr. Robin Jakeways encouraged me, pointed me forward, occasionally with a gentle but necessary prod from behind. Dr. Richard Rastall undertook the unenviable task of inspiring me to achieve the self-discipline needed to arrange my thoughts into coherent and cogent expression. His criticism was always constructive; his exposure of specious argument always uncovered the way through.

My son, Alastair, agreed to become my computer consultant. With meticulous care he devised programs to suit all my requirements.

Who then was it who tolerated me from the beginning through to the end, who chivvied and cajoled, who would make suggestions or remain silent, as the need arose ? It was my long-suffering typist, who incidentally, is also my dear wife, Patricia.

Barnard Castle, February 1985. Victor Pollard.

INTRODUCTION.

The southern area of the land occupied by the German-speaking peoples has always been, by its geographical position, a region of movement and transition. Its inhabitants are open to influences from all points of the compass. Nevertheless, over the centuries they established their own culture. During the sixteenth and seventeenth centuries a significant tradition of keyboard music developed there. This study isolates the musical culture of the region in regard to the relationship between its keyboard music and the available temperaments.

Part I contains a threefold approach. Firstly, there is an exposition of the tenets on which German writers based their musical theories, of the theories themselves, and of the consequent difficulties which arose when the theories were required to endorse the music practice of the period. The even greater difficulties which occur when theory and practice meet at the keyboard in the uneasy truce of temperament are discussed. English translations of the writings were not always available to me; accessible translations were not always reliable, and so I had to make my own English translations of some of the important texts, a selection of which appears in Appendix 1. Secondly, the keyboard instruments of the period are taken into account, insofar as some of their makers and builders tried to accommodate just-intonation, or to widen the temperamental limitations of their instruments, by mechanical contrivances. Thirdly, the study tries to ascertain how far the available temperaments were adequate for the note and harmonic vocabularies of the keyboard music of the period, and how the choice of temperament might affect musical style. Hundreds of pieces of music were studied in a variety of editions. The task was considerably eased by having to hand the comprehensive and reliable texts of the series <u>Denkmäler der Tonkunst in Österreich.</u> The series includes the complete keyboard works of J.J.Froberger, a composer whose music invites scrutiny in a temperamental context, because he is known to have resided in Italy, France and England, apart from his native Germany. I decided to make an extended study of his music in relation to the available temperaments.

The tools required for the study thus far were, in order of importance, a good ear, a harpsichord and an electronic tonemeter. Since pitches, intervals and temperamental specifications can be accurately measured, I was much exercised during the earlier part of the research by the desirability of assessing the aptness of any temperament when applied to specific pieces of music. The later chapters of Part 1 contain my gropings towards an objective assessment of temperaments. Part 2 contains a full explanation of the comprehensive scheme I worked out which, when applied to any piece of keyboard music in any specified temperament, will assess the suitability of the temperament in objective terms. Only when the scheme is computerised does it become a practical proposition. The list of the tools required had to be extended to include a computer and its accessories. Armed with a viable means of temperament assessment I returned to the music of Froberger, not so much to test the scheme, but to discover more about the keyboard music/temperament relationship. The results are to be found in Chapter 10. The research ends by suggesting further lines of enquiry. The scheme (Chapter 9) and its computerisation (Appendix 3) provide a future researcher with a new tool of investigation.

Explanatory notes.

We refer nowadays to the 'black notes' of a keyboard. Neither this expression, nor 'chromatic notes' is particularly appropriate in a Renaissance or Baroque context. In the text, the expression 'raised notes' is used instead, although this expression is not wholly without ambiguity.

Convenient, terse expressions were needed to identify the wind keyboard instruments, and the stringed keyboard instruments of the period. These two groups are referred to in the text by 'organ' and 'clavier', respectively.

The specifications of temperaments (see Chapter 4) are given in cent values, as components of a broken or an unbroken circle of fifths. Tempered fifths are shown by a thin line; pure fifths by a thick line. The presence of a wolf is indicated by a break in the circle.

Every specification is accompanied by a table giving the sizes of the minor third, major third and perfect fifth built on each of the twelve degrees of the temperament.

Appendix 3 contains a computer program to calculate the specifications of all possible regular meantone temperaments.

Abbreviations.

abs.	absonance	ma.	major
a.l.	absonance level	mi.	minor
aug.	augmented	m'tone	meantone
dim.	diminished	pr.	perfect
d.q.	dissonance quotient	Py.	Pythagorean
		temp.	temperament

D.T.B.	Denkmäler der Tonkunst in Bayern.
D.T.Ö.	Denkmäler der Tonkunst in Österreich.
H.A.M.	Historical Anthology of Music.

PART I

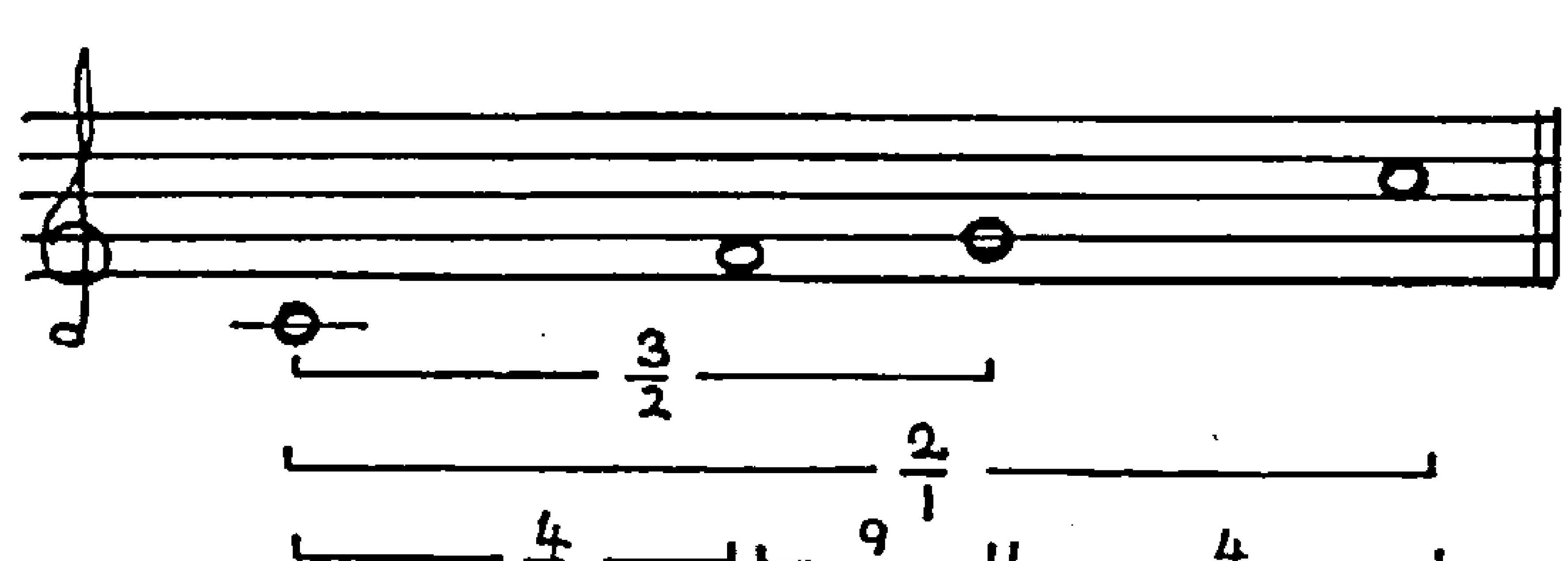
CHAPTER 1.

CONCEPTS OF CONSONANCE, ANCIENT AND MODERN.

Man has been making his music for a long time. He has made it through the use of instruments; first, his own voice, and later through sound-making media which he found, adapted or made, such as shells, horns, pipes and lyres. If he made music well he was a musician. He investigated the origin and nature of musical sounds and their place in the order of things. The investigator became the theorist, but a theorist is not necessarily a musician, nor a musician a theorist.

The Pythagorean concept of consonance.

There is a fascinating story of how Pythagoras, in the sixth century B.C., discovered the basic proportions of the sounds of music after observing a blacksmith at work at his anvil. He perceived relationships between the sizes, weights and sounds of the hammers. Posterity has to rely on Nicomachus and Boethius for the story, for there are no known writings attributed directly to Pythagoras. (1) Renaissance and Baroque writers have shown varying amounts of conviction and scepticism, but have continued to tell the story, if for no other reason than that it serves to register indelibly in the mind these basic acoustic facts: that the relationship of any note with its octave above is in the proportion 1 : 2, (for musical convenience this is often written $\frac{2}{1}$); similarly that a perfect fifth is $\frac{3}{2}$; that a perfect fourth is $\frac{4}{3}$; that the difference between these last two intervals is a whole tone in the proportion $\frac{9}{8}$. Posterity acknowledges its indebtedness by naming the system after Pythagoras and it can be applied to the note middle C as follows:



1) A lucid version of the story is to be found in Martin Agricola: Musica Instrumentalis Deutsch, (Wittenberg,1529) ch.14. A translation by J.V.P. of all relevant parts of the chapter is to be found in Appendix 1.

The ratio $\frac{9}{8}$ is of less importance than the others because of its residual nature; it is the difference between the perfect fifth $\frac{3}{2}$, and the perfect fourth $\frac{4}{3}$, calculated thus:

$$\frac{3}{2} \div \frac{4}{3} = \frac{9}{8} \qquad \text{(pr.5 - pr.4 = Py. tone.)}$$

It is not on comparative weights, however, that the Pythagorean system is based. Legend is superseded by fact when these proportions are applied to tensile string lengths. Pythagoras discovered that the most important notes of Greek melody were produced from vibrating strings whose comparative lengths could be expressed as simple ratios. This observation was of great significance to Pythagoras and his disciples, because it demonstrated his philosophical doctrine that the world and ultimately the universe were governed by an underlying logic whose consistency was revealed in numbers. "All nature consists of harmony arising out of number", (2) Pythagoras is reputed to have said. The same proportions which were believed to be present in the music of the spheres were evident also in the music of the world. As the universe was an entity, so the nearer music approached a state of unity or 'oneness', the nearer it was to ultimate truth or perfection.

For those who wonder how the Greek musical system, believed to be wholly melodic, could involve intervals and harmony which add the dimension of simultaneous sounds, a brief explanation is justified. Plato makes a direct reference to harmony:

> "A diversity of notes, when the strings give one sound and the poet or composer another; also when they make concords and harmonies in which lesser and greater intervals, slow and quick, or high and low notes are combined." (3)

Contemporary scholarship still has to rely more on iconographical evidence and deduction than on extant music of ancient Greece. Concerted voices would sing at the unison or octave. Instrumental accompaniment of a supportive nature might be supplied, probably above the voice part and at acceptable intervals with the melody. Drones were a possibility. The most commonly used instrument was the pipe, the aulos, often seen in pictures being played in pairs. Auloi

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(2) Sir James Jeans: Science and Music, (Cambridge, 1937), p.154.

(3) C.Gray: The History of Music, 2nd edn. (London,1945),p.29.

could speak together in unison or at different intervals. (4)

Intervals possess physical characteristics and are measurable. To those who hear them they have sensuous and aesthetic characteristics. Pythagoras classified intervals by their proximity to unity. The smallest ratios coincided with the aurally most acceptable intervals, which in turn were the most important notes in the heirarchy of melody. There is a chicken and egg situation here which can never be completely resolved, but here too is an essence so crystalline and elemental that for centuries Pythagorean concepts were believed to be distillations of ultimate truth. Nothing could be neater than the numerical progression 4 : 3 : 2 : 1 . The sounds which these ratios represented, $\frac{4}{3}$ the perfect fourth. $\frac{3}{2}$ the perfect fifth and $\frac{2}{1}$ the perfect octave, demonstrated also a progression towards ultimate aural unity and satisfaction. These intervals, said Pythagoras, to the exclusion of all others had the quality of consonance. By means of adding to and subtracting from these consonant intervals, all the scalic intervals of the Greek system could be obtained.

Post-Pythagorean developments.

In the fifth century B.C. Plato ratified the Pythagorean proportions, but by exalting mathematical reasoning as the ultimate authority, he put musical theory at a disadvantage, through its intractability. Art and language reflect the life of the people who make and use them, in that they undergo change and development. It is not surprising that a century later Aristoxenus went to the other extreme, by rejecting reason and giving the final judgement to sense.

> "He taught that as the ear is the ultimate judge of consonance, we are able by the sense of hearing alone to determine the measure of both the consonants and the dissonants, and that both are measured not by ratio but by intervals." (5)

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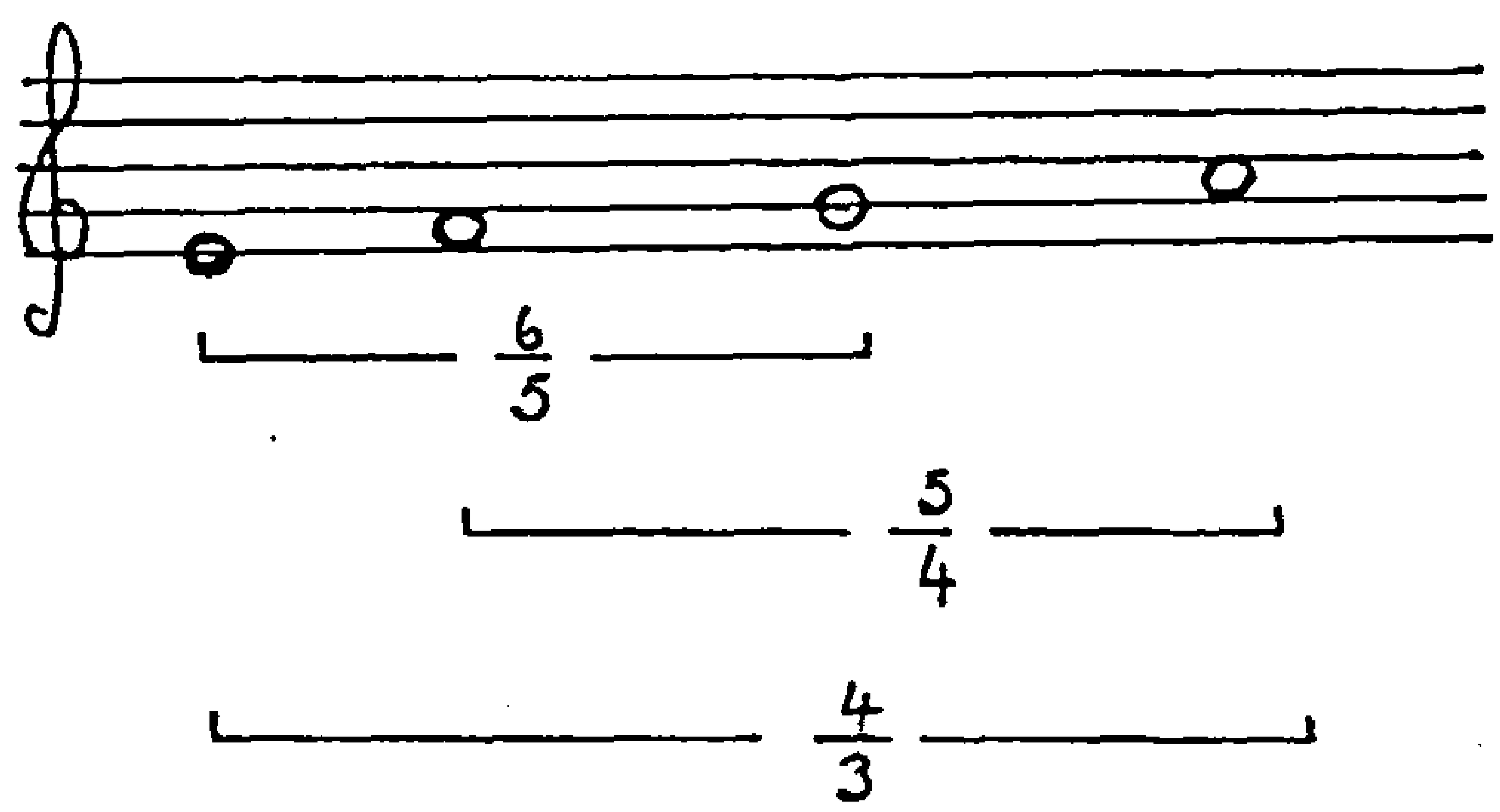
(4) This account is based on R.P.Winnington-Ingram: 'Greece' in The New Grove: Grove's Dictionary of Music and Musicians, ed. Stanley Sadie, 6th edn. (London, 1980), vol. 7, pp. 659 - 662.

(5) Sir John Hawkins: A General History of the Science and Practice of Music, (London, 1776: Dover reprint/New York, 1963), vol. 1, p.24.

Hawkins goes on to say that by rejecting reason and referring all to sense, Aristoxenus rendered the fundamentals of musical knowledge incapable of demonstration. He disqualified all speculation based on the monochord, which from Pythagoras onwards had been the instrument of musical experiment, demonstration and justification.

By the first century A.D., the pendulum had swung back part way. Didymus divided the tetrachord in such a manner that two hitherto unused intervals, the major third $\frac{5}{4}$ and the minor third $\frac{6}{5}$, became integral parts:



A century later Ptolemy brought the whole of Greek musical thought into perspective by reviving the opposing claims of Pythagoras and Aristoxenus. He admitted the existence of the proportions of the major and minor thirds, together with those of their inversions the minor and major sixths, $\frac{8}{5}$ and $\frac{5}{3}$ respectively. He did not go so far as to call these four intervals consonant, but agreed with Pythagoras that ratios beyond the quaternary, 4, were dissonant. In balancing reason with sense, he saw the need to refer to the intellect and scientific instruments, because the sense of hearing showed inadequacy, especially in dealing with the smaller intervals. (6)

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(6) Claude V.Palisca: 'Theorists', in The New Grove, ed. S.Sadie, vol.18, p.742.

The Greek intervals mentioned so far may be summarised diagrammatically as follows:

Consonant ←			⋮	→		Dissonant
$\frac{2}{1}$	$\frac{3}{2}$	$\frac{4}{3}$	⋮	$\frac{5}{4}$	$\frac{6}{5}$	$\frac{9}{8}$
pr.8ve	pr.5	pr.4	⋮	ma.3	mi.3	Py.tone
	Inversions		⋮	$\frac{8}{5}$	$\frac{5}{3}$	
			⋮	mi.6	ma.6	

Figure 1. Consonant and Dissonant Intervals.

All the proportions in the upper part of the diagram are members of a mathematical series known as super-particular proportion, in which the components of any ratio have a difference of 1. Ptolemy advocated the use of super-particular proportions. Seven scales attributed to him and seven others ascribed to other writers are composed entirely of such ratios. (7) Between $\frac{6}{5}$ and $\frac{9}{8}$ there are two ratios in the series, $\frac{7}{6}$ and $\frac{8}{7}$ whose intervals belong neither to ancient Greek nor to Western music. In exactly the same way, there is no place nor recognition for the proportions $\frac{5}{4}$ and $\frac{6}{5}$, their intervals and their inversions, in the Pythagorean system. The fact that they adjoin the three consonant intervals beyond the dividing line has no more than academic interest for the moment. Pythagoras rests secure.

Modern concepts of consonance.

Let us be clear about contemporary concepts of consonance, in the light of which we may more fully understand Renaissance and Baroque practice and thought. (8)

The world of today has as much respect for the nineteenth-century physicist Helmholtz as the Renaissance world had for Pythagoras. Building on the observation of d'Alembert and the

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(7) J.Murray Barbour: 'The Persistence of the Pythagorean Tuning System' in Scripta Mathematica, i. (1933), p.288.

(8) The psychological implications of consonance will be discussed more fully in Part 2, chapter 9.

practical application of Tartini, Helmholtz condensed his own investigation of consonance into the following definitions which he applied to the sounds of musical instruments:

> "When two musical tones are sounded at the same time, their united sound is generally disturbed by the beats of the upper partials, so that a greater or less part of the whole mass of sound is broken into pulses of tone, and the joint effect is rough. This relation is called Dissonance.
>
> But there are certain determinate ratios between pitch numbers, for which this rule suffers an exception, and either no beats at all are formed, or at least only such as have so little intensity that they produce no unpleasant disturbance of the united sound. These exceptional cases are called Consonances." (9)

Instead of using mathematical argument as Pythagoras did, it is on physical grounds that Helmholtz bases his definition. No specific allusion to combinational tones is included in the definition, but Helmholtz makes a full analysis of their contribution to consonance in the text. Subsequent scholars do not so much disagree with Helmholtz as point out the shortcomings of his definition, and "its failure to provide a fundamental explanation. Nothing better was found." (10) There is a consensus of opinion that consonance/dissonance is a linear concept, and that the dividing line between the two extremes is debatable and depends partly on context.

> "Consonance and dissonance are the two opposite poles of an effect which occurs when two or more tones of differing frequencies are heard simultaneously." (11)

A linear concept implies a hierarchy, and some scholars disagree about the order of the least perfect consonances. Helmholtz's order is as follows, perfect consonance first :-

$\frac{2}{1}$	$\frac{3}{2}$	$\frac{4}{3}$	$\frac{5}{3}$	$\frac{5}{4}$	$\frac{6}{5}$	$\frac{8}{5}$
pr.8ve	pr.5	pr.4	ma.6	ma.3	mi.3	mi.6

Figure 2. Helmholtz's Hierarchy of Consonances. (12)

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(9) H.Helmholtz: On the Sensations of Tone, tr.A.J.Ellis, Dover edn. (New York, 1954), p. 194.

(10) G.Révész: Introduction to the Psychology of Music, (London, 1953), p.84.

(11) J.Booth Davies: The Psychology of Music, (London, 1978), p.156.

(12) H.Helmholtz: op. cit., p.194.

The phenomenon of 'roughness' which he mentions in the first part of his definition is caused largely by the incompatibility of the overtones of the two notes of a dissonant interval. This incompatibility is revealed in the sensation of beating. Any pair of overtones, one each from the two notes concerned, beat or pulsate if their frequencies lie near each other. They beat slowly near the unison, and beat with increasing rapidity as the frequencies diverge. At some point the beats become so rapid that they cease to be perceptible. The amount of irritation caused, the roughness, is a subjective thing and varies with individuals. Lloyd's analogy with the sense of sight may be helpful here:

> "The irritation caused to the nerves of the ear by beating is to be compared to that caused to the nerves of the eye by a flicker ... As the rapidity of the change (of light) increases the flicker becomes intensely irritating. But if it increases still further the flicker becomes less irritating and eventually ... the eye fails to observe the flicker" (13)

It is impossible to describe the aural effect of consonance/dissonance without using emotive expressions. 'Pleasantness/unpleasantness' seems to be the contemporary psychological term. Perhaps Helmholtz's roughness for dissonance might be turned on its head, and 'stillness' for consonance be used as a positive term. A harpsichord tuner expects to hear roughness or lack of stillness when first he sounds an octave. The amount of roughness does not initially concern him. He listens intently, however, for the moment of absolute stillness when the overtones of both notes synchronise.

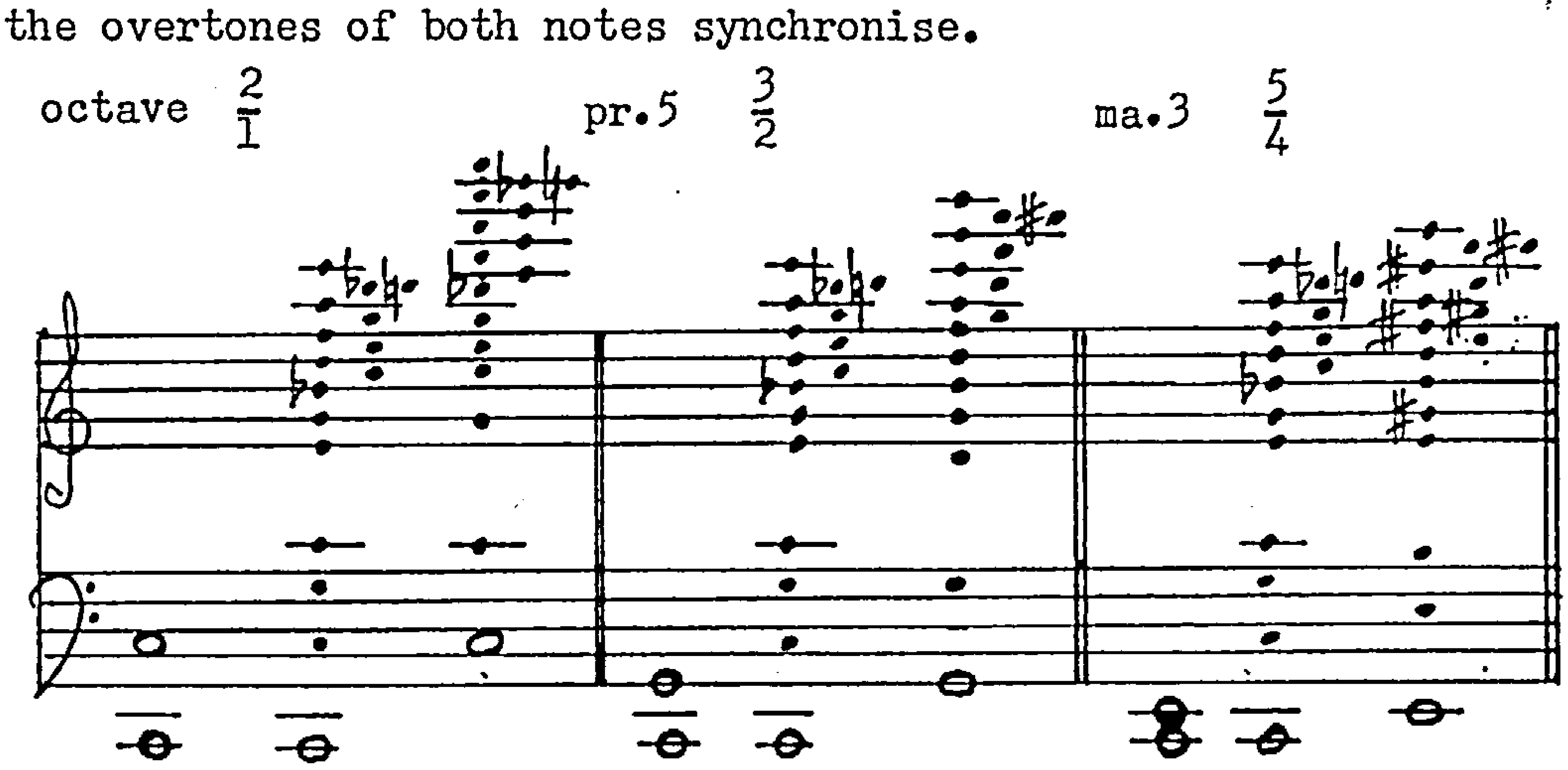

Figure 3. The Overtones of three Consonances.

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(13) Ll.S.Lloyd: Music and Sound, (london, 1937), p.42.

Figure 3 goes some way to justifying the Helmholtz hierarchy of consonance. All the lower overtones of the upper note of an octave coincide with and reinforce those of the lower note. The overtones of the perfect fifth also coincide at a very early and audible stage - the third harmonic of the lower with the second harmonic of the upper note. Slight roughness may be caused in the higher harmonics, and perhaps the seventh harmonic of the lower note may beat audibly with the fifth harmonic of the upper note. (14) The major third is less perfect still. The first harmonics to coincide are the fifth of the lower and the fourth of the upper note; the sixth and fifth harmonics respectively beat at the distance of a semitone, and above those several harmonics fail to coincide.

The sensation of stillness is enhanced in four of the seven consonances shown in Figure 2 because the combination tone of each of the four intervals lies at the octave or double octave of one of the notes:

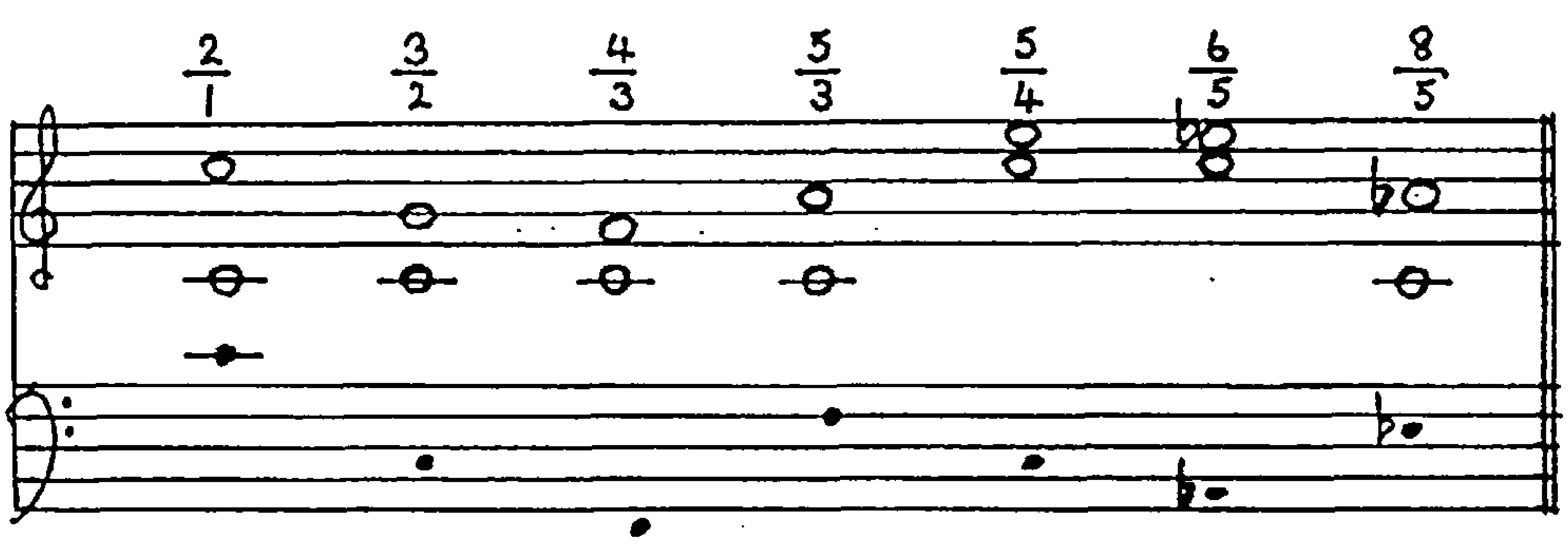

Figure 4. Combination Tones of Helmholtz's Consonances.

Helmholtz's line of demarcation between consonance and dissonance is drawn after the least perfect consonance, the minor sixth $\frac{8}{5}$. Seen in perspective with that of Pythagoras in Figure 1, Helmholtz's line occupies the gap made by the two missing super-particular proportions $\frac{7}{6}$ and $\frac{8}{7}$. Helmholtz justifies his line of demarcation in this way:

> "The scales of modern music cannot possibly accept tones determined by the number 7. But in musical harmony we can only deal with chords formed of notes in the scale. Intervals characterized by 5, as the thirds and sixths, occur in the scale, as well as others characterized by 9, as the major second 8 : 9,

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(14) On stringed keyboard instruments the seventh harmonic is sometimes completely avoided by causing the quill to pluck, or hammer to strike, at a node of the seventh harmonic.

> but there are none characterised by 7, which should form the transition between them. Here then is a real gap in the series of chords arranged according to the degree of their harmonious effect, and this gap serves to determine the boundary between consonance and dissonance." (15)

Helmholtz's comprehensive Table of Intervals not exceeding one octave (16) contains no reference to any musical interval in any culture, whose ratio included the number 7. It does, however, contain a reference to the ratio $\frac{7}{4}$, an acoustic fact, the seventh harmonic. (17)

Purity of interval.

The consonances enumerated so far have been discussed in their ideal or 'pure' state, as if they were incapable of deviating from their given ratios. In the course of a piece of music, however, for example in the performance of a madrigal, it is sometimes unavoidable that some of these intervals have to be momentarily widened or narrowed by a very small amount. At these moments they actually become, and have the sensuous characteristics of dissonances, without losing their identities. They may be called paradoxically 'mistuned consonances'. The scales of music, stepwise divisions of the octave determined by melodic and harmonic practice, have been codified by theorists according to the criterion that all intervals should be as pure as musical contexts will allow. This entails using intervals with small ratio numbers, and as often as possible numbers in super-particular proportion. Even a dissonance can be pure, and achieves a state of purity when the numbers defining its ratio are the lowest possible for the interval to retain its function and identity. For instance, the pure diatonic semitone has a ratio of $\frac{16}{15}$; it is very dissonant, its harmonics create much roughness and do not coincide until the sixteenth of the lower with the fifteenth of the upper note, but it cannot be made more acceptable,

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(15) H.Helmholtz: op. cit., p.228.

(16) Ibid., pp. 453 - 456.

(17) The musical exception which proves the rule is B.Britten's Serenade for Tenor, Horn and Strings, in which Britten specifies the use of the seventh harmonic of the horn as a melodic note. Elsewhere in music the seventh harmonic is of expedient, practical use, especially to wind players.

and therefore $\frac{16}{15}$ defines its pure state. Inevitably there are compromises to be made. The pure minor seventh $\frac{7}{4}$ is as alien to Western music as was the pure major third $\frac{5}{4}$ to Pythagoras. The minor seventh used instead is either $\frac{9}{5}$ or $\frac{16}{9}$. This is not so much a case of sense overruling reason as the Western harmonic system's inability to cope with the new and complicated tonal relationships which the admission of the pure minor seventh would involve. Western music cannot deal exclusively in absolutes. Most of its intervals are pure, the rest approach purity as near as the system allows.

To sum up, there are two classifications of consonance; ancient and modern. The one is achieved partly by mathematics, the other partly by physics, and both partly by aural observation and the practice of music. The musical systems which each classification justifies have much in common, but they can never be happily married. They are incompatible.

CHAPTER 2.

CONSONANCE, A DILEMMA OF THE RENAISSANCE.

Renewed interest in the theory of music was part of the revolution known as the Renaissance. Two events, the fall of Constantinople (1453), and the publication of the first printed edition of Boethius's De Institutione Musica (1492), can serve to focus attention on a period highly significant in the history of temperament. It was the beginning of a period when the classical literature was studied with great ardour, and the search for old manuscripts was enthusiastically pursued by prince and cleric. Artistic expression and the thirst for knowledge forged ahead for the good of mankind and to the glory of God, probably in that order. Greek sources were studied, and translations of classical works became increasingly available. The pursuit of music could no longer be considered the prerogative of the church, and the widespread desire to make music produced many amateur composers. Music was held in high esteem and practised by all strata of society. Instruments were used largely in a supportive role to the voice, and instrumental music independent of the voice had vocal origins. As successors to the melodic instruments of antiquity there rose to popularity instruments whose notes were rigidly controlled by their design and construction, such as the fretted instruments, the organ, largely associated with the church, various plucked keyboard instruments and the clavichord, the keyboard application of the respected Greek instrument, the monochord. In concerted music, music for the keyboard and music for the lute, interest swung away from a rigid linear imitation of ideas to a simultaneous vertical appreciation of momentary tension and relaxation. Moreover, the act of playing a keyboard instrument or lute encourages a momentary sensational appraisal of as many sounds as the fingers wish to motivate. Linear practice on these instruments is secondary. A new way of listening was needed which entailed vertical intervallic and chordal perception. Scholars sought to apply to their own age the principles and scientific knowledge of the revered ancient Greeks, and polemical works maintained the sanctity of the ancients' laws as seen in the previous chapter, but practical musicians are rarely as articulate as their theoretical counterparts, and an uneasy truce reigned between theory and practice.

German scholars of the period, in their innate preoccupation with order and mathematical regularity, inhibited musical development by requiring a pedagogic conformity to the strict reproduction of the methods of classical antiquity, and that usually meant, primarily, accepting as gospel the beliefs and prejudices of Boethius. His De Institutione Musica discusses the work of all the Greek patriarchs, but "he must everywhere be understood to speak in the sense of the Pythagoreans". (1)

> "Although Boethius made clear distinctions between the three great Greek theorists, he favoured the Pythagorean system, and the countless medieval writers to whom Boethius was a sort of musical Bible were content to ring the changes upon doctrines of Pythagoras". (2)

Pythagorean principles applied.

Renaissance scholars were stimulated to search for Boethius's own references, but meanwhile they formulated a theory of Western music based on Boethius, and therefore on the far-reaching assumption that Western music should conform to Pythagorean principles. Although Boethius provided no model for the chromatic division of the octave, the diatonic notes according to Pythagorean principles can be produced in one continuous operation by building perfect fifths one above the other starting with the note F, and dropping an octave where necessary to keep within the octave. An alternative way of expressing the same scale is to apply the ratio $\frac{9}{8}$ of the Pythagorean tone to the two tetrachords C - F and G - C, separated by a Pythagorean tone. The Pythagorean semitone, the limma or

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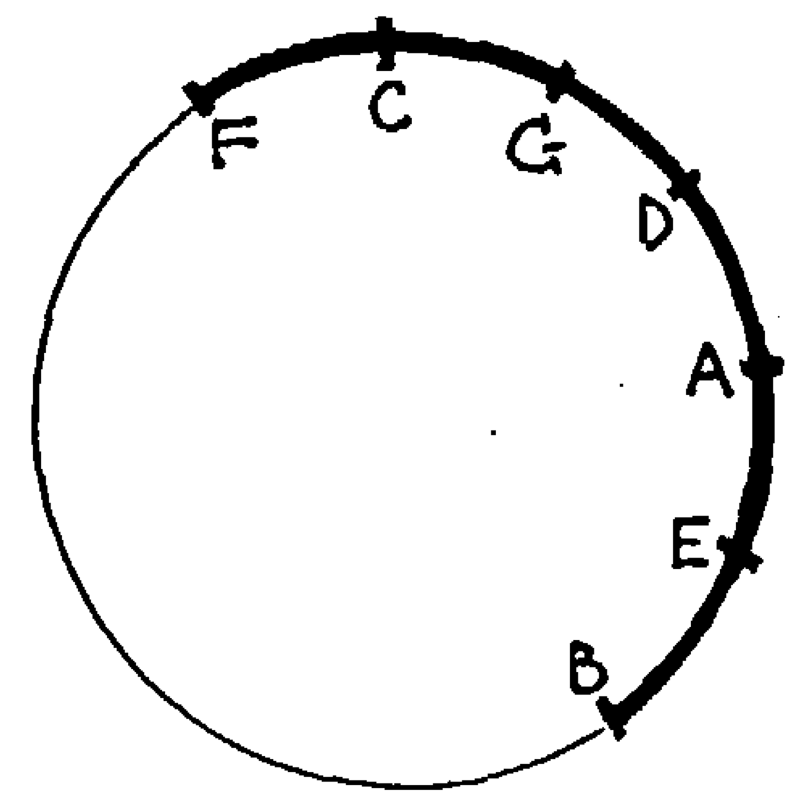
(1) Sir John Hawkins: op. cit., p.27.

(2) J. Murray Barbour: 'The Persistence of the Pythagorean Tuning System', p.288.

Chain of fifths.



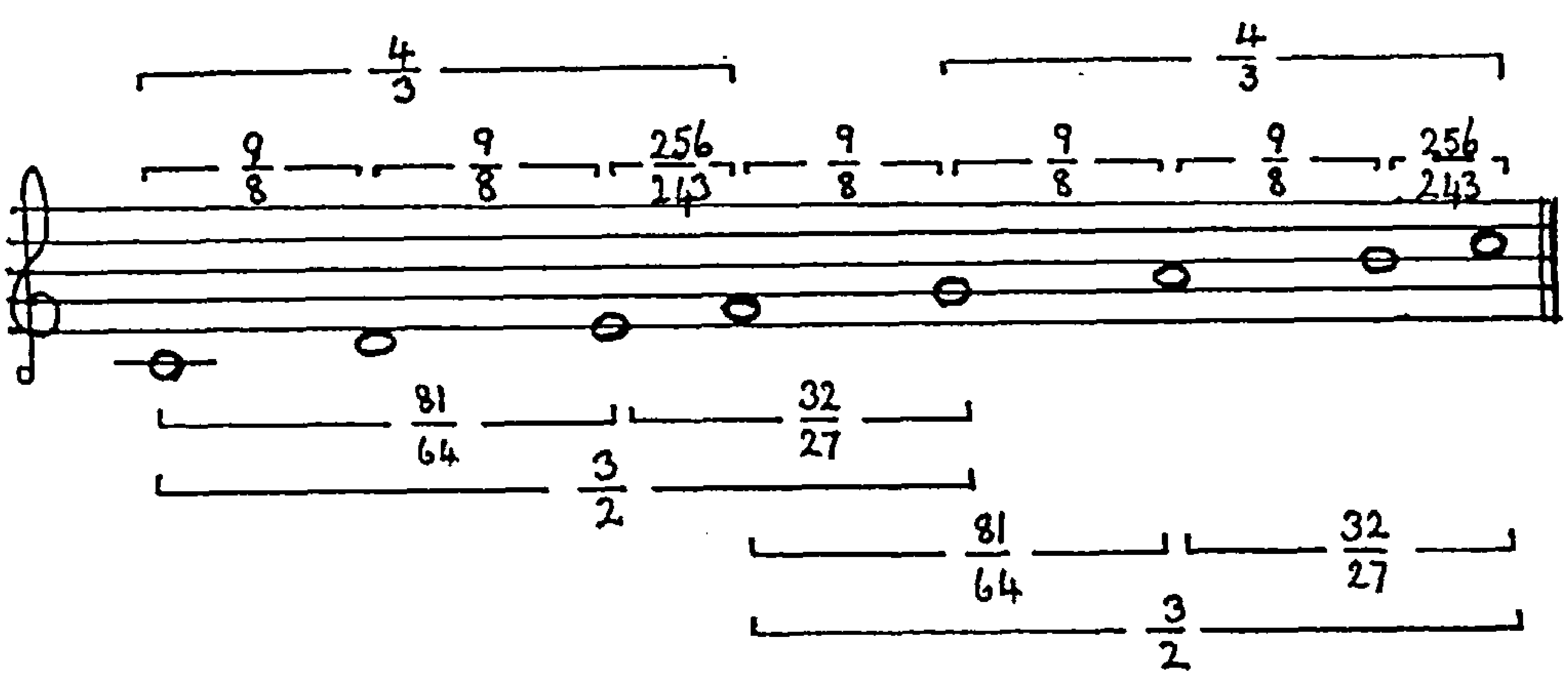


Figure 5. Basic Pythagorean Intervals.

hemitone, is a residual interval: its ratio determined by subtracting a ditone, two Pythagorean tones, from a perfect fourth:

$$\frac{4}{3} \div \frac{81}{64} = \frac{256}{243}$$

pr.fourth - ditone = Py. limma

The size and content of the Pythagorean major third, the ditone, is determined thus:

$$\frac{9}{8} \times \frac{9}{8} = \frac{81}{64}$$

Py.Tone + Py.Tone = ditone

The Pythagorean minor third, the semi-ditone, is determined thus:

$$\frac{3}{2} \div \frac{81}{64} = \frac{32}{27}$$

pr.fifth - ditone = semi-ditone

These intervals have neither of the attributes of perfect concords; their ratios have neither low numbers, nor are they in super-particular proportion. Pythagoreans rejected them and their inversions as concords, and with good reason, because Pythagorean major and minor thirds are respectively too wide and too narrow to be consonant. The ear confirms this, and finds their rapid beating uncomfortable, particularly that of the major third, about 16 beats per second between middle C and E.

The amazing regularity and simplicity of the system appealed to the ordered logic of German Renaissance scholars. Aesthetically, the large tones and small semitones were ideal for the austere melody of plainsong. Provided that music remained melodic, or that melody was reinforced only by the parallel consonant intervals of organum, Pythagoras could not be faulted. Musica ficta were no problem: the sequence of fifths could be extended as the need arose. A widely travelled German theorist, Ornithoparchus (d.1535), gave precise instructions not only for the calibration of his monochord, but even for the dimensions and materials required to build the instrument. (3) Figure 6 is a construction of the monochord, drawn according to the instructions. Entirely Pythagorean, his ratios are $\frac{9}{8}, \frac{4}{3}, \frac{3}{2}, \frac{2}{1}$. Every fifth is pure. The string is shown divided three times into nine parts, three times into four parts and, using a third of the string's length, three times into two parts. No mention is made of C♯ and F♯. The range is roughly that of the human voice. The monochord's purpose was exclusively didactic and corrective:

> "To be judge of Musical voices and intervals: as also to try whether the song be true or false furthermore, to shew haire-braind false Musicians their errors, and the way of attaining the truth." (4)

The word 'song' (Latin original 'cantus') may have been used in a general sense, or specifically for plainsong and counterpoint. The text certainly implies the use of the monochord for concerted music:

> "That we may know how much each voice is higher or lower than the other."

Dowland's translation of Cervicosis by 'haire-braind' may be slightly misleading for us today. Retranslated as stubborn, stiff-necked, the inference is that musicians were thus condemned, and false, for

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(3) A.Ornithoparchus: Musicae ActivaeMicrologus. (Leipzig,1517); tr. Dowland, (London, 1609: R/New York 1973), p. 142.

(4) Ibid. p. 143.

Figure 6. The Monochord of Ornithoparchus.

(1517)

rejecting the approved ditones and semiditones which they found ungrateful to sing harmonically. The musicians may have found empirically the consonant quality of pure thirds.

There was no lack of German scholars to proclaim the overall authority of Pythagoras. One of the first to apply his proportions to a twelve-note octave was Hugo von Reutlingen (d.1360), a fourteenth-century theorist, who extended the existing system by adding two notes on the sharp side and three on the flat side. (5)

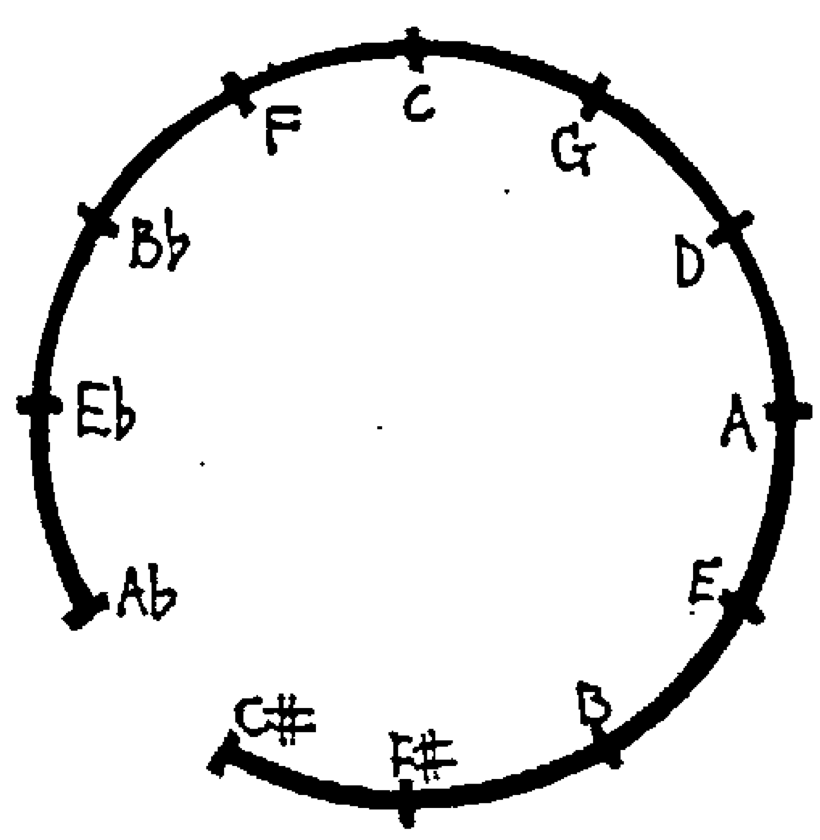

Figure 7. Hugo von Reutlingen's Monochord.

The title of Hugo's treatise, The Flowers of all Music, Gregorian Chant, (Strassburg, 1488), indicates the specific purpose of his monochord.

The Encroachment of the Pure Thirds.

As soon as music began to acquire the added dimension of harmony and harmonic progression anomalies arose, and the preference and evidence of the human ear began to be asserted and demonstrated, in direct conflict with the overriding and constricting argument of Pythagorean logic. Pythagorean consonances were acceptable as vertical intervals. There were other simultaneous pairs of notes particularly those near the ditone and semi-ditone whose sweetness and unity could not be ignored. The ears of sixteenth-century polyphonists corroborated empirically an acoustic fact which the

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(5) J.Murray Barbour: Tuning and Temperament, 1st ed. (East Lansing, 1951) p.89.

Pythagorean system chose to ignore, namely, that the major third could be consonant, within the definition of the word, but that the pure major third was a different interval from the ditone. It was somewhat smaller, and determined by a further division of the monochord, or as we think nowadays, by the progression of the notes of the harmonic series. The pure major third is the note given out by $\frac{4}{5}$ of the monochord, or the fifth harmonic of the series. At the same time, a complementary acoustic fact can be acknowledged, that since the pure major third is smaller than the ditone, then the minor third must be larger than the semi-ditone, if the perfect fifth is to remain consonant:

$$\frac{5}{4} \quad \times \quad \frac{6}{5} \quad = \quad \frac{3}{2}$$

pure major third + pure minor third = perfect fifth.

Both of these thirds have the consonant properties of low numbers and super-particular proportion. Of the ancients, both Didymus and Ptolemy applied the pure major third to the Greek genera in different ways. Western music's indebtedness to them is acknowledged by referring to the measure of the difference between the Pythagorean and the pure thirds as the comma of Didymus or Ptolemy.

A major third is smaller than a ditone
A minor third is larger than a semi-ditone } by a comma ($\frac{81}{80}$).

This important small interval is also known as a syntonic comma, or, for there are other sorts of comma in music, it is also given the ultimate address of respect, the word "comma", plain and simple, to the exclusion of all other commas.

The reverence in which Pythagoras was held over the centuries can be estimated by the length of time it took for scholars to accept the pure thirds as part of the system, and by the deviousness of those scholars who sought to evade the issue. The practising musicians who found euphony more important than the dictates of the monochord were, whether they knew it or not, latter-day followers of Aristoxenus, the champion of sense over reason.

Franco of Cologne at the end of the thirteenth-century was probably the first Western musician to admit the pure thirds as consonances. (6) He was followed a century later by Johannes of Garlandia, who made a comprehensive system of consonances, classified as perfect, imperfect and intermediate. (7) A Benedictine monk, Walter Odington of Evesham, admitted in his early fourteenth-century treatise De Speculatione Musices, that singers used intuitively the pure thirds and major sixths, which he called "concordant discords":

> "If in numbers they (the Pythagorean ditone and semi-ditone) are not found consonant, the voices of men with its subtlety leads them into a smooth mixture of full consonance". (8)

Two centuries later Gafurius (1451 - 1522) conceded to Spataro in his Apologia Gafori adversum Spatarum (1520), that musicians did not use the Pythagorean limma , (9) a piece of circumstantial evidence apparently more grudging than the rest of his speculation would suggest. Not content with Boethius, he had Ptolemy and other Greek sources translated for him, and in his De Harmonia Musicorum (1518) he showed the pure thirds, which he called "irrational consonances", according to Ptolemy's syntonic diatonic. Although he is remembered for his attempts to reconcile past truths with present practice, even to the extent of minimising the aural differences between Pythagorean and pure thirds, he never renounced Pythagorean principles.

> "Therefore, we call intervals irrational and indefinite, which on a chordotonus are not included in the first three multiples and the first two superparticular ratios ... The irrational intervals suitable for this art are an imperfect third (tritecordus), and an imperfect sixth (exachordus); from their extremities concords are formed which with good reason we call surd (surdae)." (10)

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(6) H.Helmholtz: op. cit., p.196.

(7) Claude V.Palisca: op. cit., p.748.

(8) Ibid., p.750.

(9) Mark Lindley: 'Early 16th-century Keyboard Temperaments', in Musica Disciplina, xxvii (1974), p.129 fn.

(10) F.G.Gafurius: Practica Musicae (Milan,1496), book III ch.1 , tr. by C.A.Miller: (American Inst. of Musicology, 1968), p.117.

Much the same attitude was adopted by Gafurius's contemporary Faber Stapulensis (c. 1455 - 1537), another Pythagorean aware of the discrepancies between musical practice and theory:

> "An outstanding musical theoretician, not yet prepared to include thirds and sixths among the concords, because of the excess of a comma." (11)

A frequently quoted, but cryptic remark of Faber only helps to highlight the confusion of the time:

> "The fact that a semi-ditone sounds pleasing to the ear is proved by one's experience in listening to musical compositions. It is not a consonance, however, because its ratio $\frac{32}{27}$ is not super-particular." (12)

Three questions arise from this statement. First, were the compositions instrumental, vocal or both ? If we knew the answer to that question, we might be able to answer the second: How did he know that the intervals really were semi-ditones, as opposed to pure minor thirds ? Thirdly, if the 'pleasing sounds' were pure minor thirds, did he not find their complement, the pure major thirds also pleasing ?

A follower of Gafurius, Heinrich Glareanus (1488 - 1563) had a rather more concessionary attitude to tuning problems:

> "Heinrich Glareanus, a capable man, after his instruction by Fr. Gafurius, ... had been the first among the theoretical musicians to reckon the thirds and sixths among the consonant intervals, although he still used the old diatonic genus,in which he followed his hearing rather than the verdict of the intellect, since according to the intellect it was quite impossible to accept them as consonant intervals because they possessed very awkward proportions and thus were unpleasant to the ear. Solely because the practical musicians gave to them, although unknowingly, the right proportions, and consequently roused in the hearing a gracefulness, did Glareanus give them his approval, irrespective of the real reason." (13)

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(11) W.K.Printz: Sing= und Kling=kunst. (Dresden, 1690: R/Graz, 1964), p.119 tr. J.V.P. Printz's comments, translated J.V.P., on the ambivalence of the period add useful background knowledge, and therefore have been included in Appendix 1.

(12) H.Riemann: History of Music Theory, tr. R.M.Haggh, (Lincoln, U.S.A., 1962), p.283.

(13) W.K.Printz: op. cit., p.122.

As late as 1592 Sethus Calvisius (1556 - 1615) wrote:

> "The semi-ditone falls on the ear quite pleasantly and acceptably, but it is still not taken as a concordant interval ...
> The ditone, placed between the sesquitertia (perfect fourth) and the sesquiquarta (pure major third) in no way makes their sounding together complete." (14)

Scientists were transforming traditional ideas of the universe. The harmony of the world and the harmony of Western music were changing. The Pythagoreans were in a quandary.

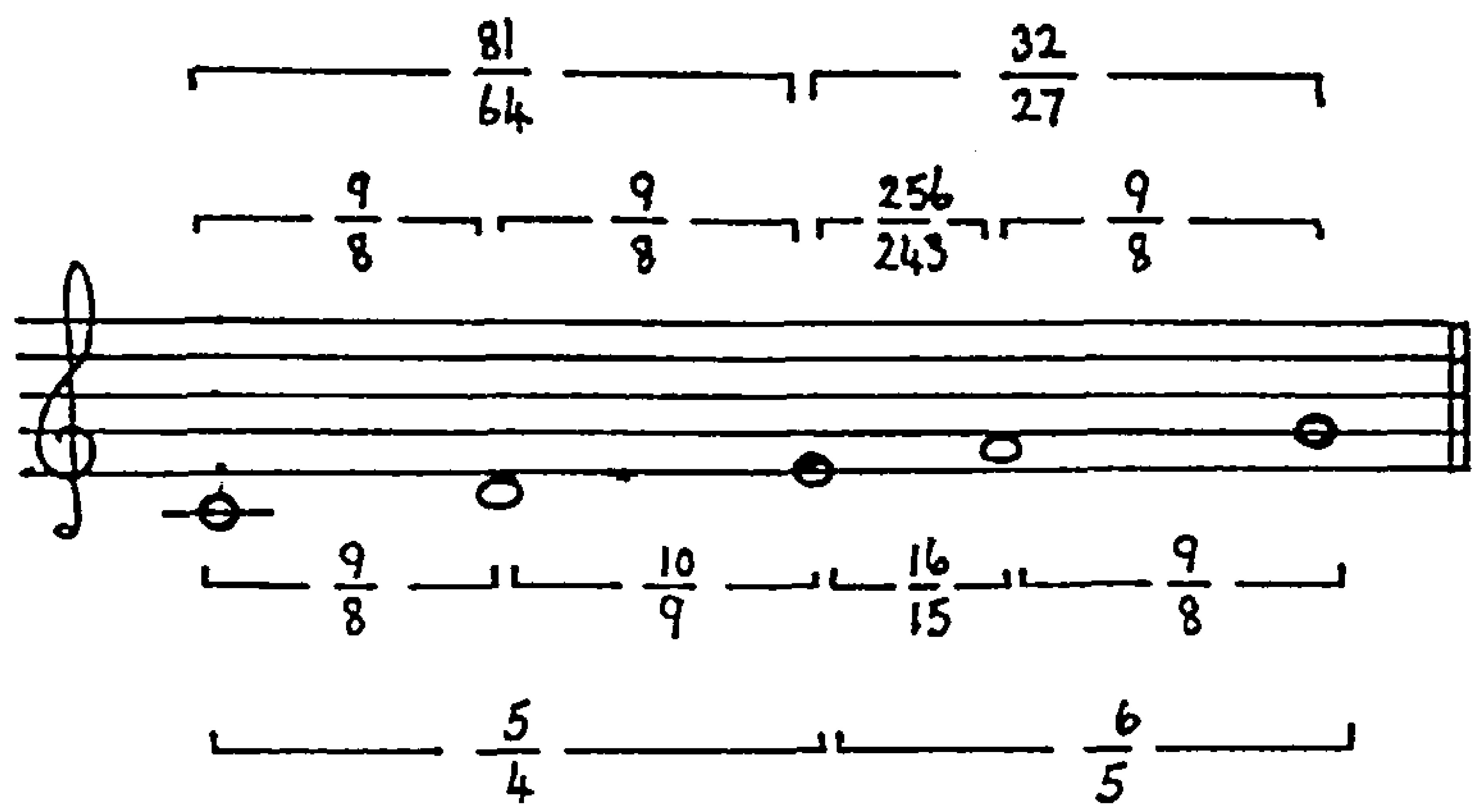
Just-Intonation.

Boethius, however, had also provided an anti-Pythagorean reaction among a few scholars. Ramos (1440 - c.1491) led the way boldly. His own empirical discoveries coincided with Didymus's beliefs. He made no apology for asserting the consonance of and right of recognition for the pure thirds. Pure thirds were to Ramos facts to be proclaimed loud and clear, and a means of escape from Greek domination. Prevarication and embarrassment could be swept aside, but in so doing, the Pythagorean system was revolutionised, or superseded. The tetrachord gave precedence to the perfect fifth. By substituting the proportion of one interval, that of the pure major third for that of the ditone, the perfect fifth and its components assumed a new and integrated identity. Figure 8 shows the basis upon which the system known as just-intonation, or syntonic tuning, is founded. Besides the Pythagorean perfect fifth and fourth, the system requires:

2 sizes of tone: (greater and lesser, or major & minor)	$\frac{9}{8}$ and $\frac{10}{9}$	(difference: a comma).
2 sizes of minor third:	$\frac{6}{5}$ and $\frac{32}{27}$	(difference: a comma).
1 (new) diatonic semitone:	$\frac{16}{15}$	(greater than limma by a comma).

(14) Ibid. p. 119.

Pythagorean:



Just-intonation:

Figure 8. Pythagorean and Just-intonation proportions compared.

Only after the lapse of centuries were the proportions of just intonation and the syntonic scale rehabilitated and given scholastic authority. An Italian theorist, Gioseffe Zarlino (1517 - 1590) is usually given the credit for this. Printz goes into considerable detail, (15) and Hawkins reproduces Zarlino's diagram of Ptolemaic proportions, which is presented below. (16) Figure 9 has the superficial appearance of the carefully calibrated diagrams of previous treatises, but although all the intervals can be worked out from the figures given, confusion may arise when the actual sizes of the degrees are examined. The major and minor tones and semitones are all drawn equal in size. The pure thirds therefore appear to be equal in size, and are given Pythagorean names. A diagram claiming to show proportions might be expected to be itself proportionate.

Zarlino asserted that the number 6, the senary, was rationally included within the new limits of consonance. Not only were both thirds and the major sixth $\frac{5}{3}$ approved by <u>sensus</u>, they also had the authority of <u>ratio</u>. Musically he can be thought of as the pivot between the ancient and the modern world. His thesis of the human pulse as the source of the musical pulse reflects the humanistic

(15) Ibid. p.123.

(16) Sir John Hawkins: op. cit., vol 1, p.399.

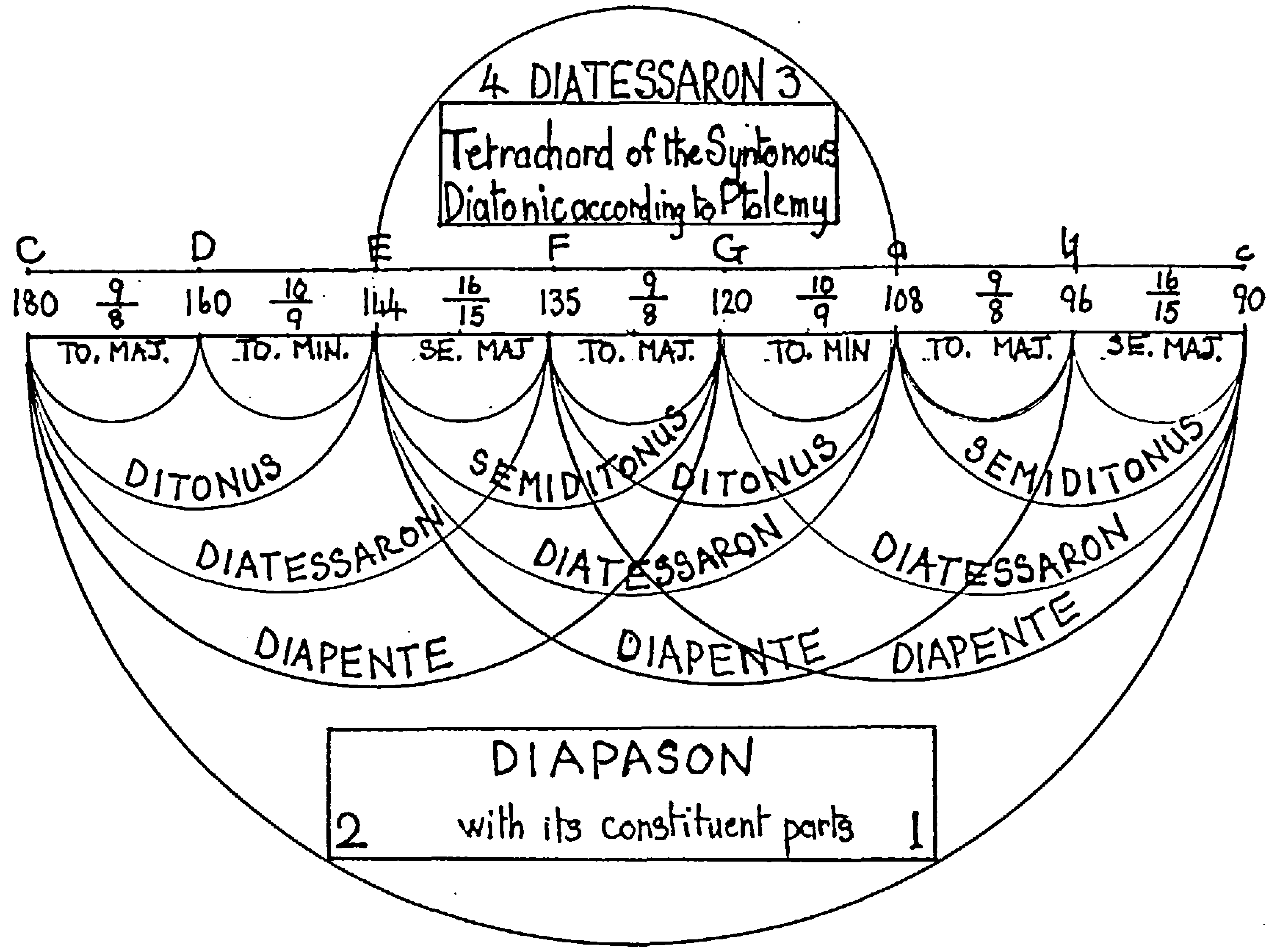


Figure 9. Ptolemaic Proportions as drawn by Zarlino.

attitude of his age, but he glances back to Pythagoras and forward to a Christian synthesis:

> "Everything that exists, simple or composite, corporal or spiritual, comes from ONE". (17)

Zarlino's beliefs were ratified by the discoveries of Johann Kepler (1571 - 1630), an astronomer held in great respect, even today. Once the thirds were accepted as consonances, the acceptance also of both major and minor sixths was a logical progression. Kepler was able, to his own satisfaction, to reconcile the seven consonances of just-intonation with the harmony of spheres and his discovery of the planetary system. In De Harmonice Mundi (1619) he attempted to explain how the coherence of the universe was centred upon God, who had created His universe according to geometrical laws. Boldness to defy established precedent and authority, as Luther had shown in 1517, was being shown by German theorists of the late Renaissance.

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(17) G.Zarlino: Istitutioni armoniche, (Venice,1558), part 1, chap. 12, tr. B.V.Rivera.

It was not until the Baroque period, however, that just-intonation ideas of consonance were seen to be endorsed from the immediate physical world by the behaviour of an overblown organ pipe:

> "When an open organ pipe of long and narrow measurements is overblown a number of times, the consonances follow exactly in the order C - c g c e g $\bar{c}$. Thus in a wonderful way all the consonances stick together in an undivided corpus according to the order mentioned earlier ... From this we observe the order of consonances, and also perceive that nature does not go by leap but by step." (18)

The Rise of the Triad.

The Pythagoras/just-intonation controversy might have been even more prolonged had it not been for the concept of the triad, whose multiple harmonic relationship was unknown to Pythagoras. Johannes de Muris is acknowledged as the first person to refer to the vertical distribution of three notes. His *Ars Discantus secundum Johannem*, a fourteenth-century manuscript, contains rules and tables about the vertical arrangements of three notes, not all of them triads. Two voices can be as effective as three sometimes, he said. The distribution now known as the second inversion he rated as 'poor'. (19) Gafurius, as usual, was content to sit on the fence. On the same page on which he defined the ditone and semi-ditone in Pythagorean terms, and gave them the names major and minor thirds, he wrote that the perfect fifth could be divided, so that three notes might sound together in harmony. His expositions are usually pedantically explicit, but from the quotation which follows, and in light of subsequent developments, Gafurius is perhaps withholding information, or reticent to face truth which Pythagoras had not discovered.

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(18) A.Werckmeister: *Musicalische Temperatur*, (Quedlinburg,1691), p.23, tr. J.V.P.

(19) B.V.Rivera: *German Music Theory in the Early 17th-Century*, 2nd edn. , (Ann Arbor, 1980), pp.127f.

The passage comes from Book 3 of Practica Musicae, his exposition of counterpoint, and not from Book 1 which is devoted to plainsong. It is quite obvious that he is not speaking of thirds with ratios of $\frac{81}{64}$ and $\frac{32}{27}$.

> "A diapente or perfect fifth ... containing three whole tones and a small semitone , has an intermediate note concordant with the outer tones, for it is composed of the first two single intervals, a minor third and a major third meeting in the middle on a common tone. Thus its outer tones produce a more pleasant concord, as if the concord were related to the middle division in a certain harmonious imitation." (20)

Ramos was one of the first to declare the triad a natural phenomenon, but a number of Germans, Kepler among them, found that by emphasising the union between theology, number and music, new truth was revealed, and Pythagoras was irrelevant. The mystery of the Trinity was analogous with the mystery of the triad. The one was used to elucidate the other. The harmonic division of the octave revealed the next two consonances: $\frac{2}{1} = \frac{3}{2} \times \frac{4}{3}$. The harmonic division of the fifth revealed not only the two pure thirds : $\frac{3}{2} = \frac{5}{4} \times \frac{6}{5}$, but also revealed the three-in-oneness of the triad, whether it be major or minor. Its sweetness and unity were axiomatic and completely outside the experience of Pythagoras.

The study of Johann Lippius (1583 - 1612), Disputatio Musica Tertia (1610) was the most comprehensive of the many treatises covering the harmony and mathematical arguments of the time. At the end of the seventeenth century Werckmeister spent the first fifteen chapters of his Musicalische Temperatur (1691) on elaborate mathematical justifications of the then accepted consonances. Buelow, one of today's authorities on German music theorists, sums up the period : (21)

> "The intensity of the preoccupation of German theorists with the triad as an expression of order, number and perfection in its ratio of 4 : 5 : 6 , and its symbolic representation of the Trinity played a significant role in the ever-increasing vertical emphasis of compositional style ... The impact of triadic symbolism and triadic verticality is one result of the musica theoretica of German theorists and composers." (21)

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(20) F.Gafurius: Practica Musicae, p.120.

(21) G.J.Buelow: 'Symposium on 17th-Century Music Theory: Germany', in Journal of Music Theory, xvi (1972).

By this time other sacrosanct musical tenets had been or were being superseded by others reflecting the practice of the time: ideas concerning the inversions of intervals and triads anticipated Rameau by a century or more: the hexachord system had fallen into disuse: ancient modes were reclassified according to their harmonic potential. Lippius gave affective significance to certain modes according to their triadic potential. Modes with a predominance of important major triads he classed as lively and happy, those mainly with important minor triads he classed as mild. sad and serious. He also declared that the Ionian mode was the "most natural mode in the music of today, contrary to the assertion of many in the past and present." (22)

The Pure Scale.

The Ionian mode with just-intonation proportions is identical with the modern pure major scale. Figure 10 shows the major thirds on F and G which replace ditones, but of course the major scale has complete freedom to overrun its octave.

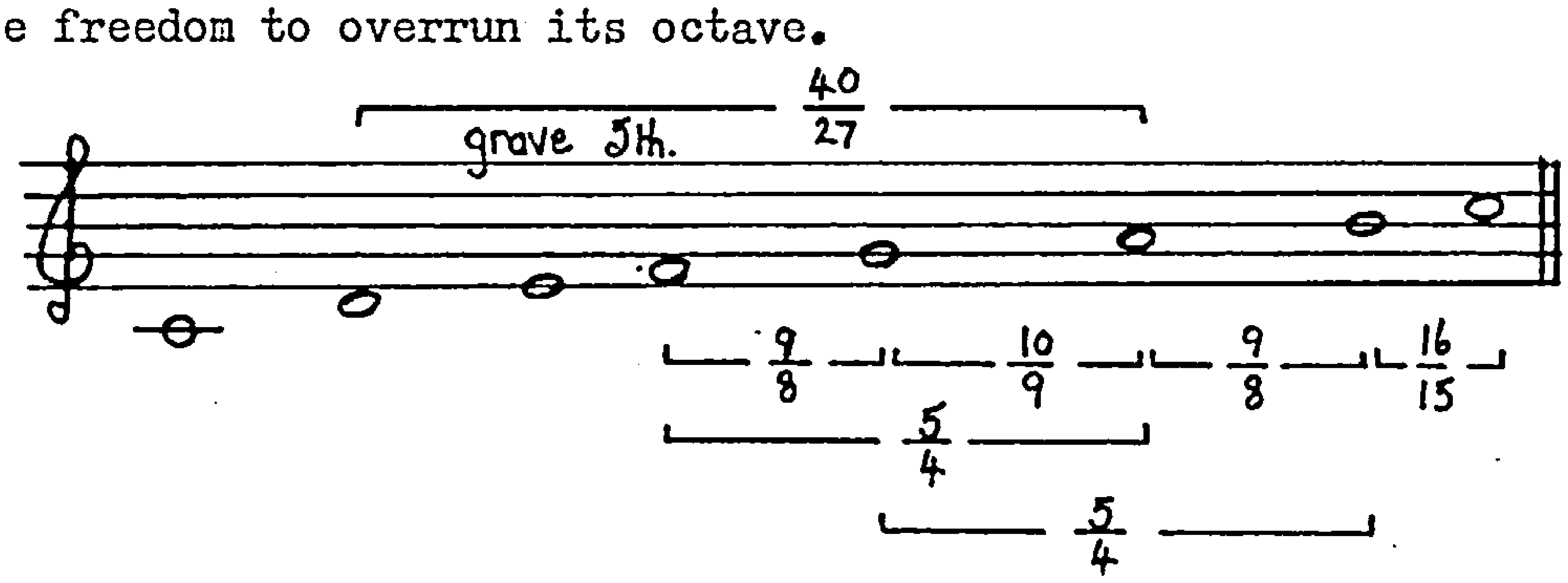

Figure 10. The Pure Major Scale.

With pure thirds and two sizes of tone, complications arise. When F - A is made a pure major third, the fifth D - A is made up of the sum of its parts as follows:

$$\frac{10}{9} \times \frac{10}{9} \times \frac{9}{8} \times \frac{16}{15} = \frac{40}{27}$$

2 minor tones + 1 major tone + 1 diatonic semitone = grave 5th.

This small fifth of just-intonation, known as a grave or imperfect fifth, is smaller than a pure fifth by a comma:

$$\frac{3}{2} \div \frac{40}{27} = \frac{81}{80}$$

pure fifth - grave 5th = comma.

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(22) from Lippius: Synopsis Musicae Novae (1612), quoted from B.V.Rivera: op. cit., p.201f.

Helmholtz, the theorist, makes this gratuitous remark about the fifth, "It sounds like a badly tuned fifth." (23) Stanford, the musician, describes the procedure whereby polyphonists solve the problem unwittingly:

> "When harmonies are added to the notes of the scale of C, one note has to be liable to change, and is termed 'mutable'. This note is D, which must be the lesser tone from C in order to combine with F and A, the supertonic triad, and the greater tone from C in order to combine with G." (24)

Stanford goes on to say that the minor scale has two mutable notes. The above adjustment by a comma is the answer to the problems of maintaining simultaneous consonant intervals and complete triads, but no farther than the scale of C. As soon as any other note becomes the tonal centre, a new arrangement of the degrees within the octave C to C is made immediately necessary. Provided that the music is sung by unaccompanied voices, or played in consort on accommodating instruments, these small changes in interval size can be made and were made. Every major or minor triad can be given concordance. (25) Instruments with fixed intonation cannot cope harmonically beyond the primary triads. Just-intonation poses as many problems as it seeks to solve, which may be one of the reasons why little enthusiasm was raised to adopt it. In an age when knowledge was considered absolute and God-given, solutions involving compromise must have smacked of heresy.

From this point onwards the argument concerns not only intervals, but notes and their precise positions in the octave, usually using C as a datum. It will be convenient to use the cent unit of measurement, which was invented by A.J.Ellis, the translator into English of Helmholtz. There are

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(23) H.Helmholtz: op. cit., p.335.

(24) C.V.Stanford: Musical Composition, (London, 1911), p.15.

(25) This word is used by Révész and other psycho-musicologists to describe the composite consonant effect of chords.

100 cents in an equally tempered semitone, and therefore 1200 cents to the octave. Since the unit is logarithmic, interval sizes can be expressed in simple numbers - ratios of impure intervals become very unwieldy - and calculations are made easy.

As soon as the two systems are extended according to their own principles to include notes beyond the naturals, their incompatability is completely irreconcilable.

The Pythagorean System Extended.

Gafurius extended the Pythagorean system to include fourteen notes in a chain of fifths from A♭ to D♯. If the chain of pure fifths is extended sharpwards from B, the sharpest natural note, and flatwards from F, the flattest natural note, neither series will ever return in circular fashion to C, but will progress in a regular divergent spiral, to think for a moment in visual terms.

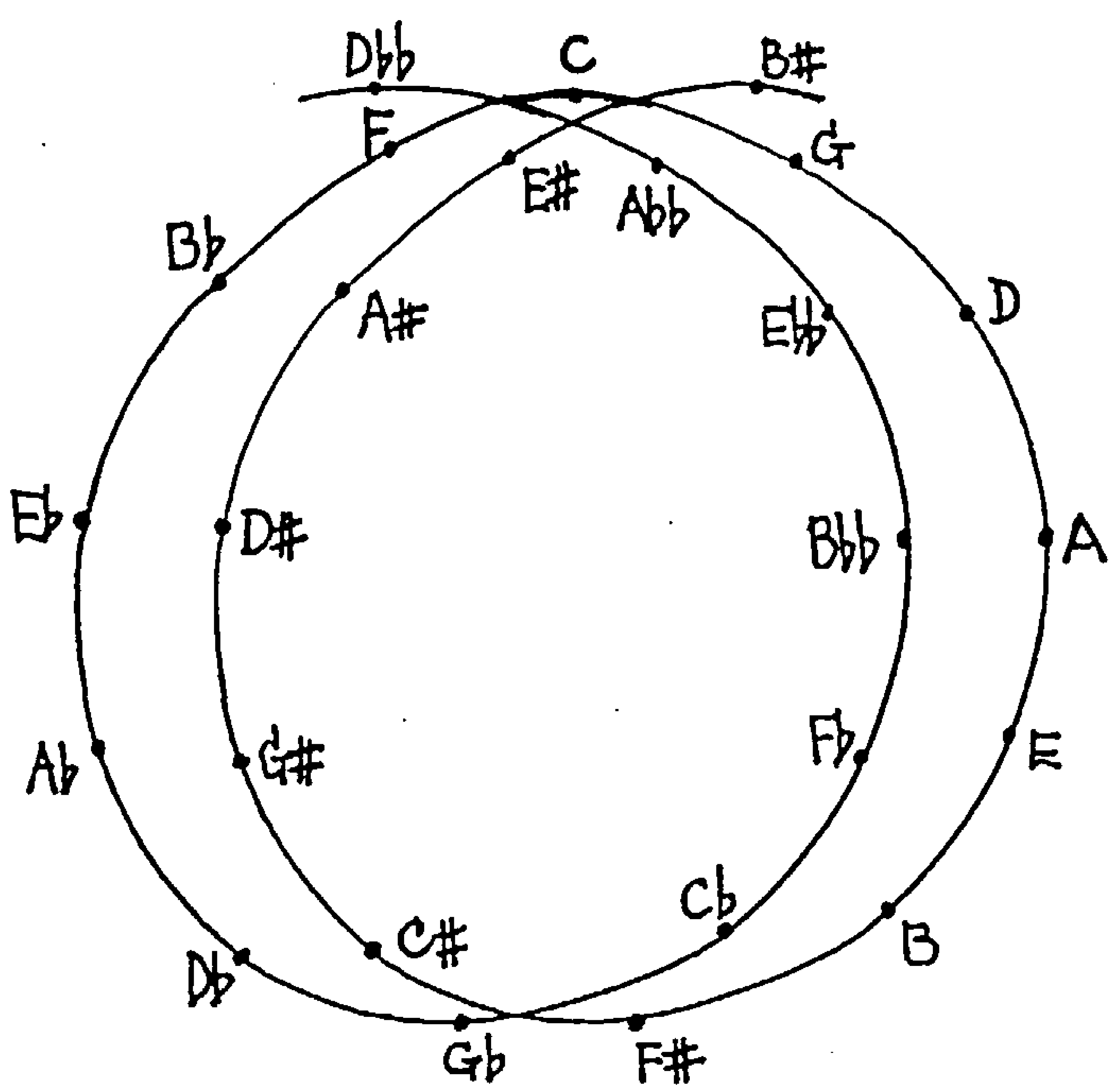


Figure 11. The Pythagorean Spiral.

cent values:-

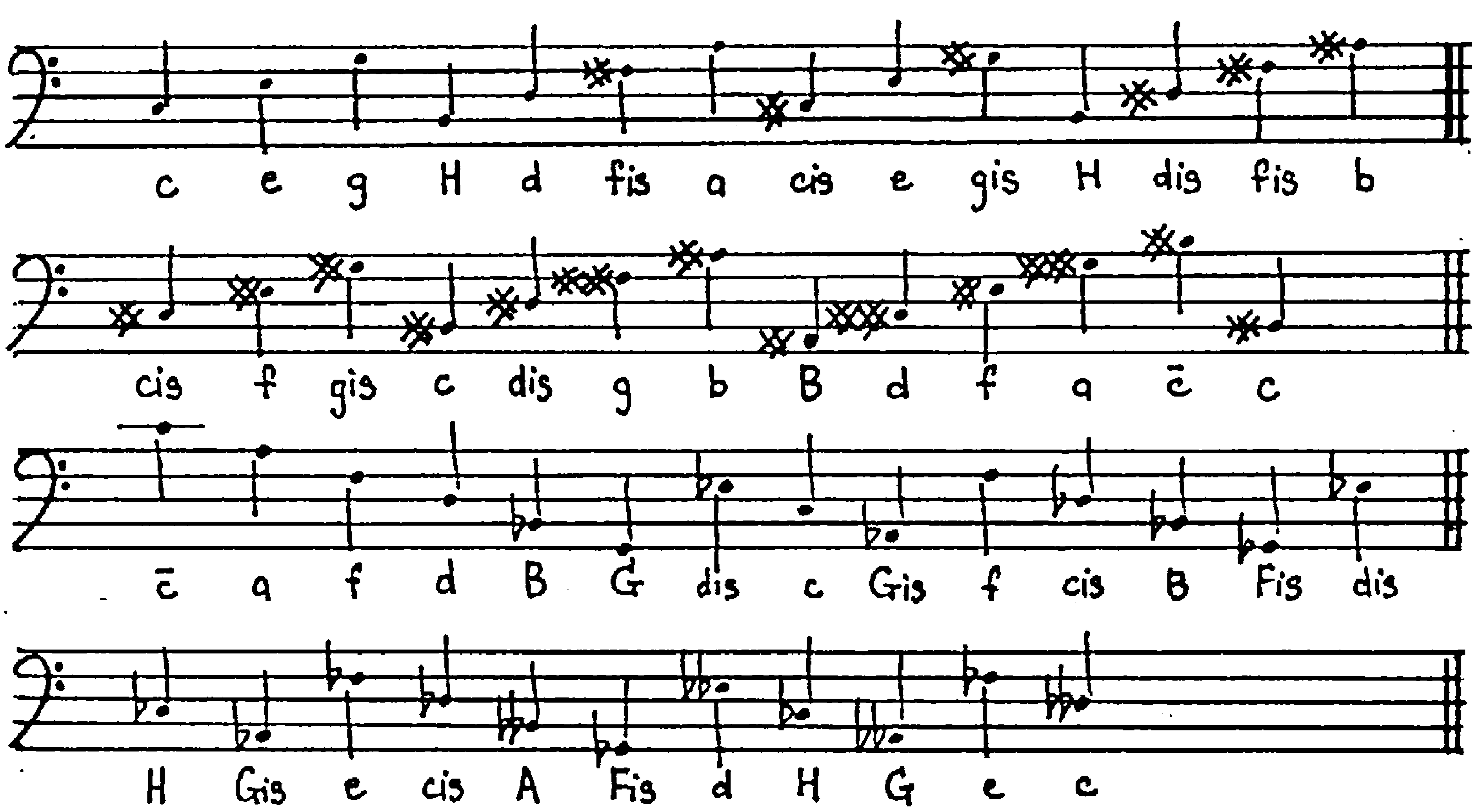
C	B♯	D♭	C♯	E♭♭	D	E♭	D♯	F♭	E	F	E♯	G♭
00	24	90	114	180	204	294	318	384	408	498	522	588

F♯	A♭♭	G	A♭	G♯	B♭♭	A	B♭	A♯	C♭	B	D♭♭	C
612	678	702	792	816	882	906	996	1020	1086	1110	1176	1200

At a point just over seven octaves above the fixed note, C, B♯ is sharper than C by 24 cents. Similarly at a point just over seven octaves below the same note, D♭♭ is flatter than C by 24 cents.

12 x p.5th	=	12 x 702c	=	8424c.	
7 x p.8ve	=	7 x 1200c	=	8400c.	
		by subtraction		24c.	ratio $\frac{531441}{524288}$

This small discrepancy is called a Pythagorean or ditonic comma. Each enharmonic equivalent, for want of a more suitable name, is separated by a ditonic comma, the sharp being higher than the flat. Werckmeister showed that a chain of alternate major and minor thirds, none other than a chain of perfect fifths in disguise, never returns to its starting point:



(26)

Figure 12. Werckmeister's chain of alternate major and minor thirds.

(26) from A.Werckmeister: Die Notwendigsten Anmerkungen (1698), quoted from F.T.Arnold: The Art of Accompaniment from a Thorough-Bass, (Oxford,1931), p.205, fn. 3.

Just-Intonation Extended.

The chromatic extension of just-intonation is even more complicated and more fragmented. As a result of the two sizes of tone, each key demands its own exclusive note series. Limited to a 17 note system, four sizes of semitone are needed. Three pure major thirds fall short of an octave by a diesis (42 cents). The sharps are lower than their adjacent flats by the same amount, as can be seen from the following 17 note octave. Figure 13 is little more than an academic exercise, because it cannot show the mutable quality of the notes, the pitches of which have been worked out to show as many pure thirds in familiar triads as possible. Here there are 13 pure major thirds and 11 pure minor thirds.

C	C♯	D♭	D	D♯	E♭	E	F	F♯
00	70	112	204	274	316	386	498	590
G♭	G	G♯	A♭	A	A♯	B♭	B	C
632	702	772	814	884	976	1018	1088	1200

Figure 13. Some Just-Intonation cent values for C major.

Only when these two systems of tuning are required to perform duties beyond their natural practice or within over-restrictive limits do the systems break down. Faults of intonation arise when the Pythagorean system, designed for, and applied to, melodic use is put to harmonic use. The major thirds beat unpleasantly sharp. Similar difficulties arise when just-intonation is restricted to a very limited number of notes per octave, like the keyboard is restricted. No accepted system of notation can accurately express just-intonation. This must be left to the aural judgement of the performers. Attempts have been made from time to time to provide the keyboard with more notes per octave, but the twelve note keyboard remains secure. Its visual ambiguity serves as the raw material for a great variety of musical and notational puns. The human ear is a highly discriminatory organ which immediately recognises musical puns and rejects those in bad taste.

Some early keyboard music, requiring very simple harmony and a maximum of twelve unequivocal notes, can be performed using just-intonation intervals. Keyboard music, however, requires the freedom which vocal music enjoys. But even singers have to make adjustments. Theorists of the Renaissance had to revise their dearly held ideas that God's laws were immediately recognisable by their simplicity and coherence of pattern. If the triad were accepted as a symbol of the Trinity, then the ditonic and syntonic commas might be said to peep out like the horns of the Devil. Based on the belief that consonance in general was the most desirable state for music to be in, purity of octaves, fifths and thirds could not be maintained consistently, and it was in the use of keyboard instruments that any fall from grace was most obvious.

Keyboard deficiences.

The struggle of fixed note instruments during the sixteenth century was two-fold. The struggle for solo instrument status against the tyranny of the voice was matched by that to accommodate the voice with accurate and euphonious support. The answer to the problem of inherent untidiness of the law of musical sounds lay in compromise. The answer to the problem of the inadequacy of the keyboard lay in compensatory adjustments of any intervals except the octave, which alone remained untouched, unchallenged. If the fifths remained pure the thirds had to be very sharp. If the thirds were made pure the fifths suffered, and in both cases the number of keys available was strictly limited. Werckmeister highlights the problem in his usual, straightforward way:

> "It is surprising that one cannot have or use in practical music the pure consonances as nature fashioned them ... Now when we want to tune a keyboard ... so that all fifths and fourths are pure, several thirds and sixths would become so impure as to become unusable. If one wanted to have the thirds and sixths pure, then several fifths and fourths would remain impure." (27)

This is the heart of the problem. Since neither comma can be eliminated, their disorganising influences must be curtailed by

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(27) A.Werckmeister: Musicalische Temperatur, dedication, p.2.

distributing the comma among the consonances, that is, by slight mistuning, or tempering, of the consonances.

> "So in musical tuning, temperament fails by a small amount to coincide with the completeness of the musical proportions which regulate the blending of the progressions and are gratifying to the hearing. Unless one can move from one harmonious combination of notes to the next and have a pleasant blending, we should have little use or joy in music." (28)

How was the compromise to be made ? Was there a single and ultimate temperament ? Marpurg, some sixty years later, sums up the whole situation, and has the grace and integrity to offer no facile or ultimate solution.

> "There is no other way except by adding something to a certain interval, or taking something away. Adding or taking away from an interval is known as making an interval beat, and the process of causing intervals to beat in such a way that the ear does not suffer thereby, is called a temperament. The necessity for temperament has been proved sufficiently. No composer doubts it; but how is the temperament of the twelve semitones to be arranged ? Opinions differ on this point." (29)

Did the period, style and note vocabulary of a piece of keyboard music affect the choice of temperament ? These many considerations were the joint responsibility of theorists, instrument makers and performers. The composer did not get away scot-free. He had to learn to condense his thought into the musical vocabulary available. But art flourishes in confined conditions. Perhaps the word temperament should lose its narrow interpretation as applied to the fluctuation of one interval against another related to the keyboard and similar instruments. Perhaps it ought to apply to the whole creative and reproductive process from embryo idea in the mind of the composer to realisation in the experience of the listener.

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(28) Ibid. dedication, p.3.

(29) F.W.Marpurg: Anfangsgründe der Theoretischen Musik, (Leipzig, 1757: R/New York, 1966), p.117, tr. J.V.P.

CHAPTER 3

THE SEMANTICS OF TEMPERAMENT.

There are a number of words associated with music which, chameleonlike, change their meaning to suit their context. 'Tone' is probably the most notorious and overused, but 'tune' runs a close second. In the study of temperament 'tune' and 'tuning' depend very much on their context for their meaning, and may have to be used in close proximity to mean different things. A few less familiar words, which meant or mean different things to different people are mentioned later in this chapter.

Tuning and Temperament.

Tuning can be the act of adjusting the pitch of a note on an instrument. A tuning, as opposed to a temperament, is an arrangement of the twelve notes of the scale which preserves consonant intervals in their pure state. A temperament differs from a tuning in that at least some of the notes of the scale are deliberately mistuned, so that their so-called consonant intervals can only be defined by ratios which betray their dissonance; for example the ratios of the fifth of equal temperament (700 cents) is $\frac{433}{289}$. The expressions 'system of tuning', and 'tuning scheme' usually mean series of verbal instructions which lead to the successful application of a tuning or a temperament to an instrument.

Monochord.

The word monochord is open to similar confusion. Besides being the name of a scientific instrument, the word is also used for the specification of a tuning or temperament. Monochords of specification were originally given in string lengths, but here they will be translated into cent values with C as 0 (zero). The monochord of Ornithoparchus on page 15 is an application of Pythagorean proportions. The positions of its notes might also be expressed in terms of stopped string lengths between a moveable and a fixed bridge, if the open string length were divided into a graduated scale. With every copy of Musicalische Temperatur Werckmeister supplied a copper engraving two feet long, for use as the scale and base plate of a monochord (instrument) which the reader was encouraged to construct for himself. The engraving gave the string lengths, i.e. the precise positions of the moveable bridge, of six monochords; a 'pure scale' of C and five temperaments.

> "He who wishes to draw out a monochord for himself from the copper engraving can make it twice, or half as big again, so that it can be demonstrated more clearly. Very small monochords are liable to a greater degree of error ... If the copper engraving has been properly mounted, three strings of about brass no.5 can be stretched over it, and the monochord is complete. A single string could also be used, but it is so much better with three strings because triads, syzygias and so on can be presented to the ear simultaneously. (1)

Scholars showed great diversity in the number of linear units they worked with, which appears to depend on type of temperament and mode of calculation. Like many others before him, Werckmeister worked with a string length of 3,600 units, a very modest number compared with later monochords. Marpurg, whose lengths were 96,000, and sometimes 480,000, explained his choice:

> "We take as our basic number 96,000. It is big enough to calculate accurately, because only the first four digits are taken into account on a monochord of the usual size. Then what is the purpose of the remaining numbers ? ... The reason is to discount remainders. One can always ignore such remainders without disadvantage, because with the number 96,000, visually they count for nothing on a two foot monochord. As the temperament is for the ears as opposed to the eyes, the eye should not jib at a discrepancy in the last figure." (2)

Tuning Note.

The note of a monochord's open string was originally a matter of choice. The ancient Greeks had used E, the majority of Renaissance theorists used F, and by the end of the seventeenth century, C was the accepted note. The note of a monochord's open string may or may not have been the tuning note from which

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(1) A.Werckmeister: op. cit., Foreword, tr. J.V.P.

(2) F.W.Marpurg: Anfangsgründe der Theoretischen Musik, (Leipzig,1757 : R/New York, 1966), p.120, tr. J.V.P.

the instrumental tuner began to tune an instrument, particularly a keyboard instrument. Schlick and Ammerbach were typical of the Renaissance by starting on F. Lanfranco justifies his reason for his choice of F, and with it gives posterity a guarantee that the octaves of his time were inviolable:

> "One can start from whatever key one wishes, but for greater convenience (speaking of clavichords, organs and the like) I would take the Fs because they span the whole instrument, so that one can through them judge the height and depth of the outermost sounds." (3)

After being given the tuning note, there were two different practices by which the Germans used to tune the keyboard.

Laying the Bearings.

From the tuning note the tuner would 'lay the bearings' or 'set the scale', terms which indicate the act of giving to the middle octave of the keyboard the precise pitches the temperament required. The aural characteristics of the notes around middle C are usually the easiest to recognise. 'Bearings' suggests both the effort needed to turn the pin, and also the admission that the intervals produced may not be completely acceptable to the ear. During the laying of the bearings the tuner makes every interval pure before mistuning it. Fifths are usually made small or narrow; fourths are made large or wide. The rate of beating is the only guide to the size of interval. Schlick likened the sensation of beating to hiccups. Praetorius is more urbane. He explains the phenomenon and at the same time apologises for having to accept an artisan's expression because there was no scholarly Latin equivalent:

> "The expression 'to beat' is an organbuilder's term and is used by them if any consonant interval does not stand pure. It is such a common term among them and therefore among many organists, that it is difficult not to accept it. Therefore henceforth I must use it with regret ... The presence of beating is to signify the amount of impurity, tuned either too high or too low. In organs, particularly when one wants to

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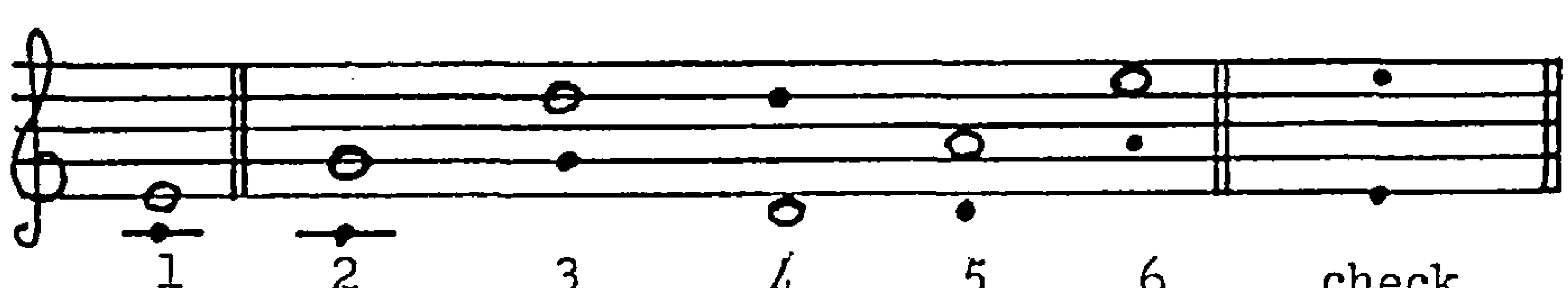
(3) G.M.Lanfranco: Scintille di Musica, (Brescia, 1533), p.134 tr. M.Lindley, in 'Early 16th-century Keyboard Temperaments', in Musica Disciplina xxxviii 1974, p.144.

> tune the octaves, 5ths and 4ths, the resonance and sound in the pipes beats and pulsates just like the vibrations of a tremulant. The nearer (an interval) is brought to absolute purity, the more the beating gradually subsides, and the pulsations become fewer and fewer until the moment of absolute purity of the octave or other concord." (4)

It can be seen from Praetorius's explanation that interval purity is not necessarily absolute. As soon as the concept of tempering is admitted, that of comparative purity of interval must also be admitted.

<u>Checks</u>.

The process of laying the bearings may be wholly consecutive, in which any errors made are cumulative, or it may continue from the tuning note or some intermediate note in a different direction or with a different interval. To keep errors to a minimum a tuner relies on 'checks', which usually entail arriving at precisely the same note by different means. For instance, here is a method of checking the first five notes of quarter comma meantone temperament.



1. Tune the major third from C to E pure.

2. to 6. Tune all fifths to beat a quarter comma narrow and the octave D to D pure.

7. This check should give a pure octave E to E if steps 2. to 6. are right. If the octave contains any beating every step must be revised.

Other checks involve being able to recognise the equal beating of two different intervals.

The second and less skilful tuning practice was to use the monochord itself to lay the bearings. The tuner would probably tune first to the open string of the monochord, and complete a chromatic octave as a succession of unisons with the stopped notes produced by placing the moveable bridge at specified positions on the scale. This method had to be used for temperaments whose bearings could not be laid by aural judgement.

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(4) M.Praetorius: <u>Syntagma Musicum</u>, vol.II (Wölfenbüttel, 1618: R/ Kassel, Basel, 1958) p.150 tr. J.V.P.

The Tuning Pipe.

The wind-blown equivalent of the monochord used for tuning purposes, and a forerunner of the modern tone meter, was available and encouraged in the latter half of the seventeenth century. In Propositiones Mathematico - Musicae (Münden,1666), Otto Gibelius described and presented an engineer's drawing of a 'mono-pipe', a variable-pitch organ pipe designed for laying the bearings of a meantone temperament. The detailed drawing incorporated an end correction 8/3 the width of the pipe's mouth. (5) Several specimens of this type of pipe still exist. Adlung also described a tuning pipe. What he lacked in precision he made up for in precept:

> "But what about the placing of the remaining notes, if the first note is correct.? Answer: It was from Herr Bach of Jena that I originally heard the following suggestion which also pleased me. Namely: you ought to take a pipe, throughout a certain width. Then you have a cylinder turned (on a lathe) for you which makes a good fit inside the pipe, and which can be pushed inside. You should mount the pipe on a board, and fix below it a pair of dependable bellows, whose wind supply is the same whenever it is used. You push the cylinder into the pipe, so that it becomes stopped as required for the tuning note when the cylinder is pushed a little way in. The first note of the organ can thus be obtained instead of using trumpet or pitch pipe, and you can even adjust the pipe afterwards. You mark on this cylinder or stopper the divisions according to the scale as it is marked on the monochord, using either paper glued round the stopper, or everything shown on the stopper itself by means of dividers. Now if you want to tune, you always push the stopper in, according to the markings, and tune immediately from c to b and so on, by semitones (Hemitonia) for you no longer need to tune by fifths. If you think that in using one pipe the stopper will go too deep, then make two pipes next to each other, the one standing in c, the other in g or f. The first pipe needs by means of the stopper the range upwards of only a fourth; the other must be somewhat narrower and shorter, and so its marked scale will be different. Both pipes must be strong. By this means you can tune a thousand organs, carrying it from organ to organ. The division must be really accurate. Right first time means right for all time. The pipe has a long sound which makes it possible to hear the beating of a pipe against the other correctly. Good quality wood, which neither shrinks nor swells, must be used for the stopper, otherwise it is liable either to let wind through or to squeeze the pipe. It must also be completely round and of the same thickness throughout." (6)

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(5) J.Murray Barbour: Tuning and Temperament, pp.85 - 87.

(6) J.Adlung: Musica Mechanica Organoedi, (Berlin,1768: R/Kassel, 1961), paragraph 405, tr. J.V.P.

The inventor of the tuning pipe may have been inspired by the fact that it is easier to tune strings from strings, and pipes from pipes.

> "It would be better to tune and temper pipes from pipes." (7)
> "Stringed instruments are rather different ... The monochord would be of benefit here, because strings are easily tuned against strings." (8)

Categories of Temperament.

Temperaments fall into two categories, regular and irregular. All the fifths of a regular temperament are equal in size, therefore there is equality in the sizes of all other respective intervals. Irregular temperaments may also be classified as linear, or circulating or cyclic. Circulating or cyclic temperaments contain the maximum number of twelve fifths, all usable but varying in size, All keys and triads are available, although the sizes if the respective intervals vary slightly. There is sufficient tolerance for enharmonic equivalents to be used; for instance, B♭ may be used as a substitute for A♯. Linear temperaments are conceived as an infinite chain of fifths, the two ends of which can never meet.

The Wolf.

The keyboard, however, is finite when the rule of one note per key is applied. Then, when a chain of eleven fifths is applied, the two ends face each other across a no-man's land of a false fifth, a diminished sixth, in fact. Into this space, whose precise size varies from temperament to temperament, are placed the accumulated errors which accrue by tempering the fifths to accommodate the thirds. This residual dissonance, a perfect fifth plus or minus accumulated errors, was given the name of 'wolf'. Historically it was given no unemotive name, but took its place alongside that other musical anathema, the tritone, the diabolus in musica. A consonance was called 'pure', but a wolf 'howled' to greater or lesser degree, according to the tuning or temperament and the harmonic vocabulary of the piece of music played.

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(7) Ibid. para. 404.

(8) Ibid. para.607.

The word 'wolf' could also be used to describe other unpleasant intervals. According to Praetorius, its meaning could be transferred to the false thirds of quarter comma meantone temperament, such as F - G♯ (270 cents), which by definition is an augmented second, and unusable as a minor third.

> ..."Some people will say that the wolf is not F and G♯, but rather between G♯ and E♭ ... Some are of the opinion that the wolf is between E♭ and F♯, and B♭ and C♯, but I leave to one and all his own opinion. The best thing is to leave the wolf howling in the wood where he belongs, and let him not disturb our harmonious concords." (9)

Adlung described an entirely different kind of wolf:

> "In the writings about the organ at Weissenfels Schloss concerning organ wolves, Trost reports that the ancients had called it a wolf when the pipes lacked correct proportions, and thus could not be brought to purity. That sort of wolf nobody could dislodge, and so the pipes had to be thrown away." (10)

Subsemitonal intervals.

Adlung, however, gave a conventional meaning to the word wolf, and also specified, if not by name, the schisma (2 cents), which is an interval so small that it lay either undiscovered or ignored until the later seventeenth century. The schisma was of little importance to linear temperaments, where it could be lost in the main wolf, but in a circulating temperament it had to be accounted for. Adlung, who gave Neidhardt the credit for first being aware of it, rectified earlier negligence by drawing attention to the schisma, and called the comma the wolf. He expressed the excess of twelve fifths over seven octaves thus:

> "As a remainder, approximately ... a comma 81 : 80, and still needs 32805 : 32768 (schisma) to be exact ... These small amounts are called the wolf because the wolves howl, and so does an impure organ. Wherever the comma lies, there lies the old wolf, but the schisma constitutes only a wolf cub." (11)

Confusion over the comma does not stop at the syntonic and ditonic commas already described. The word might be taken to mean any of the following: the diaschisma, also known as the Erlangen comma (20 cents), the syntonic comma (22 cents),the ditonic comma

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(9) M.Praetorius: op. cit. , p.155.

(10) J.Adlung: op. cit., para . 400.

(11) Ibid. para. 399.

(24 cents), and the Kirnberger comma (26 cents). Ultimately it depends on the context, but the list is easy to remember, for the step between each is a schisma wide.

Care must also be taken over the interpretation of the word diesis. Lindley's greater diesis is equal to Marpurg's Drittheilston, or third of a tone (62·5 cents). Helmholtz's greater diesis (42 cents) is Marpurg's small and Lindley's lesser diesis, which is different again from the Greek diesis. Zarlino and Vicentino had other values for the diesis. Out of this semantic quicksand rises one slippery rock. Most scholars nowadays will accept the word diesis, although they may qualify it with 'lesser' or 'greater', as the excess of the octave over three pure major thirds:

$$\frac{2}{1} \div \frac{5}{4} \times \frac{5}{4} \times \frac{5}{4} = \frac{128}{125} = \text{diesis(42 cents).}$$

In this study this is taken as the size of the interval, and the explanation of its existence.

If any further justification is needed for treating the names of subsemitonal intervals with caution, one need only look at Kircher's diagram of the subdivisions of a Pythagorean tone. (12) According

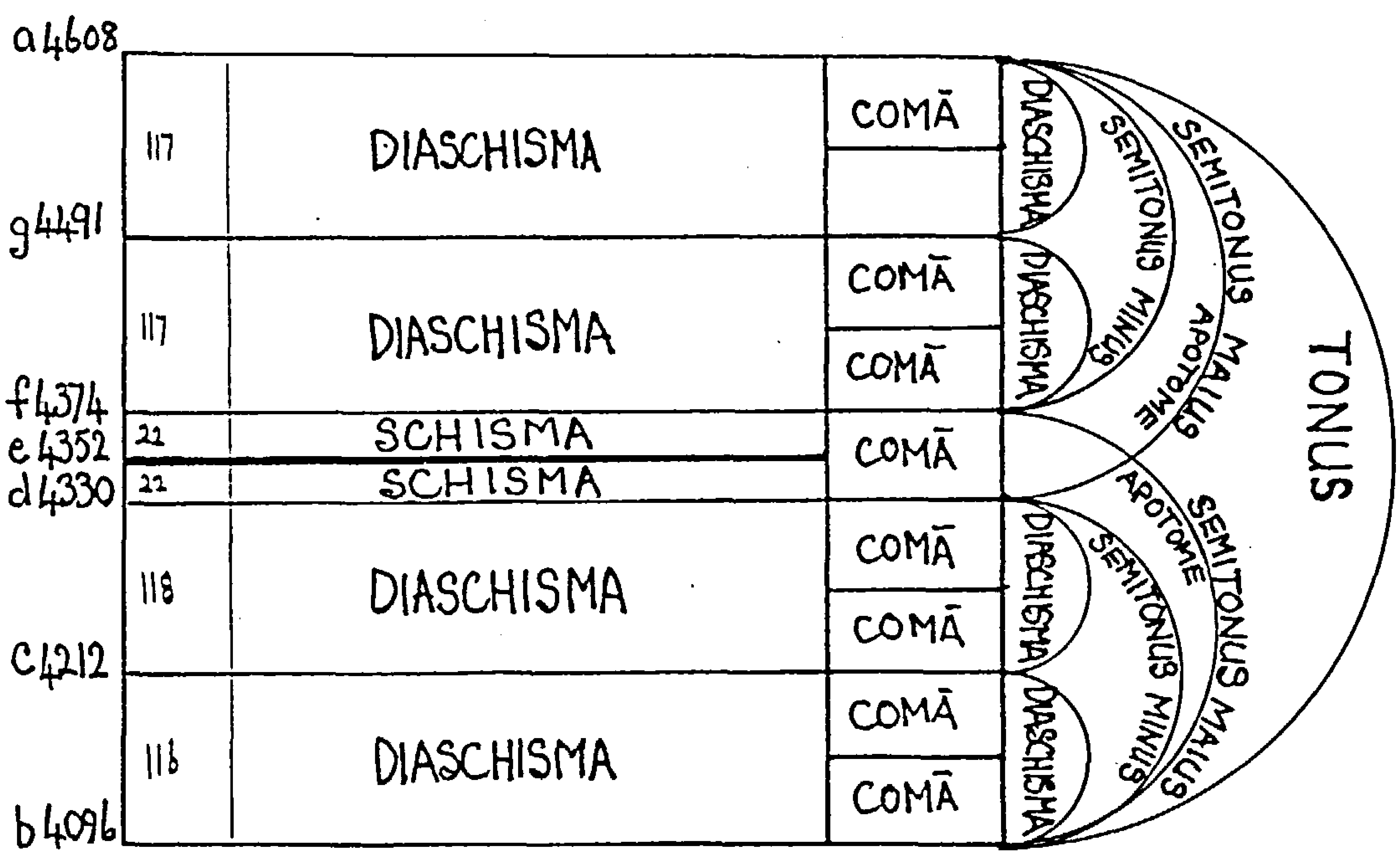

Figure 14. The Divisions of a Tone, according to Kircher.

to Boethius, Pythagoras's disciple Philolaus divided the tone into minor semitones and a comma, nine commas in all. The comma of the Greeks works out then at 22·666 cents, which is the value of a mean

(12) A.Kircher: Musurgia Universalis, 1st edn. (Rome,1650), p.103.

comma between the ditonic and the syntonic. Kircher shows an equal linear division into nine parts. The proportions suggest that two commas equal one diaschisma, and therefore a Greek diaschisma equals 45 cents. The comma also divides into two schismata; consequently the Greek schisma equals 11•3 cents. Unfortunately this scarcely tallies with Kircher's string lengths. None of these three names and quantities reflect later or present usage.

Notation and the Keyboard.

A glance at Figure 12 is quite sufficient to alert the reader to the confusion which may arise between notation, the naming of notes, the keys of the keyboard and their corresponding pipes and strings. Werckmeister is quite consistent here, however, in that his notation gives theoretically correct notes, whereas the letters below the notes give the German organ-builders' names for the respective keys on the keyboard, or pipes in the rank, correct even to the octave.

> "As a matter of fact, Fis, Cis, etc., are still the German names for F♯, C♯ and the rest: and organ-builders and tuners still use only the sharp designations for organ-pipes. B♭ and B♮ were normally distinguished as before-b and h, respectively." (13)

It is important that the student of German temperament is prepared for a variety of ways of expressing the names of the notes of the intervals to be tuned. Usually the notes defining a temperament are written on the monochord or in the text simply as letters, but there is rarely any confusion, because the engraved arcs of the monochord, or the verbal instructions, confirm the relationships and derivations of any doubtful notes. Early tuning schemes often use the Guidonian symbols, and may refer to the sizes of intervals by the hexachord note-names, for example, 'ut-mi' for a major third and 're-fa' for a minor third. Schlick is precise in his instructions, but remarkably casual:

> "Now when the B♭ (B fa B mi) is tuned thus, take the fifth below it, E♭ or D♯ (post re/oder Dis), call it what you will...". (14)

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(13) R.Rastall: The Notation of Western Music, (London,1983), pp.144f.

(14) A.Schlick: Spiegel der Orgelmächer und Organisten, 1st edn. (Speyer, 1511: R/Mainz 1959) p.92, tr. J.V.P.

Praetorius uses the letters of German tablature and suffixes the Latin -is abbreviation sign (ƒ) for all sharpened notes, even though the interval being described is defined by the flatted equivalent: for example he invariably uses Dis or Dƒ for E♭. b remains the symbol for both B♭ and A♯. The division of Werckmeister's monochord into the proportions of the pure scale uses the same naming scheme as Praetorius with three added notes, Am, Em and Ais, at the interval of a major third, below C,G, and above F♯, respectively. The 'm' is, no doubt, an abbreviation of the German 'moll'.

CHAPTER 4.

TUNINGS AND TEMPERAMENTS.

This chapter attempts to trace the development of temperament as far as the end of the seventeenth century in southern and central Germany, to show how practical musicians solved the problem as the need arose, how musicians and theorists solved the problem in different ways as music and concepts of consonance changed, and how the inherent disadvantages of temperament were tuned to enhance the expressive qualities of music.

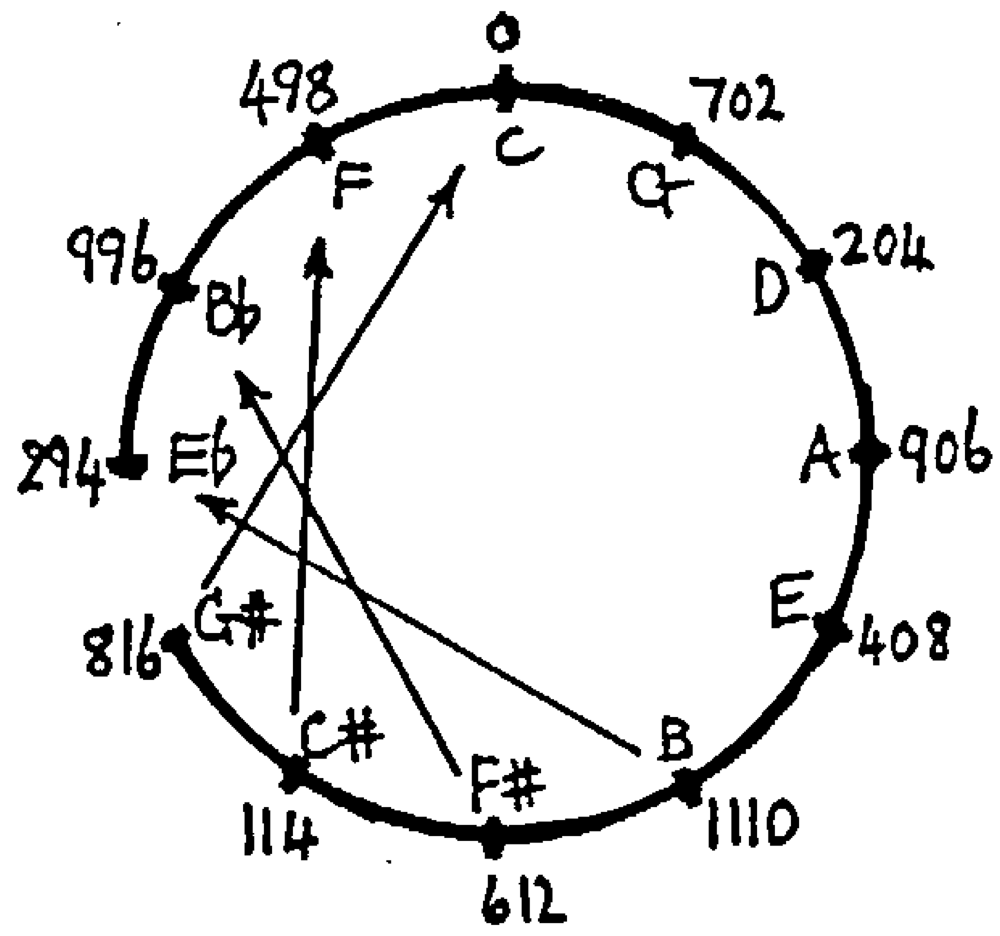
Each temperament is presented diagrammatically as a circular chain of fifths. Pure fifths are shown by a thick line, tempered fifths by a thin line, and a wolf by a break in the circle. The sizes of all thirds and fifths, or their enharmonic equivalents, have been calculated and are presented as major and minor triads.

Early Pythagorean Tunings.

The earliest twelve note monochords reflected Pythagorean beliefs. They were regular and identical except for the position of the wolf, whose size was always that of a pure fifth minus a ditonic comma (678 cents). They provided accurate pitches for plainsong, and early theoretical and didactic justification for western music following in the Greek tradition. Their application to the keyboard was of secondary importance. Nevertheless, they must be taken into account, for the history of the organ, the oldest keyboard instrument, is not much shorter than the history of music itself, and the tuning of the instruments other than to the notes used by the voice was inconceivable.

Hugo von Reutlingen's treatise (see p. 16) must have been written before 1360, the year of his death. It was obviously not outdated when it was first published in 1488, about thirty years after the Gutenberg Bible, and ran to several editions. Even more typical of Renaissance times than Hugo's monochord was the disposition of the chain of fifths G♯ - E♭ shown in Figure 15.

Figure 15. Pythagorean Monochord, G♯ - E♭

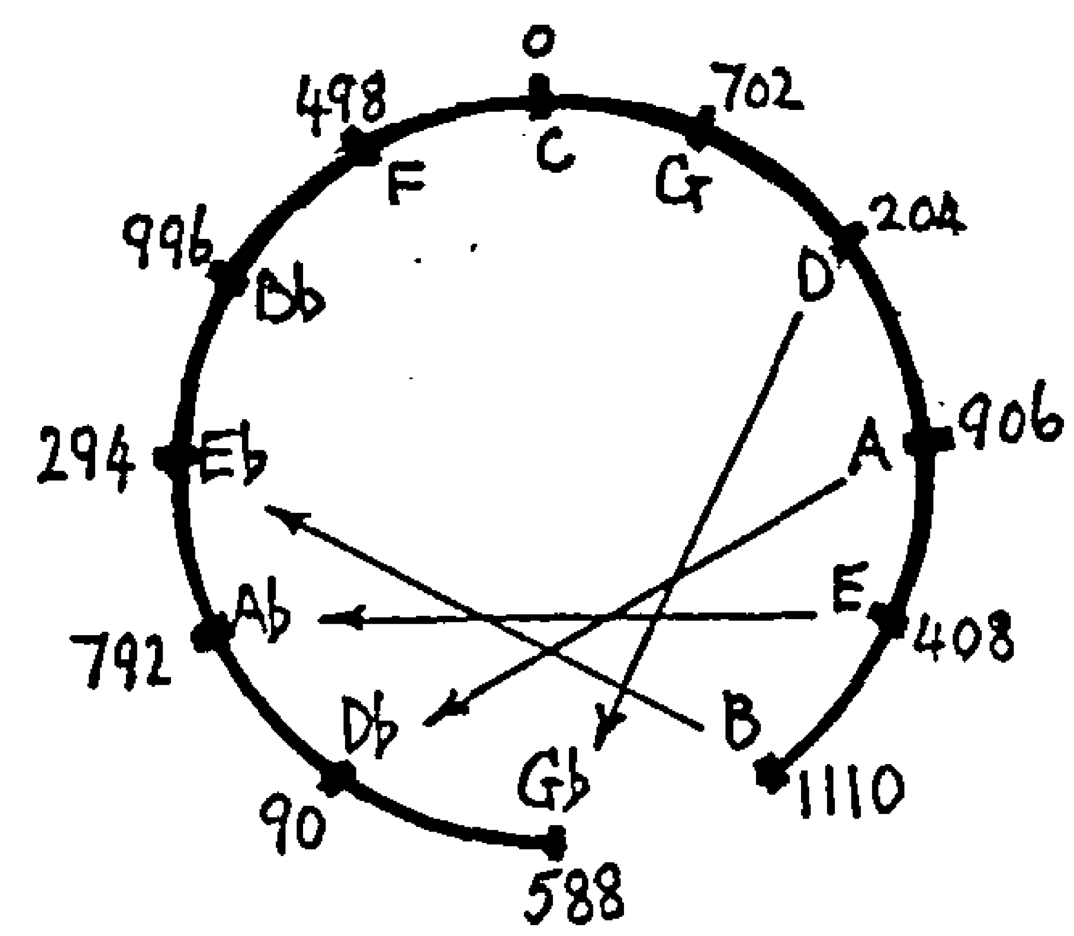


	mi.3	ma.3	5								
C	294	408	702	E	294	408	702	G♯	294	384	678
C♯	294	384	702	F	318	408	702	A	294	408	702
D	294	408	702	F♯	294	384	702	B♭	318	408	702
E♭	318	408	702	G	294	408	702	B	294	384	702

Not all are triads in the strict sense of the term, because the so called wolf is by definition a diminished 6th, and in the same way there are four false major 3rds (dim.4ths) and three false minor 3rds (aug.2nds). Here is an anomalous situation which can be turned to the advantage of instrumental practice, in that the keyboard is visually and palpably ambiguous, and a fretted instrument relying on a tablature is both visually and palpably ambiguous. It will also be noticed that these false thirds are almost the size of just-intonation major and minor thirds. Shown by arrows in the diagram, each false major third is a ditone minus the wolf in size, that is, 384 cents, a schisma less than a pure major third, and each false minor third is 318 cents, a schisma more than pure minor thirds. Unfortunately these thirds are components of triads disallowed or seldom used at that time.

Whilst theorists, mainly Italian, struggled to reconcile the ancient Greek genera with instrumental requirements, Arnolt Schlick, a most revered organist and lutenist, swept aside all convention, and with the confidence of combined theoretical knowledge and executive skill, preferred to refer to the accidentals of the keyboard by any convenient name. (See Schlick quotation on p.40). Necessity being the mother of invention, Pythagorean tuning could be successfully applied to fifteenth-century counterpoint, with hardly any concessions for expediency's sake. By means of tuning transposition and re-naming of parts of the incomplete circle of fifths, the euphonious thirds could be made to occur as components of some of the familiar triads.

Figure 16. Pythagorean tuning transposed to the disposition B – G♭.



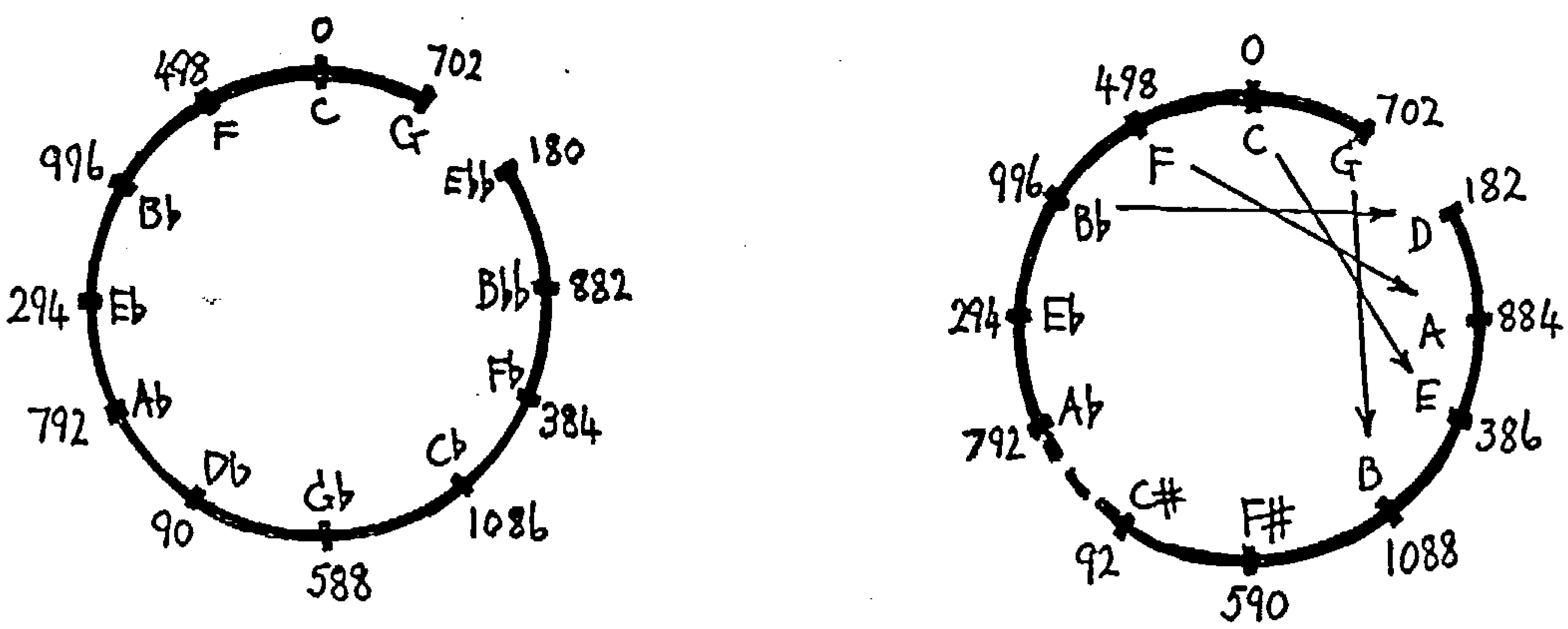
	mi.3	ma.3	5								
C	294	408	702	E	294	384	702	A♭	318	408	702
D♭	318	408	702	F	294	408	702	A	294	384	702
D	294	384	702	G♭	318	408	702	B♭	294	408	702
E♭	294	408	702	G	294	408	702	B	294	384	678

Figure 16 shows Pythagorean tuning transposed towards the flat side by three fifths. If all keyboard raised notes are spelled as sharps, the chain of alternate major and minor thirds on the sharp side between D and D♯ is almost pure. There are three good serviceable triads, and the wolf is contained in a seldom used fifth.

D F♯ A C♯ E G♯ B D♯
384 318 384 318 384 318 384
702 702 702

This disposition was referred to more than any other in Renaissance times. Gafurius gave its specification in Theorica Musicae (Milan, 1492), and it was similarly referred to by scholars throughout Europe, including Arnault de Zwolle, Agricola and John Holtby. It shows that a partial solution to the problem of consonant triads, with Pythagorean justification, afforded some appeasement to the admitted practices of the singers of fifteenth-century counterpoint. Whether the theorists reproduced the general practices of their time, or documented earlier or even outdated practices is a moot point, but it is obvious that by transposition Pythagorean dogma was being twisted for expediency's sake. Just-intonation had its foot in the door.

The history of temperament scarcely shows a uniform development. Pythagorean tuning held its ground for centuries. Its intonation, admirably suited to the liturgy of the church, must have been considered inviolable, and any system which sought to supersede it would for the same reasons have been considered anti-Christian. There were, however, three almost identical slight modifications to pure Pythagorean tuning within a matter of about sixty years. Ramos transposed the Pythagorean Tuning flatwards to the G - E♭♭ disposition, and then made pure the false thirds by adding to each a schisma. He then renamed them. (1)



a) Transposition to G - E♭♭ disposition.

b) Pure third adjustment and renaming. (The arrows now show pure major thirds; the dotted line the schisma fifth).

	mi.3	ma.3	5								
C	294	386	702	E	316	406	702	A♭	296	408	702
C♯	294	406	700	F	294	386	702	A	316	408	702
D	316	408	702	F♯	294	406	702	B♭	296	386	702
E♭	296	408	702	G	294	386	680	B	294	406	702

Figure 17. Ramos's Just-Pythagorean Temperament.

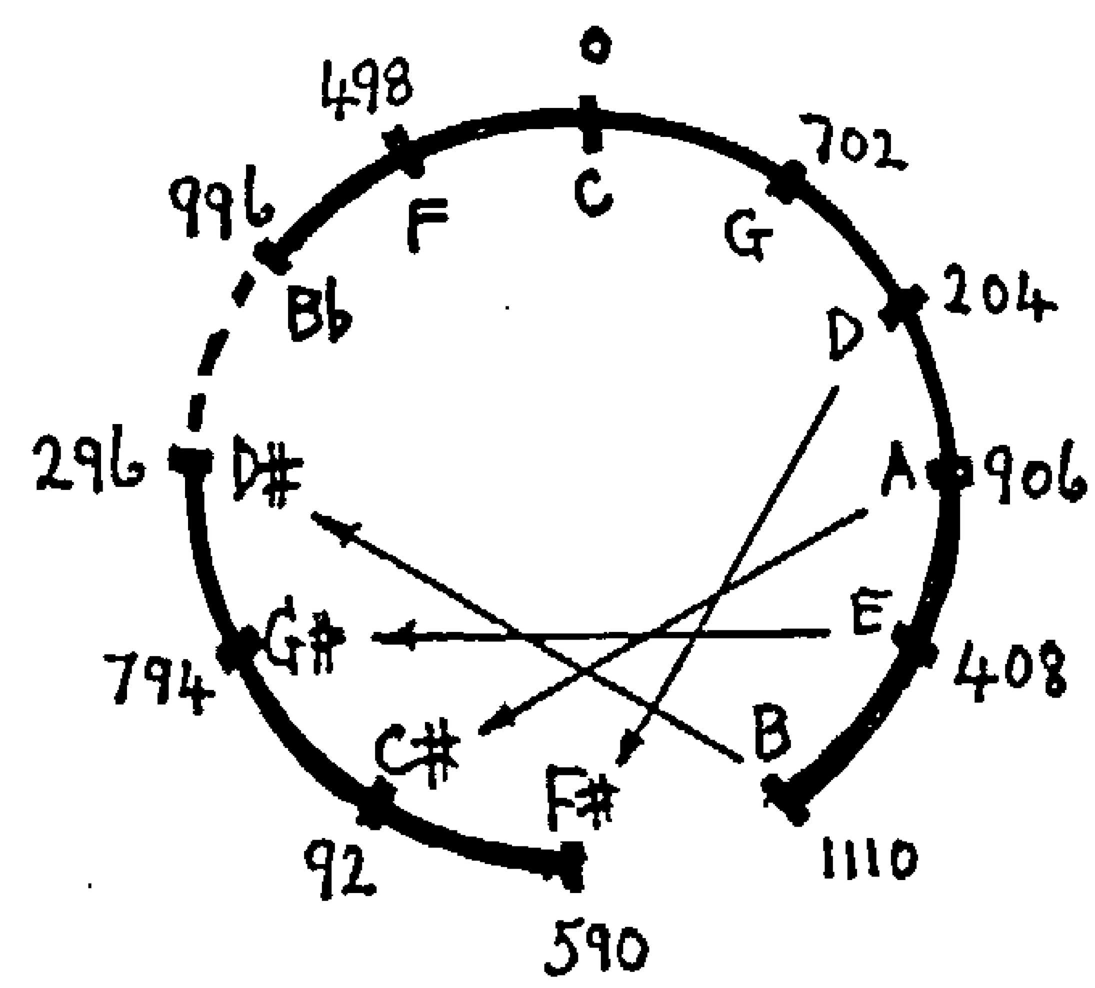
Two different sizes of whole tone, greater and lesser, are produced among the natural notes; around C are arranged four pure major thirds and three pure minor thirds, and so here is demonstrated the first known attempt to reconcile Ptolemaic with Pythagorean principles, and since Ramos's scheme interferes deliberately with the tuning of pure intervals, it is among the first temperaments. To compensate for making the pure thirds, the fifth separating the flats from the sharps becomes two cents narrower than pure - a schisma fifth. Ramos said that he intended it for the convenience and utility of singers.

(1) Ramos de Pareja: Musica Practica, (Bologna, 1482).

Theoretically it was inconsistent, and practically it had one grave drawback in that the wolf fifth, admittedly a schisma nearer perfection than previous tunings, could not have been in a worse place.

A transposition towards the sharp side and similar modification of false thirds was published by Agricola, (2) which is little more than the Pythagorean tuning B - G♭, but the wolf is in a much less inhibiting position, compared with that of Ramos half a century earlier. Like Ramos, Agricola renamed the false thirds, in this case making all the raised notes sharp except B♭, and gave them pure syntonic values. Interference with Pythagorean values was beginning to be accepted.

Figure 18. Agricola's Just-Pythagorean Monochord.



	mi.3	ma.3	5								
C	296	408	702	E	294	386	702	G♯	316	406	702
C♯	316	406	702	F	296	408	702	A	294	386	702
D	294	386	702	F♯	316	406	702	B♭	296	408	702
D♯	294	406	700	G	294	408	702	B	294	386	680

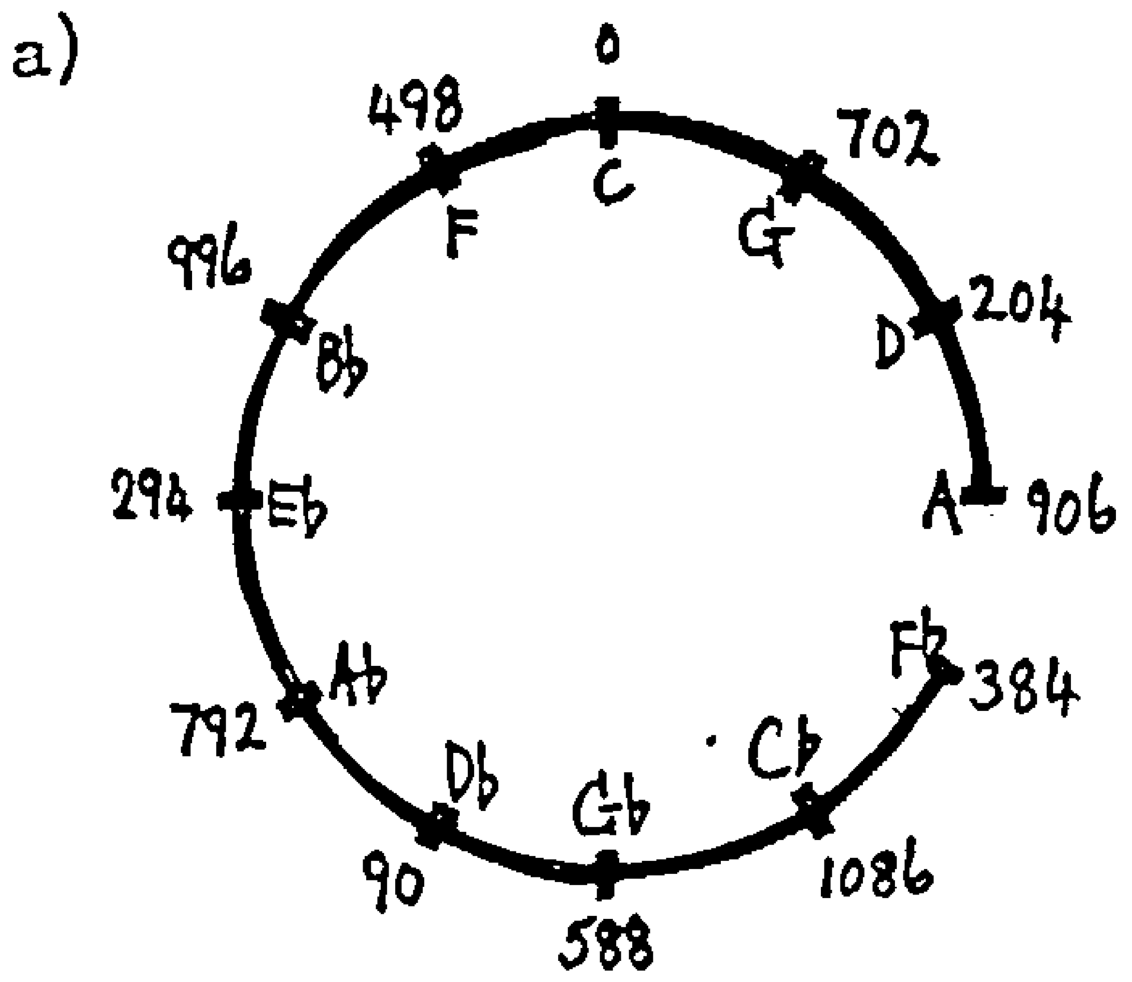
Yet another German modification of the Pythagorean monochord was discovered from a manuscript in Erlangen University by Wilhelm Dupont.(3) From the title of the manuscript Pro Clavichordiis Faciendis it may be assumed that this monochord was intended for keyboard use. The precise details of this temperament are open to interpretation, because neither D nor A are named and the raised notes are referred to only by numbers. The manuscript states that C, G and E are pure semitone , minor sixth and fourth respectively from B, that G♭ lies a pure major third above (D) which itself lies a pure fifth below (A). From G flatwards to G♭ is a chain of pure fifths. (4) It could well be

(2) M.Agricola: Rudimenta Musices, (Wittenberg, 1539).

(3) Pro Clavichordiis Faciendis, n.d. Manuscript, second half of 15th century. Erlangen is a few miles north of Nürnberg.

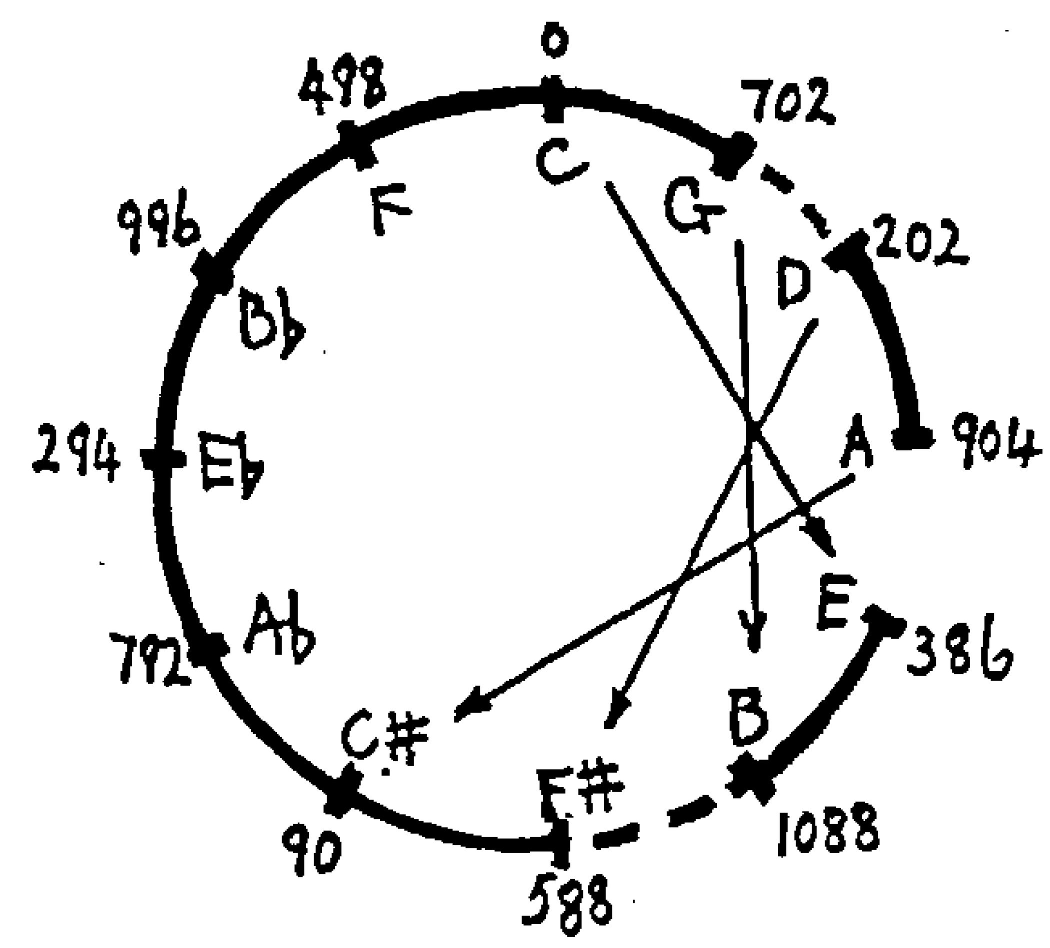
(4) O.Jorgensen: Tuning the Historical Temperaments by Ear, (Marquette, Michigan, 1977), pp. 79f.

a)



a) Transposition to A – Fb disposition.

b)



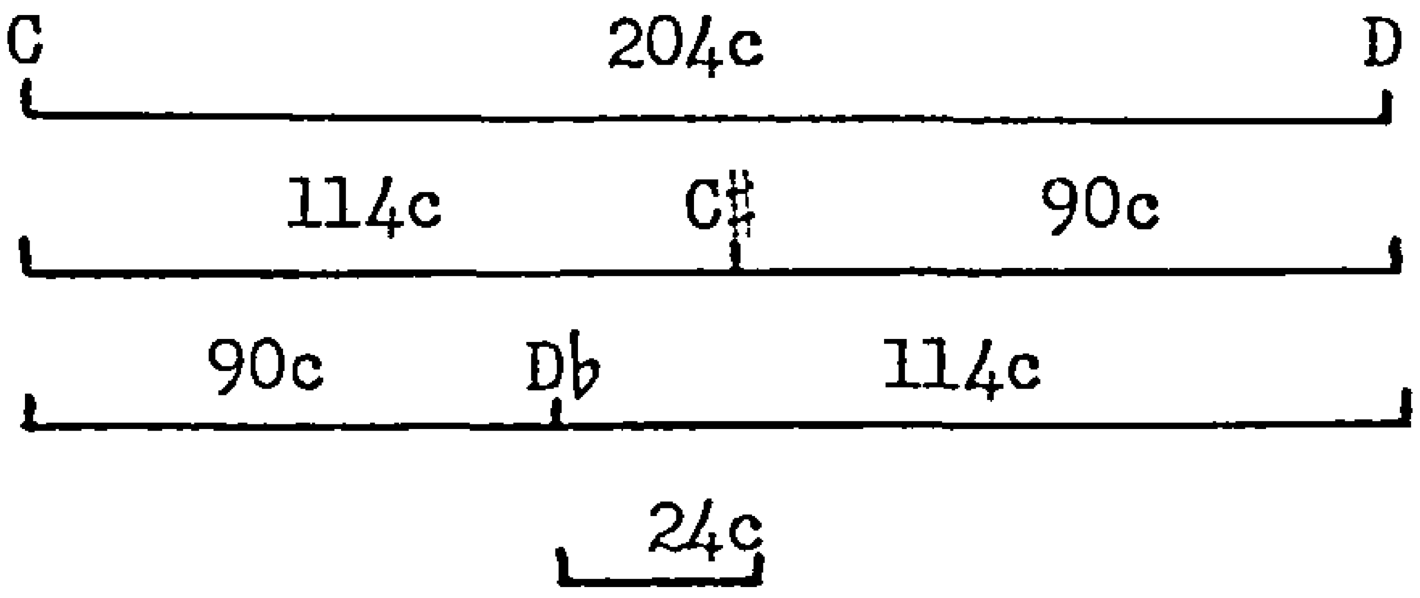
b) Pure third adjustment and renaming.

	mi.3	ma.3	5								
C	294	386	702	E	316	406	702	Ab	296	408	702
C♯	296	408	702	F	294	406	702	A	296	386	682
D	296	386	702	F♯	316	408	702	Bb	294	406	702
Eb	294	408	702	G	292	386	700	B	314	406	700

Figure 19. Erlangen Just-Pythagorean Monochord.

derived from making five transpositions towards the flat side from the original G♯ – Eb position, to the disposition A – Fb. It possibly predates Ramos's monochord, in which case it is the first retuning to provide a pure C major triad. This disposition provides two schisma fifths symmetrically arranged one fifth removed from the wolf fifth, which is a diaschisma narrow. Here is a slight improvement on Ramos, a compound manipulation of the chain of fifths, and a step towards real temperament.

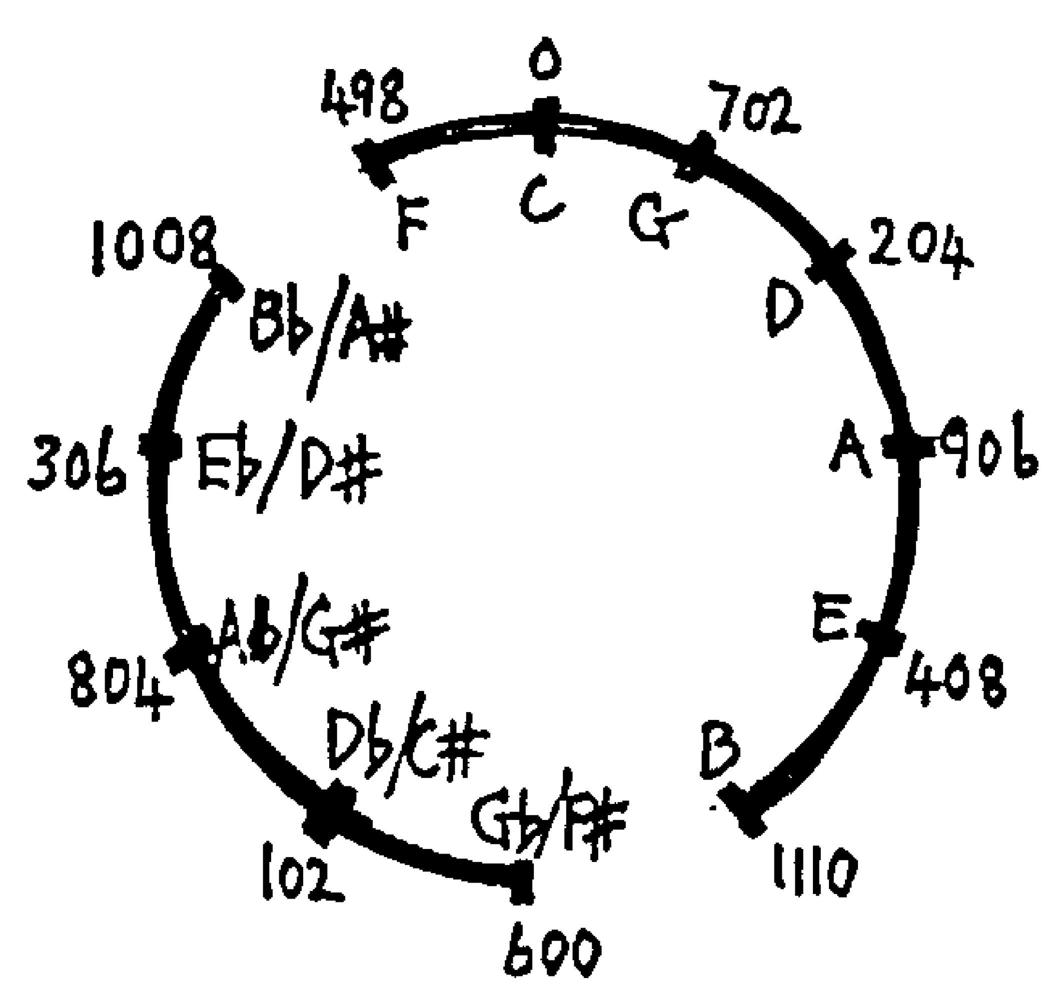
Grammateus, also known familiarly as Schreyber of Erfurt, approached the Pythagorean tuning problem in a different way, which allowed him to keep faith, if not precisely with Pythagorean principles, with more radical aspects of Greek musical belief. Centuries earlier Aristoxenus had earned the disdain of the Pythagoreans by asserting that the human ear could divide the tone into semitones. Ptolemy had provided the knowledge of the ratios of two virtually equal semitones, $\frac{17}{16} \times \frac{18}{17} = \frac{9}{8}$, also the authority, since he advocated the use of super-particular proportions in scale construction. Grammateus must have realised that the visual aspect of the keyboard and the frets of the lute gave no support to the chromatic extension of Pythagorean principles, where flat and sharp overlap each other by a ditonic comma thus:



Despite philosophical and practical difficulties, Grammateus fashioned a new keyboard temperament, on the authority of Aristoxenus and Ptolemy, the monochord of which gave Pythagorean values to the seven natural notes, and divided the whole tones equally. (5) Although Grammateus intended it for the organ, it was found to be equally appropriate for the lute. It must be remembered that this temperament contains two sizes of semitones. The equally divided tones provide ten so-called 'minor' semitones (102 cents), and the two natural semitones between E and F, B and C, which retain their Greek hemitone status (90 cents).

A convenient method of conceiving this temperament is to think of the natural notes on the one hand and the raised notes on the other as two chains of pure fifths, separated by two equally sized wolf fifths each accounting for half a ditonic comma.

Figure 20. <u>Grammateus's Temperament</u>



	mi.3	ma.3	5								
C	306	408	702	E	294	396	702	G♯	306	396	702
C♯	306	396	702	F	306	408	702	A	294	396	702
D	294	396	702	F♯	306	408	702	B♭	294	396	690
E♭	294	396	702	G	306	408	702	B	294	396	690

(5) H.Grammateus: <u>Ayn new kunstlich buech</u>, (Nürnberg,1518). The monochord is to be found in an appendix called <u>Arithmetica applicitet oder gezogen auff die edel kunst Musica</u>.

This temperament seems to require no further justification than freedom and usefulness. It is certainly the first of its kind in that it provides in a limited way for an octave of seventeen notes. Grammateus anticipated by two centuries the temperaments of Kirnberger and Weise which contain the syntonic or ditonic comma in two equal wolf fifths. Indeed, the only difference between Weise's No. 3 temperament is that Weise extended the chain of natural fifths to include B♭ before accommodating the other half-ditonic comma.

The method Grammateus used for finding the correct pipe length for a note half way between those of two pipes in the ratio $\frac{9}{8}$ he could have gathered either from the writings of Faber Stapulensis, or direct from Euclid's Elementa (printed 1482). Two pipes in the ratio $\frac{9}{8}$ were laid end to end. A semicircle was drawn, of which the combined pipe length made up a diameter, and a perpendicular dropped from the circumference to a point 9 : 8 along the diameter gave the length of the required pipe. (6)

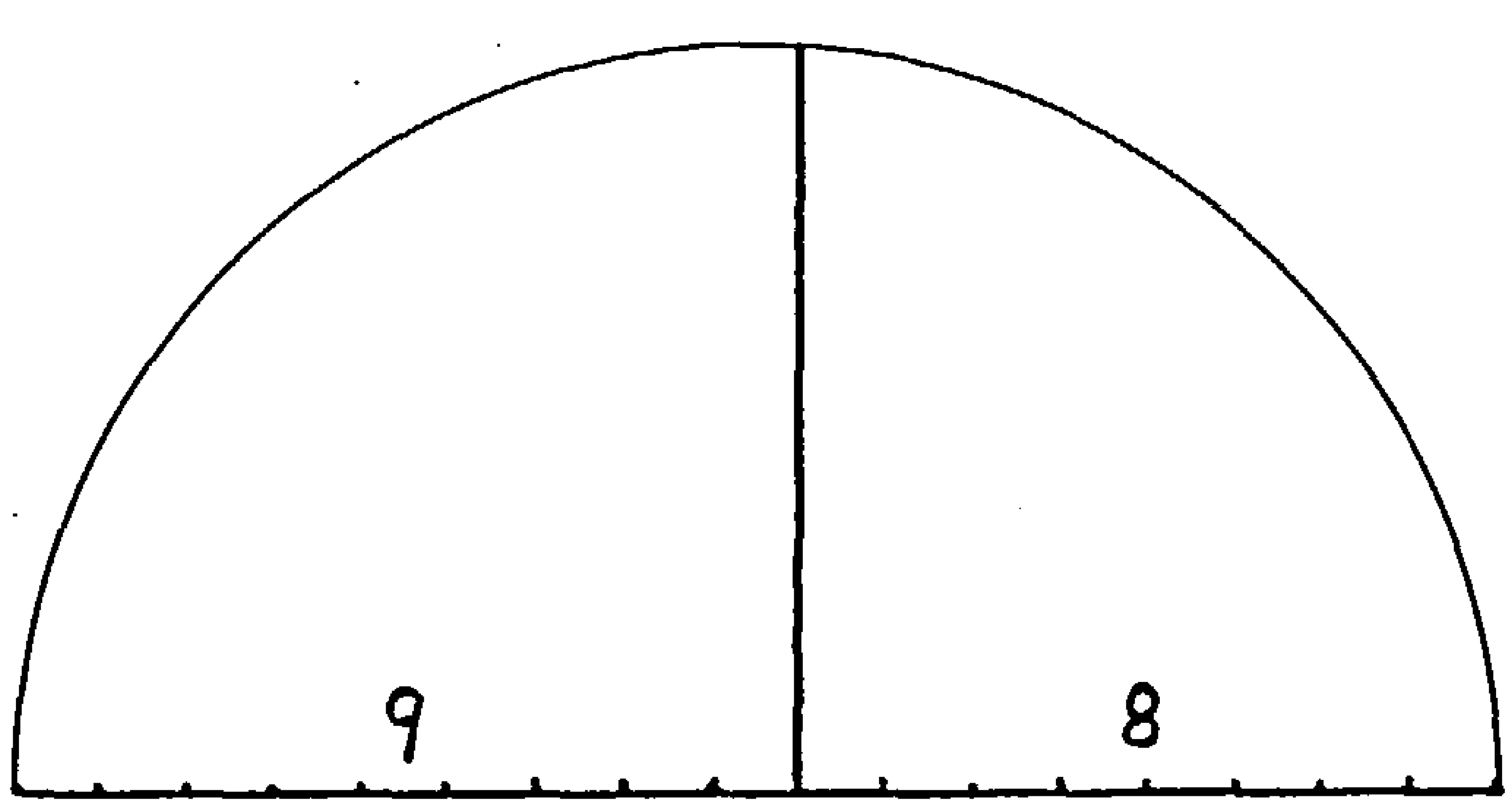


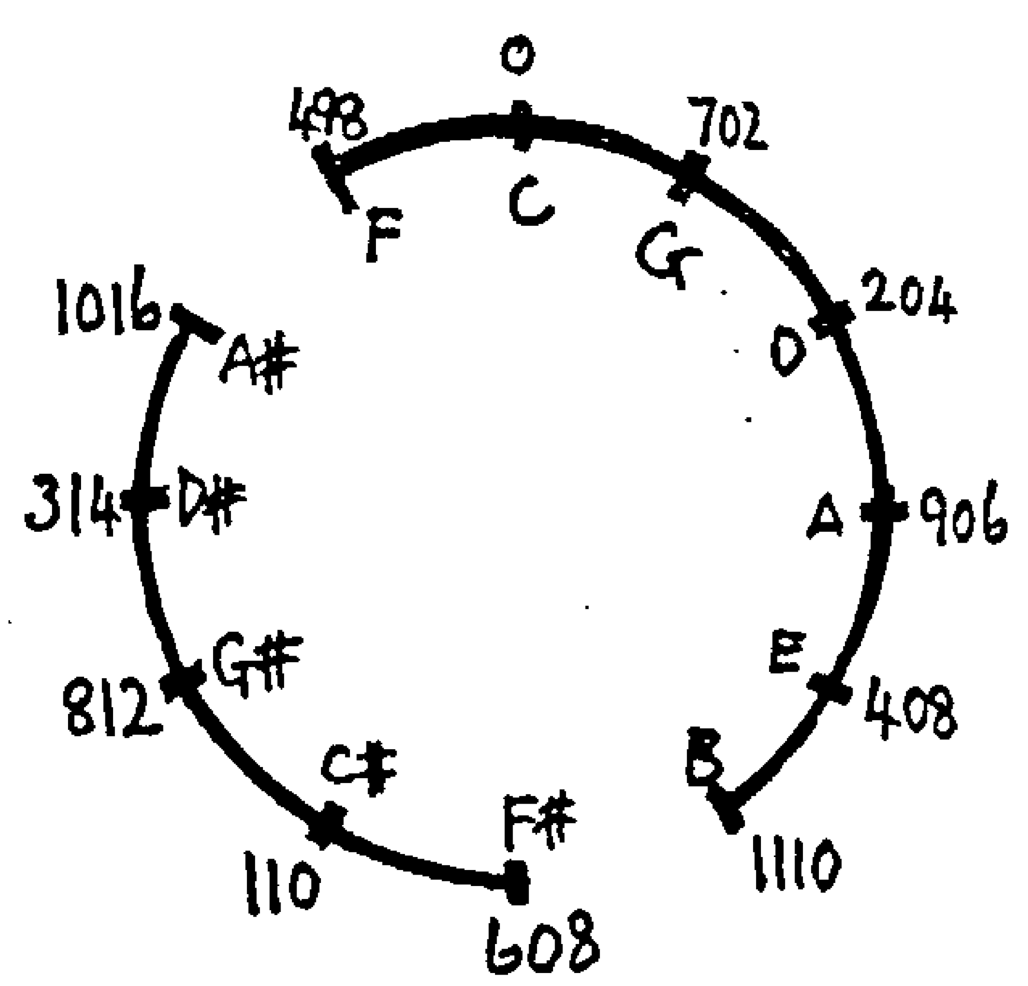
Figure 21. Grammateus's chromatic pipe length.

With this temperament a practical difficulty arises not encountered before. How did the organist or tuner temper a fifth exactly half a ditonic comma flat without checks, or how did he divide a Pythagorean tone into two equal semitones by ear ? The latter half of the question puts Aristoxenus on the spot. Grammateus himself admitted in his introduction that it probably needed to be applied from a monochord. It was an organ temperament and the difficulty of tuning pipes from a string has already been mentioned (p.37). It is therefore unlikely that organists who tuned by ear would normally use this temperament.

(6) For this account I am indebted to M.Lindley: 'Temperaments' in The New Grove , ed. S.Sadie, vol.18, p.663, and J.Murray Barbour: Tuning and Temperament, p.139.

Another early irregular Pythagorean temperament, similar in conception to Grammateus', took as its justification to modify pure Pythagorean tuning the ancient tenet that a Pythagorean tone can be divided into nine commas. Like all faithful Pythagoreans, Agricola believed that a chromatic semitone contained five commas, and a ditonic semitone four commas. His Pythagorean temperament shown below can be described as a chain of pure fifths going sharpwards from F, broken at B to adjust the chromatic semitone, making F♯ five commas above F. Thereafter the chain of pure fifths continues sharpwards to A♯ where once again the chain is broken to adjust the diatonic semitone making B four commas above A♯. Here also the residue of the ditonic comma requires further adjustment. Agricola calculated his monochord using arithmetical rather than geometrical proportions and so it lacks accuracy. Furthermore his monochord, primarily for fretted instruments, was subject to other inconsistencies inherent in irregular fretted systems. The temperament given below is a theoretical reconstruction of Agricola's intentions.

Figure 22. Agricola's Pythagorean Temperament.



	mi.3	ma.3	5								
C	314	408	702	E	294	404	702	G♯	298	388	702
C♯	298	388	702	F	314	408	702	A	294	404	702
D	294	404	702	F♯	298	408	702	A♯	294	388	682
D♯	294	388	702	G	314	408	702	B	294	404	698

Pure Intervals Abandoned.

In their agonizing over the Greek theorists some of the Renaissance theorists must have been emboldened by the realisation that the ancients were as heated in their controversy as they themselves were. The questing and questioning spirit of the Renaissance jibbed at the inflexible simplicity of the Pythagorean dogma, and its inadequacy to modern needs. The sympathies of humanism were more sensitive to the synthesising influence of Ptolemy, for his acoustic principles require ratio and sensus to work together. In fact in the early part of the sixteenth century the pendulum seemed to be swinging the other way, because Aristoxenus's and Ptolemy's assertion of sound being sensation of the human ear was given pride of place. But tradition dies hard. Out of the welter of partisanship and conflicting opinion there emerged three categories; first the ostriches, secure in the exclusive and ultimate truth of Pythagoras, secondly the fence sitters, who recognised the efficacy of just-intonation, but who adhered theoretically to Pythagoras, for the difficulties which just-intonation brought were unsolvable, and thirdly the radicals, who canonised the pure third and relegated the pure fifth. Practice led theory. Composers required an increasingly chromatic and modulatory freedom which transgressed the old systems. Instrument makers struggled to accommodate the demands of old truth and newly revealed truth, and both composers and instrument makers needed a new definition of the raw materials within the octave. By the end of the sixteenth century acoustic problems had been well aired (7) and Zarlino in his writings had codified a musical theory consistent with modern practice, and restored an uneasy equilibrium between theory and practice.

Gafurius, who rebuked Ramos on account of his theoretical innovations, and who quoted the Pythagorean tuning B - G♭ as the acceptable alternative to Ramos's monochord, may be classed as a fence sitter. He it was who gave the first documented hint of real temperamental compromise. In a chapter devoted to the rules of vocal counterpoint he casually and gratuitously wrote:

> "A fifth can be diminished by a very small, hidden and somewhat indefinite amount (as organists assert), which they call participata." (8)

We can read into this statement that before 1496 the tempering of organs was an established practice in part of Europe at least, and that the residues resulting from the narrowing of the chain of fifths

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(7) The treatise E.Bottrigari: Il Desiderio, (Venice,1594) pin-points the problems of the new tonal and instrumental liberty, particularly applied to concerted music.

(8) F.Gafurius: op. cit., p.125

had acquired their own explanatory and expedient term, participata. In De Harmonia Musicorum (1518), Gafurius mentioned, in conjunction with participata, that organists made the Pythagorean major sixth slightly smaller. (9) The picture becomes clearer. By tempering the fifths, organists helped to alleviate the agitated beating of the wide major thirds and wide major sixths. Fifths are never tempered to enhance their own quality. There is no record of Gafurius discovering the nature of the temperament, which is surprising, taking into account his scholarly curiosity. He neither condoned nor condemned the practice. Moreover he did not explain it.

Ramos, among the first of the radicals, was paralleled in Germany by Arnolt Schlick, (c.1460 - 1517+) who, lacking the usual Teutonic reverence for the status quo, incorporated as many nearly pure thirds into his organ temperament as he thought possible, but at the same time tried to make provision for less familiar but effective harmonies. He was also probably the first to mention how organists overcame weaknesses within a temperament by distracting the ear by ornamentation and ambiguity. He instructs the novice how to listen, especially to the hiccup-like quality of the beats of an interval nearing purity. (10) Like a modern-day theologian, his argument is based ultimately on situational ethics. No interval need be absolutely pure. His instructions bristle with admonitions later to become the familiar mode of expression of the temperament engineer, such as "a tolerable third", and "let it beat ... as much as can be borne". The absolute yields to the expedient in every case. Here follows a synopsis of Schlick's tuning instructions from which can be abstracted a probable temperament. Schlick divides the laying of the bearings into three stages, carefully giving reasons for each operation; not for him the arbitrary dictates of the monochord, but the fine judgement of his ear towards definite musical ends.

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(9) Ibid. p.125, fn.

(10) A. Schlick: Spiegel der Orgelmächer und Organisten, (Speyer, 1511). A complete translation by J.V.P. of Chapter VIII on the tuning of the organ, is to be found in Appendix 1.

The Tuning Instructions of Arnolt Schlick, 1511 (Synopsis).

1) "Begin at F on the manual."

5ths slightly narrower than pure.
Octaves pure.

Drop octaves to keep fifths within audible range.

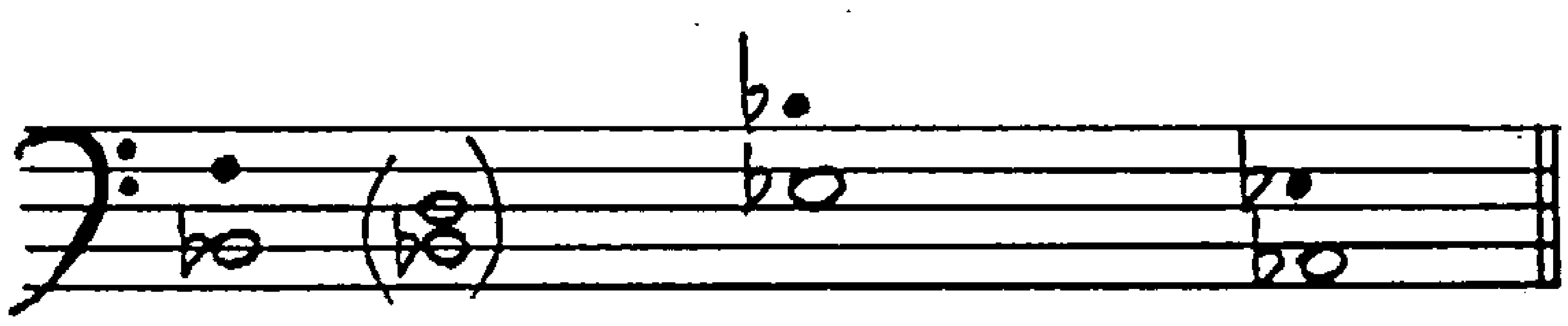
"Then you have tuned the basic notes with each other."

Tune the octaves above and below each of the notes.

"Although the major thirds are collectively too wide care must be taken that the three most important C - E, F - A, G - B♮, are tuned more pure, as good as their corresponding fifths will allow."

Schlick warns at this point that the already accumulated errors in the thirds will cause difficulties with G♯/A♭.

2) "Start again on F."



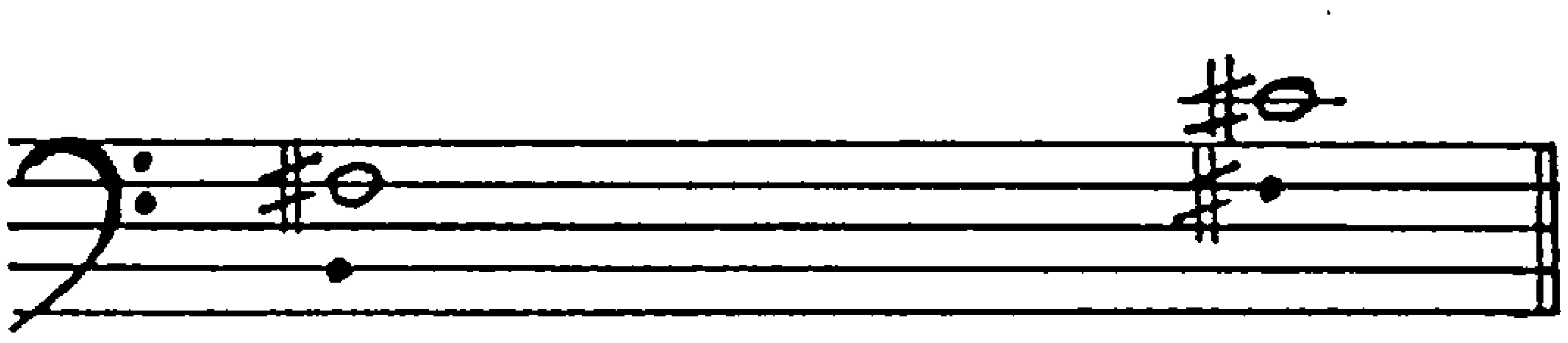
B♭ to make a tolerable 3rd with D

"E♭ or D♯ call it what you will."

narrow 5ths

A♭ or G♯. A WIDE 5th, so that the note may serve as a G♯ to E - B♮ triad. As a G♯ in a perfect cadence on A it will best be tolerated if camouflaged by ornamentation.

3) "Continue then at B♮."

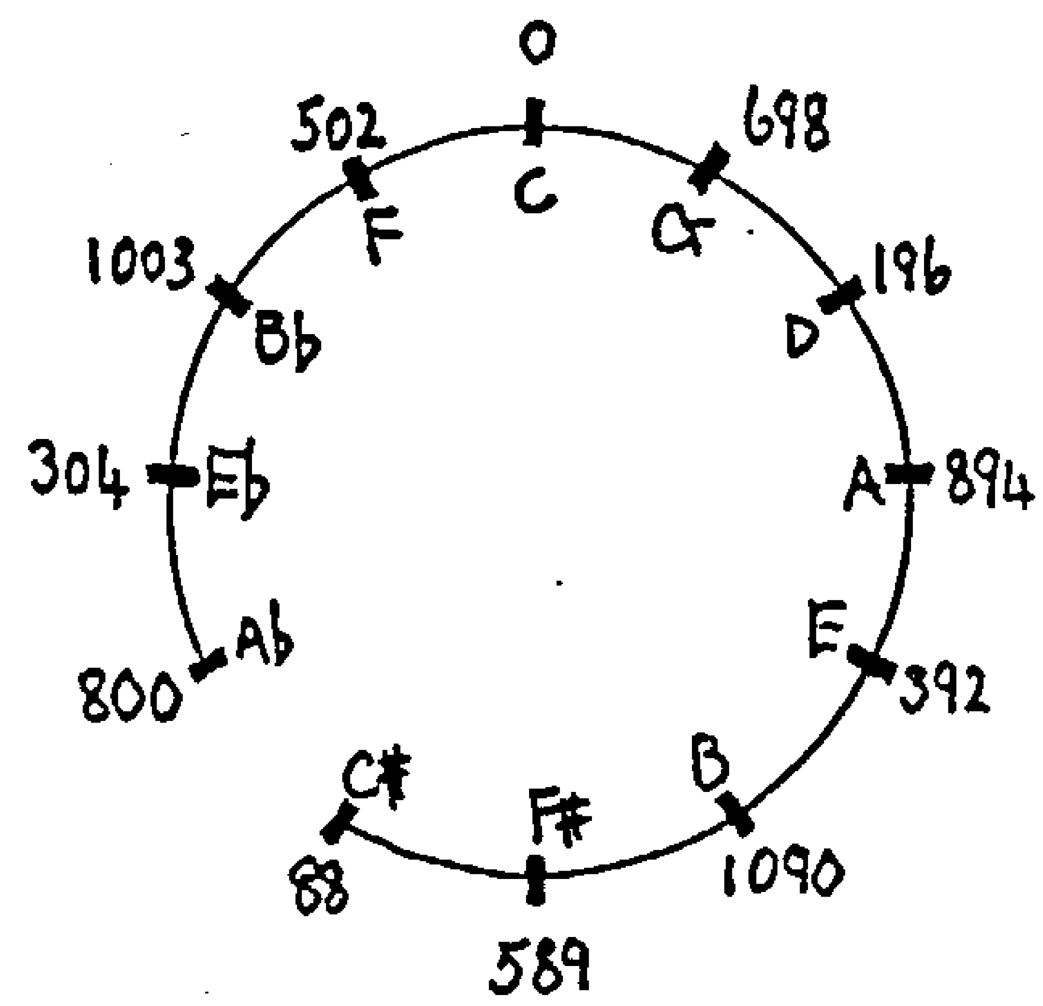


"F♯ to beat gently on the low side", so that D makes a tolerable 3rd.

C♯ or D♭. The note to serve as the 3rd in the triad A - E. "Admittedly this will be too low against the 5th above G♯, but that does not matter, since it is not used."

In general Schlick shows a complete lack of partisanship. He concedes that the major thirds are greater than pure, which is an admission that he is no Pythagorean, but he is unwilling to sacrifice other considerations for the sake of pure thirds. Schlick follows the admitted practice of organists of tuning the fifths slightly on the narrow side, but there is one noticeably wide fifth, a new development in the history of temperament and preferably avoided.

Figure 23. Schlick's Temperament.



	mi.3	ma.3	5								
C	304	392	698	E	306	408	698	Ab	290	400	704
C#	304	414	712	F	298	392	698	A	306	394	698
D	306	393	698	F#	305	414	699	Bb	285	393	699
Eb	285	394	699	G	305	392	698	B	306	414	699

(11)

The wolf fifth is a component of no practical use, he says, but his comments on the raised note G#/Ab suggest that he encourages harmonic boldness and experiment. He is concerned more with Ab and the adventurous sonorities it encourages rather than G#, whose imperfections at a cadence point can be camouflaged by any organist worth his salt. This idea will be followed up later when the music is discussed.

Schlick expresses a harmonic conception which is strongly to influence the construction of temperaments by German musicians from this time and until the universal acceptance of equal temperament. He requires that the thirds of familiar triads should be as pure as their corresponding fifths will allow. He may not have an explicit hierarchy of triads but he states that some are more important than others, and that one of them is expendable. Apart from the expendable triad, these thoughts cover the main arguments for keyboards to be well-tempered (wohltemperiert), an expression coined by Werckmeister and borrowed notably by J.S.Bach. Schlick's encouragement of strange and unfamiliar sonorities is more in sympathy with Baroque rather than Renaissance thought, and yet Schlick was no iconoclast: "There is never any need for all the semitones." He was held in highest

(11) Calculations here are based on a conjectural temperament reconstruction by M.Lindley in 'Early 16th-Century Keyboard Temperaments' in Musica Disciplina, xxxviii (1974), pp. 129 - 138.

regard by his generation, his organ music reached the highest point in Renaissance keyboard style, he travelled widely in Germany and Holland winning fame as an instrumentalist, and one of the great Pythagoreans dedicated his treatise to him in a panegyric which is full of expressions like this:

> "There is no man either learneder or subtler in his art than yourselfe." (12)

Although his prowess was also great as a lutenist, there is no record of his views on the temperament of the lute. To compare his ideas on both instruments would be fascinating. He had a lasting influence upon the music and keyboard practice of the German speaking peoples and the Netherlands.

Meantone Temperaments.

In 1526 Erasmus complained of the cacophony of flutes, pipes, trumpets and trombones which resounded in churches. By the end of the century there was much greater opportunity for music, sacred and secular, with a greater variety of instruments, with or without voice than ever before. Music was made in all strata of society; it was introduced as a subject of study and practice in the universities; it became an end in itself. Dilettante jostled with professional. The lute became a most popular and ubiquitous instrument. Spinet and harpsichord arrangements and variations were made of popular airs and dance tunes. In this atmosphere of diversity and freedom there was a new confidence and a falling away of the medieval sense of guilt. The major third was accepted by all but the most conservative Pythagoreans as a consonance. It needed no apologist. Diversity in the tuning needs of different kinds of instruments was acknowledged. For instance Galilei, who was familiar with both Pythagorean and syntonic tunings, advocated an approximation of equal temperament, with a semitone ratio of $\frac{18}{17}$ (98·95 cents) for the lute, but not for keyboard instruments. This kind of attitude may have been fostered by the realisation that on some instruments and in some contexts wide major thirds could be tolerated. It was common

(12) A.Ornithoparchus: Musicae Activae Micrologus, tr. Dowland. Book 4, Dedication.

experience that Pythagorean ditones on an organ produce an unpleasant harshness. Just-intonation ratios, used by the category of instruments Bottrigari called "completely alterable", namely, voices, trombones and rebecs, were much to be desired on keyboard instruments, classified by Bottrigari as "stable". The keyboard realisation of these ratios was so restrictive that compromise was sought more rigorously than ways and means to overcome the restrictions. A system of tuning and temperament based on the inviolability of the pure major third at the expense of the pure fifth - the very antithesis of Pythagorean principles - was increasingly used during the sixteenth century. This system, known as meantone temperament, was first described by Pietro Aron in 1523, but was probably introduced much earlier. (13) Aron's instructions are not absolutely explicit, but since that date this temperament has been accurately described by many sixteenth- and seventeenth-century writers.

There are many varieties of meantone, but the basic system, quarter comma meantone temperament, of which all others are variants, was described first in Germany by Sethus Calvisius, a forerunner of J.S.Bach at St. Thomas's, Leipzig. (14)

Calvisius works from the assumption that for any major third to be pure, of the four perfect fifths which contain that major third in a just-intonation scale, one of them is narrower than pure by a comma. For example, the pure major third C - E of C major implies a partial fifth circle C - G - D - A - E , of which D - A is what is known nowadays as a grave fifth. This fifth is smaller than pure by the same amount that a Pythagorean ditone exceeds a pure major third, that is, a comma. Calvisius adjusted the major and minor tones of just-intonation, so that by taking from the major tone and adding to

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(13) P.Aron: Toscanello della Musica, (Venice, 1523).

(14) P.G.Bunjes: The Praetorius Organ, (St. Louis, 1966). Pages 781 - 801 of this dissertation contain a detailed account of Calvisius's specifications for this temperament. Bunjes says that Calvisius, using the just-intonation ratios of $\frac{9}{8}$, $\frac{10}{9}$ and $\frac{16}{15}$ for the major and minor tones and diatonic semitone, adjusts the temperament using, as expected, fractions of the syntonic comma . Bunjes refers to no published work of Calvisius by name, but his major works were published between 1592 and 1600.

the minor tone in both cases half a comma, the tones become exactly equal, and the major third remains unchanged. He eliminated the grave fifth by making every available fifth a quarter comma narrower than pure. Hence 'quarter comma meantone temperament' is as succinct and precise a description as it is possible to have.

Michael Praetorius (1571 - 1621), a friend of Calvisius and his junior by fifteen years, describes the temperament accurately, with a minimum of mathematical detail. (15) It is obvious that Calvisius is his main source, whom he acknowledges in a cryptic or perfunctory way:

> "N.B. In all this I have not wanted to ignore the opinion of Calvisius concerning the temperament of instruments."

Calvisius provided the mathematical explanation. Praetorius is one of the first to provide a specific tuning method for the meantone temperament, complete with checks. He apologises for his lack of scientific confirmation and promises to remedy the omission, but of course the planned volume 4 of Syntagma Musicum was never published.

> "But this subject is to be discussed in detail, after this, from a consideration of the monochord, in a treatise, if God wills, on the basic rules of proportion. For here the desire is solely to establish good practice for organ makers and organists, so that even the simplest could understand something of what has been written here and would have gathered something from it."

For the keyboard tuner he has three basic precepts: firstly that the tuning must start on one certain note chosen by the tuner, secondly that all octaves and major thirds are to be 'completely pure', and thirdly that all fifths are to be made slightly narrow. Praetorius could not be more precise. It is of paramount importance, however, to remember that quarter comma meantone temperament provides for twelve unequivocal notes; for example B♭ can only be B♭, and cannot be A♯ or C♭♭. The temperament provides the maximum number of pure thirds in familiar keys, eight thirds in all, but to compensate for this purity there are four diminished fourths which must accept the whole of the diesis to complete the octave; For example:

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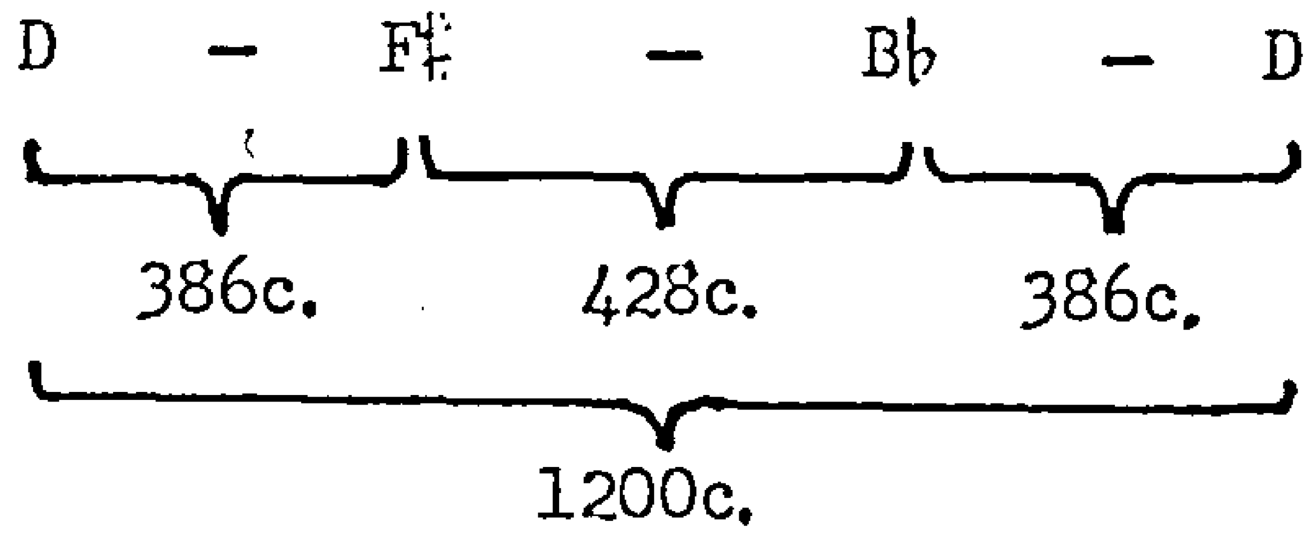
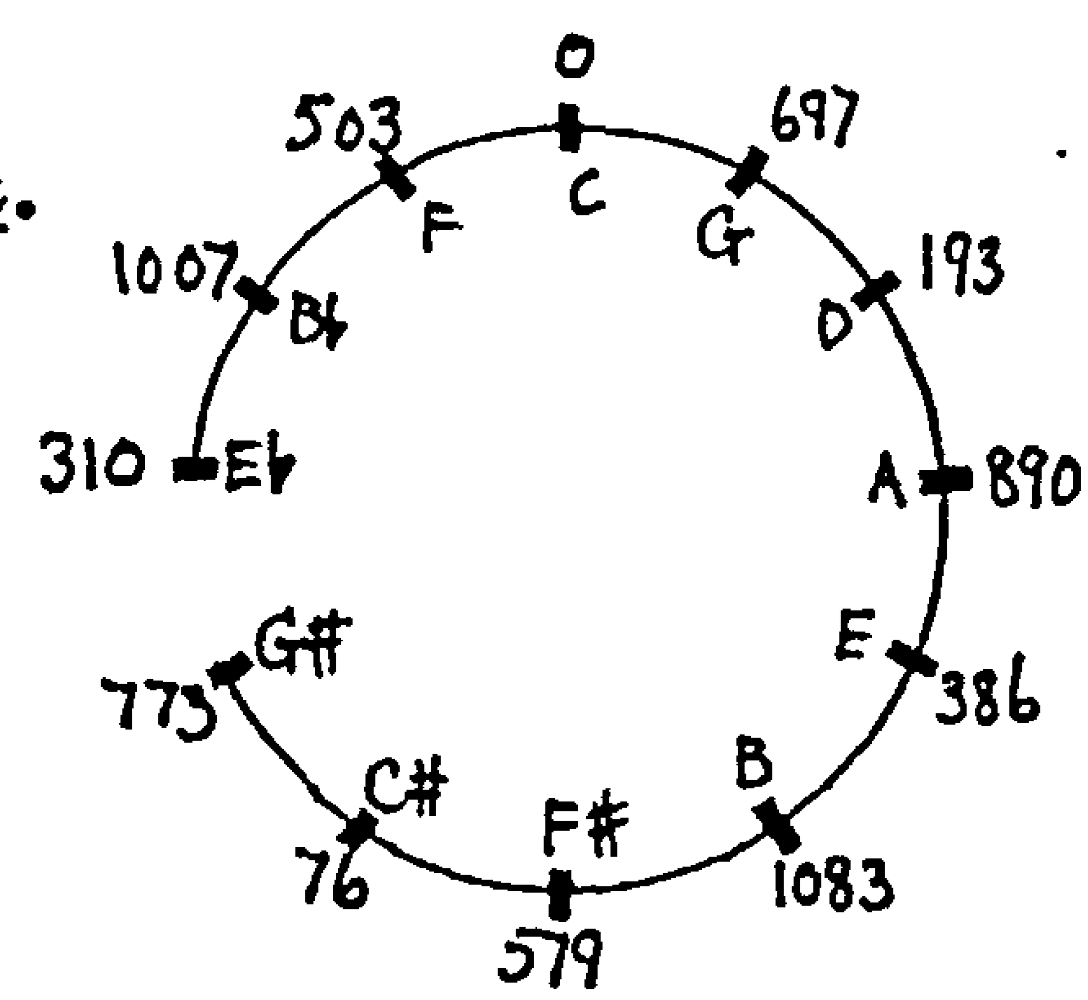
(15) M.Praetorius: Syntagma Musicum, vol. 2, De Organographia, (Wölfenbüttel, 1619: R/Kassel, Basel, 1958). A translation by J.V.P. of the relevant parts of the chapter is to be found in Appendix 1.



All the fifths, eleven of them (697 cents), are made narrower than pure by about five cents, which creates a beating rate rather quicker than that of the equal temperament fifth. (16) The twelfth fifth is by definition a diminished sixth, and with a size of 737 cents is quite unusable. All nine of its minor thirds are good, only five or six cents narrower than pure. The other three residual augmented seconds are more than a diesis narrower than minor thirds and unusable. In general, any meantone temperament may be thought of as a chain of narrow fifths, reaching flatwards and sharpwards to the extremes, usually E♭ and G♯, between which is a wolf.

Praetorius is thorough: he provides three sets of tuning instructions, the first and third of which are very closely alike, the main difference being the starting notes, F and C respectively. They describe unequivocally quarter comma meantone temperament, the triadic cent values for which are shown in Figure 24.

Figure 24. Quarter comma meantone temperament.



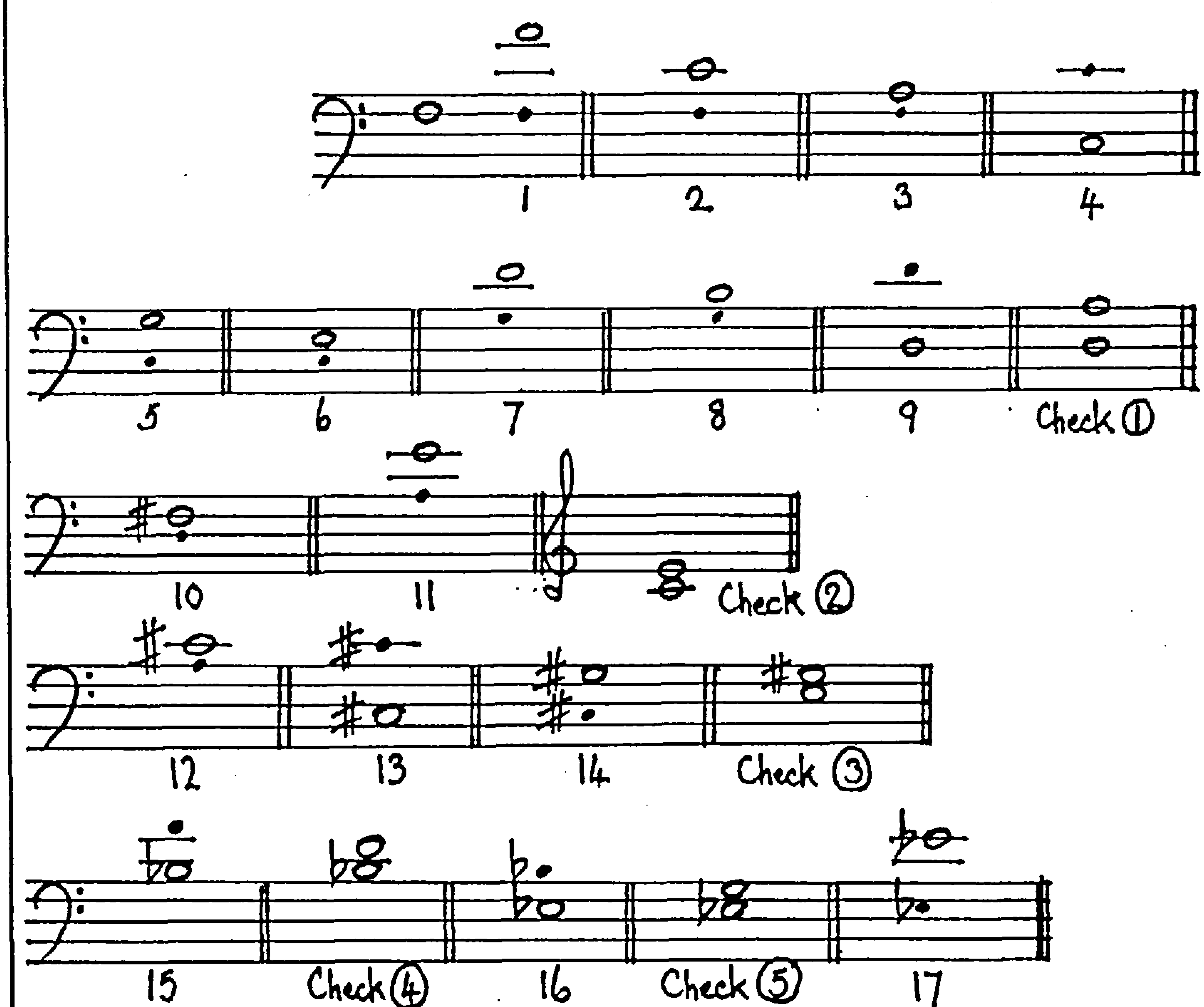
	mi.3	ma.3	5								
C	310	386	697	E	311	387	697	G♯	310	427	737
C♯	310	427	697	F	270	387	697	A	310	386	696
D	310	386	697	F♯	311	428	697	B♭	269	386	696
E♭	269	387	697	G	310	386	696	B	310	427	696

(16) The quarter comma meantone fifth = 696·5785c. For general purposes 697c. or 696c. is adequate. In the calculation of the meantone temperaments for this dissertation a high degree of accuracy has been used before rounding up or down to the nearest cent.

Earlier temperaments, as opposed to tunings, have been irregular, but here is the first regular one, and by definition the first equal temperament, in that all similar named intervals are of equal size, and therefore there is no difference of quality in the playable keys.

<u>The Tuning Instructions of Michael Praetorius</u> 1619 (synopsis)

"<u>The First Kind</u>".

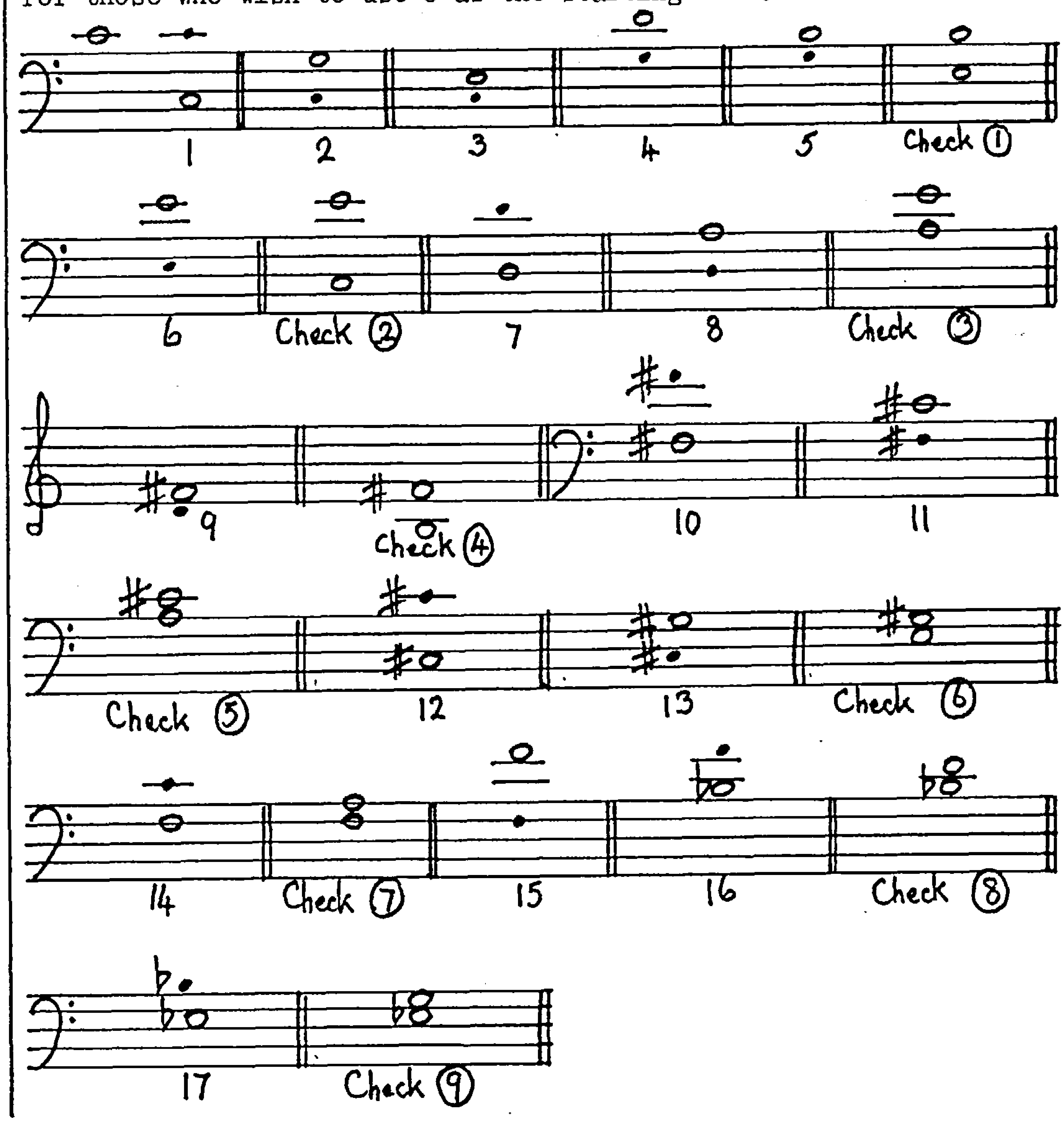


Starting at b♭ tune in octaves right to the lowest note. "Take care that these octaves are just, and that each one is not in the least sharp to its corresponding note which has been tuned pure." Then tune in pure octaves ascending, f'♯ with f♯ already tuned, right to the highest note, and constantly check with major thirds.

Praetorius lays the bearings on the sharp side first, using fifths and thirds. Then at step 15 he returns to the beginning for the flat side. The logical place for his 'Third Kind' is next to his 'First Kind' because the only real difference is the tuning note.

"The Third Kind".

For those who wish to use C as the starting note.



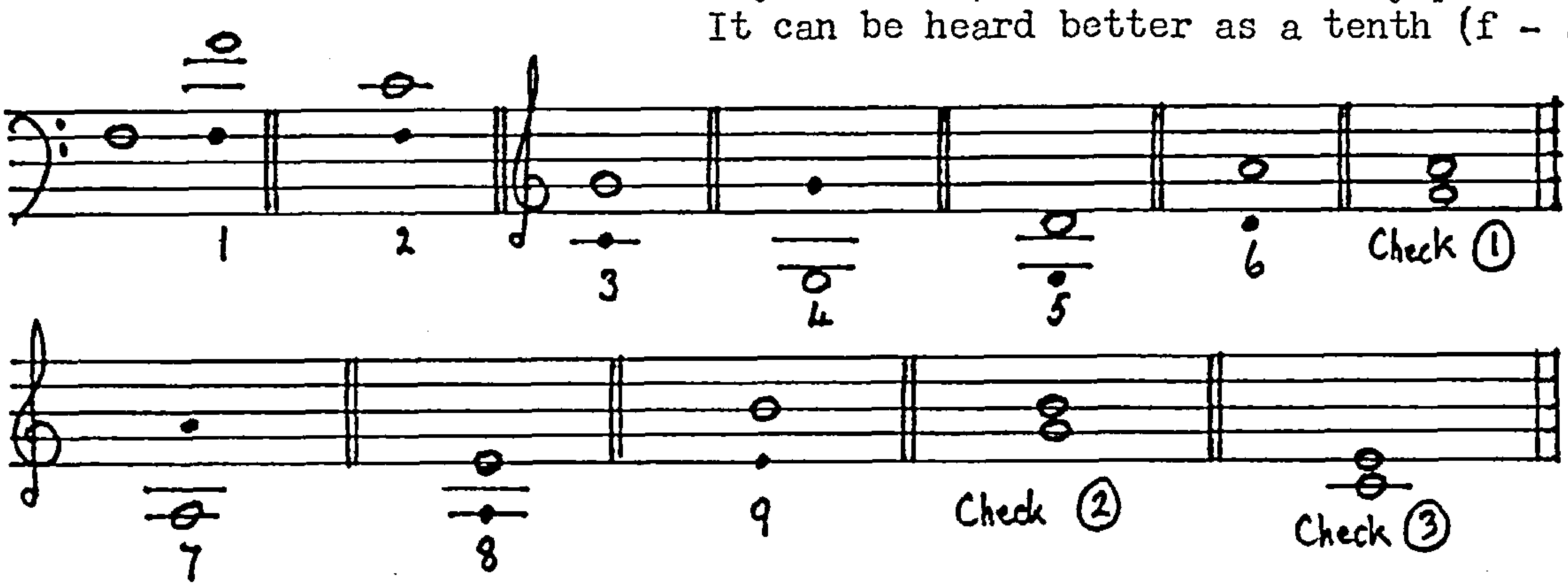
Praetorius's 'second kind' is consistent with his other methods except for the tuning of C♯, F♯ and G♯, which in the first case are tuned to their major thirds below, (steps 14 - 16). A problem arises over these three sharp notes, and, as in the case of Schlick, the crux of the problem is G♯.

Praetorius was against transposing the first mode on G down a tone to F, which would require A♭. G♯, 270 cents above F, could not possibly serve as A♭, which in this temperament would stand a diesis above this at 311 cents from F. Praetorius rather reluctantly suggests the raising of both C♯ and G♯ by very small unspecified amounts so that at least G♯ might substitute for A♭ if the necessity arose.

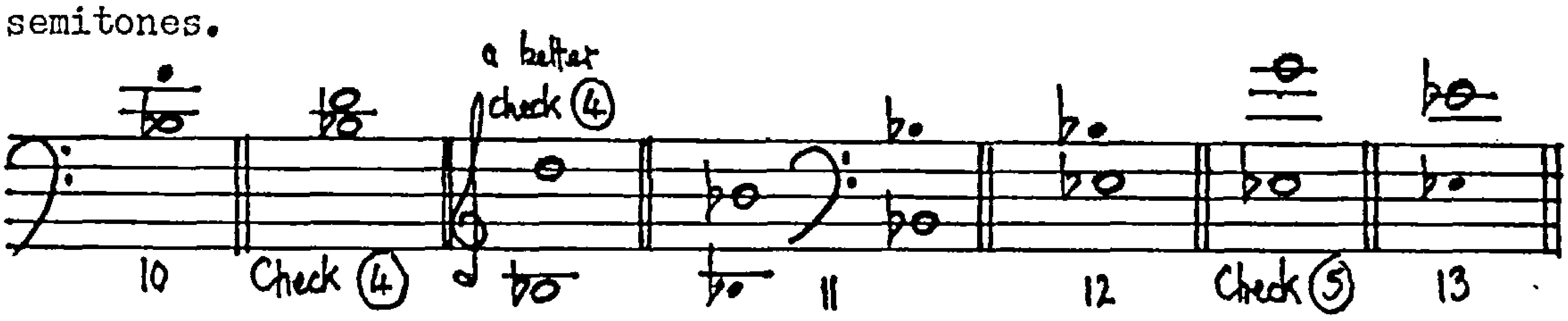
He will not countenance any fifth being as great as a pure fifth - Schlick's C♯ fifth was probably considerably wider than pure - and so Praetorius tackles the raising of G♯ in two stages from F♯.

<u>"The Second Kind"</u>.

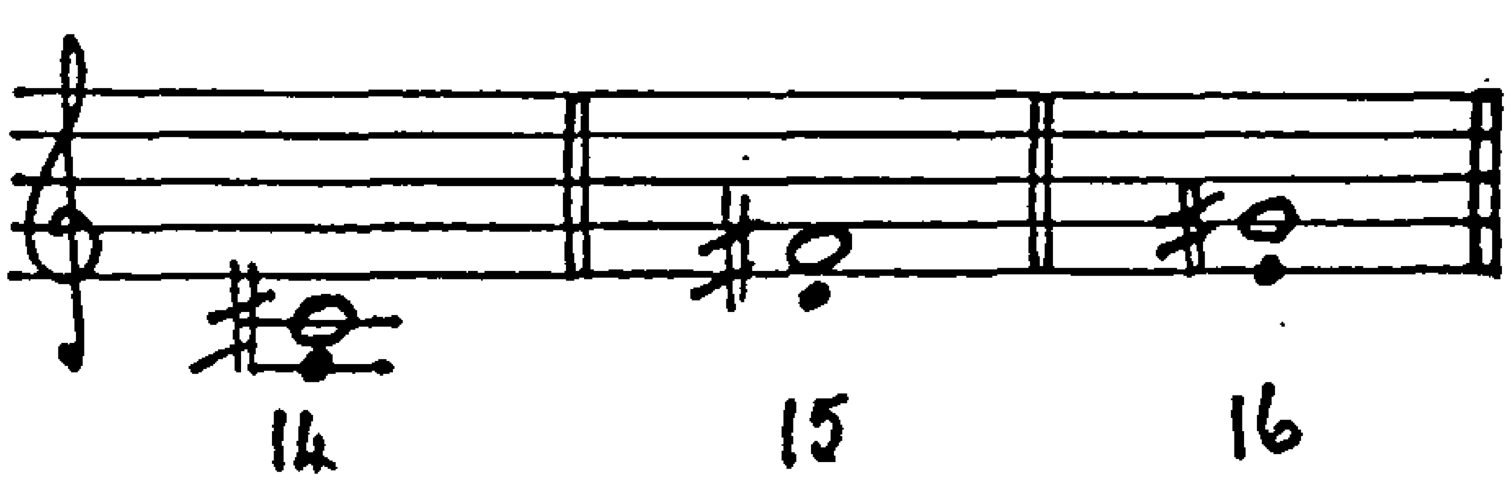
"This major third (as indeed all other major thirds) must be absolutely pure." It can be heard better as a tenth (f - a').



The octaves and thirds must be absolutely pure: the fourth greater than pure, and the fifths "somewhat in the manner described earlier. Tune octaves, above and below to the limits of the keyboard, ignoring the semitones.



The following thirds are then tuned pure, but are better grasped as tenths.



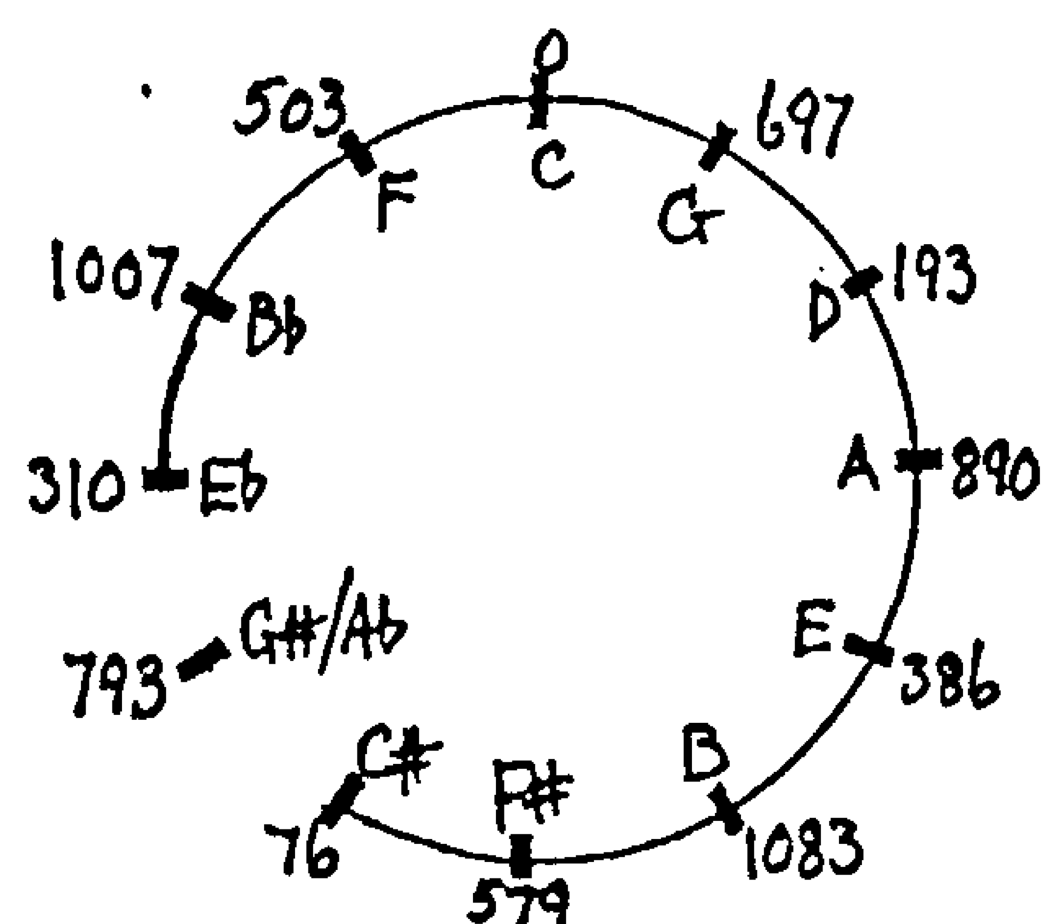
"The fifths C♯, G♯ and F♯, C♯ must be neither too pure nor too impure, but must measure slightly greater, beating not so much as other fifths, so that when something from foreign keys or among semitones is struck (with it) it does not jar so much."

F G♯ is a wolf. G♯ is not always tuned quite pure, but a little wider to be used as a minor third with F, "at a pinch".

Praetorius, however, is asking the impossible. Unless the two fifths F♯ - C♯ and C♯ - G♯ are to be made greater than pure, the most that the G♯ can be raised is 11 cents, which would make these two fifths pure and the major thirds A - C♯ and E - G♯ beat gently wide at 392 cents. F - G♯ at 281 cents would still be unacceptable as a minor third (316 cents). Praetorius points out an example of the inherent weakness of this temperament, as committed to the major third as Pythagoras was to the perfect fifth, but it is surprising that a musician of such erudition should recommend an expedient which is completely ineffective, and interferes with the temperament as a whole. The diesis between all the enharmonic equivalents in this temperament is far too great a disparity to disguise.

Irregular modifications of quarter comma meantone temperament seem to have been practised elsewhere in Europe and Britain more than in Germany. The nearest historical modification corresponding to Praetorius's 'second kind' has two wide fifths, (17) and demonstrates how wide Praetorius's two 'slightly greater' fifths might have to be. The wolf between G♯ and E♭ is divided equally to make two wide and lesser wolf fifths of 717 cents each. The intention is obviously to make G♯ available as A♭, but Figure 25 reveals that there is little to be gained and much to lose. The A♭ major and the F minor triads remain very impure, and apart from the loss of purity in other intervals, the regular intonation of meantone, considered at the time one of its benefits, is destroyed. Werckmeister mentioned a similar practice; of lowering the quarter comma E♭ a little towards a D♯, but obviously deplored it, and so gave no details.

Figure 25. Meantone with Two Wide Fifths.



	mi.3	ma.3	5								
C	310	386	697	E	311	407	697	G♯	290	407	717
C♯	310	427	717	F	290	387	697	A	310	386	696
D	310	386	697	F♯	311	428	697	B♭	269	386	696
E♭	269	387	697	G	310	386	696	B	310	427	696

To return to regular quarter comma meantone temperament, Praetorius regrets the impossibility of plagal cadences or perfect cadences involving a leading note, on C♯, F♯ and G♯, and hints at mechanical means for achieving these. The attraction of the meantone temperament for Praetorius is its pure thirds, who then proceeds to enumerate some of the wolves of the temperament, which is interesting not so much in what he mentions as in what he fails to mention:

(17) J.Murray Barbour: Tuning and Temperament, p.133.

1) The wolf 'fifth' G♯ - E♭ (mentioned)
2) The wolf 'minor thirds' B♭ - C♯, E♭ - F♯, F - G♯.(mentioned)
3) The wolf 'major thirds' B - E♭, C♯ - F, F♯ - B♭, G♯ - C. (not mentioned)

In the case of Germany, the quarter comma meantone temperament seems to have been adopted generally and used in the Praetorius version, sometimes with temporary modifications (to be discussed later), during much of the sixteenth and seventeenth centuries. What Zarlino in 1571 called a "new" temperament, Werckmeister in 1698 referred to as the "old" or "common" temperament. At this late date he felt the need to mount a campaign against "those who say they want the temperaments of the ancients and of Praetorius to remain without change". (18)

Orgelprobe reads like a radical's manifesto against the establishment. He makes an impassioned plea for modern music to be served by "good and adequate" temperaments. Praetorius's temperament was excellent for the music of Praetorius's time, when chromatic notes and transpositions were more occasional than integral. In his zeal for circular temperaments, Werckmeister overstates his case against quarter comma meantone temperament. His composite monochord of 1691 shows string lengths for this temperament starting from C in an unbroken chain to E♯, which he calls F. (see Figure 26). There is little wonder that he gives the monochord the title "The incorrect temperament where all the fifths beat a quarter comma under", for he puts the wolf in a most awkward and unprecedented place; between F and c. This of course is the best place to support his argument:

> "If it were to be called a temperament,(the fifth) F - C ... would be two commas too big, which simply could not be tolerated. In the same way the major thirds E♭ - G, F - A, A♭ - c and B♭ - d would all be two commas too big, which also cannot be allowed. These things cannot be allowed. These things can be referred to the monochord for both eyes and ears." (19)

The amount of verbal energy Werckmeister used to persuade late seventeenth-century musicians of the need of temperamental reform

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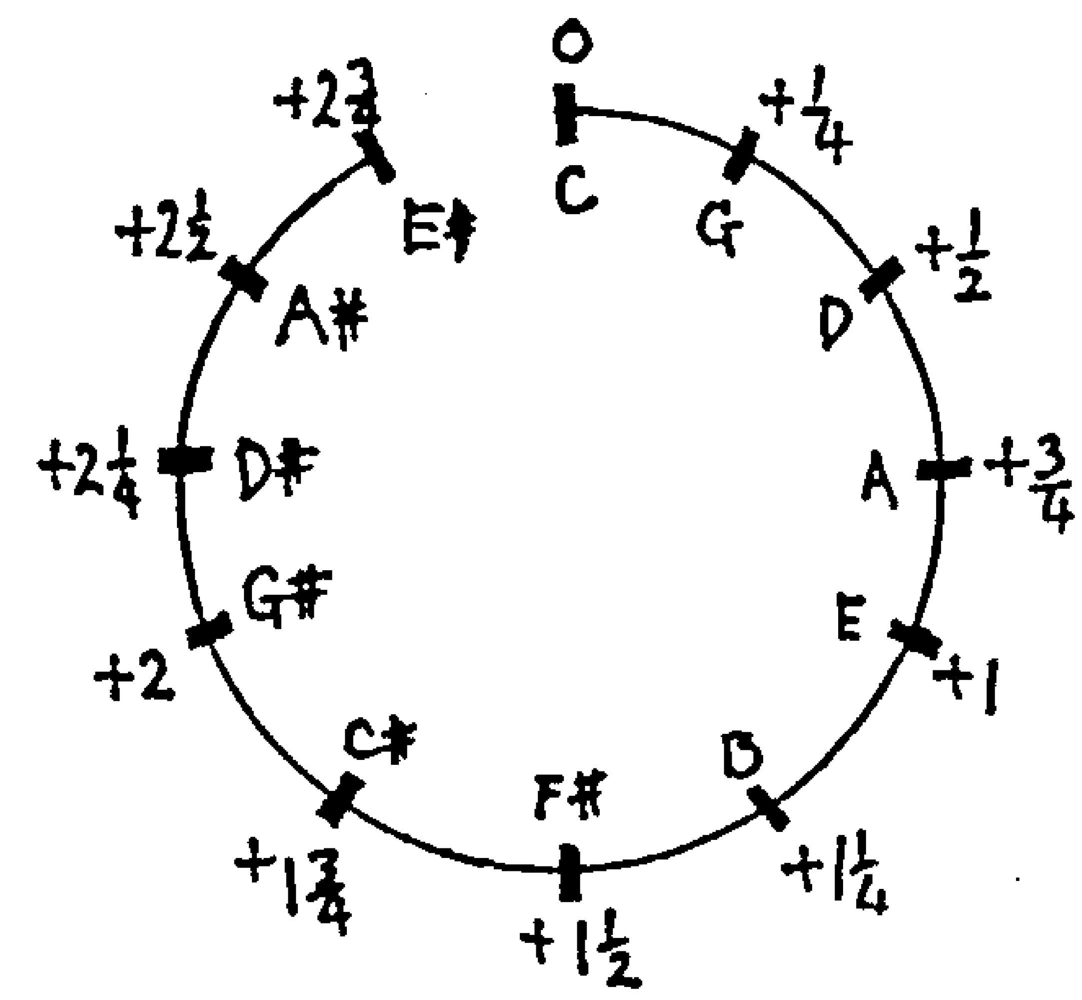
(18) A.Werckmeister: Orgelprobe (Frankfurt and Leipzig, 1698). For a complete translation into English (by J.V.P.) of the section on temperament, see Appendix 1.

(19) A.Werckmeister: Musicalische Temperatur, p.2, tr. J.V.P.

shows how firmly established quarter comma meantone temperament must have become over the two centuries since its introduction.

Figure 26 Quarter Comma meantone Temperament E♯ - C.

(The fractions show the accumulated deficiencies of the fifths.)



	mi.3	ma.3	5								
C	310	386	697	E	311	387	697	G♯	310	427	696
C♯	310	386	697	E♯	310	428	738	A	310	386	696
D	310	386	697	F♯	311	386	697	A♯	311	428	697
D♯	310	428	696	G	268	386	696	B	310	386	696

The Meantone Variants.

With the acceptance of quarter comma meantone the regular temperament principle was established. During the period regular variants were introduced, whereby eleven fifths were equally diminished by other fractions of the syntonic comma, and the residue of dissonance accumulated in a wolf fifth. The larger the fraction, the smaller are the fifths and major thirds, and the greater is the wolf fifth. The controlling interval in every case is the tempered fifth, for from the size of this fifth the pitches of the eleven variable notes are calculated. The notes must consist of an unbroken chain of fifths. The size of the tempered fifth equals that of the pure fifth minus the fraction of the comma being used.

Example: To find the size of fifth required for $\frac{1}{7}$ comma meantone temperament, and the pitches of the notes in cent values:

(1) $702c. - \frac{22}{7} c. = 702 - 3\cdot142 = 699c.$

size of fifth = 699 cents.

(2) Sharp side fifths:

	C = 0c.		G =	699 cents.	
699c. + 699c.	- 1200c.		D =	198 cents.	
198c. + 699c.			A =	897 cents	etc.

(3) Flat side fifths:

C = 1200c.	1200c. - 699c.	F =	501 cents	
501c. + 1200c.	- 699c.	B♭ =	1002 cents.	etc.

Because these temperaments are regular, it is not necessary to quote in detail every triad and interval on every degree of the scale. It is sufficient to know the sizes of the several intervals within any particular temperament. Figure 27 gives the basic information of the regular meantone temperaments mentioned, documented and probably used in Germany before 1700. (20)

The vertical lines mark the pivotal point of the whole series, the pure major third.

Tempering fraction of comma	$\frac{1}{3}$	$\frac{2}{7}$	$\frac{1}{4}$	$\frac{2}{9}$	$\frac{1}{5}$	$\frac{1}{7}$	$\frac{1}{8}$
Size of minor third:	315	313	310	309	307	303	302·5
Size of major third:	379	383	| 386 |	389	390	395	397
Size of perf. fifth:	695	696	696·5	697	698	699	699·25
Size of wolf fifth:	755	747	737	732	726	712	708

In $\frac{1}{3}$ comma the minor third is pure.

In $\frac{2}{7}$ comma the chromatic semitone is pure.

In $\frac{1}{4}$ comma the major third and augmented second are pure.

In $\frac{2}{9}$ comma the augmented second is pure.

In $\frac{1}{5}$ comma the diatonic semitone is pure.

Figure 27. Regular Meantone Temperaments before 1700.

(20) Appendix 3 contains a computer program written by J.V.P. to calculate accurately any regular meantone temperament in any note disposition.

Some of the regular meantone variants are attributed to different scholars: Salinas's $\frac{1}{3}$ comma, Zarlino's $\frac{2}{7}$ comma, and so they can be roughly dated. According to Printz, $\frac{2}{7}$ and $\frac{2}{9}$ comma are among the earliest variants, and not until towards the middle of the eighteenth century is there any reference to $\frac{1}{6}$ comma, Silbermann's probable temperament. Werckmeister cited $\frac{1}{7}$ as an example of an inadequate temperament. Later German writers confirm the widespread use of the quarter comma meantone temperament up to 1700 but present little or no evidence of the variants being widely or specifically in use up to that time. (21) There is considerable discussion of expedients, such as modifications to the keyboard, which will be dealt with in a later chapter, but even the use of expedients may add weight to the argument that a rigid system with acknowledged weaknesses was the status quo, and ways and means to avoid or mitigate them were found.

Cyriac Schneegass of Erfurt, one of the earlier writers of the period, describes a temperament very similar to, and probably contemporary with, $\frac{2}{9}$ comma, but conceived in an entirely different way, not unlike that of Agricola's Pythagorean monochord, but with different proportions. (22) The tones he uses are single sized or mean tones, and his diatonic semitones are greater than his chromatic semitones. His unit of measurement he calls a 'comma', and to avoid confusion, for its size bears no resemblance to either syntonic or ditonic commas, it will be referred to here as a snowcomma. His primary statement is that a diatonic semitone has a size of $3\frac{1}{4}$ snowcommas and a chromatic semitone a size of $2\frac{1}{4}$ snowcommas.

Then a tone $= 3\frac{1}{4} + 2\frac{1}{4} = 5\frac{1}{2}$ snowcommas,

an octave $= (5 \times 5\frac{1}{2}) + (2 \times 3\frac{1}{4})$ snowcommas $= 34$ snowcommas,

a snowcomma $= 1200c \div 34$ $= 35{\cdot}29411$ cents.

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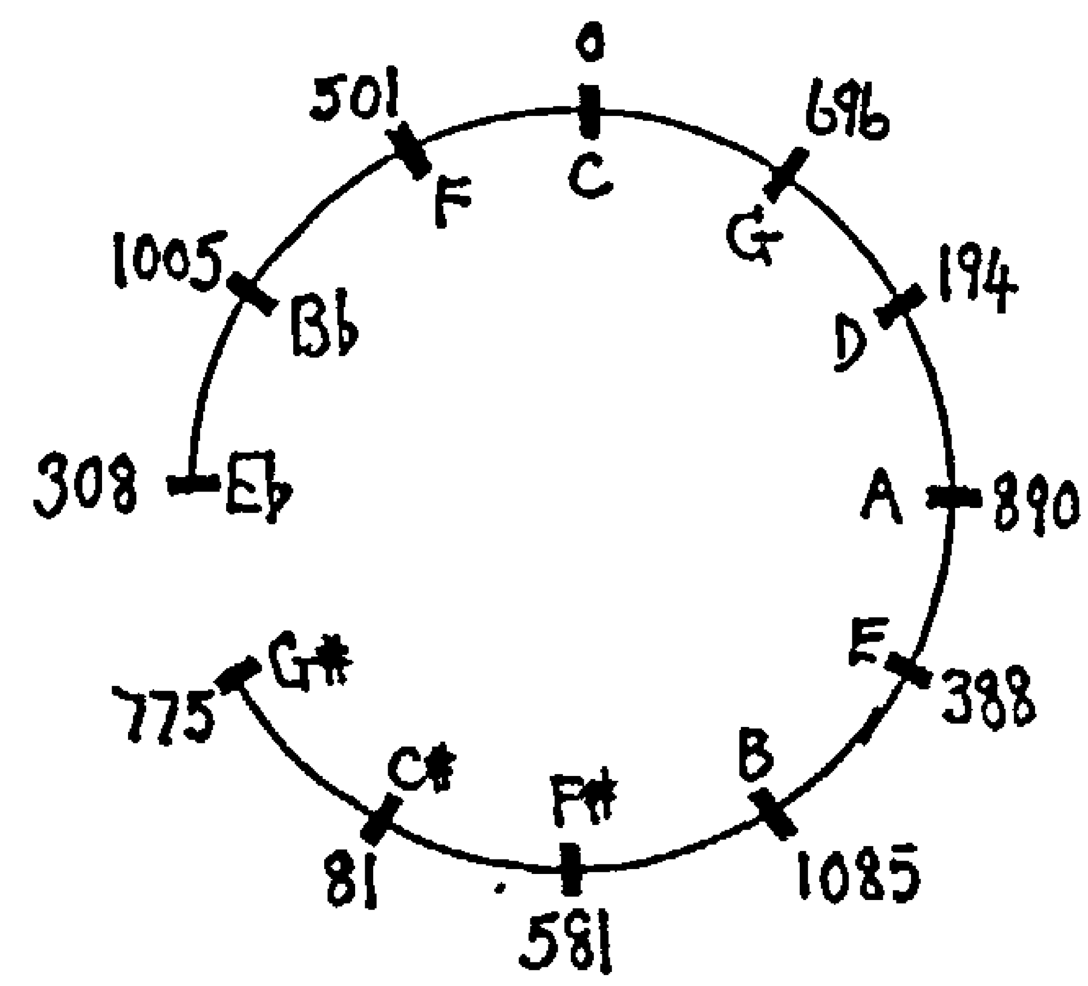
(21) Adlung (1768), Helmholtz (1885), Kinkeldey (1910), Flade (1953), Riemann (1962).

(22) C.Schneegass: Nova et Exquisita Monochordi Dimensio, (Erfurt, 1590), chapter 3.

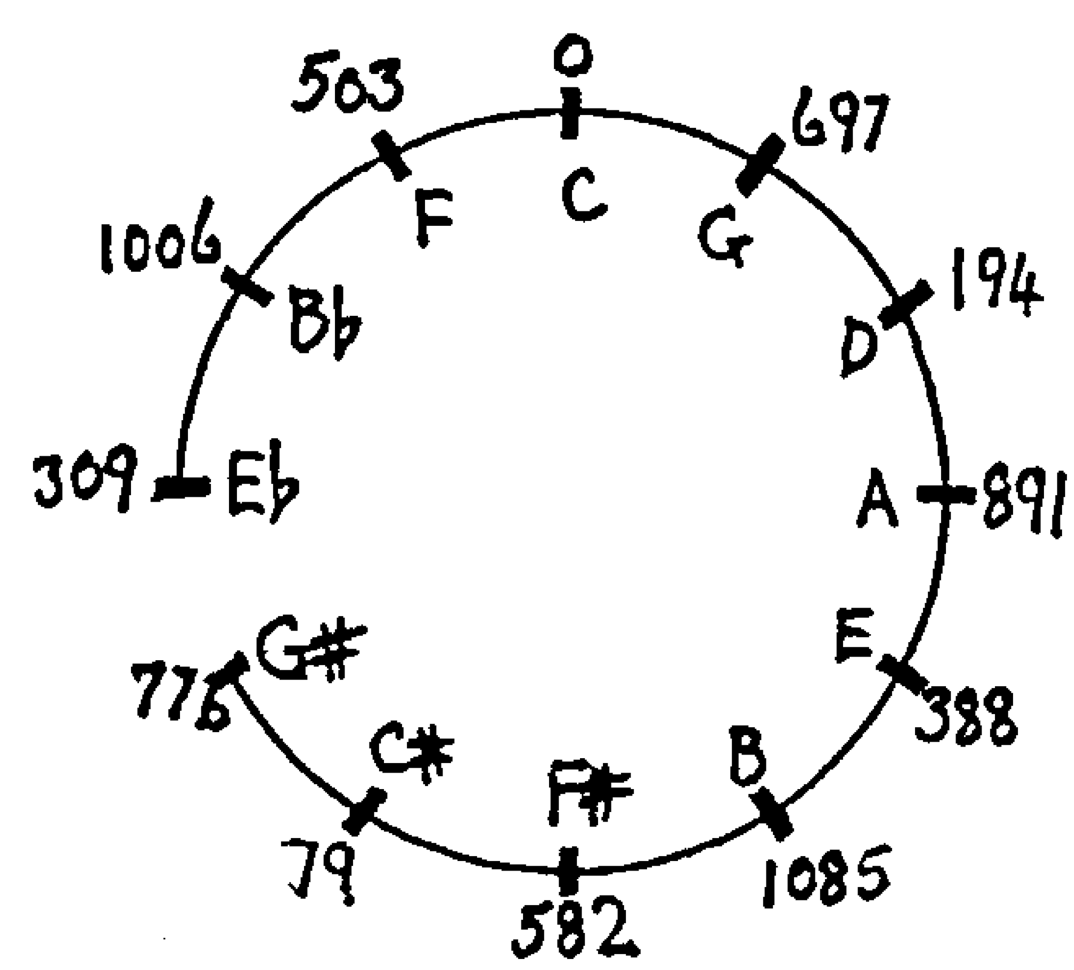
Schneegass calculated his monochord by means of geometry. The practical application of his ideas does not quite tally with the facts as stated above. J.Murray Barbour gives the figures for Schneegass's original monochord with a string length G = 900,000. In order to aid comparison, Figures 28, 29 and 30 show Schneegass's actual monochord translated into cent values based on C, his theoretical temperament according to his arrangement of snowcommas, and the regular $\frac{2}{9}$ comma meantone temperament, which is virtually identical with theoretical temperament.

Figure 28. Schneegass's Monochord.



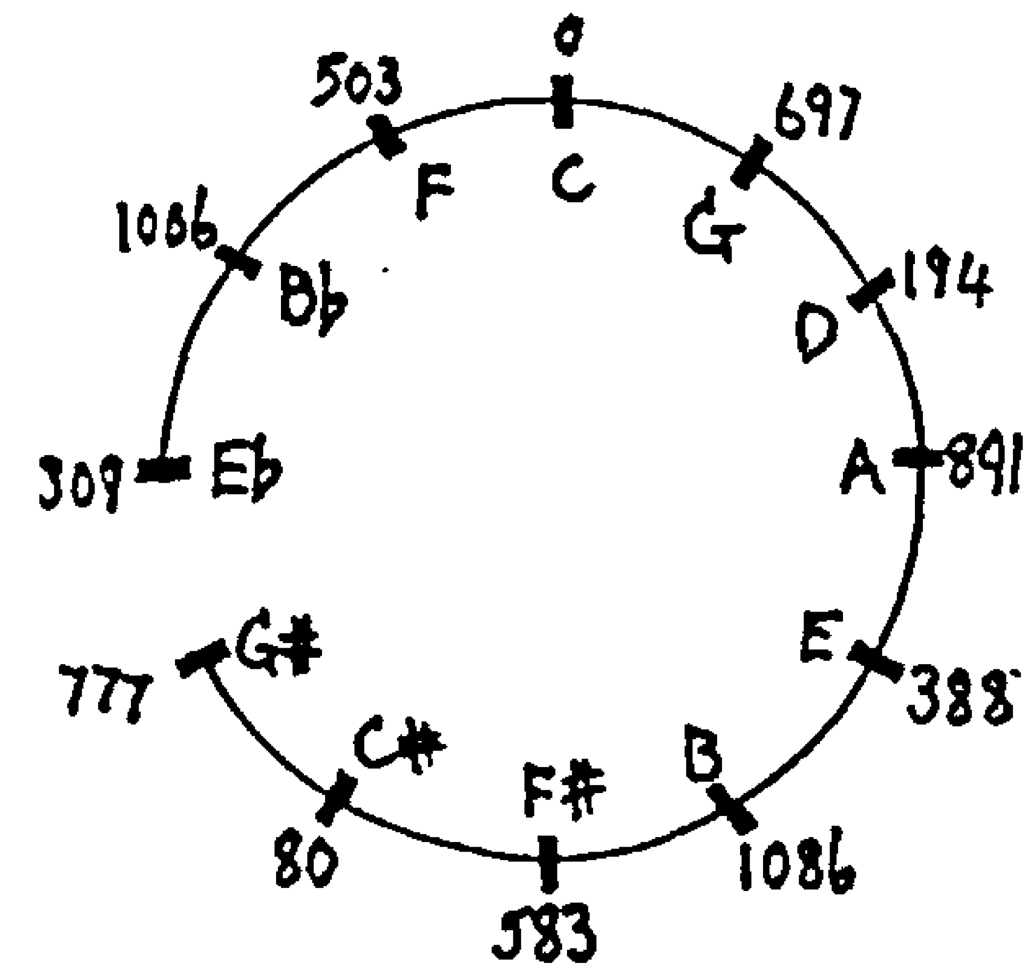
	mi.3	ma.3	5								
C	308	388	696	E	308	387	697	G♯	310	425	733
C♯	307	420	694	F	274	390	699	A	309	390	698
D	307	387	696	F♯	310	424	700	B♭	276	389	696
E♭	273	388	697	G	309	389	698	B	309	423	696

Figure 29. Schneegass (Theoretical).



	mi.3	ma.3	5								
C	309	388	697	E	309	388	697	G♯	309	424	733
C♯	309	424	697	F	272	388	697	A	309	388	697
D	309	388	697	F♯	309	424	697	B♭	272	388	697
E♭	273	388	698	G	309	388	697	B	309	424	697

Figure 30. $\frac{2}{9}$ comma Meantone Temperament.



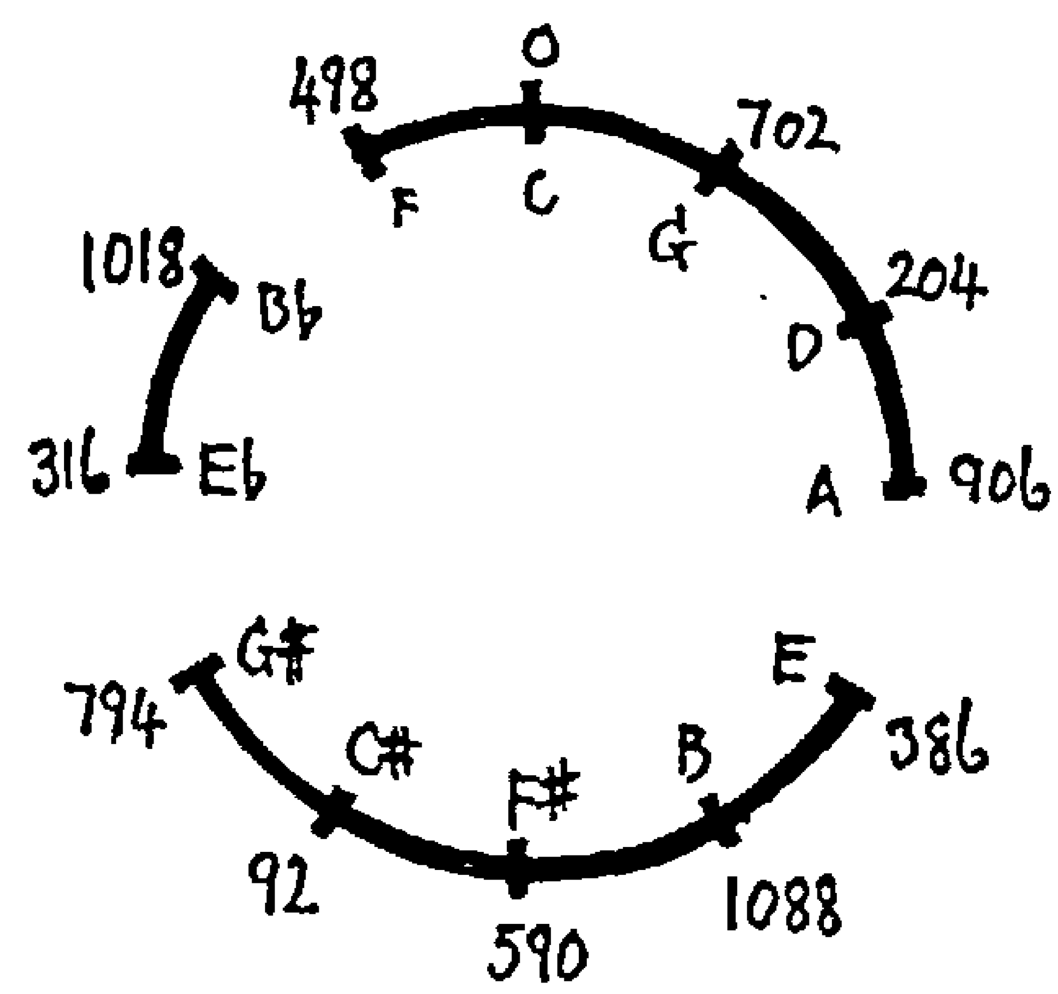
	mi.3	ma.3	5								
C	309	388	697	E	309	389	697	G♯	309	423	732
C♯	308	423	697	F	274	388	697	A	309	389	697
D	309	389	697	F♯	308	423	697	Bb	274	388	697
Eb	274	388	697	G	309	389	697	B	308	423	698

This period was one of change in musical perception. The modes were being superseded by the diatonic system, with its attendant freedom to modulate and its major-minor polarity. Unique to Germany was the rise of the Lutheran chorale, with its frequent cadences in nearly related keys and above all its vertical harmonic interest. Among the variants listed above there seems to be not one whose qualities overall render it significantly and unquestionably more suitable for the music of the time than the original quarter comma meantone temperament itself. The purity and consequent aural stillness of its major thirds tip the balance in its favour.

Just-Intonation Monochords.

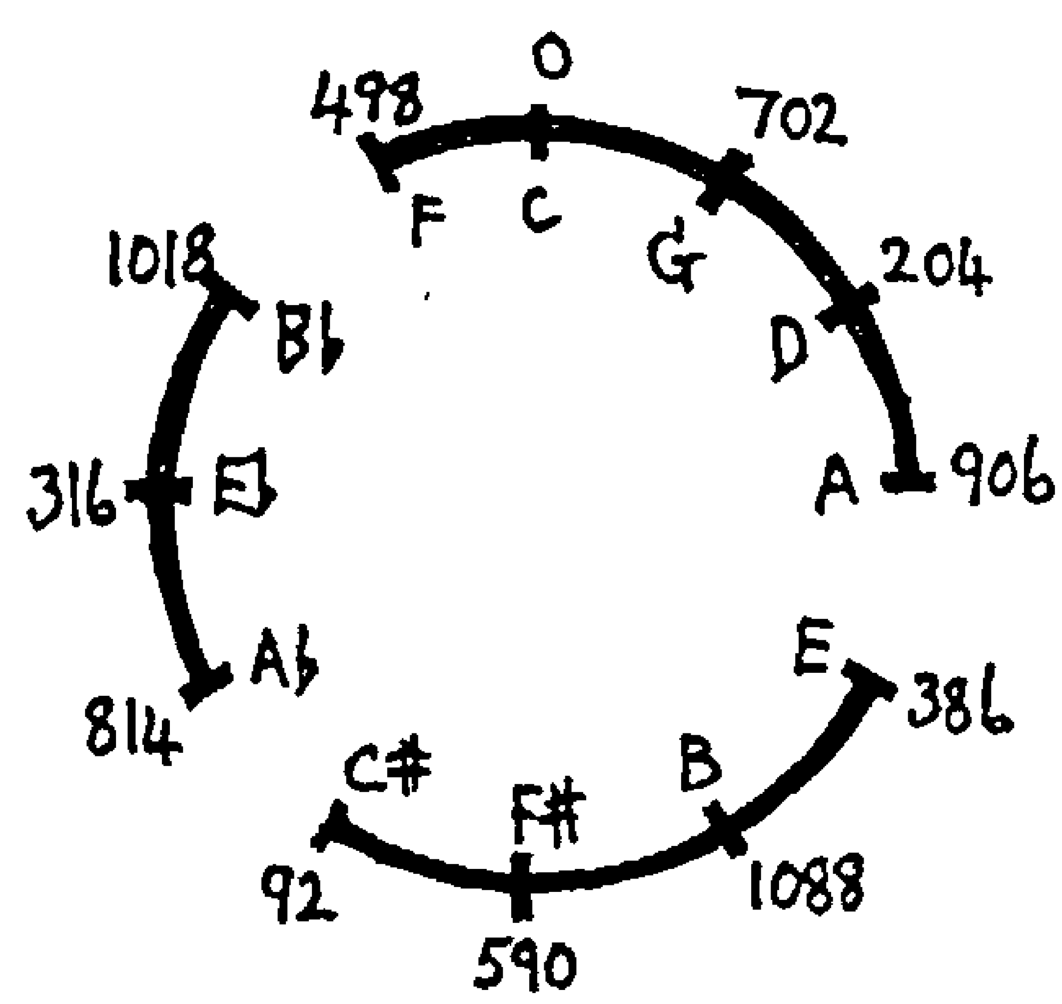
To uphold the purity of the major third to the detriment of that of the fifth, or vice versa, was unacceptable to some scholars of the period, in that either solution to the tuning problem lacked the orderliness, perfection and inevitability of eternal truth. German theorists of the earlier seventeenth century searched for an all-embracing theory of the universe into which music was woven as an essential strand. Music should be as consistent at the human level, they said, as it was at the cosmic level in the music of the spheres. Born of the attitude of thinkers like Lippius and Kepler was the belief that pure ratios must be divinely sanctioned, and humanly heeded. Kepler was against compromise. He proclaimed the validity of the pure consonances, both thirds and fifths. He admonished Galilei for advocating a temperament for the lute. Just-intonation was inviolable. It is not without significance that its great advocates were primarily theoreticians. The first published monochord for just-intonation was that of Salomon de Caus, 1615. Those of Kepler came to light four years later in De Harmonice Mundi, a work of considerable weight and substance, dedicated to James I of England, where he was invited but did not go. He published two monochords which were identical except that one contained G♯ and the other A♭.

Figure 31. Kepler's No. 1 Monochord.



	mi.3	ma.3	5								
C	316	386	702	E	316	408	702	G♯	294	406	722
C♯	294	406	702	F	296	408	702	A	294	386	680
D	294	386	702	F♯	316	428	702	B♭	274	386	680
E♭	274	386	702	G	316	386	702	B	316	428	702

Figure 32. Kepler's No. 2 Monochord.



	mi.3	ma.3	5								
C	316	386	702	E	316	428	702	A♭	274	386	702
C♯	294	406	722	F	316	408	702	A	294	386	680
D	294	386	702	F♯	316	428	702	B♭	274	386	680
E♭	274	386	702	G	316	386	702	B	316	428	702

Fifteen years before Kepler published his monochords, which he considered suitable for keyboard instruments, Andreas Reinhard published a monochord for fretted instruments which had just-intonation ratios for the diatonic notes, but for the semitones, whose names he did not specify, he divided each tone equally by linear means. (23) Providing unequal frets for the diatonic notes raises its own problems, but then to make equal linear divisions for the semitones produces not mean semitones, but five different sizes of semitone, as Figure 33 shows. Apart from concordant triads on C, F and G, there is a fourth concordant triad on F♯, but this triad is rather too isolated to be of much use in the music of the period. The chromatic notes, which Reinhard did not name, have been given appropriate names here.

	C		C♯		D		D♯		E		F		F♯		G		G♯		A		B♭		B		C
semi-tone size		99		105		88		94		112		99		105		88		94		99		105		112	
Ratio			$\frac{9}{8}$				$\frac{10}{9}$				$\frac{16}{15}$				$\frac{9}{8}$				$\frac{10}{9}$				$\frac{9}{8}$		$\frac{16}{15}$
cents	0		99		204		292		386		498		597		702		790		884		983		1088		1200

sizes of semitone: 112c, 105c, 99c, 94c, 88c.

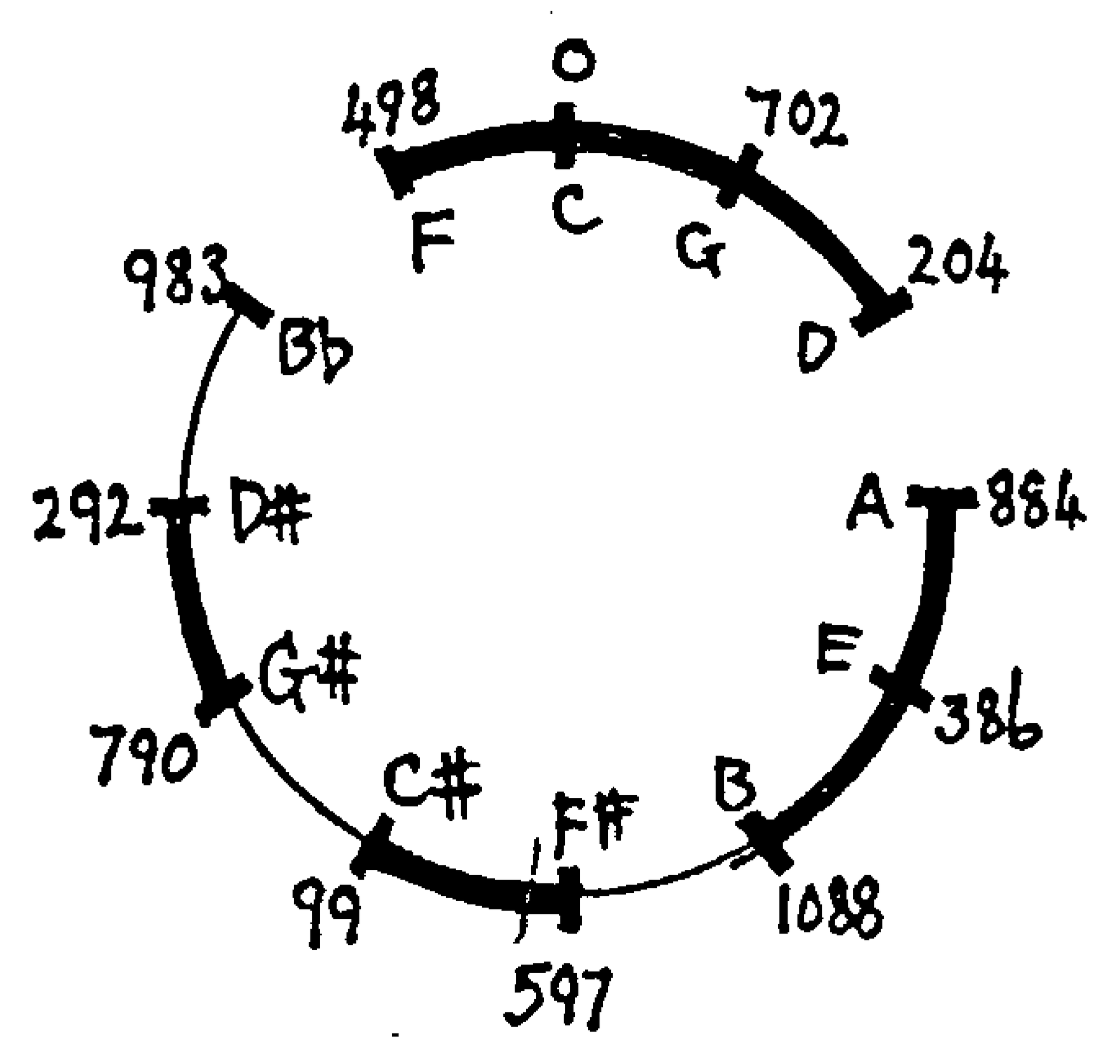


Figure 33. Reinhard's Monochord.

	mi.3	ma.3	5								
C	292	386	702	E	316	404	702	G♯	298	410	702
C♯	287	399	691	F	292	386	702	A	316	415	702
D	294	393	680	F♯	287	386	702	B♭	316	421	715
D♯	305	410	691	G	281	386	702	B	316	404	709

The same method of monochord division was published ten years later by a fellow countryman of Reinhard, Abraham Bartolus. (24)

(23) A.Reinhard: Monochordum, (Leipzig, 1604), see J.Murray Barbour: Tuning and Temperament, p.144

(24) A.Bartolus: Musica Mathematica, (Altenburg, 1614), see J.Murray Barbour: Tuning and Temperament, p.144

The only difference between the two was that Bartolus started his monochord on E, a semitone below that of Reinhard, whom he acknowledged as his source. Bartolus, however, recommended his monochord for keyboards, and only later for fretted instruments and bells. The category of just-intonation monochords could also include some monochords described earlier in the chapter, such as Agricola's. Those of Kepler, Reinhard and Bartolus, however seem to be more purpose-built than derivative. The advantageous placing of the major thirds results in irregular temperaments whose wolves are distributed around the circle. Just-intonation is achieved on a very limited scale.

From time to time during the period musicians have published their own tuning methods, which do not amount to prescriptions or formulas for temperaments. Lanfranco, Ammerbach and Antegnati and even Schlick fall into this category.(25) Lanfranco is said to have been a <u>maestro di capella</u> at Brescia cathedral. His twelve rules amount to a procedure which if followed could result in a keyboard instrument being tuned in equal temperament, or some variant of meantone, but there is considerable latitude. He requires fifths to be smaller than pure and thirds to be larger than pure. Both Ammerbach and Antegnati were eminent organists and composers, the latter a member of a famous organ building family. Their instructions show definite note sequences to be followed. Antegnati requires the fifths to be rather less than pure and the major thirds as pure as possible. They all fall short of giving the unequivocal information of a monochord, but because the instructions stem from the experience and empirical discoveries of practical musicians, there may be implications which can be followed up.

Ammerbach's tuning scheme can be put into modern notation as follows:

---

(25) G.M.Lanfranco: <u>Scintilla di musica,</u> (Brescia, 1533).
E.N.Ammerbach: <u>Orgel oder Instrument Tablatur,</u> (Leipzig,1571).
C. Antegnati: <u>L'Arte organica,</u> (Brescia, 1608).

See O.Kinkeldey: <u>Orgel u. Klavier in der Musik des 16ten Jahrhunderts,</u> (Leipzig, 1910), pp. 76 -78 for Ammerbach's tuning scheme.

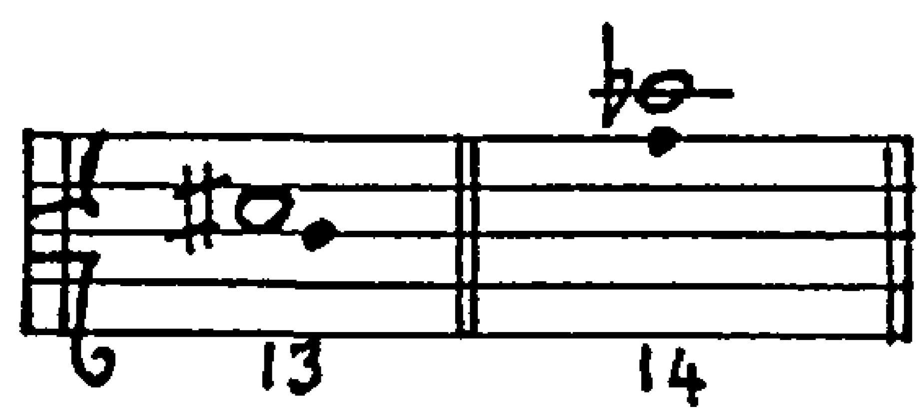
1) 'Das gelbe Klavier' (the naturals - the yellow keys).

2) Now tune all the natural octaves.

3) 'Die Obertasten' (the raised keys).

'ut - mi'

These must be major thirds.
(müssen grosse Terzen sein).



're - fa'

These sound lower.
(tiefer erklingen).

4) Now tune the remaining octaves.

If, for the sake of argument, we attempt the tuning in the set order, assuming that all the given intervals are pure, we come across an anomaly, for if we tune g' of step 3 pure to c' and later in the sequence tune g pure to d' in step 7, then g' is different from g by an octave plus a comma. It is possible, however, to make the tuning feasible if we remove the anomaly by omitting either step 3 or step 7. The results are as follows:

a) <u>The omission of step 3.</u>

The transition from step 6 to step 8 then entails an octave adjustment or tuning up a fourth instead of down a fifth. "Some skilled tuners can also tune from octaves and fourths." (26) The tuning produced has just-intonation characteristics with five good minor triads and four good major triads. The 'wolf' is extreme, at almost three commas wide, and the whole tuning absurdly extravagant.

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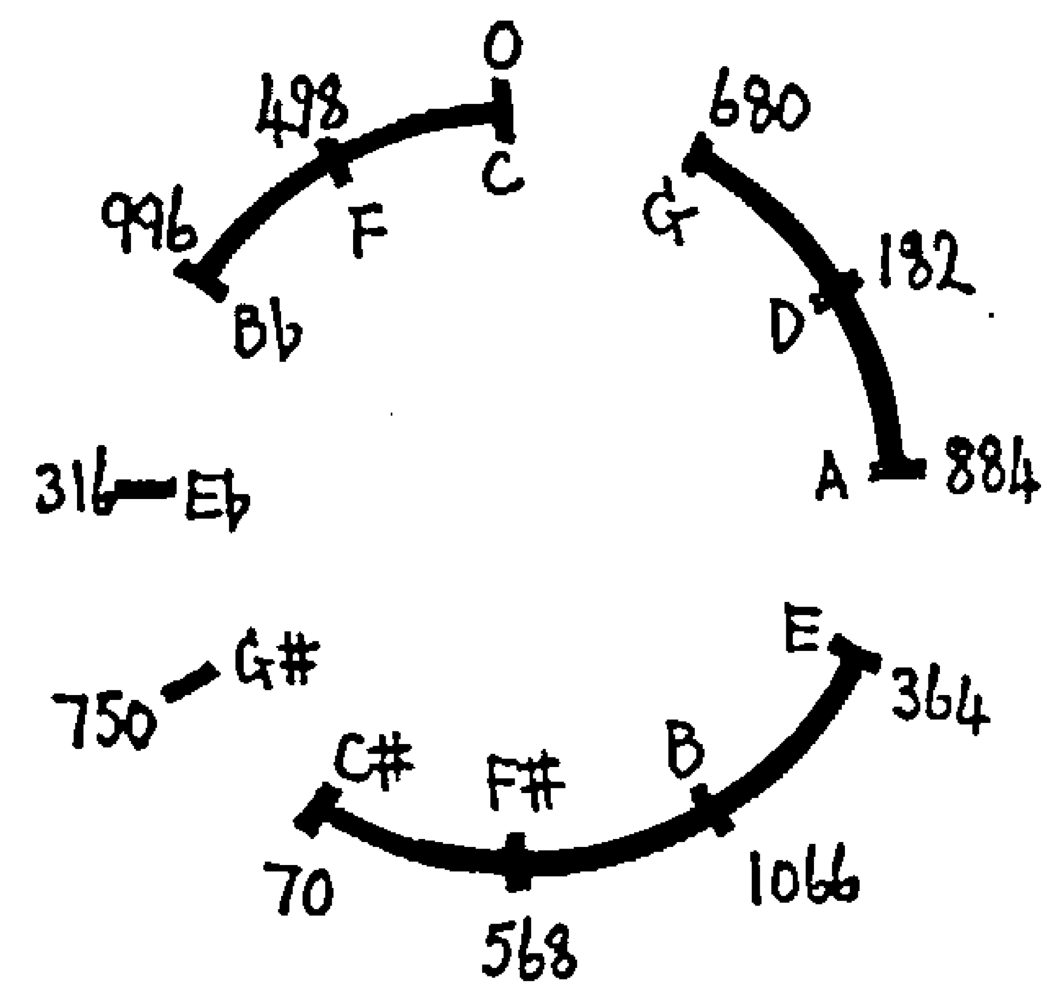
(26) M.Praetorius: op. cit., vol.2 p.151, tr. J.V.P.

Figure 34. Ammerbach: conjecture No. 1.

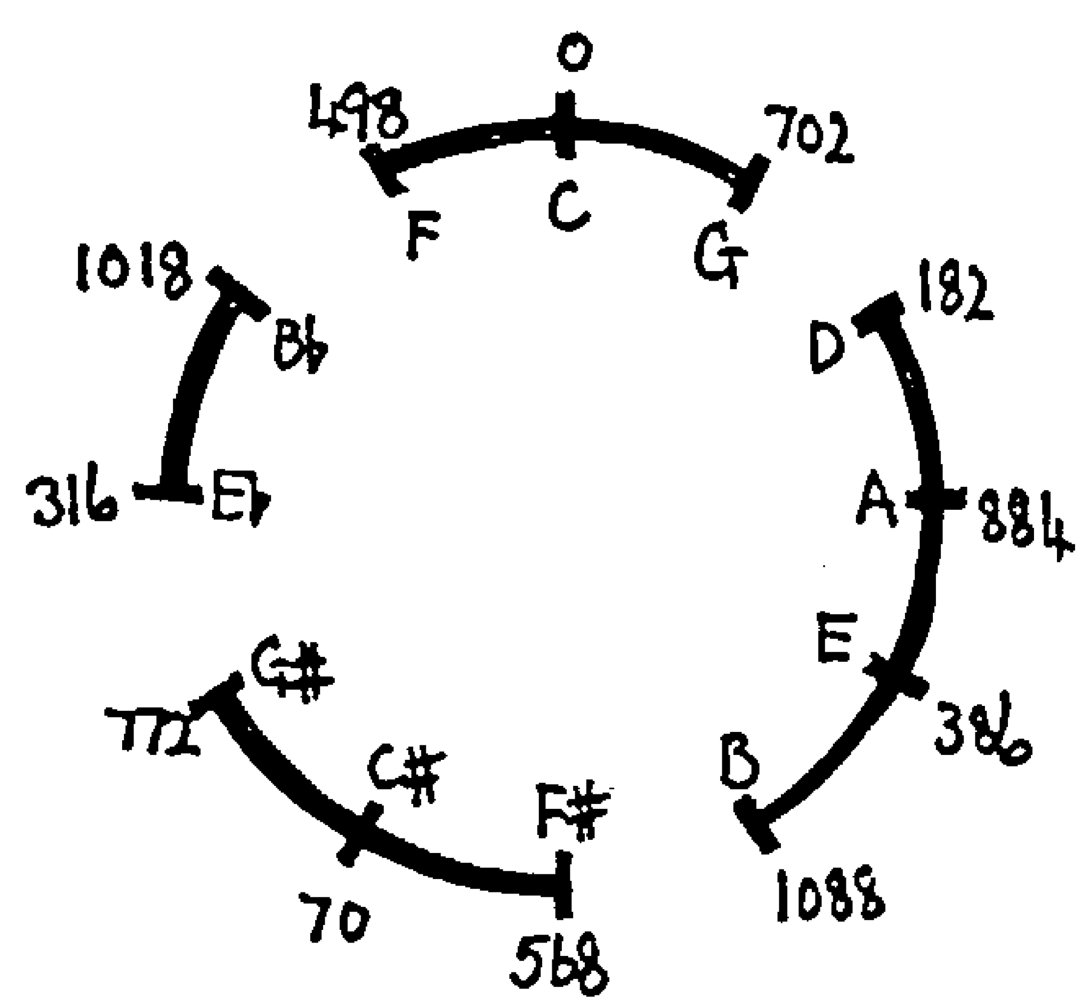


	mi.3	ma.3	5								
C	316	364	680	E	316	386	702	G♯	316	450	766
C♯	294	428	680	F	252	386	702	A	316	386	680
D	316	386	702	F♯	316	428	702	B♭	274	386	702
E♭	252	364	680	G	316	386	702	B	316	450	702

b) The omission of step 7.

The tuning produced is a respectable version of just-intonation similar to Kepler's monochord No. 1 (1619), even more allied to one of Fogliano's just monochords (1529), and equal in all respects to one of four monochords produced by Marpurg (1757). (27) There are six good minor triads and six good major triads on useful notes. Its great weakness is that B♭ has neither good thirds nor fifth .

Figure 35. Ammerbach: conjecture No. 2.



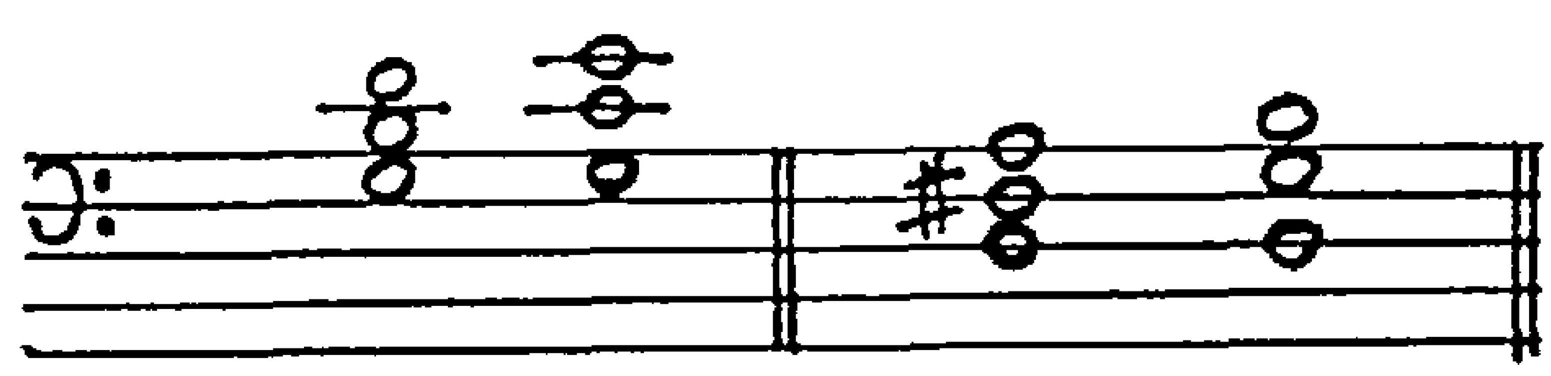
	mi.3	ma.3	5								
C	316	386	702	E	316	386	702	G♯	316	428	744
C♯	316	428	702	F	274	386	702	A	316	386	702
D	316	386	702	F♯	316	450	702	B♭	252	364	680
E♭	252	386	702	G	316	386	680	B	294	428	680

(27) J. Kepler: De Harmonice Mundi, (Augsberg, 1619).
L.Fogliano: Musica theorica, (Venice, 1529).
F.W.Marpurg: Anfangründe der theoretischen Musik, (Leipzig,1757).

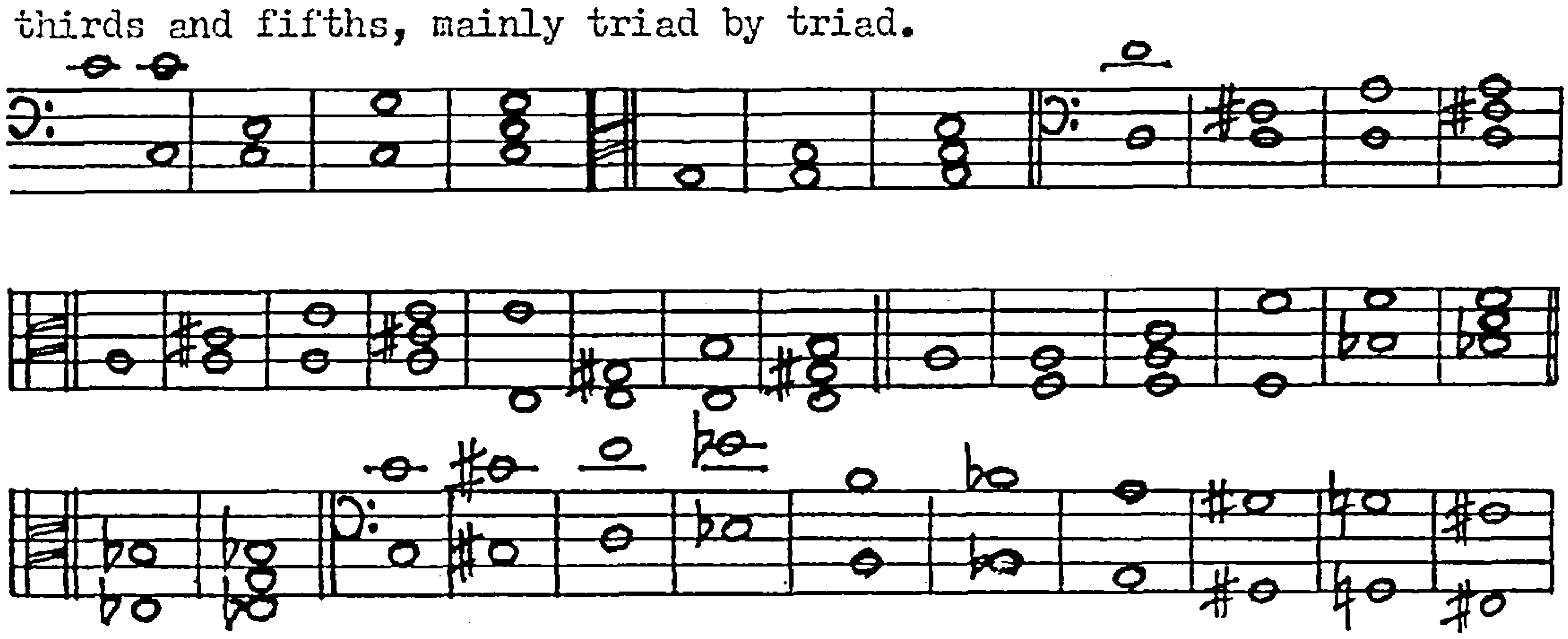
The question now is, "Is this how Ammerbach tuned his organ ?" Both Fogliano and Marpurg, the latter a member of the great German triumvirate of temperament which included Werckmeister and Neidhardt, modified their tunings into temperaments, and it is possible that he did the same. His instructions are explicit except for one detail, which in itself may create another anomaly. There is no mention of fifths, but he uses them to tune with. They are not taken in an order associated with Pythagorean tunings or with the meantone temperament, and unless step 7 is some kind of check, there are no checks. The natural notes are likely to be pure. The major thirds involving sharps are referred to specifically as 'ut - mi', which is a vocal hexachord interval. Furthermore the minor thirds are referred to in a similar manner as 're - fa'. Some Kapellmeister used the monochord for the teaching of correct intervals to singers, intervals which might be Pythagorean or syntonic. There is nothing to indicate anything here, except that Ammerbach said that the major thirds must be "grosse Terzen". Would he not have put "ditoni " if he had been an ardent Pythagorean ? The anomaly comes with the expression "these sound lower" to describe the minor thirds. Why did he say "tiefer erklingen", instead of "müssen kleine Terzen sein" (these must be minor thirds) ? He used the comparative "tiefer" which suggests being smaller than something else, or smaller than their usual size. Of course they are smaller than the major thirds but if they are to be smaller than their usual size, then that adjustment makes the fifths smaller or the major thirds greater, or both at the same time. Ammerbach had knowledge of both French and Italian music. His Tabulatur of 1571, which contains his tuning instructions, contains transcriptions of and variations on Italian music. He may have been acquainted with Italian tuning methods and Italian theorists, Fogliano included. He may have wished to safeguard his professional secrets by withholding the key without which the rest of his information remains of little use, but it is quite likely that he is giving his complete method and stating his faith in his form of just-intonation.

A German tuning scheme of a different kind, probably of the later seventeenth century, came to light first in London. In 1707, a London publisher, John Cullen, issued an engraved folio edition of A Compleat Method for attaining to play a Thorough-Bass ... by the late famous Godfrey Keller. It was probably much acclaimed during the next few decades because in 1731 William Holder reprinted it in full, with corrections, as an appendix to his own Treatise on Harmony, 3rd edition. In the same year Peter Prelleur published Keller's tuning scheme in his Modern Music Master, without acknowledgement. Gottfried Keller, whose dates are unknown, settled in London towards the end of the previous century, and must have died before 1707. I have been unable to trace any reference to his tuning scheme being published in Germany. According to Prelleur, the scheme starts with instructions and finishes with actual intervals. (28)

> "First set your instrument to concert pitch ... taking your pitch from C - sol - fa - ut ... Then tune your octaves, thirds and fifths, as the scale dictates. Observe that all sharp thirds must be as sharp as the ear will permit, and all fifths as flat as the ear will permit. Now and then while you are tuning you may, by way of tryal, touch the unison, third and fifth, and afterwards the unison, fourth and fifth, example :"



In the old tradition, he tunes the harpsichord or spinet by means of thirds and fifths, mainly triad by triad.

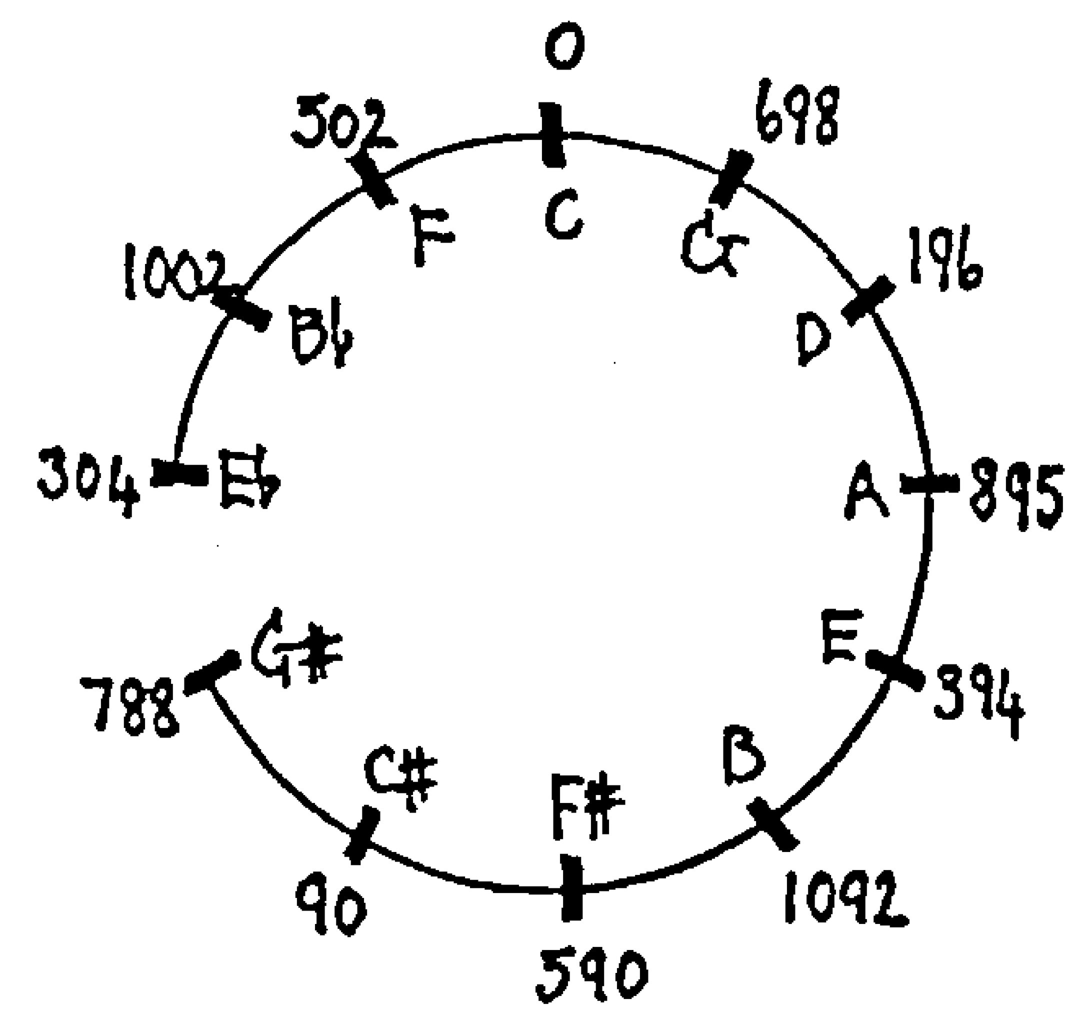


Meffen looks at the implications of the scheme and comes to the reasoned conclusion that Keller's temperament is fairly regular, with fifths about 4 cents narrow and major thirds about 8 cents wide:

(28) P.Prelleur: The Modern music master or Universal Musician, (London, c. 1730/31), quoted from John Meffen: The Temperaments of Keyboard instruments in England.., unpublished doctorate dissertation (University of Leeds, 1977), pp. 63 - 65.

"This scale would narrow some of the discrepancies of quarter comma meantone. The wolf fifth would be 21 cents better, and the wolf thirds would all be equally bad at 412 cents instead of the 426 or 427 cents of quarter comma meantone. These advantages are gained at some expense to the thirds, but not so much as would be required for equal temperament."

Figure 36. Keller's Temperament. (reconstructed by J. Meffen.)



	mi.3	ma.3	5								
C	304	394	698	E	312	394	698	G#	304	412	716
C#	304	412	698	F	286	393	698	A	305	393	699
D	306	394	699	F#	305	412	698	Bb	288	394	700
Eb	286	394	698	G	304	394	698	B	304	412	698

Multiple Division of the Octave.

During the period of the Thirty Years War (1618 - 1648) no books on musical temperaments were published in Germany. A century before, Virdung and Schlick risked the contempt of the academic world by writing in the vernacular, precedents which Ammerbach and Praetorius found worthy enough to follow. After the war the first book on musical theory by a German was Athanasius Kircher's Musurgia Universalis,1650, which was published in Rome and in Latin. An exile from the homeland owing to the war, Kircher had lived in Avignon, Vienna and Rome and shows more a Latin than a Teutonic attitude. Although this impressive work is often referred to by posterity he has little original to say. Even Printz dismisses him with "It is unnecessary to say much of him because his learned writings have been made known throughout the world." He was familiar with the writings of Mersenne, and is considerably indebted to him. His importance to us here is that he represents the antithesis of the work of, for example, Ammerbach: the avid theorist against the inarticulate practitioner.

Difficulties of consonance would be non-existent if keyboards could be modified to accommodate every required interval ratio. The theory behind radical changes of this kind have usually originated among Italian theorists attempting to reconcile Greek genera with keyboard facilities, and is referred to as multiple division. Kircher was acquainted with the work of Vicentino and Doni in this direction, and provides figures and six diagrams of keyboards with twelve to thirty-one keys. He had a method for dividing the octave into twelve equal semitones after Aristoxenus, and a further method for dividing into two each semitone, which seems very much an experimental and theoretical activity, unsupported by tradition or present requirement. There was however precedent for his calculation of the division of the octave into 53 parts. Mersenne had done something very similar before him, and of course Philolaus centuries before Mersenne. Figure 14 is a reproduction of Kircher's diagram of the tone consisting of nine commas. Kircher applies this to arrive at an octave of 53 commas. In Pythagorean scale terms the argument is this:

$$9 + 9 + 4 + 9 + 9 + 9 + 4 = 53 \text{ commas.}$$

The Greek hemitone or diatonic semitone is the smaller of the two semitones. The argument however works perfectly well for a scale of just-intonation proportions, provided one remembers that a lesser tone is smaller than a greater tone by a comma (204c - 182c = 22c), and that the chromatic semitone is larger by a comma than the hemitone.

$$9 + 8 + 5 + 9 + 8 + 9 + 5 = 53 \text{ commas.}$$

The comma which Kircher envisaged had a size of 22•6415 cents (1200c ÷ 53), which is the approximate mean between the size of a syntonic comma (21•506c) and that of a ditonic comma (23•460c).

By adding and subtracting commas here and there as required, according to the divisions of the natural notes into semitones, and the necessities of mutation and modulation, it is possible to produce sounds and progressions faithful either to Pythagoras or just-intonation. There are two great difficulties. First, there was no notation explicit enough for keyboard composers to avail themselves of, even if they understood all the intervallic implications, and second, there was no keyboard which provided for 53 divisions of the octave. Not until 1875, when R.H.M. Bosanquet invented a harmonium with a symmetrically arranged keyboard, was this division realised in practical terms. (29)

(29) H.Helmholtz: op. cit., pp. 328f.

The 'well-tempered' concept.

Towards the end of the seventeenth century musical composition in general and keyboard music in particular were being extended in two interrelated ways. First, with the rise of the diatonic system, composers seized the opportunity of regaining something akin to modal freedom by extending their musical language into unfamiliar keys. Every required tonic triad demanded an equally acceptable dominant triad for cadential and modulatory purposes. Secondly although keyboard temperaments revealed their weaknesses and irregularities even to uninitiated ears, irregularities could be exploited to enhance the baroque belief in the affections. Temperament was accepted as a necessity, but the leaders of German temperamental experiment made great efforts to make a virtue out of this necessity. Perfect consonance was not only unattainable but undesirable all of the time, but its impairment could be so carefully controlled that the musical sound would never become aurally intolerable. Werckmeister provided comprehensive vehicles for the doctrine of the affections by his tempering of the range between the aurally impeccable and the intolerable.

In a cogent, reasoned, but not necessarily objective appraisal of attitudes to temperament over the previous century, he declared new music needed new temperaments. He argued from first principles: he accepted the consonance of both fifth and third, but not their consonant equality. The third could endure greater mistuning than the fifth. Chapter 1 of Musicalische Temperatur contains much of his thesis of aural intolerance and mistuned consonances, and it is here he makes the point:

> "The resistance of the perfect consonances to any tempering, and for the impurity to be noticed earlier in them than in the imperfect consonances, have their origins in nature, for the purer and more delicate something is, the sooner one notices the flaws and blemishes in it, especially in white colours and exquisite precious stones." (30)

His attitude was that not all triads could or need to be pure, but rather than collect the impurities in one huge and useless wolf, put the impurities to expressive use by making the natural triads

(30) A.Werckmeister: Musicalische Temperatur, p.5, tr. J.V.P.

most pure and gradually increase the amount of impurity towards the unfamiliar triads. The most unfamiliar thirds should contain the greatest dissonance. Werckmeister scathingly accused ninety-nine organists out of a hundred of being unable to use the major thirds on C♯, F♯ and G♯ even when the temperament provided them. The wolf fifth or triad was dissolved, and instead a spectrum of temperamental colour was provided from the near stillness of slightly wide thirds to the bizarre quality of thirds a comma wide or narrow, the provision of a vocabulary to express joy and grief, exultation and remorse. For evidence of this attitude applied one needs to look no further than J.S.Bach's Orgelbüchlein; the easy joy of "In dulci jubilo" in A major, and the supplication of "Ich ruf' zu Dir, Herr" in F minor. With reservations, all triads were possible, and greater responsibility together with greater potential for expression was given to the composer. For such temperaments Werckmeister coined the expressions "circulating" and "well-tempered". The latter expression "wohltemperiert" has in the past been misguidedly equated with "equally tempered" or "gleichschwebend". It is now established that each expression is accurate and self-explanatory. Besides the attributes already mentioned, a "well-tempered" temperament has major thirds in the middle of the range; E♭ and E♮, about the size of equally tempered major thirds(400c), and semitones of different sizes ranging from the largest, the natural semitones, to the smallest, usually between C and D♭ and E♯ and F♯. (31) Every key of the keyboard has a legitimate multiple function.

Figure 37 takes part of Werckmeister's own diagram (see Figure 12) to demonstrate the progressive and circular nature of an actual well-tempered temperament (Werckmeister's "Correct No. 1"). The thirds of the natural notes are fairly pure, but as the thirds move flatwards or sharpwards the major thirds increase and the minor thirds decrease, until at the most distant point thirds (and triads) have Pythagorean values.

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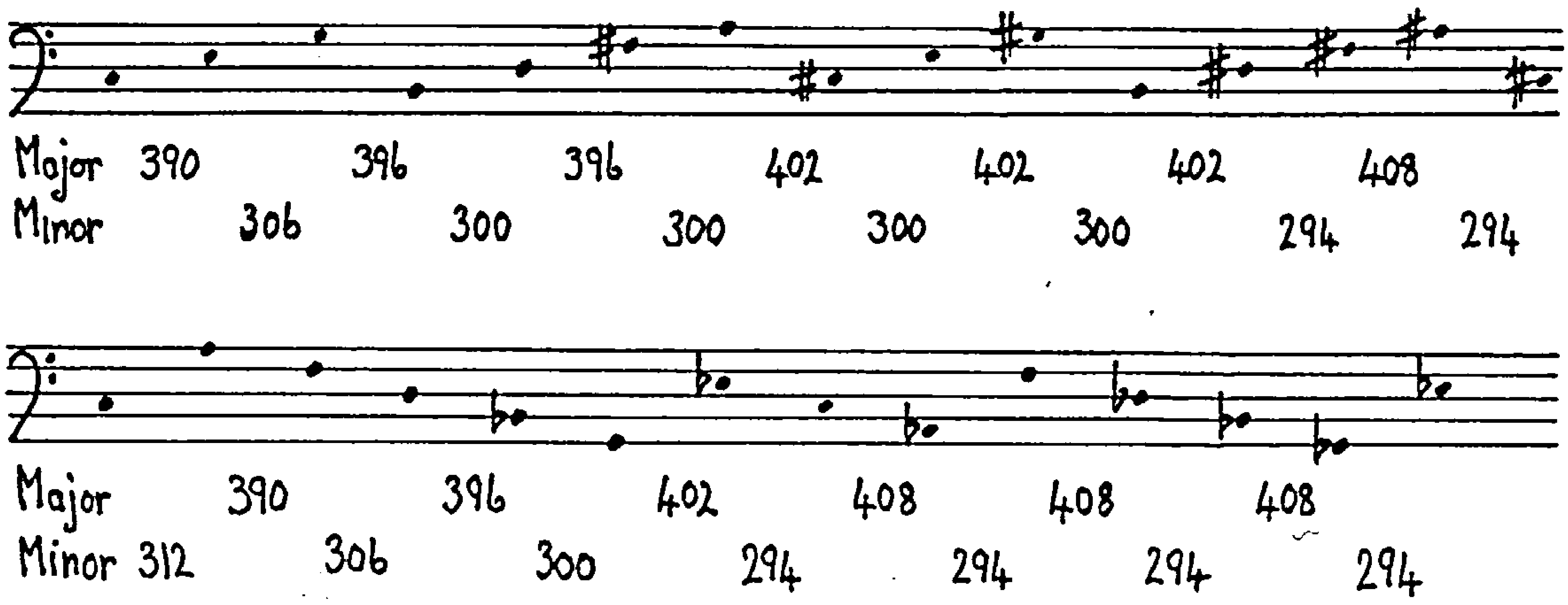
(31) In his book Tuning the historic temperaments by ear, (pp.246f) Owen Jorgenson lists thirty five 'rules' which apply to a well-tempered keyboard. Rule 35 reads: "Breaking any of the above 34 rules ruins the evenness of chord-color , progression or the basic tonality of C major. Also unnecessary extra beatings or wolf sounds could be introduced".



(Please read all sixths as thirds).

Pure major third = 386 cents. Pure Minor third = 316 cents.

Figure 37. Well-tempered Distribution of Thirds.

If what Werckmeister claimed is true, then there is ample justification, apart from association, for the existence of key colour. There is also the limitation that transposition to another key might dramatically interfere with a composer's intentions.

By the latter half of the century too, mathematics and technology had advanced. Napier's first work on logarithms had been published in 1614 and a French version appeared in 1624. The facility which logarithms provide was quickly put to use, although their use was not universally acceptable. Marpurg, as late as 1757, in his publications did all his calculations first arithmetically and then by logarithms. (32) About this time the need for greater accuracy and the concept of circulating temperaments may have been largely the reasons for the adoption of the ditonic comma as the unit of tempering. The syntonic comma sufficed when temperaments were linear, where the schisma could be lost in the wolf, if necessary. Many earlier writers chose to ignore it completely, and with little consequence.

The two exponents of circulating temperaments in Germany of the period lived, worked and published in the same region at the same time.

(32) F.W.Marpurg: op. cit..

Werckmeister (1645 - 1706) and Bendeler (1660 - 1708) were professional musicians in the central part of Germany around Quedlinburg and Halberstadt. Werckmeister was also inspector of all the organs of the district. It is surprising that the records of these two men, with so many points of likely contact, do not show them as colleagues, correspondents, friends or even enemies, for their thoughts are so obviously new and on similar lines. Both men published within a year of each other circulating temperaments which divide the ditonic comma into three and four parts. (33)
As can be seen from the diagrams the main component of these temperaments is the pure fifth. Bendeler's temperaments are more equable. Werckmeister's "Correct Nos. 2 and 3" show considerably greater contrast in their triad structure than the rest, because they contain at least one sharp or wide fifth, which results in a greater compensation in the remaining eleven fifths. Werckmeister's most famous temperament "Correct No. 1", shows no extreme qualities of this kind. Its worst triad is C minor, followed closely by F minor, but the narrowness of their minor thirds compared with the different qualities of other triads is the very stuff of the evocative qualities of a keyboard well-tempered. Figures 38 to 43 demonstrate the well-tempered concept before the beginning of the eighteenth century.

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(33) J.P.Bendeler: Organopoeia, (Frankfurt and Leipzig, 1690).
A.Werckmeister: Musicalische Temperatur, (Frankfurt and Leipzig, 1691).

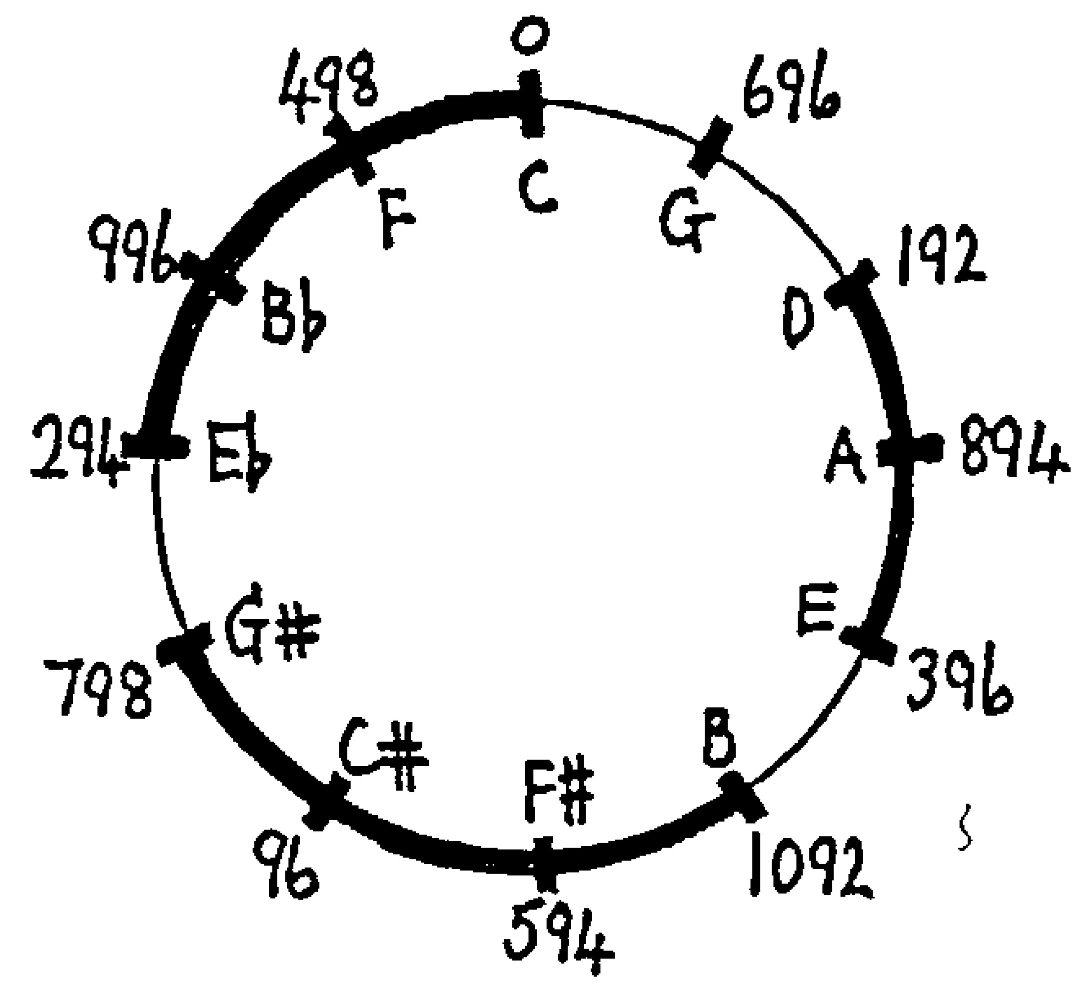


Figure 38. Bendeler's No.3.
(¼ ditonic comma)

	mi.3	ma.3	5								
C	294	396	696	E	300	402	696	G♯	294	402	696
C♯	300	402	702	F	300	396	702	A	306	402	702
D	306	402	702	F♯	300	402	702	B♭	300	396	702
E♭	300	402	702	G	300	396	696	B	300	402	702

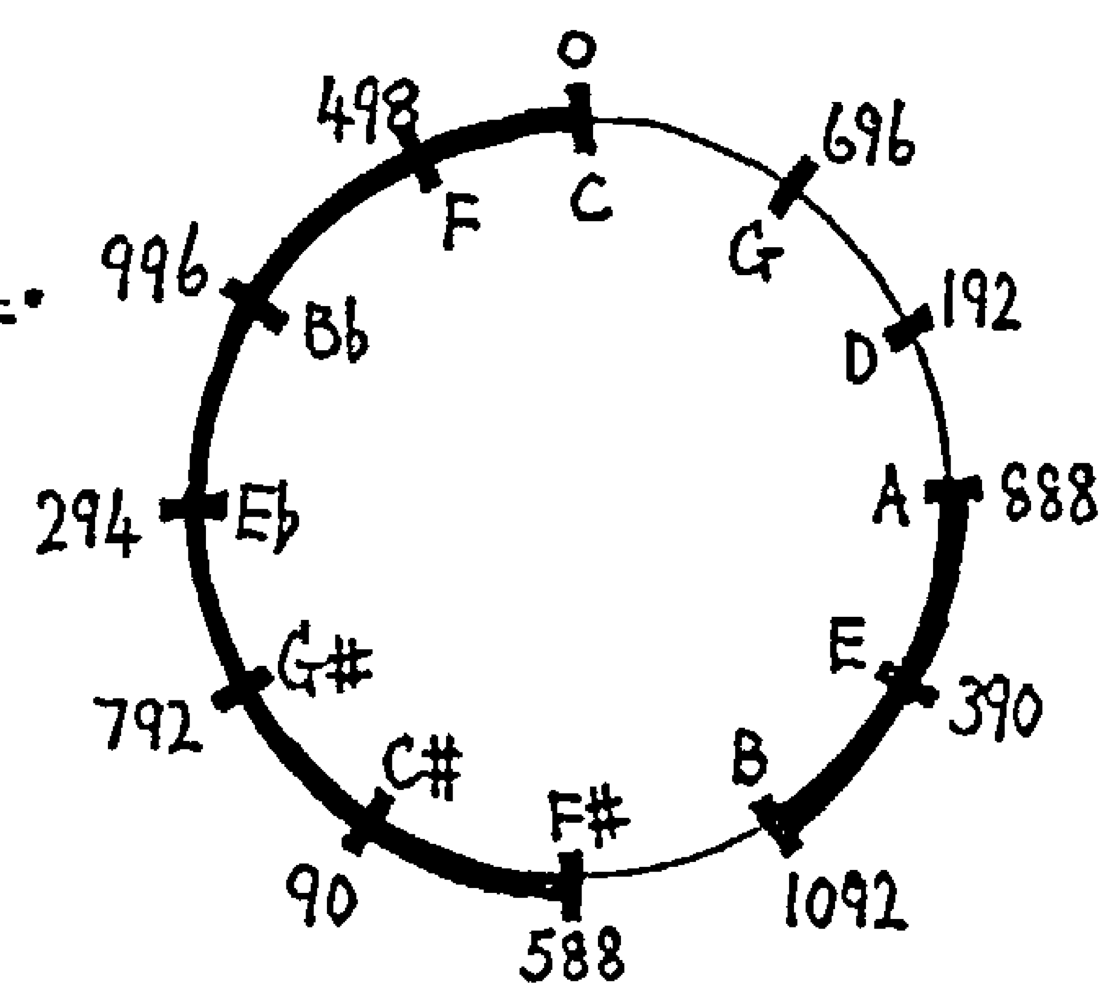


Figure 39. Werckmeister's Correct No.1.
(¼ ditonic comma)

	mi.3	ma.3	5								
C	294	390	696	E	306	402	702	G♯	300	408	702
C♯	300	408	702	F	294	390	702	A	312	402	702
D	306	396	696	F♯	300	408	702	B♭	294	396	702
E♭	294	402	702	G	300	396	696	B	300	402	696

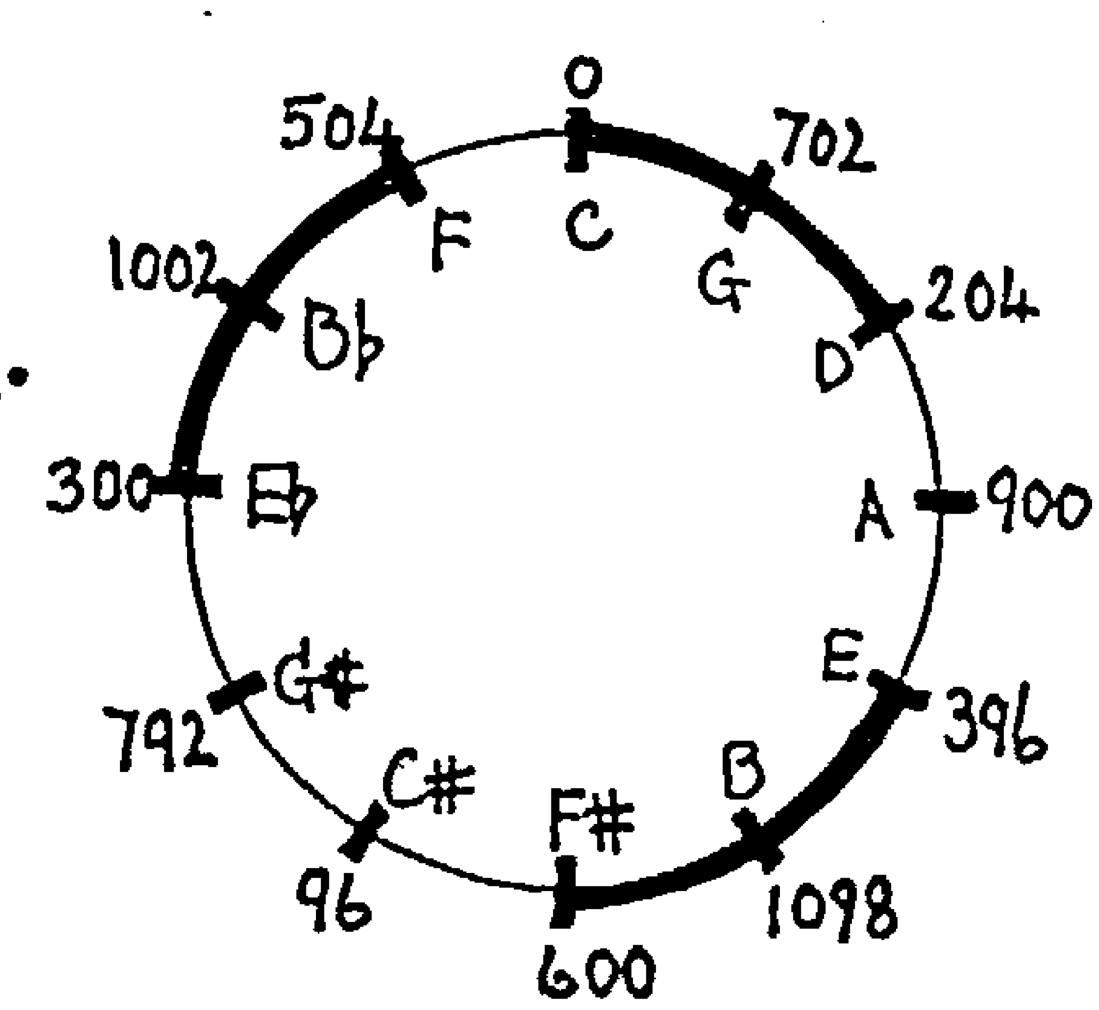
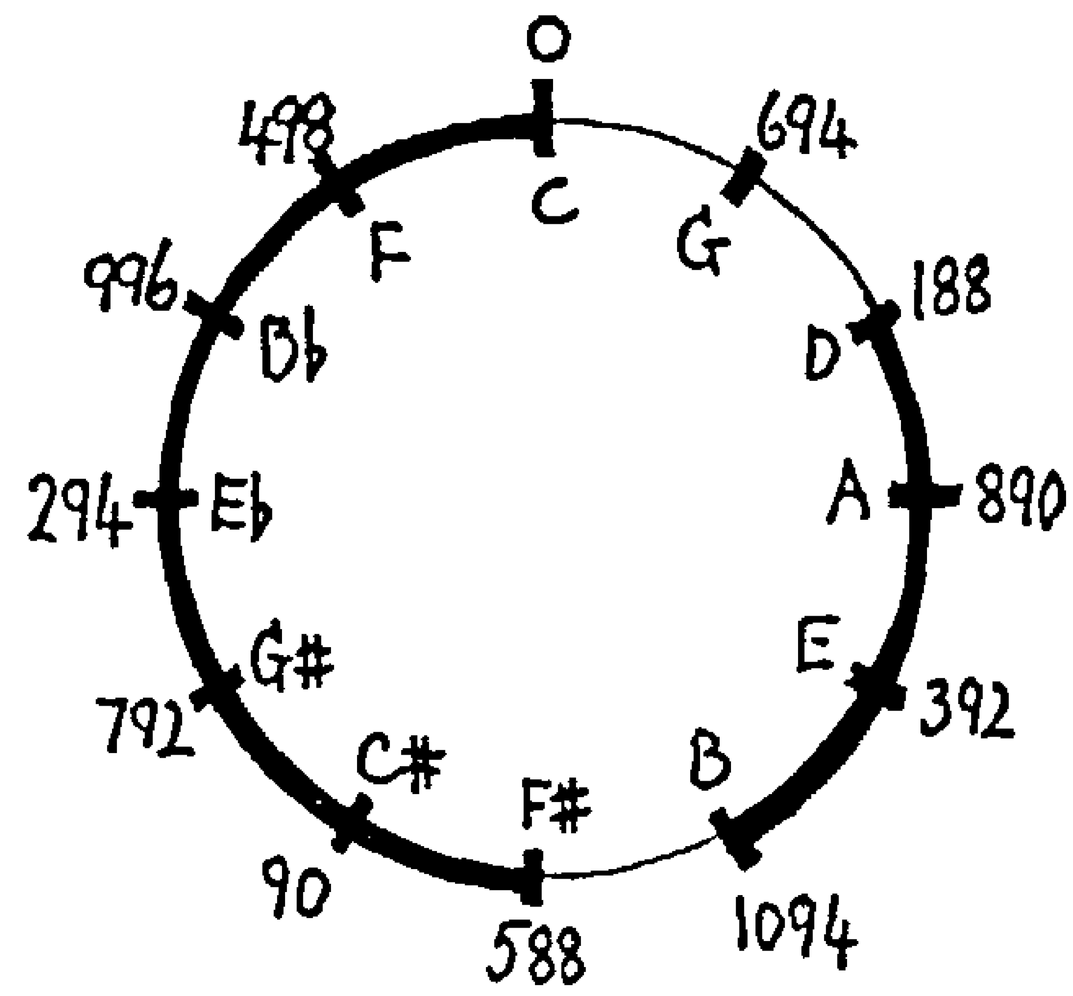


Figure 40. Werckmeister's Correct No.3.
(¼ ditonic comma)

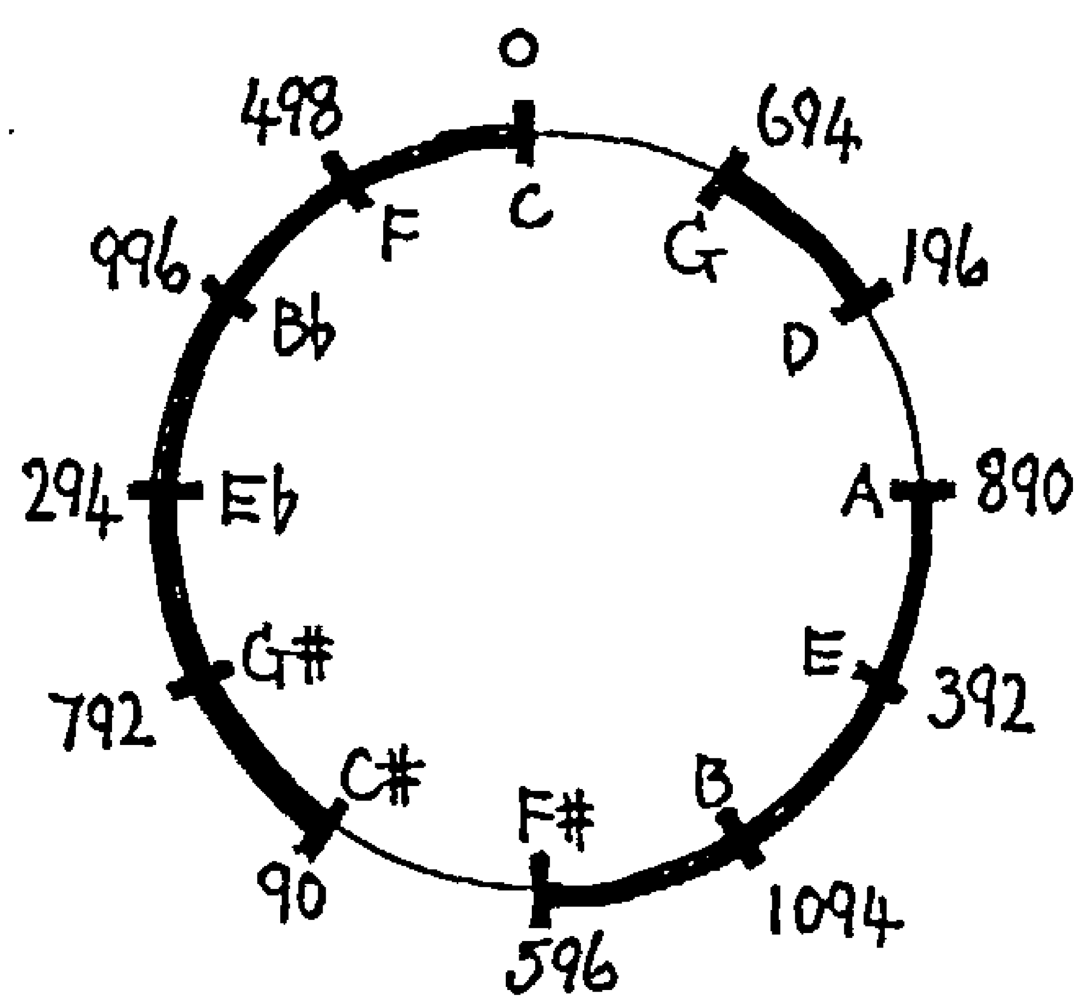
	mi.3	ma.3	5								
C	300	396	706	E	306	396	702	G♯	306	408	708
C♯	300	408	696	F	288	396	696	A	306	396	696
D	300	396	696	F♯	300	402	696	B♭	294	402	702
E♭	300	402	702	G	300	396	702	B	306	402	702

Figure 41. Bendeler's No.1.
($\frac{1}{3}$ ditonic comma)



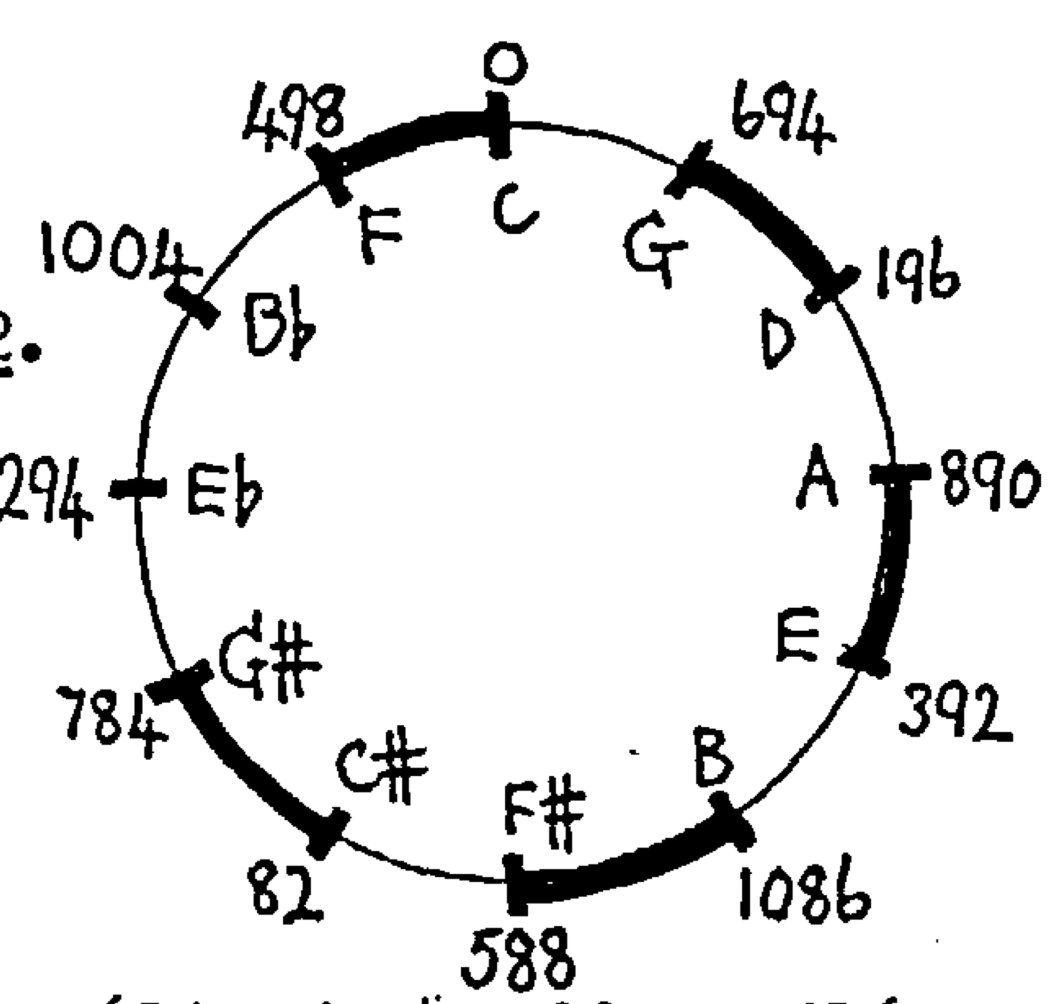
	mi.3	ma.3	5								
C	294	392	694	E	302	400	702	G#	302	408	702
C#	302	408	702	F	294	392	702	A	310	400	702
D	310	400	702	F#	302	408	702	Bb	294	392	702
Eb	294	400	702	G	302	392	694	B	294	400	694

Figure 42. Bendeler's No.2.
($\frac{1}{3}$ ditonic comma)



	mi.3	ma.3	5								
C	294	392	694	E	302	400	702	G#	302	408	702
C#	302	408	702	F	294	392	702	A	310	400	702
D	302	400	694	F#	294	400	694	Bb	294	400	702
Eb	302	400	702	G	302	400	702	B	302	400	702

Figure 43. Werckmeister's Correct No.2.
($\frac{1}{3}$ ditonic comma)



	mi.3	ma.3	5								
C	294	392	694	E	302	392	694	G#	302	416	710
C#	310	416	702	F	286	393	702	A	310	392	702
D	302	392	694	F#	302	416	694	Bb	278	392	694
Eb	294	400	710	G	310	392	702	B	310	408	702

At this point I should like to clear up any misunderstandings which may have occurred elsewhere over the naming of Werckmeister's temperaments. Confusion arises from the arrangement of Werckmeister's composite monochord in <u>Musicalische Temperatur</u>. The monochord shows first of all the usual arcs, representing pure consonances, fifths and thirds. Six monochords are then drawn out, one below another each about a centimetre apart, and numbered I, II, III, IV, V, VI. Werckmeister names III, IV, V "correct" (richtige). Therefore III can also be called "Correct No. 1" and V "Correct No. 3". Figure 44 should make the numbering clear.

Monochord	Werckmeister's names	Barbour	Benade	Klop (34)
I	pure scale	-	-	-
II	$\frac{1}{2}$ comma incorrect	-	-	-
III	correct	correct no.1	no.3	III
IV	correct	correct no.2	-	IV
V	correct	correct no.3	-	V
VI	septenarium	septenarium	-	VI

Figure 44. <u>The Identification of Werckmeister's Temperaments</u>.

In the same way as he condemned quarter comma meantone temperament in <u>Musicalische Temperatur</u> (see p. 63 above) Werckmeister condemned regular $\frac{1}{7}$ comma meantone in <u>Orgelprobe</u>. He placed the wolf between E♯ and C, a most unusual and unfortunate place, and then deprecated the F major triad whose third and fifth were respectively $\frac{8}{7}$ and $\frac{4}{7}$ comma too wide. Werckmeister had assembled his data to suit the point he was about to make:

"Nowadays one needs to use the whole keyboard in a circular fashion". (35)

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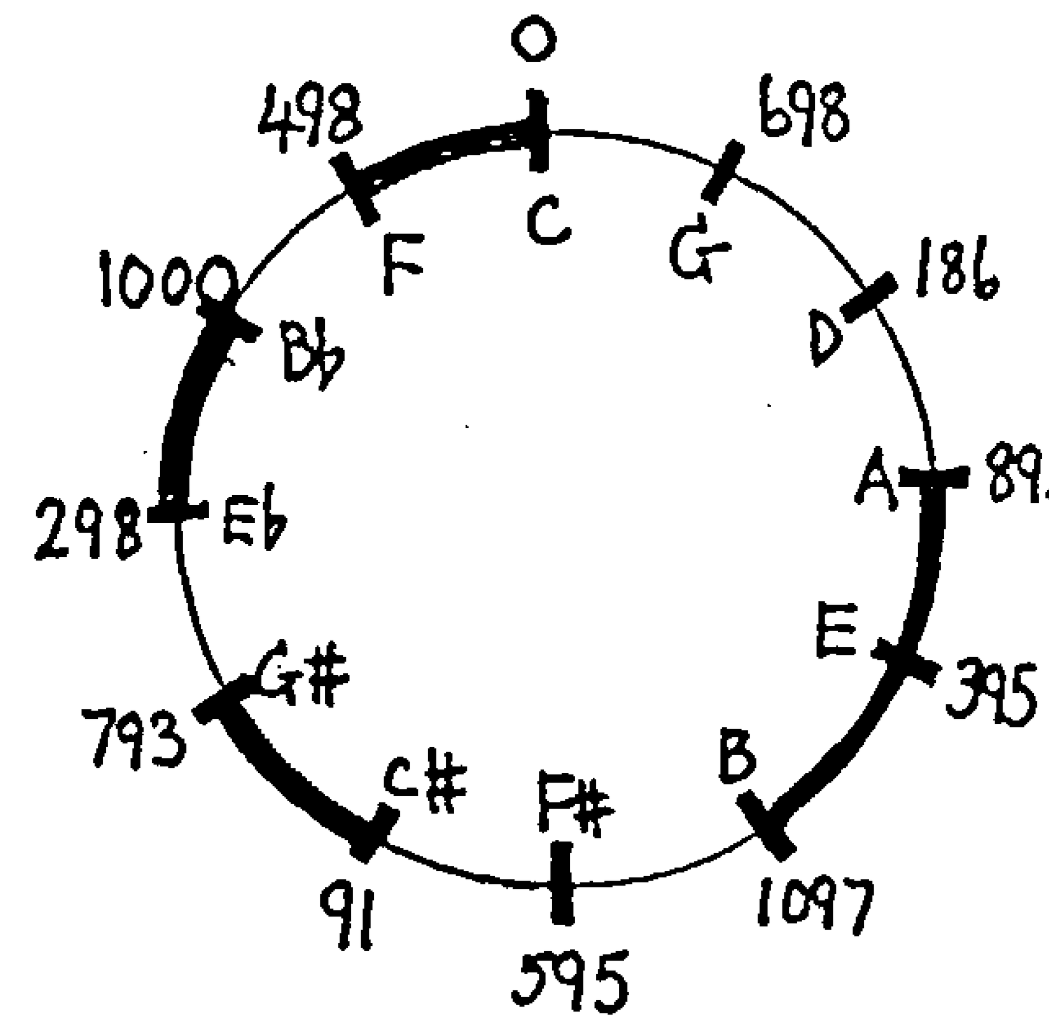
(34) J.Murray Barbour: <u>Tuning and Temperament</u>.
A.H.Benade : <u>Fundamentals of Musical Acoustics</u>, (Ann Arbor, 1980).
G.C.Klop: <u>Harpsichord Tuning; Outline Course</u>, (Garderen, 1974).

(35) A.Werckmeister: <u>Orgelprobe</u>, p.79.

Ten years later he published his own irregular $\frac{1}{7}$ ditonic comma temperament, in which the size of fifth varies from $\frac{4}{7}$ comma narrow to $\frac{1}{7}$ comma wide. The temperament takes its place alongside his other well-tempered monochords.

Figure 45. Werckmeister's Irregular $\frac{1}{7}$ ditonic comma temperament.



	mi.3	ma.3	5								
C	298	395	698	E	303	398	702	G#	304	407	705
C#	304	407	702	F	295	395	702	A	307	398	702
D	312	409	707	F#	298	405	696	Bb	291	386	698
Eb	297	400	702	G	302	399	688	B	289	401	698

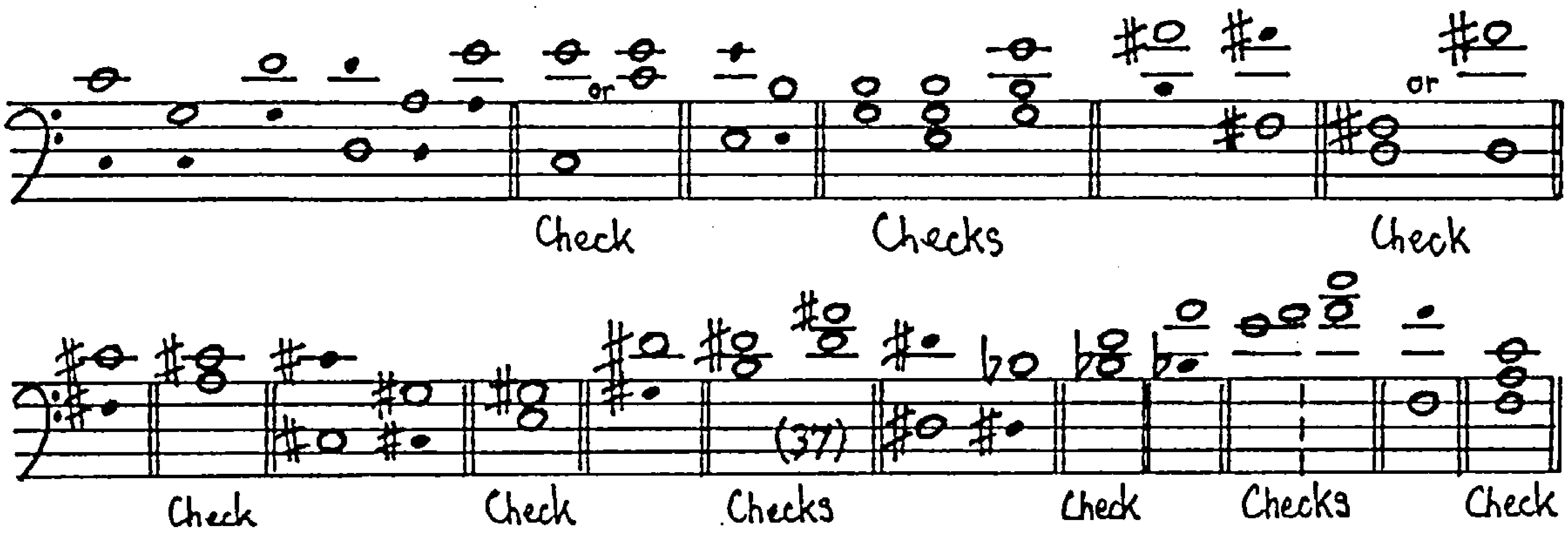
A Werckmeister Tuning Scheme.

Bendeler's and Werckmeister's temperaments were primarily for organ, but arising out of a set of tuning instructions and compiled like Ammerbach's but with much more guidance, is an enigmatic temperament designed probably more for the harpsichord than for the organ. (36) An appendix to Werckmeister's Anmerckungen u. Regeln is entitled "Kurzer Unterricht u. Zugabe wie man ein Klavier stimmen u. wohl temperieren könne" (brief guidance on the tuning and well-tempering of a keyboard). Note that 'Klavier' in a context of this kind means most probably harpsichord. Werckmeister obviously thinks that here a tuning scheme, with checks and precepts, is more appropriate to an instruction manual on thorough-bass than monochord string lengths. Werckmeister was a renowned teacher, and no doubt his manual would be a valuable vade mecum for his own students, but outside the master-apprentice relationship it is difficult to be sure of Werckmeister's exact requirements. Be that as it may, a possible solution to the problem which he set posterity

(36) A.Werckmeister: Die notwendigsten Anmerckungen u. Regeln wie der Bassus Continuus oder General=Bass wol könne tractiret werden, (Ascherleben, 1698). This information is to be found in F.T.Arnold: The art of accompaniment from a Thorough Bass, (London, 1931), pp. 204f.

follows. The tuning scheme pinpoints the difficult and controversial areas of most temperaments.

The Tuning Scheme. (Synopsis)



All tuning is done by octaves and fifths. Nearly all checks are thirds or tenths.

The Precepts.

a) All major thirds are sharp.
b) Apart from the exceptions listed below all fifths are narrow.
c) Exception: (in Werckmeister's own words.) To this c♯ the fifth g♯ can be tuned almost true. The test of the g♯ is e; this third is usually a little too much on the sharp side, but if one contemplates using the g♯ in the place of a♭, as f - a♭ - c, it cannot be helped.
d) Exception: (ditto) To g♯ tune the fifth d'♯. The d'♯ may be just a little sharp in relation to g♯, in order that it may be tolerably consonant as major third to b, and as major third to g'.
e) Exception: (ditto) With d♯ the fifth b♭ may be tuned which may also be slightly sharp, in order that the d' may be tolerable as its appropriate third.
f) Exception: (ditto) With b♭ the fifth f' may be tuned, again slightly sharp, or quite true, according to how the f' sounds in relation to the e', as in the last terminus, or again to the last test note a' as a major third f' - a'.
g) The major thirds are to be used as checks throughout. If their sharpness is excessive, the fifths must be made narrower.

---

(37) According to Arnold this interval d' - f♯. According to W's words "d'♯ ... tolerable major third to g'," there is probably a misprint in the original or in Arnold. The interval ought to read d'♯ - g', and not d'♮ - f'♯, which has already been checked.

From the above precepts there seems to be some room to manoevre. The master ought to be looking over the apprentice's shoulder. The tuning precepts rule out any possibility that Werckmeister is describing how to tune one of his published temperaments. This temperament does not necessarily contain any pure fifths. Certain assumptions or deductions have to be made. The arrangement of the tuning scheme follows a conventional meantone pattern. The first check is at the first available major third. It is much easier and credible to tune with one constant amount of tempering in mind and ear, and so the immediate aim is to find out which, if any, of the historical divisions of the comma could be applied, irrespective of whether a fifth was tempered too wide or narrow. Only one historical fraction was found to be appropriate: $\frac{1}{5}$ comma could be applied fairly consistently throughout, but two major thirds at the far side of the circle were considered too wide to be useful, too much akin to wolves: C♯ - F (419 cents) and A♭ - C (417 cents). However, by changing the tempering interval slightly to $\frac{1}{6}$ ditonic comma, whose fifth (698 cents) is one half cent wider than $\frac{1}{5}$ syntonic comma, it is possible to arrive at an irregular temperament which fulfils all Werckmeister's requirements.

This, then, is the method:

1) Tune a chain of seven fifths, each $\frac{1}{6}$ ditonic commas narrow, from c - g to f♯ - c'♯. The major third checks given should beat gently wide (392 cents).

2) Tune the fifth c♯ - g♯, narrow by 2 cents (700 cents), or pure. The check e - g♯ should make a fairly good major third (394 cents, or if the fifth is pure, 396 cents).

3) Tune the fifth g♯ - d'♯ wide by 2 cents (704 cents) to beat as wide as the previous fifth beats narrow. The check b - d'♯ should be a running third (400 cents). (38)

4) Tune the fifth d♯/e♭ - b♭, wide by 4 cents, to beat as wide as any fifth of the chain of fifths on the sharp side beats narrow. The check b♭ - d' should be a running third (400 cents).

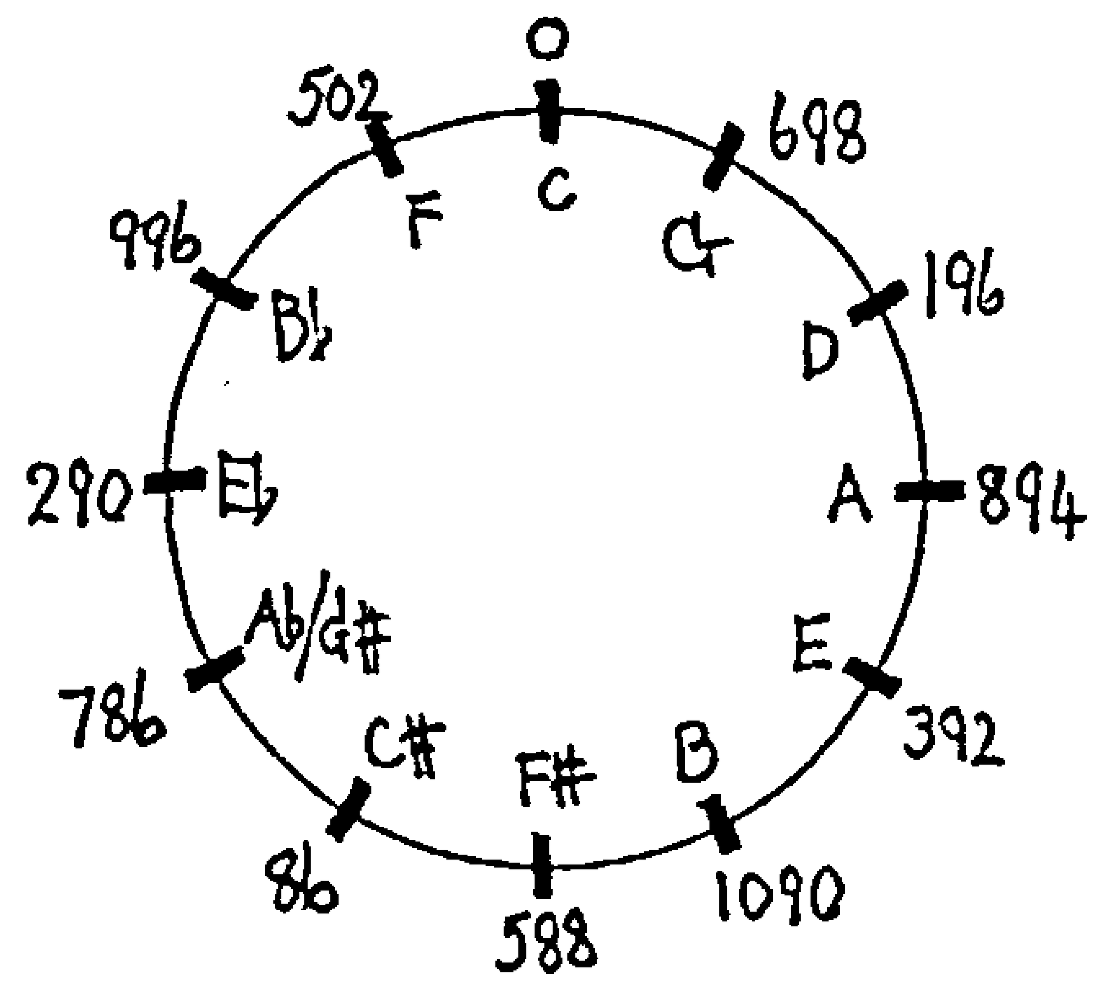
5) Tune the fifth b♭ - f', wide by 4 cents, similar to the previous fifth e♭ - b♭. The check of e - f, a leading note-tonic relationship, should be quite satisfactory at 110 cents: (112 cents is a pure

(38) 'Running third' is a present-day tuner's term for such as an equal temperament third, which beats wide and faster than the ear can count, but not as agitatedly as a Pythagorean third (408 cents).

diatonic semitone). The check f' - a' should reveal a major third as good as any in the temperament (392 cents).

6) The remaining fifth f - c' needs no tuning. It is a check, $\frac{1}{6}$ comma narrow like the rest of the chain of fifths. The whole triad is checked for general effect.

Figure 46. Werckmeister's 'Continuo Temperament'.



	mi.3	ma.3	5		mi.3	ma.3	5		mi.3	ma.3	5
C	290	392	698	E	306	394	698	A♭	304	414	704
C♯	306	416	700	F	284	392	698	A	306	392	698
D	306	392	698	F♯	306	408	698	B♭	290	400	706
E♭	298	408	706	G	298	392	698	B	306	400	698

The scheme is feasible and allows for the sort of latitude Werckmeister implies. The only existing temperament which this 'continuo temperament' resembles is his "Correct No. 2," with its arrangement of perfect fifths alternating with fifths tempered by $\frac{1}{3}$ ditonic comma. Here the fifths progress in a regular fashion, each link of the chain tempered by $\frac{1}{6}$ ditonic comma, a regularity reflected in the familiar triads. The three wide fifths and two very wide major thirds add strangeness in the less familiar triads. If this temperament is what Werckmeister intended, then it is probably the only keyboard temperament expressly conceived for ensemble work with other instruments. It therefore raises new lines of enquiry. Why did Werckmeister slightly exaggerate the most unfamiliar triads, and conversely, do orchestral musicians achieve their effects by well-tempered means ?

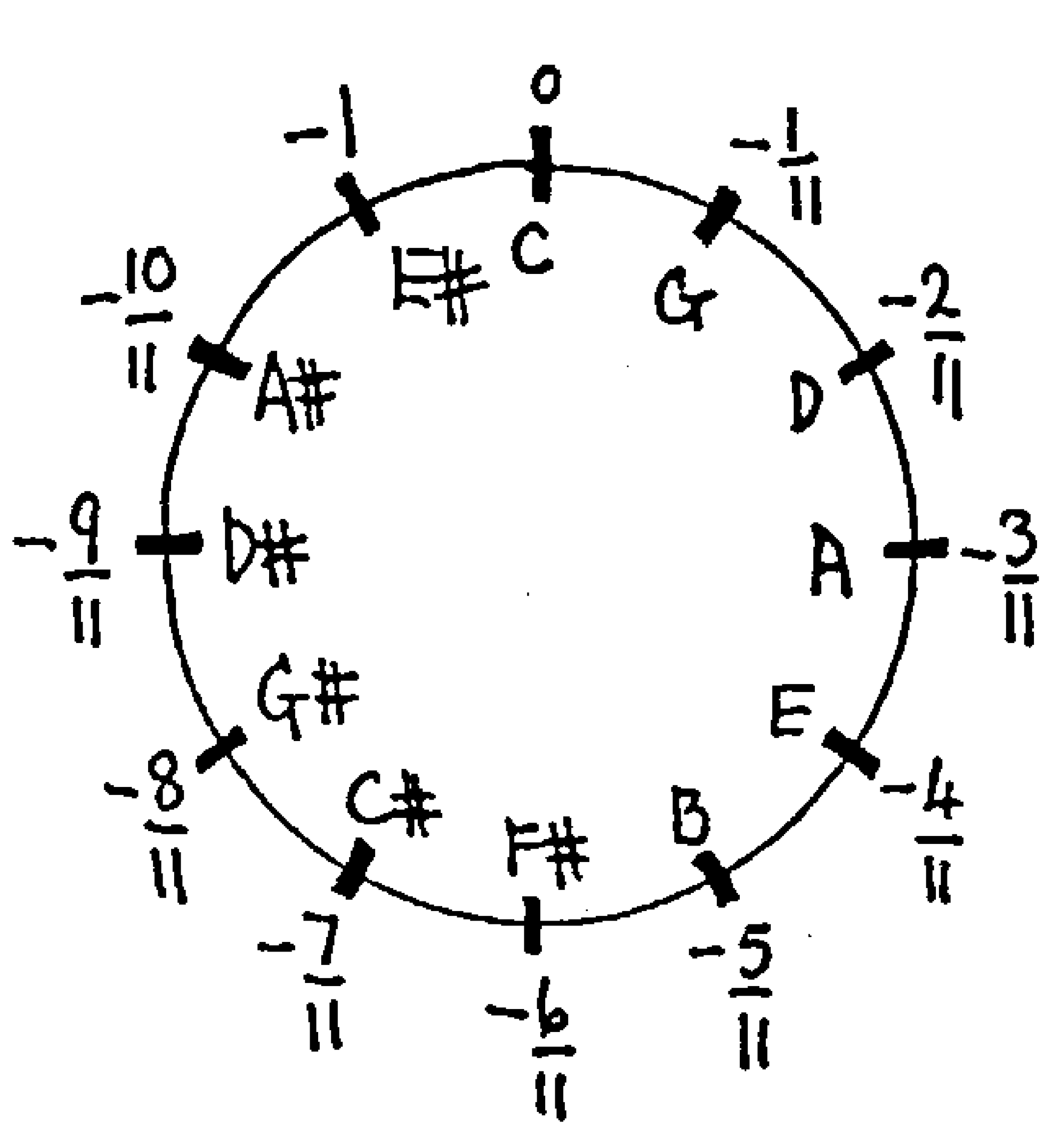
Equal Temperament.

Throughout the period of this study equal temperament seems to lurk like a shadow. The reader will accept the occasional references to it which have already been made in the text because it serves as a useful measuring stick when little else is available.

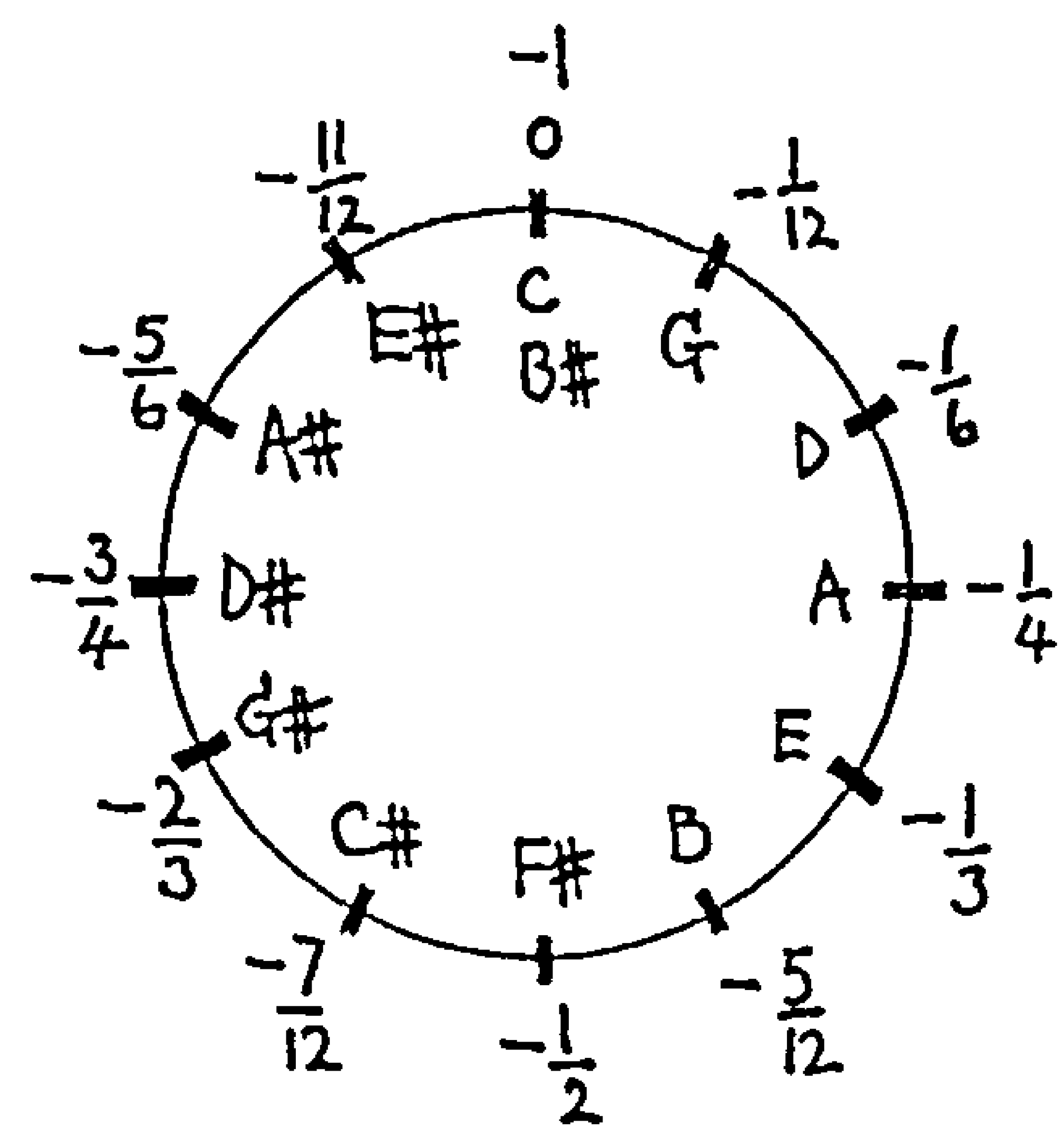
Equal temperament was known and used for fretted instruments in the sixteenth century. Its mensuration and calculation have been accomplished in many different ways. J.Murray Barbour suggested that the simplest method was to find a correct ratio for the equal semitone and apply it twelve times. Galilei (1591) found that the nearest super-particular proportion for an equal semitone is $\frac{18}{17}$, which produces a semitone of 98•95 cents. He applied it to the lute. Kepler (1619) justified Galilei's method mathematically. Frescobaldi (1583 - 1643) may have used equal temperament, and may have recommended that it be used on a new cathedral organ. Froberger (1616 - 1667), a student with Frescobaldi for about four years, may have used it for some of his later music. Werckmeister presented no monochord of equal temperament, but in a posthumously published work, Musicalische Paradoxal-Discourse (1707), he regrets being unable to publish a monochord diagram with his earlier composite monochord (1691). The reason given - and the 1691 monochord is not very skilfully drawn - is that the engraver protested because of the difficulty of dividing the small space required for a comma into twelve parts. (39) This complaint is justified when one examines the diagram. A different means of pictorial representation, probably considerably larger, would have had to be found. On the other hand, Werckmeister might have been inclined to display equal temperament only to condemn it, as he did with regular quarter comma and $\frac{1}{7}$ meantone temperaments.

After 1700 Neidhardt,Sorge, Meckenhäuser, Marpurg, Adlung and many other lesser known Germans recommended it, with varying degrees of vehemence and commitment. Some used the syntonic comma, others the ditonic comma, to arrive at the equal division of the octave. It is scarcely conceivable that scholars of the seventeenth century, who acknowledged the regular meantone variants up to $\frac{1}{8}$ comma, should not pursue the method to produce $\frac{1}{9}$, $\frac{1}{10}$ and eventually $\frac{1}{11}$ comma meantone temperament, where the wolf or residual fifth has become so small that it is identical with the tempered fifths. The other basic method is to divide the ditonic comma into twelve equal parts and from each fifth subtract the twelfth of a comma. The results are the same. The wolf has been habilitated at the expense of all the consonances: not a single consonance remains.

(39) M.Lindley: 'Temperaments', in The New Grove, ed. S.Sadie, vol. 18, p. 666.



semitone = 100c.
mi.3 = 300c.
ma.3 = 400c.
5 = 700c.



a) Regular $\frac{1}{11}$ comma meantone temperament.

b) Regular $\frac{1}{12}$ ditonic comma temperament.

Figure 47. <u>Equal Temperament</u>.

Equal temperament was practised on fretted instruments in the sixteenth century for practical reasons. During the Renaissance and early Baroque periods keyboard music did not require unlimited modulation and a large note vocabulary, but ears were attuned to clarity of sound and purity of interval. Reeds, mixtures and mutation stops tuned to equal temperament would have produced a <u>Hollenlärm</u>, a hell of a noise. (40)

During the later seventeenth century the well-tempered idea began to take precedence. Werckmeister's attitude sums up the preference of the age. He thought meantone temperaments inadequate not only for their harmonic restriction, but also because their useful triads and intervals were identical. Equal temperament too was beyond constructive comment therefore, because it was a negation of his principles. Every major third's amount of dissonance was the same; every minor third provoked the same pinched sensation; the only difference between one triad and another was pitch. The well-tempered concept would allow mistuned consonances for aesthetic reasons. There was as yet no call for the pragmatism of equal temperament. It was inferior. It did not fill the bill.

(40) H.Helmholtz: op. cit., p. 323.

CHAPTER 5

TEMPERAMENTAL EXPEDIENTS APPLIED TO THE INSTRUMENTS OF THE PERIOD.

The previous chapter deals with some of the attempts which were made to reproduce music faithfully on the keyboard, a rigid note arrangement which lacked the versatility of the human voice and many other musical instruments. A question which might be raised by a practical musician with an inventive bent is: unless the twelve-note keyboard is sacrosanct, why not modify the keyboard to accommodate the needs of harmony ? This chapter attempts to provide some answers to this valid question.

Keyboard inadequacy.

The Greek system of modes was always a controversial issue. Those who tried to revive the Greek culture did not agree among themselves concerning the practice of the system, which in any case had to be interpreted in the light of more recent and local traditions. The enlightenment provided by the theorists of Medieval, Renaissance and early Baroque times failed to clarify musical practice or to achieve consistency, even as to the number of modes available. A keyboard which provided no more than the natural notes represented the basis of theoretical agreement in Medieval times, although Lindley quotes the Robertsbridge Codex as containing evidence that a fully chromatic keyboard was in use about 1340. (1) In general, the Italian theorists of the Renaissance were those most concerned with the reproduction of the Greek genera in later music. Applied to the twelve-note keyboard, it is obvious that only the diatonic genus is available, and even that is limited when transpositions occur. Complementary to that was the hexachord system, and by the middle of the sixteenth century musica ficta hexachords were being used on almost every natural step. Aaron allowed them on the notes A,B,D and E in his Lucidario in musica (1545). Zarlino accepted the twelve modes of Glareanus in his Istitutioni armoniche (1558) but changed their numbering in his Dimonstrationi armoniche (1571) so that the series started on C. Such a change implies conformity to aural rather than visual arrangement.

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(1) M.Lindley: 'Pythagorean Tuning', in The New Grove, ed. S.Sadie, Vol. 15 p. 486.

There seems to be no evidence that any alternative keyboard pattern seriously challenged the seven natural and five raised notes, although its inadequacy was recognised as soon as it was established and accepted. Zarlino believed that the founder of the keyboard was at the same time the founder of temperament. (2)

The twelve notes proved inadequate in three ways. Printz cites this threefold inadequacy when cursorily he mentions an instrument to overcome them:

> "During this century (17th) Johannes Baptista Doni ... wrote a little book called De generibus et modi. In it he describes a threefold keyboard for the presentation of the three genera, of modulation, and of the changing of the tones." (zur Veränderung der Tonarum). (3)

The inference here is that the twelve-note keyboard, as much then as now a utilitarian instrument, was limited in its diatonic, chromatic and enharmonic provision, and failed to provide modulation and transposition facilities. Printz does not elaborate.

Schlick's evidence.

Almost two centuries before this Schlick was not only one of the first writers to mention the difficulties arising from keyboard inadequacy, but described expedients to overcome these difficulties:

> "There has been built during these twelve years an organ which possessed double semitones in both manual and pedal. If the usual semitones were too high or too low, then the others known as 'half-semitones' or 'ignoten' would eliminate this flaw by means of different pipes and choirs." (4)

Schlick makes no mention of how many, or where notes were added to the octave, nor is he forthcoming about the method of introducing the 'ignoten' which could have been made available either by extra draw stops or divisions of some of the notes of the twelve-note keyboard known later as 'split keys'. (5) The first known instrument to have split keys was the organ of St. Martin's, Lucca, in 1484 or

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(2) H.Riemann: op. cit., p. 287, from Zarlino: Sopplimenti musicali, (Venice, 1558), p. 260.

(3) W.K.Printz: op. cit., p. 140, tr. J.V.P.

(4) A.Schlick: op. cit., tr. J.V.P.

(5) gespaltene Tasten (German) ; Tasti scavezzi (Italian).

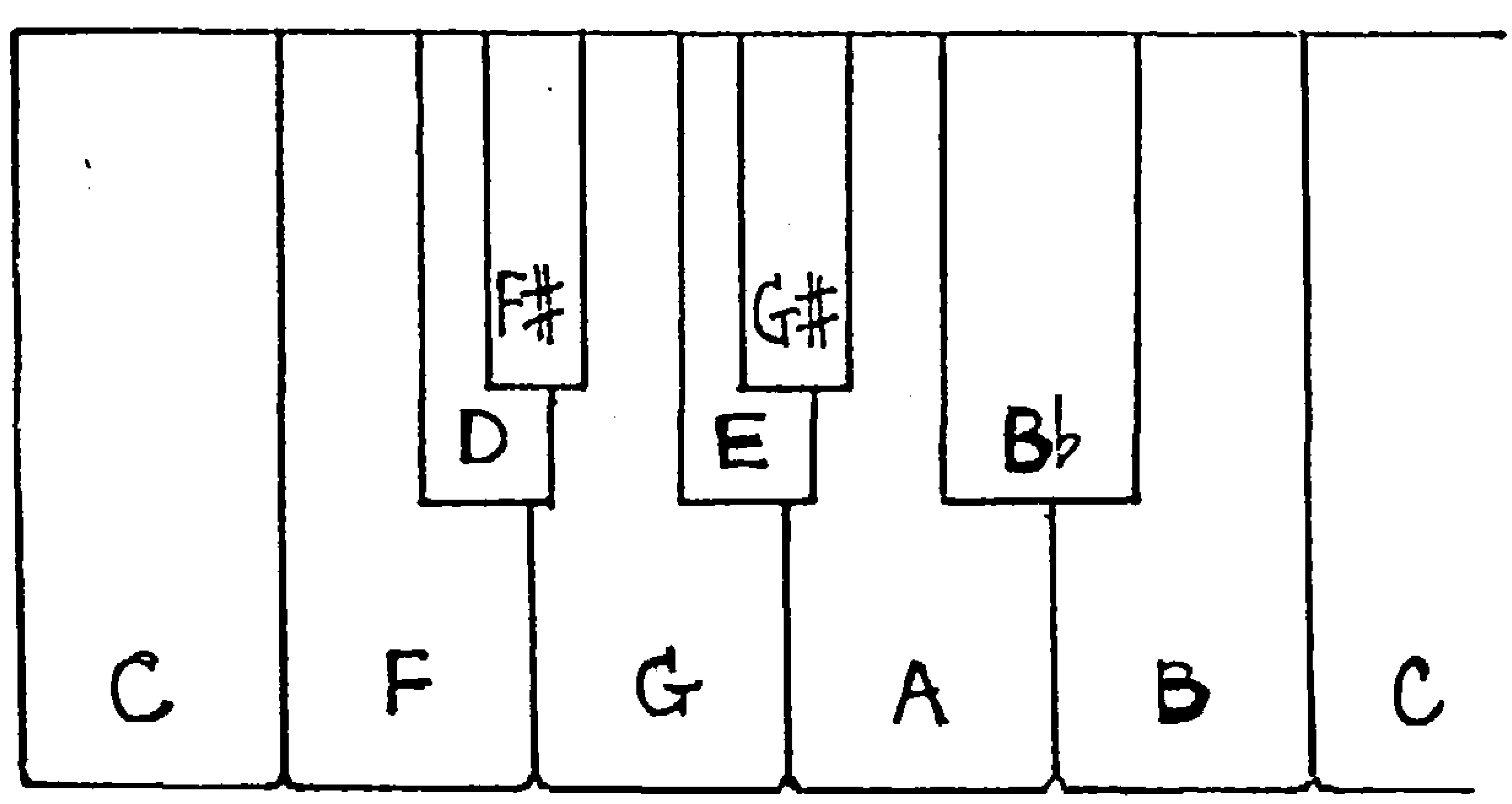
perhaps a little before, and therefore preceding the German organ by about fifteen years. Schlick gives the outcome of the German experiment:

> "It was in vain, futile, and could not be used. And so this innovation was removed from the organ. This curious idea was not expiated with negligible costs. The two organ makers who built the aforesaid organ thought to accomplish something original which would bring them recognition from other organ builders. They had tried to do the same thing many times before but had lacked the skill."

This scathing account suggests that split keys were far from common in Germany at the beginning of the sixteenth century. It must also be borne in mind that Schlick is about to describe his temperament which he believes to be a superior method.

Split keys would occupy the spaces usually given to the usual raised notes, and might be split lengthways or laterally, and perhaps raised to a third plane. It is important to differentiate between split keys, which would be consistent throughout most of the keyboard, and 'broken octaves' which had the appearance of split keys, but which performed a different function. The lowest few notes of some keyboards and pedalboards might be arranged in a manner similar to that of Figure 48.

Figure 48. A Broken Octave.



The lowest fifth of natural notes was compressed into the space of three keys. The normal chromatic arrangement began at B♭. This This was a space saving device and not a temperamental expedient. A glance at the rest of the keyboard should leave no room for doubt whether split keys or a broken octave, or even both, had been installed.

The only inconsistency was likely to occur in the top octave of a manual, which was hardly ever split. This was an anomalous situation, in that the sensitivity to pitch change of the human ear ranges from being very acute at the frequencies of the upper keyboard, to being much less acute at the frequencies of the lower end. The pedalboards of organs usually had the same octave division as the manuals. (6) Split keys, however, were only one method of providing more than twelve notes to the octave. On some organs extra pipes controlled by draw stops could be used to substitute D♯s for E♭s, for example, and the actual keyboard would remain unchanged. In the passage quoted above Printz writes of a "threefold keyboard" mentioned by Doni(d.1647). It is most likely that in this case extra strings would be built into a harpsichord and controlled by a selective mechanism to provide the varieties of pitch required. A more elaborate method was the provision of additional manuals for the same purpose. Multiple manual instruments of this kind were usually experimental, and were the attempted application of some particular theory.

Praetorius's evidence.

The standard work of reference of German instrumental practice for the century after Schlick is undoubtedly Praetorius's "Syntagma Musicum", Vol.II De Organographia (1619). Praetorius visited all parts of German-speaking Europe in pursuit of information. From places he was unable to visit he collected information from Kappelmeister and organists by correspondence. The result is a factual and comprehensive survey of German keyboard practice, although his illustrations of keyboard instruments more often than not show imported and foreign instruments. Evidence of contemporary German practice, however, is to be found in his specifications and descriptions of organs. He has invaluable if sometimes confusing comments to make on split keys as opposed to temperament. It seems safe to assume from his writings that the first raised note to be split was D♯/E♭, and split in accordance with the principles of just-intonation, where D♯ lies below E♭. His only illustration of a keyboard with split keys is that of a spinet with duplicated D♯/E♭ keys throughout. (7) This keyboard also incorporates a broken octave, exactly as shown in Figure 48, but there cannot be any

(6) An exception was the organ at Bayreuth (1618). Praetorius specifies twelve notes for the pedal board octave, thirteen for the manuals.

(7) M.Praetorius: Syntagma Musicum: De Organographia, plate XIV.

confusion because throughout the rest of the keyboard F♯ and G♯ are never split. Praetorius gives manual and pedalboard details of four organs, recently built in different parts of Germany, which have up to fourteen notes per octave:

Date	Organ	Builder	Keys split	
1614	Dresden, Schlosskirche	G.Fritzsche	D♯/E♭	G♯/A♭
1615	Bückeburg, Stadtkirche	E.Compenius	D♯/E♭	G♯/A♭
1616	Schöningen, Schlosskapelle	G.Fritzsche	D♯/E♭	
1618	Bayreuth	G.Fritzsche	D♯/E♭	

Praetorius refers to the provision of D♯/E♭ on harpsichords, the purpose of which is to facilitate transposition, by making a pure major third possible above the note B♮. He suggests that key duplication should not stop there, but be extended to G♯/A♭ and even further. A modest system of duplication would be of greater benefit to organs rather than domestic keyboard instruments, because occasional notes on the latter can be quickly retuned.

> "A number of harpsichords and symphonies have been produced before now for discerning organists, on which the D♯ key is divided and duplicated so that one can have a pure and just third between B♮ and D♯, a necessary modification if the Aeolian mode is to be transposed down a perfect fourth.
>
> In my humble opinion, this would be just as useful and necessary on positives and organs as it is on harpsichords etc., for which one needs only to retune the strings by slackening them off, and later put them to rights. Besides the D♯ key, let the G♯ be divided and duplicated to facilitate playing in the hypodorian mode, for when this mode is transposed down a tone from G to F, the minor third above F, adjacent to G♯ is then made really pure." (8)

He describes in enthusiastic terms a harpsichord with all raised notes divided and the semitones E - F and B - C also divided, making an octave of 19 notes. This instrument, a 'clavicymbalum universale', which he saw in Prague in the house of the famous musician Carl Luython, had been made in Vienna in the latter part of the sixteenth century. Its main virtue, says Praetorius, excelling in this respect the viol da gamba and lute, was that it could play accurately in tune in the three genera, and even the highly chromatic madrigals of Marenzio could be realised on it. On the historical and liturgical side, the intervals of plainsong melody could be faithfully reproduced. Praetorius also mentions an enharmonic clavichord and an Italian positive imported

(8) Ibid. p. 63.

to Graz, which incidentally was convenient to play, but he nevertheless admits the rarity of instruments with split keys. He does not underestimate the spatial and notational difficulties to be encountered, because he includes three explicit keyboard diagrams to illustrate only one instrument. (9)

Praetorius makes a further contribution to the split keys issue in his chapter on temperament, but he only adds to the confusion. His ideal system is just-intonation, he says, as shown by the human voice,

> "for the human voice guides itself in the right proportions and increases them whenever something is found to be lacking, and takes from them whenever there is found to be too much." (10)

He goes on to explain the natural deficiency in the minor triad on D, and gives a remedy:

> "Therefore keyboards ought to be made available more cheaply to provide two Ds, one a comma distant from the other."

This näive statement is contradicted in the next paragraph, after which he explains the method of calculation and advantages of mean tones:

> "But because this happens in other keys too, it would become too much for the keyboards, especially if the duplicated semitones were added to them."

Here it might be worth giving Praetorius the benefit of the doubt, and affirm that Praetorius was really advocating temperament, and in a pedagogic manner conveys an image of a keyboard littered with split naturals as well as split raised notes. Not only is the point taken, but it helps the evidence to accumulate that the German attitude was in favour of temperament for practical and financial reasons.

Kircher's evidence.

In 1650 Kircher included in Musurgia universalis a finely drawn plate illustrating keyboards with 12, 16, 18, 26 and 31 divisions to the octave. Kircher's information was gathered over a wide field and his plate has definite similarities with keyboard drawings in Mersenne's Harmonie Universelle (1636). Otherwise his information reflects most of all the Italian developments of the time. (11)

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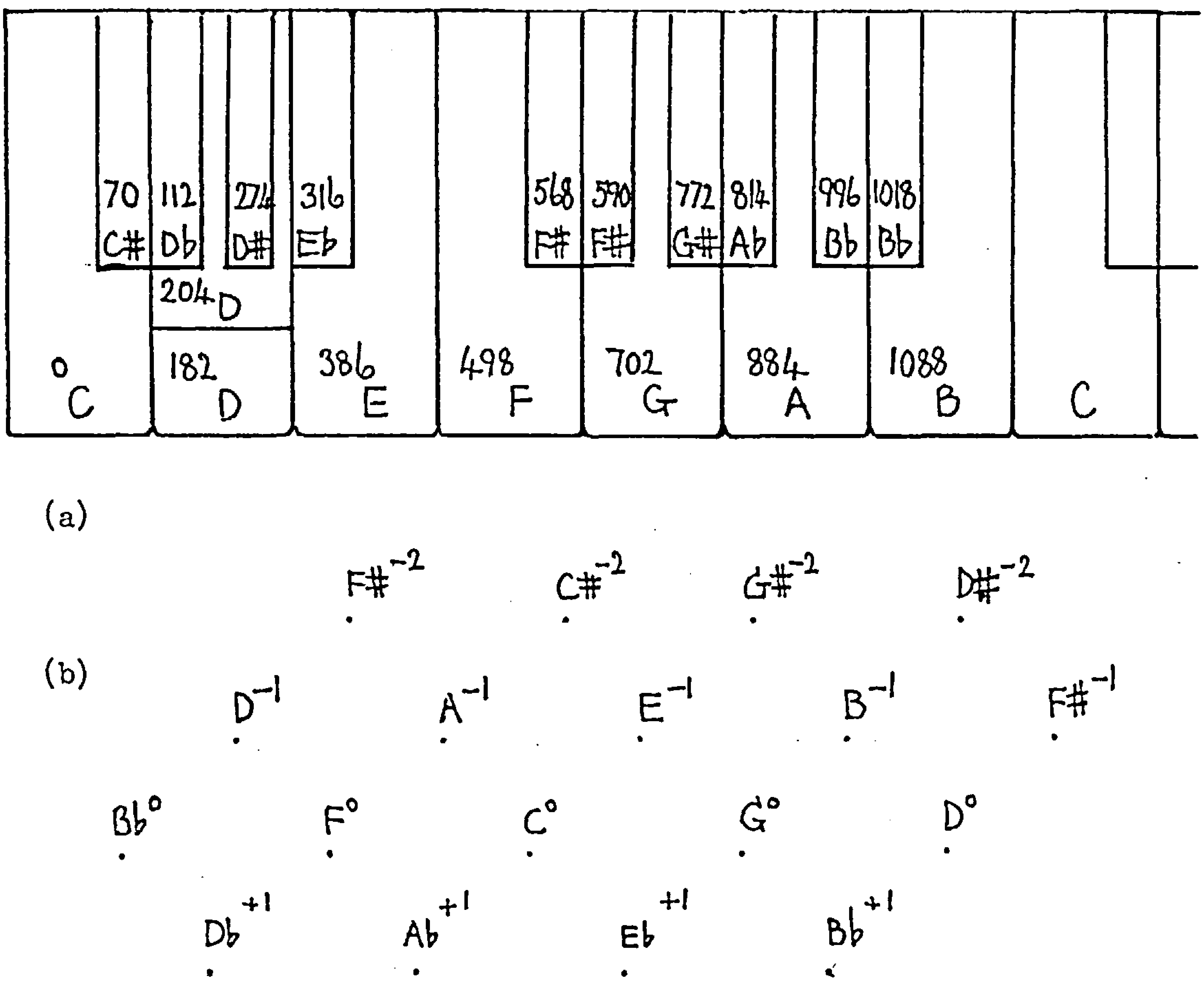
(9) A translation into English of the complete text of Chapter 40, 'The universal or perfect harpsichord', together with diagrams, is to be found in Appendix 1.

(10) M.Praetorius: op. cit., p. 157.

(11) A. Kircher: Musurgia universalis, 1st edn. (Rome, 1650), Plate VI, opposite p. 457.

Figure 49 illustrates Kircher's irregular eighteen note division. Calculations of cent values from the string lengths given reveal a well organised attempt to provide just-intonation. (12) It is no more than a partial success, but from the notes omitted, something can be gathered concerning the demand for distant accidentals. The only natural to be split is D (requiescat Praetorius), to provide a pure fifth from A, and pure thirds with F♯ and B♭. A♯, G♭ and all accidentals beyond are unavailable.

Figure 49. Kircher's Eighteen-note Keyboard.



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(12) It is important to verify Kircher's information and figures, because misprints and other inaccuracies occur. The keyboard illustrated in Plate VI contains three inaccuracies in the string lengths, which destroy the regular argument of the keyboard:

Kircher's lengths				Corrected.
C, c	=	26000,	18000	For 26000 read 36000
E♭	=	3060		For 3060 read 3000
B♭	=	2090		For 2090 read 2000

In diagram (b) all notes on the same horizontal line (and with the same exponent) make a chain of pure fifths. Pure major and minor thirds are to be traced along the diagonals. The exponents show by how many syntonic commas a note is removed from its Pythagorean counterpart: for example E^{-1}

C^{0} = a just-intonation major third.

= 0 + 408c - 22c = 386c.

Other German evidence.

There are only few records of German organs of the period being equipped with temperamental expedients. If there were many organs so equipped, Praetorius should have known. Esais (II) Compenius, of the famous family of organ builders, was a friend of Praetorius, but apart from the Bückeburg organ, there is no specific reference to any other organs of his with refinements of this kind. Another famous organ builder, Fritzsche, was of Saxon origin, and moved to north Germany during, and probably because of, the Thirty Years War.

> "Fritzsche's contributions to the organ include ... occasional quarter-tones (a♯/b♭ at Hamburg Jacobikirche Rückpositiv, as well as the more common quarter-tones elsewhere)." (13)

This slightly ambiguous statement is taken to mean that elsewhere, i.e. in the other sections of the Jacobikirche organ, D♯/E♭ and G♯/A♭ were available, but that the Rückpositiv contained also one further duplication, probably to provide a more versatile organ for continuo and other supportive purposes. Fritzsche was one of the builders who developed the mutation stops tuned in just-intonation and powerful reeds of north-German organs. Their tone quality would certainly be enhanced by mechanical temperamental expedients.

Praetorius's mention of an enharmonic clavichord breaks a virtually complete silence about temperamental expedients applied to the clavichord, an instrument most popular in Germany. If the twelve note keyboard was found to be adequate for the clavichord, one reason may be that a sensitive player has to some extent control of the temperament by the amount of key depression made, just as a lute or viol player can momentarily adjust the temperament imposed by the frets.

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(13) P.Williams: The European Organ 1450 - 1850, (London, 1966), p. 105.

Werckmeister's evidence.

Werckmeister has a different criticism of temperamental contrivances to make:

> "These half-semitones, a mixed blessing during the progression of the harmony, cause much dissonance and confusion when a player needs to hold on to a key whilst wanting to play a different chord." (14)

He does not elaborate. Perhaps he means the difficulty of changing a draw-stop, manual or split key during a progression, for example, from an E major to an F minor triad, which includes a sustained G♯ - A♭. Enharmonic progression of the kind was scarcely a seventeenth-century technique. On the other hand, he may be referring to tactile difficulties which a player has to face on a keyboard or pedalboard with notes on three different planes.

At the end of the century when mechanical aids to keyboard just-intonation had been tried, and had time to be assimilated if successful, Werckmeister, composer, scholar, organist and inspector of organs reviewed the progress in Germany which had been made both in the construction of organs and in the music written for them. The great difference between early and late seventeenth-century music was, he says, in the greatly increased use of chromatic notes.

> "Where necessary (Praetorius) has been able to put a subsemitonal interval with the note D♯, and that was all that was needed. Nowadays, however, since one needs as it were to use the whole keyboard in a circular fashion, it is impossible to make do with such a keyboard." (15)

He is no less scathing than Schlick had been two centuries before, over the provision of split keys on instruments.

> "If an organ, however splendid and expensive were not well tempered, but botched with lots of sub-semitonal intervals, there would be little satisfaction or pleasure to be had from it." (16)

Like Schlick, he is stating his case for temperament. With the fervour of the man who knows he is right Werckmeister exaggerates to the point of absurdity:

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(14) A.Werckmeister: Musicalische Temperatur, tr. J.V.P. Dedication,

(15) A.Werckmeister: Orgelprobe, p.79.

(16) Ibid., p. 79.

> "Sub-semitonal intervals have deceived many, and even if there were a hundred to the octave, they would not meet requirements." (17)

He is ready to admit that old habits die hard. He suggests two expedients for organists unwilling to avail themselves of his circulating temperaments. The most critical raised note is D♯/E♭ which makes the wolf of meantone temperament. If a split key with separate pipes is not available for this note, a retuning of the pipe somewhat higher than D♯ and lower than E♭ would serve for both.

Super-duodecuple keyboards elsewhere in Europe.

Whereas the German attitude from the days of keyboard tablature had been to provide for the reproduction on the keyboard of desired and expressive harmony, the Italian attitude had been to reproduce faithfully the classically acceptable intervals. Domenico of Pesaro had made an enharmonic harpsichord for Zarlino; about 1600 Trasuntino had made a virginals with 31 keys per octave; Vicentino, the most famous keyboard experimenter of all, invented an enharmonic organ and a harpsichord with six keyboards which provided 31 pitches to the octave, and was claimed to play perfectly in tune in all modes. Unlike some of his contemporaries, Vicentino was a highly accomplished keyboard player and a composer who used a highly chromatic vocabulary for affective reasons.

In Europe generally, the farther removed from Italian influence a region was, the fewer were the examples of super-duodecuple keyboards. Both Ramos and Bermudo mention organs with split keys in Spain, but there is little evidence or mention of split keys in France. Towards the end of the seventeenth century several large south-German organs appear to have had split keys, but only wealthy churches, courts or cities could afford them, especially when various sorts of temperament were considered as alternatives, and in most cases preferable. Except for a few octavini, no German harpsichords made before 1700 have survived, owing to the Thirty Years War. (18) The greatest number of super-duodecuple stringed keyboard instruments made up to 1700 were of Italian origin; German instruments were more numerous than French ones; and the only super-duodecuple instruments on record in England were organs made by 'Father' Smith, an Englishman only by adoption, whose roots and training were in Germany.

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(17) ibid., p.81.

(18) F.Hubbard: Three centuries of Harpsichord Making, (Cambridge, Mass., 1965), p. 165.

One further use of duplicated keys was for the purely utilitarian purpose of transposition, usually in order to accompany singers or other instruments. Pitch was far from standardised, and varied from court to court, town to town, customer to customer. Although organists were expected to transpose at sight, they were extremely restricted in the transpositions they could make because the temperaments had to be transposed if the instruments were to play in tune. Only equal temperament is unaffected by transposition.

The first double harpsichords to be made were designed to transpose the temperament. During the first half of the seventeenth century Ruckers built doubles to transpose the temperament up a fourth, down a fifth, using the same strings. The upper manual was correctly scaled in C, and the lower manual's Fs were aligned with the upper Cs. A pre-1650 double now preserved at Antwerp has evidence of extra D♯s. Gustav Leonhardt's explanation, depending on the assumption that the temperament used was meantone, is that each note of the upper manual has a corresponding fifth on the lower manual except E♭ whose note on the lower manual, G♯, needs a D♯ on the upper manual to make a faithful temperament transposition:

UPPER	C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B	C	C♯	D	E♭
LOWER			G	G♯	A	B♭	B	C	C♯	D	E♭	E	F	F♯	G	G♯

Hence there was placed an extra string activated by the jack of the lower manual for every E♭. (19)

Raymond Russell gives an interesting if not complete account of the addition of a single note per octave on several early seventeenth-century Ruckers' harpsichords,

> "This was a very primitive attempt to get rid of the 'wolf' ... For each E♭ Ruckers provided two strings on both eight and four foot stops. These two strings ran almost touching, over the nut, were plucked together by one jack and were hitched together at the hitchpin rail. Signs of them can be detected at these points and also at the tuning pins ... At the E♭s a second pin standing forward from the first will often show where this crude system was in use." (20)

Russell gives no indication of the method of control of this device. If the system were to function as he explained it, the result would indeed be crude, but it would fail to get rid of the wolf. How would

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(19) ibid., pp. 65f.

(20) R.Russell: <u>The harpsichord and Clavichord</u>, 2nd edn. (London, 1973), p.46.

he temper the two strings ? If in quarter comma meantone, and the strings were D♯ (269 cents) and E♭ (310) cents, they would stand nearly two commas apart. To pluck these two correctly-tempered strings simultaneously would be intolerable, not only if sounded with any other note, but even to play a 'unison' with two strings a diesis apart would be a new experience, to say the least. The descriptions of Hubbard and Russell tally, however, if both harpsichords are Ruckers transposing instruments, but only Leonhardt's explanation of the double string and single jack bears analysis and has credibility.

Standing somewhere between the purpose of the Ruckers instrument and that of the Clavicymbalum Universale, described by Praetorius to reproduce just-intonation in any key, was the transposing harpsichord of Nicholas Ramarinus, a Florentine. This was built about 1640, appeared to be capable of playing in just-intonation at any pitch and also could make overall pitch transpositions at the drawing of a stop. Printz describes it in these terms:

> " ... a sort of harpsichord which has an ordinary keyboard but can be varied in every interval. Accordingly he (Ramarinus) divides each tone into nine commas, and arranges so many stops thereby, by means of which the sound can be altered immediately to the required comma. The first stop is set for Roman music, and is called Tonus Chorista or Chor-ton. As required either by voices or transposition of the song, this instrument can be immediately raised or lowered, for example, if the Chor-ton ought to be raised by a semitone one pulls the required stop,and the whole keyboard is raised a semitone." (21)

This is one of a dozen similar accounts of experimental keyboards. Even if the instruments actually existed and fulfilled all the claims made on their behalf by makers and owners, they did not survive until the more investigative nineteenth century. Some tuning problems may have been alleviated by the use of mechanical contrivances, but problems abounded. For every extra note there had to be an extra pipe, string, key. The instruments were more difficult to design, produce, maintain and keep in tune. A modified keyboard required a modified technique and the general complaint was that modified keyboards were difficult to play. Bottrigari makes these points, and a further point which demonstrates at least the latent impresario in him:

> "If I said that this instrument when it is played should make a new sound and render new harmonies to the ears, in the touching of the keys, it ought to provide a new sight to the eyes." (22)

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(21) W.H.Printz: op. cit. p.140.

(22) H. Bottrigari: op. cit. p. 51.

The above problems, together with the usual difficulties encountered in ordinary keyboards, such as inconsistent wind supply, irregularly drawn wire and changes of room temperature must have made the realisation of just-intonation at any required pitch a very rarely achieved goal.

It is not surprising that information on super-duodecuple keyboards is patchy and rather vague. More instruments seem to have been designed than were actually made, and the comments of many writers on super-duodecuple keyboards often merely whet the curiosity of the reader, without giving reasons for the extra notes or the method of obtaining them. Boalch's catalogue of stringed keyboard instruments makes mention that several instruments show signs of having had at an earlier time extra jacks, pins and strings etc., compatible with super-duodecuple keyboards. (23) From the entire catalogue, however, no more than five or six surviving instruments have now, or have definitely had at an earlier time, more than twelve notes to the octave. Experimental keyboards apart, the number of serviceable and practicable super-duodecuple instruments was probably much fewer than the literature of the time suggests. The governing considerations from the players' standpoint must have been that the more complicated the mechanism of the instrument, the more difficult it was to play and keep in tune, and secondly that tablature or notation must be readily transferable to the keyboard.

Conclusion.

A study of temperamental expedients reveals that modifications to the twelve-note keyboard were made for two overlapping but distinct and worthy reasons. The difference between a thirty-one-note octave and a thirteen-note octave is one of purpose, not of degree. Neither purpose fulfilled its expectations. On the one hand, makers went to great lengths to produce instruments capable of producing the intervals of just-intonation at any pitch, irrespective of practicality, playability and notation required. To these makers temperament was unnecessary and irrelevant. On the other hand, makers tried by modest means to alleviate the weaknesses of existing temperaments in an age when human ears were sensitive to pure intervals. If Schlick and Werckmeister, the practical and theoretical masters at the extremes of the period, and Praetorius right in the middle, can be said to be

(23) D.H.Boalch: Makers of the Harpsichord and Clavichord 1440-1840, 2nd edn., (London, 1974).

typical of German keyboard musicians, then Germany favoured temperament as a practical compromise. Experimental keyboards were curiosities to Praetorius; to Werckmeister, non-starters. Both Schlick and Werckmeister dismissed split keys with the same expression, "a cobbling job " (Flickwerk). When the conventional keyboard and temperaments had established their unchallenged superiority, the last word on sub- and super- semitonia might be left to Buttstett (1666 - 1727):

"mehr curieux als practicabel". (24)

(24) J.H.Buttstett: Kurze Anführung zum General-Bass, 2nd edn., (Leipzig, 1733) p. 20.

CHAPTER 6

THE SUITABILITY OF THE TEMPERAMENTS FOR THE MUSIC OF THE EARLIER PART OF THE PERIOD.

Chapter 4 was an attempt to describe temperaments mostly in quantitive terms. Chapters 6 to 8 seek to apply the temperaments to the music of the period in qualitative terms. It is axiomatic to state that the test of a tuning or temperament lies ultimately in its acceptability to those who hear it. Personal likes or dislikes of instrumental sounds are irrational. Many people prefer the deliberately mistuned unisons of certain popular pianists to the calm unisons required by most pianists; many people prefer the bass-heavy reproduction of some amplifiers to live performance under good conditions.

For the moment let us accept that the musical intervals which give us greatest satisfaction are those which coincide with the acoustic principles of consonance. Therefore the sizes of pure consonances will be the standard of measurement against which all mistuned consonances will be judged in this chapter. We shall be observing these intervals not so much in the isolation of their potential for use, but in fait accompli situations: how aurally satisfactory are the results of playing chosen pieces in certain tunings and temperaments.

Renaissance Composers.

German musicians were among the first to classify triads as the basic building material of harmony. The Renaissance recognition of the triad was automatically sanctified because the triad's analogy with the Trinity brooked no opposition. Of all instruments, keyboard instruments by their layout and aspect encouraged the players to think in successive entities of simultaneous sonorities rather than texture of melodic lines. A chordal application of the hands to the keyboard is natural, but a contrapuntal technique at the keyboard is an acquisition. It need not come as a surprise that some of the earliest keyboard music extant shows a vertical rather than a linear interest. Furthermore the vertical interest is expressed in complete triads. The earliest collections of German organ music contain several pieces, many consisting of a melody supported by long held open fifths or occasional thirds in the bass, which are really drones. (1) A praeambulum super D, A, F et G (2) from the tablature of Ileborgh shows an elaborate melody, original and uninfluenced by plainsong, which would fit exactly the oldest disposition of Pythagorean tuning, C♯ - A♭, of Hugo von Reutlingen. That is to say, its double drones, on D and A, and on E and G♯, which are sustained alternately throughout, are concordant in this tuning. On the other hand, a praeambulum in C (3) in the same tablature would require a flatwards transposition of Pythagorean tuning, B - G♭, in order to accommodate a drone on D - F♯, which in the former disposition would have sounded a Pythagorean ditone (408c.). The Renaissance repertoire does not show a well defined allegiance to any particular disposition of Pythagorean tuning. It is obvious that contemporary ears liked the open fifth, but they also liked the fuller sounds of triads. It seems likely and is feasible that the wolf was transposed to avoid the worst harshnesses, but if Pythagorean tuning, or its modifications using absolutely pure thirds were used exclusively, without the possibility of other temperaments thought to belong to a rather later period being used, then fifteenth-century ears must have tolerated spasmodic dissonance.

All Pythagorean tunings of the time have three good major and three good minor triads. These triads are strong and calm and excellent for cadential purposes. Beyond these limits are triads containing ditones and semiditones, i.e. Pythagorean major and minor thirds, the former as gross as the latter are pinched. At the ends of the chain of perfect fifths a wolf fifth howls a Pythagorean or syntonic comma narrow. The aural displeasure created by this pack of wolves is not at all relieved by the purity of the good triads.

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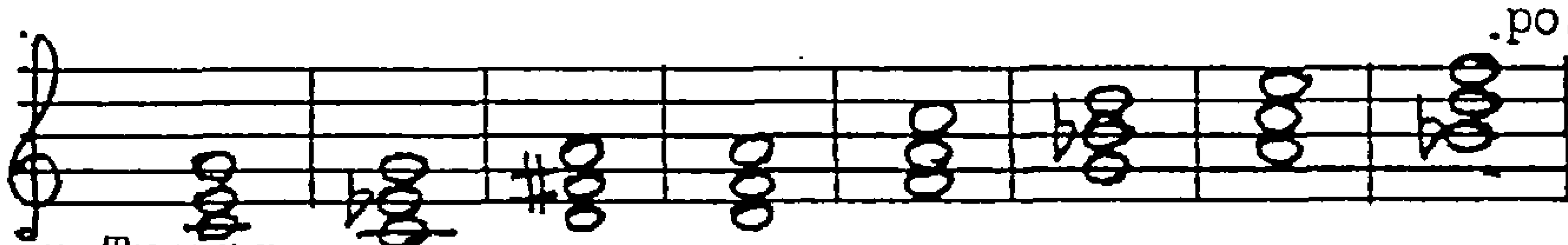
(1) Collections such as Paumann: Fundamentum organisandi, (1452), Buxheim Organ Book, and other tablatures.

(2) A.T.Davison and Willi Apel: Historical Anthology of Music, revised edn. (Cambridge, Mass., 1949), No. 84b, c. 1448. This anthology will be referred to in subsequent footnotes by the letters H.A.M.

(3) Ibid., No. 84a.

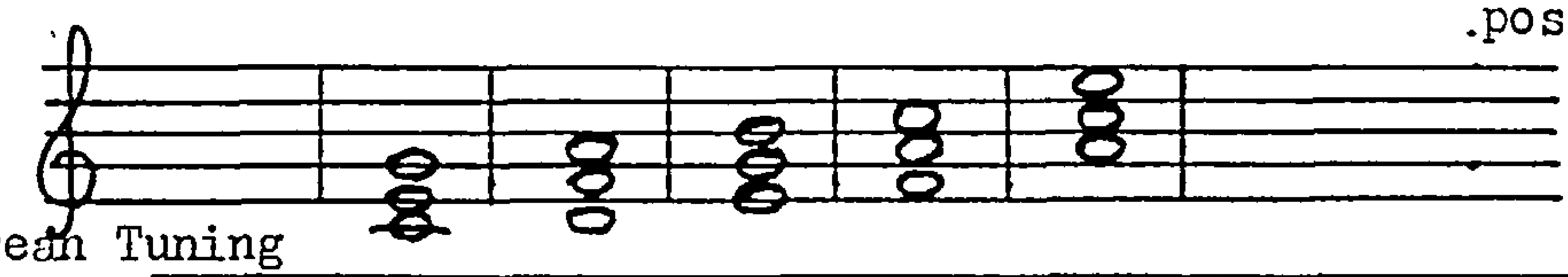
The contrast is all the greater. Therefore unless a composer keeps within the bounds of a tuning the listener is subjected to intermittent pain.

Some scholars reserve Pythagorean tunings exclusively for early Renaissance keyboard music. A short series of early organ preludes was therefore investigated. (4) Each prelude consists of extended scalic melody supported by sustained triads, and intermittent passages of block triadic harmony. Figures 50, 51, 52 show the results. The harmonic vocabulary is summarised across the top of each diagram, and the Pythagorean tunings in four historical dispositions applied. Ticks indicate consonant triads.



Pythagorean Tuning									Maximum possible 8.
C♯ - A♭									0
G♯ - E♭									0
B - G♭			✓						1
G - D	✓		✓	✓			✓	✓	5

Figure 50. Praeambulum super G. (Buxheim organ book).



Pythagorean Tuning							Maximum possible 5.
C♯ - A♭							0
G♯ - E♭							0
B - G♭							0
G - D		✓	✓	✓	✓	✓	5

Figure 51. Praeambulum in mi. (Tablature of Kleber).

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(4) Ibid., Nos. 84c, 84e, 84f.

Maximum possible 7.

Pythagorean Tuning

C♯ - A♭								0
G♯ - E♭								0
B - G♭					✓			1
G - D	✓	✓	✓			✓	✓	5

Figure 52. Praeambulum in re. (Tablature of Kleber).

It is not suggested that these three preludes comprise a representative selection, but if consonance is the criterion, it is obvious that the appropriate Pythagorean disposition for each piece must be chosen. Furthermore, although the G - D disposition looks by far the best choice for Praeambulum in re, Figure 52 fails to disclose that the G minor triad occupies a prominent position in the prelude, and that a sustained A major triad has at least half the total importance of the final cadence. If, however, these pieces are representative of early triadic practice, it is not surprising that Ramos chose the G - D disposition on which to base his modification with pure thirds.

In the case of Pythagorean tunings and temperaments the qualities of the triads are unequivocally good or bad, but beyond them the compromises of the engineered temperaments call for qualification. Purity is sacrifices for an extended vocabulary of usable triads. Black and white dissolve into shades of grey. It becomes necessary to compare the shades of grey, to discuss the relative concentrations of goodness and badness in objective terms. Until cent values became the accepted scale of interval measurement, there was no convenient method of comparing different amounts of mistuning. Recently John Meffen has made temperament comparison objectively possible, with the aid of cent values. (5)

(5) A detailed explanation and justification of the need for this kind of assessment is contained in his doctoral thesis:

J.MEFFEN : The temperament of keyboard instruments in England from the Virginalists to the middle of the nineteenth century. unpublished dissertation, (University of Leeds, 1977.).

He assessed the qualities of eighteen temperaments from the sizes of the intervals of major and minor triads on the twelve semitone degrees of the octave. He assumed that these triads are in a state of perfection and absolute consonance if the thirds from their roots and the fifths conform to just-intonation: for instance, two components of the following triads express the purity of these triads.

C major = 386c. + 702c. C minor = 316c. + 702c.

From these states of aural perfection, he argued that the amounts in cents by which the third and fifth of any major or minor triad in any temperament deviate from just-intonation can be added together to give opportunity of comparing objectively one triad or one temperament with another: for instance the deviation of the amount of impurity in an extreme case, the 'false triad' which makes the wolf triad of quarter comma meantone temperament, is as follows :-

 = (427c - 386c) + (737c - 702c) = 41c + 35c = 76c.

Meffen explained why amounts of mistuning, either wide or narrow, must be added together.

> "Since any deviation from true will cause beating irrespective of whether the interval is made greater or smaller, the plus or minus signs which show the direction of the deviation do not behave in the usual mathematical fashion. The triad of C major in equal temperament, for instance, has a fifth which is 2 cents too narrow (i.e. -2 cents) and a major third which is 14 cents wide (i.e. +14 cents), but the dissonance caused by the beating is cumulative because both intervals are "wrong"; the minus value of the fifth cannot be offset against the plus value of the major third; the -2 cents deviation on the fifth and the +14 cents deviation on the major third will add up to a deviation of 16 cents on the complete triad, not a 12 cent deviation.
>
> "This method of description may seem crude, but, in fact, it does give a reasonably accurate picture of the dissonance caused by the mistuned intervals." (6)

Figure 53 shows a typical Meffen assessment of a temperament. He used his method of assessment mostly as a probe to show the weaknesses and strengths of the intervals of one temperament compared with those of another. It is from the basic idea, rather than Meffen's application of it, that the following exposition and the eventual scheme of objective assessment described in Part Two of this dissertation has grown.

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(6) Ibid., p.233.

Figure 53. Meffen's Calculations of ¼ comma Mistunings. (7)

¼ COMMA MEANTONE.

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	76	193	310	386	503	579	697	773	890	1007	1083

5ths. True 702 cents Equal Temperament 700 cents

C - G	697	(-5)	E - B	697	(-5)	G♯ - E♭	737 (+35)
C♯ - G♯	697	(-5)	F - C	697	(-5)	A - E	696 (-6)
D - A	697	(-5)	F♯ - C♯	697	(-5)	B♭ - F	696 (-6)
E♭ - B♭	697	(-5)	G - D	696	(-6)	B - F♯	696 (-6)

Major 3rds. True 386 cents Equal Temperament 400 cents

C - E	386	(0)	E - G♯	387	(+1)	G♯ - C	427 (+41)
C♯ - F	427	(+41)	F - A	387	(+1)	A - C♯	386 (0)
D - F♯	386	(0)	F♯ - B♭	428	(+42)	B♭ - D	386 (0)
E♭ - G	387	(+1)	G - B	386	(0)	B - E♭	427 (+41)

Minor 3rds. True 316 cents Equal Temperament 300 cents

C - E♭	310	(-6)	E - G	311	(-5)	G♯ - B	310 (-6)
C♯ - E	310	(-6)	F - G♯	270	(-46)	A - C	310 (-6)
D - F	310	(-6)	F♯ - A	311	(-5)	B♭ - C♯	269 (-47)
E♭ - F♯	269	(-47)	G - B♭	310	(-6)	B - D	310 (-6)

Major Chords. Minor Chords.

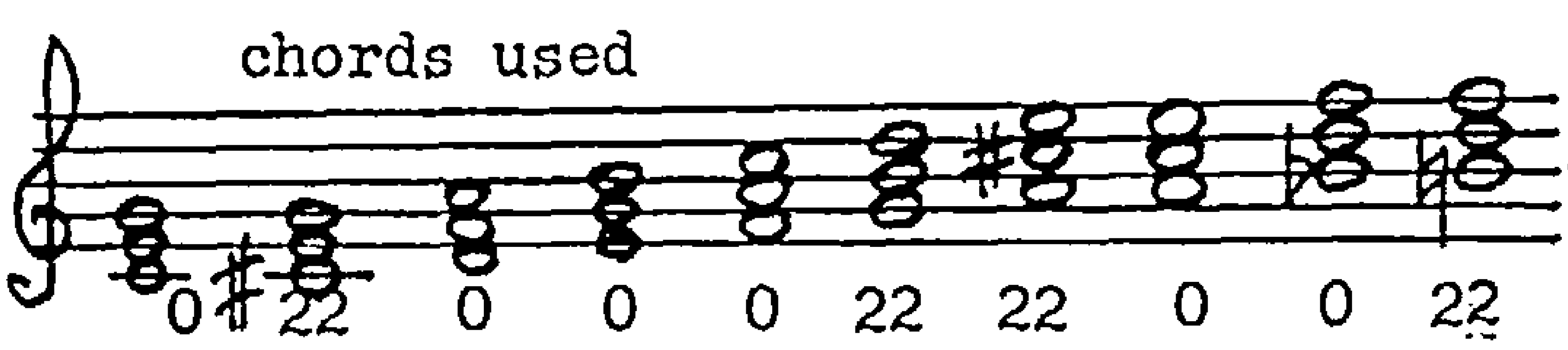
	5ths	3rds	Total		5ths	3rds	Total
C	-5	0	5	A	-6	-6	12
G	-5	0	5	E	-5	-5	10
F	-5	+1	6	D	-5	-6	11
D	-5	0	5	B	-6	-6	12
B♭	-6	0	6	G	-6	-6	12
A	-5	0	5	F♯	-5	-5	10
E♭	-5	+1	6	C	-5	-6	11
E	-5	+1	6	C♯	-5	-6	11
B	-6	+41	47	F	-5	-46	51
C♯	-5	+41	46	G♯	-35	-6	41
F♯	-5	+42	47	B♭	-6	-47	53
G♯	+35	+41	76	E♭	-5	-47	52

(7) Ibid., p. 235.

The total deviation of any mistuned triad can be given a convenient name: 'dissonance level' will serve as an interim, fairly accurate description. Then the wolf triad of quarter comma meantone temperament above may be said to have a dissonance level of 76, and so the dissonance levels of pure major or minor triads will be 0 (zero). Here are the beginnings of an appropriate method, which can be usefully extended, and then applied to pieces of music played in any given temperament. It will be possible to include diminished triads by accepting as their 'consonant' size that of two minor thirds 316 + 316 = 632c (Helmholtz's 'acute diminished fifth'). Let us assume that the vocabulary of traditional harmony up to the end of the seventeenth century consisted, with occasional exceptions, of major, minor and diminished triads. If the harmony of a piece of music is dissected into its component triads, their dissonance levels within a temperament can be compared, and their dissonance levels in various temperaments can also be compared. By adding together the dissonance levels of triads and then dividing by the number of triads used, a 'dissonance quotient' can be arrived at for a piece in a certain temperament, and by comparing dissonance quotients, the most suitable temperament for a piece of music can be determined objectively. It will be necessary to use diagrams in which chords used are placed at right angles to possible temperaments. Dissonance levels occupy the space in between. In the cases of both dissonance levels and dissonance quotients, the lower the number, the greater is the proximity to just-intonation.

The music of Conrad Paumann, sometimes called the father of German organ music, shows a well developed chordal conception of harmony. A chordal analysis of his Mit ganczem Willen, in Figure 54, will demonstrate the method of assessment described above. (8)

Figure 54. Paumann: Mit ganczem Willen.



Temperaments available	chords used										Total	÷10 D.Q.
Just-Py.Ramos	0	22	0	0	0	22	22	0	0	22	88	9
" Agricola	22	22	22	22	22	22	0	22	22	44	220	22
" Erlangen	0	20	20	0	20	2	20	40	20	22	164	16
" Grammateus	22	32	22	22	22	22	10	22	32	44	250	25
¼ comma m.tone	5	11	11	10	6	6	6	12	6	12	85	9

(8) H.A.M. No. 81.

The temperaments chosen are three near-Pythagorean tunings, those of Ramos, Agricola and Erlangen, and the rather later Grammateus temperament. Quarter comma meantone temperament is included, partly for immediate comparison and partly because, although it is more associated with sixteenth-century keyboard music, it is not known how early in the fifteenth century it was being used on organs. The near-Pythagorean tunings show clearly their 'all-or-nothing' quality. Their commonest dissonance levels are 22 or multiples of 22, because 22 cents, the comma, is the difference between a Pythagorean and a pure third. Of the Pythagorean temperaments, that of Ramos is by far the best because all its pure triad resources can be used. Its main obstacle is the wolf triad on G, which occurs at exposed places, although needed only three times. For example, in the following context of parallel consonance, Example 1, the Ramos triad (386c, 680c) demonstrates the spasmodic dissonance amounting to the intermittent pain mentioned above.

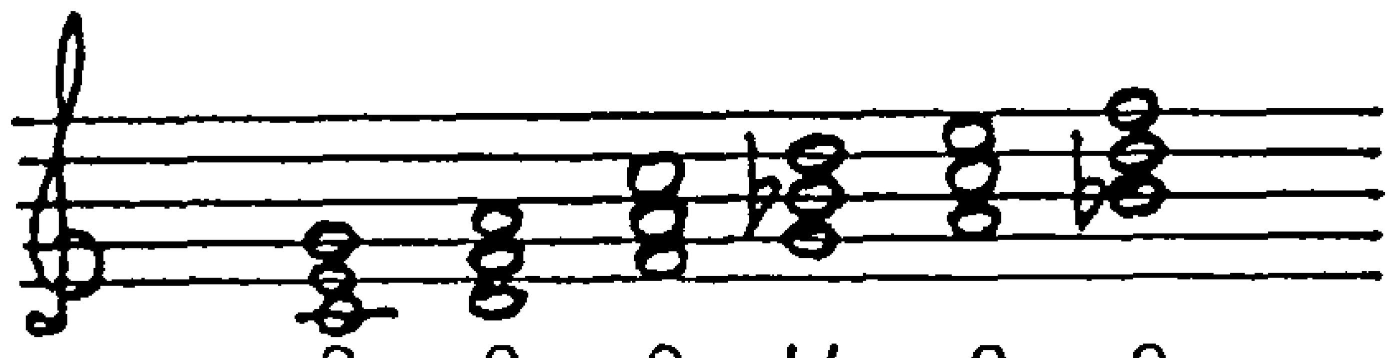
Example 1. Mit ganczem Willen (bars 14 - 15)

All the Renaissance keyboard music in Historical Anthology of Music was investigated. Using the five temperaments above, the results were similar to that of the Paumann piece. All the pieces could be played in quarter comma meantone temperament, and none of the pieces was wholly satisfactory in the Pythagorean modifications, although of these, Ramos's was best. Praeambulum in fa, a short piece in the tablature of the Early Viennese School organist Hans Kotter (1485 - 1541) gives the appearance of almost coinciding with the facilities of the Ramos temperament, but the G minor triad plays an important part in the piece. (9) It will now be appropriate to add to the available temperaments that of Schlick.

(9) Ibid., No. 84g.

Figure 55. Kotter: Praeambulum in fa.

Temperaments available — chords used

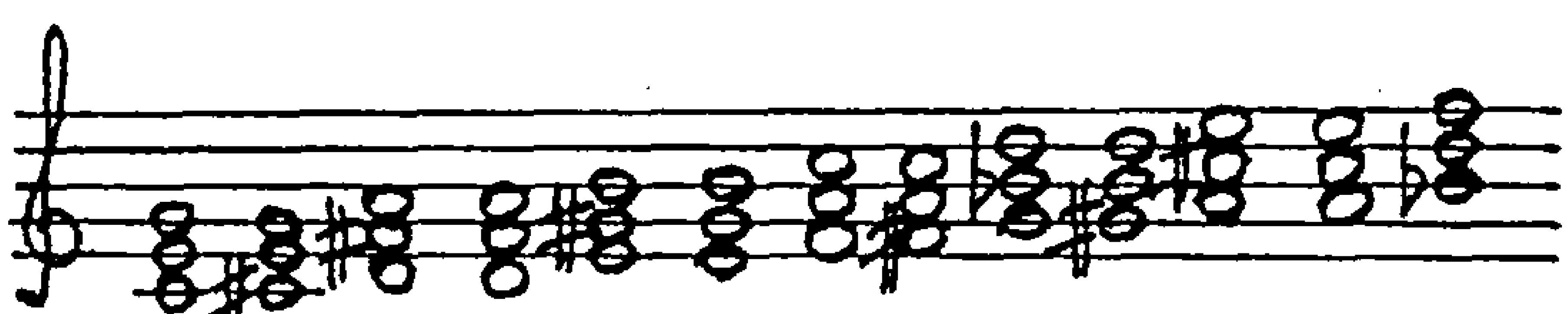


Temperaments available							Total	÷6 D.Q
Just-Py. Ramos	0	0	0	44	0	0	44	7
" Agricola	22	22	22	22	22	22	132	22
" Erlangen	0	20	20	24	40	20	124	21
" Grammateus	22	22	22	10	22	32	130	22
¼ comma m.tone	5	11	6	12	12	6	52	9
Schlick	10	14	10	15	15	10	74	12

The larger the harmonic vocabulary grows the less creditable becomes the belief that Pythagorean temperaments were suitable for keyboards in Renaissance times. The skilful keyboard setting of a popular song of the period, Ein frohlich Wesen, uses a vocabulary of thirteen triads. From its cogent style there is no reason to believe it is other than the work of Hofhaimer (1459 - 1537), although the original bears only his initials. (10)

Figure 56. Ein fröhlich Wesen.

Temperaments available — chords used



Temperaments available														Total	÷13 D.Q.
Just-Py. Ramos	0	22	22	0	20	0	0	22	44	42	22	0	0	194	15
" Agricola	22	22	0	22	0	22	22	22	22	22	0	22	22	220	17
" Erlangen	0	20	0	20	20	0	20	20	24	22	20	40	20	226	17
" Grammateus	22	20	10	22	10	22	22	32	10	32	10	22	32	266	20
¼ comma m.tone	5	11	5	11	6	10	6	11	12	12	6	12	6	113	9
Schlick	10	22	11	14	26	14	10	21	15	28	12	14	10	207	16

Figure 56 suggests that a fairly large vocabulary of triads precludes all Pythagorean tunings. Grammateus's temperament gains no

(10) From the Kleber tablature (1520 - 24) and transcribed by Thomas Warburton in Cuyler, L : The Emperor Maximilian I and Music, (London, 1973), pp. 247 - 249.

advantage from its mean semitones. The dissonance quotients show a fairly uniform unsuitability, for all Pythagorean tunings have the same weakness; a very limited number of tolerable triads.

Arnolt Schlick (1460 - after 1517)

In 1511 Schlick published his method of tuning organs, of which, as shown on p.54, Mark Lindley made a faithful reconstruction. Schlick's tablature was published in the following year, and it is highly unlikely that Schlick, composer, organist, organ-builder, author, would neglect to use or forego his own temperament except at the express desire of a customer. Furthermore, his is a case where there would be justification for believing that he wrote his music with his own temperament in mind and/or that he had his own music in mind when he conceived his temperament. The concern which he voiced in Speigel der Orgelmächer for making good common triads and interesting unfamiliar triads available should be evident in his music. The whole of the known organ works contain a harmonic vocabulary of just over twenty major, minor and diminished triads, as set out in Figure 57. (11)

Figure 57. Schlick's Harmonic Vocabulary.

(Those in brackets are triads by contexual implication, and contain two notes.)

He is one of the first composers to require an octave of thirteen notes, and Spiegel is quite explicit about how to use the 'raised' key G♯/A♭. He breaks with both practice and tradition in that he gives priority to A♭, upon which, he says, a triad can be built which has "the sweetness of good and unfamiliar harmonies". It will occur as a result of the

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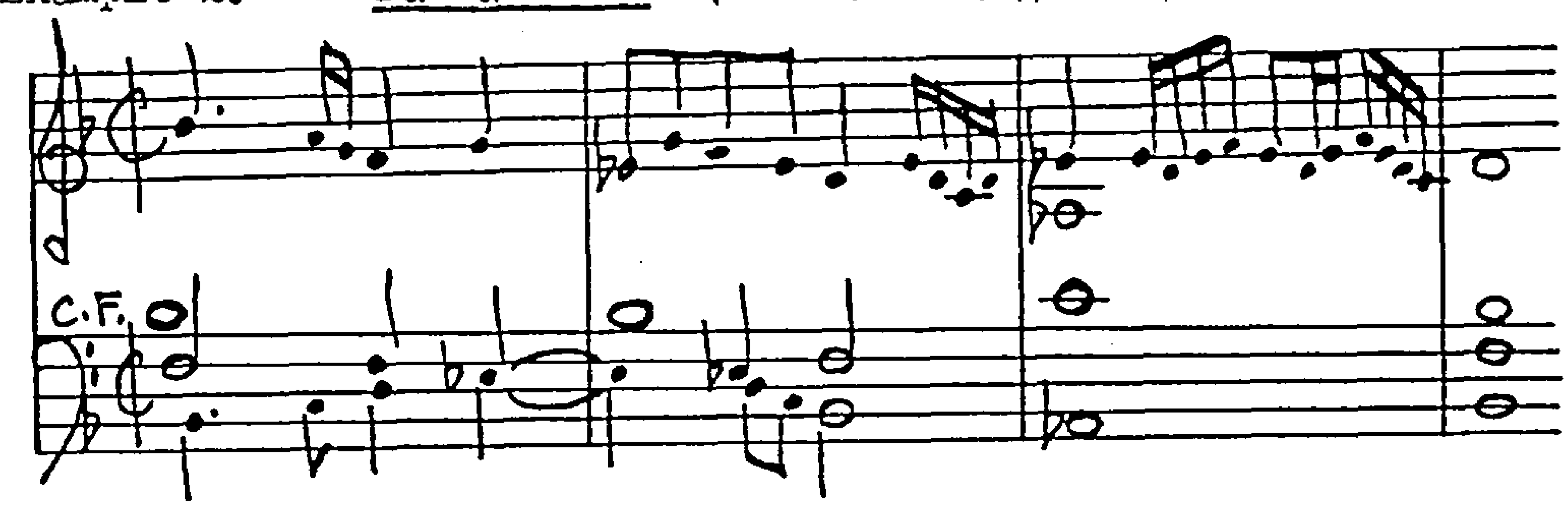
(11) The edition used is A.Schlick: Orgel kompositionen, ed. Rudolf Walter; Schott (Mainz, 1970).
Another scholarly edition of an earlier date, Harms G.(Hamburg, 1924 & 1957), transposes the complete tablature down a perfect fourth. The flattest and sharpest notes Schlick uses then become E♭ and D♯. In Speigel he mentions D♯ merely in passing, but writes at length about G♯/A♭. The Walter edition is the appropriate one for a discussion of temperament.

contrapuntal texture, and not as the penultimate chord for a full close on C♯. Schlick confirms the implied impossibility of such a progression by making C♯ his wolf triad (414c, 712c). In his entire output only once does he use A♭, and then quite consistently with his beliefs: (Example 2)

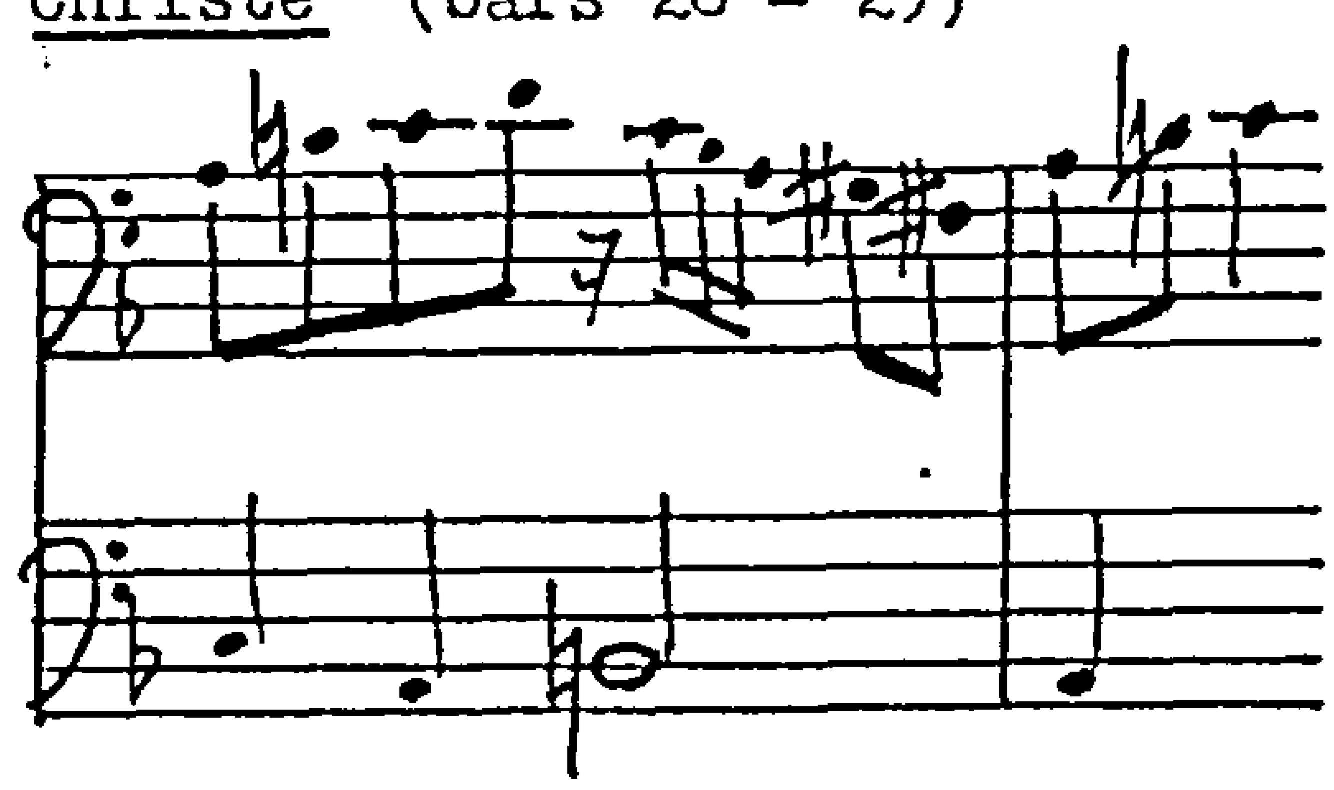
Example 2. Da Pacem II (bars 31 - 34).



The A♭ is unequivocal and bold. In a dorian piece he makes an issue of it. His use of G♯ is quite another matter. Again there is only one piece in which G♯ occurs. There are two contexts, each similar, lightweight and tentative. Each is in two part counterpoint, so that a third note which would help to give them triadic aural definition is lacking. Furthermore each context could be disguised by ornamentation to distract the ear, a practice of which Schlick approved.

Example 3.
Christe (bars 18 - 19)

Example 4.
Christe (bars 28 - 29)



Schlick admitted that the E major triad of his temperament was scarcely a good one because of his preoccupation with A♭. He advised that the best way to make a full close on A was to let the penultimate chord consist of a major sixth containing G♯. The G♯ needs only to be momentary for the human ear to supply all the sense of finality the cadence requires. (12) Schlick shows himself to be a psychologist. The most surprising thing about his G♯/A♭ is not so much

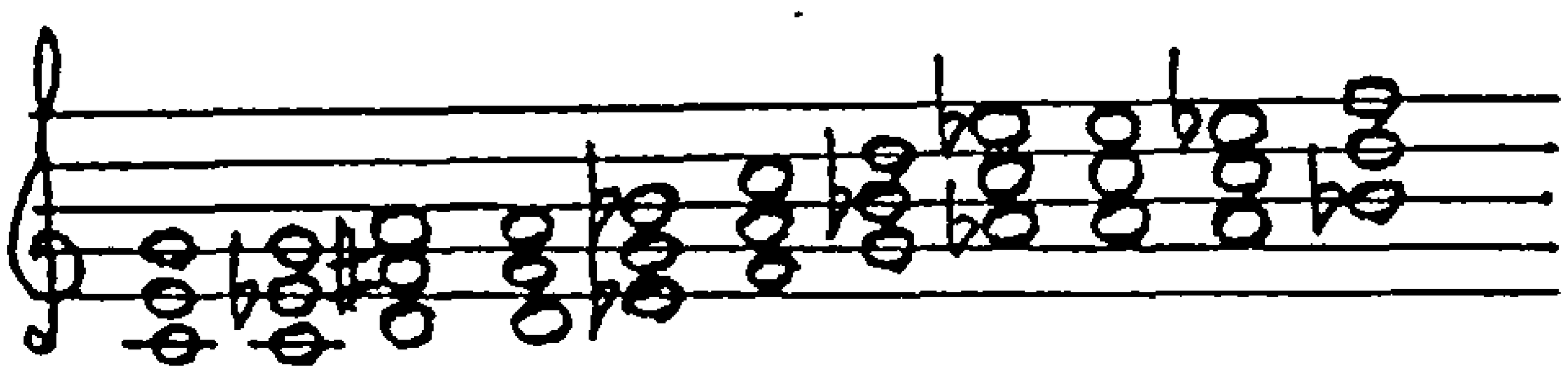
(12) The full text of Schlick's opinions on the uses of G♯/A♭ can be found in Appendix 1, p. 253.

the reasons for its tempering, but the fact that he uses it so rarely in either context after making most careful provision for its use.

Up to now the figures for quarter comma meantone temperament have shown a good and consistent performance. It is when a G♯ has to be used in default of an A♭ that the full force of the G♯ - C - E♭ wolf triad has to be taken into account. The A♭ in Schlick's temperament should provide some of the 'sweet unfamiliarity' he had designed into his temperament.

Figure 58. Schlick: Da Pacem II.

Temperaments available — chords used

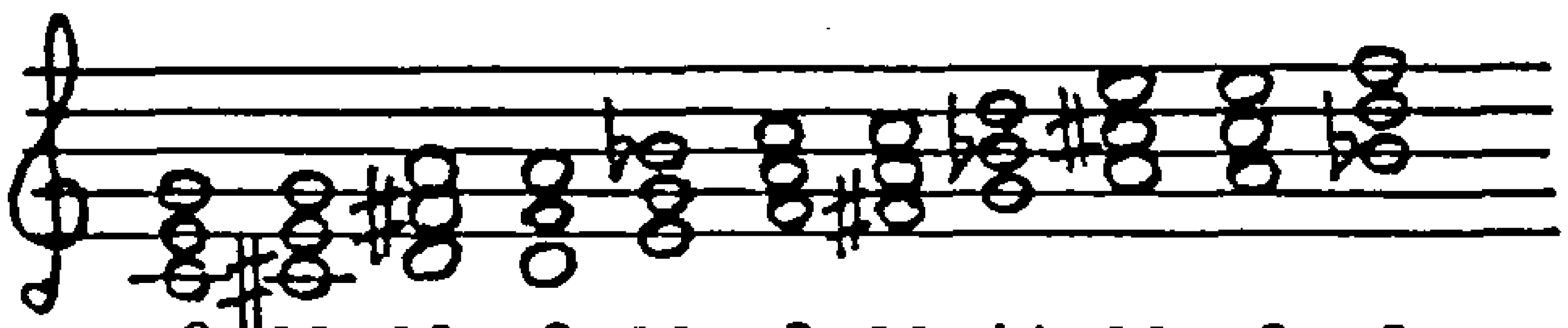


Temperaments available												Total	÷12 D.Q.
Just-Py. Ramos	0	22	22	0	22	0	44	22	0	22	0	154	13
" Agricola	22	20	0	22	20	22	22	20	22	42	22	234	20
" Erlangen	0	22	0	20	22	20	24	22	40	42	20	232	19
" Grammateus	22	10	10	22	10	22	10	10	22	32	32	202	17
$\frac{1}{4}$ comma m. tone	5	11	5	11	6	6	6	76	12	12	6	156	13
Schlick	10	16	11	14	11	10	10	16	14	22	10	144	12

Schlick's most celebrated organ piece, Maria zart, contains neither G♯ nor A♭. The dissonance quotients regain their usual positions; quarter comma meantone temperament leads with the least overall dissonance, Schlick's comes somewhere in the middle, and Ramos's is the best of the near-Pythagorean tunings.

Figure 59. Schlick: Maria zart.

Temperaments available — chords used



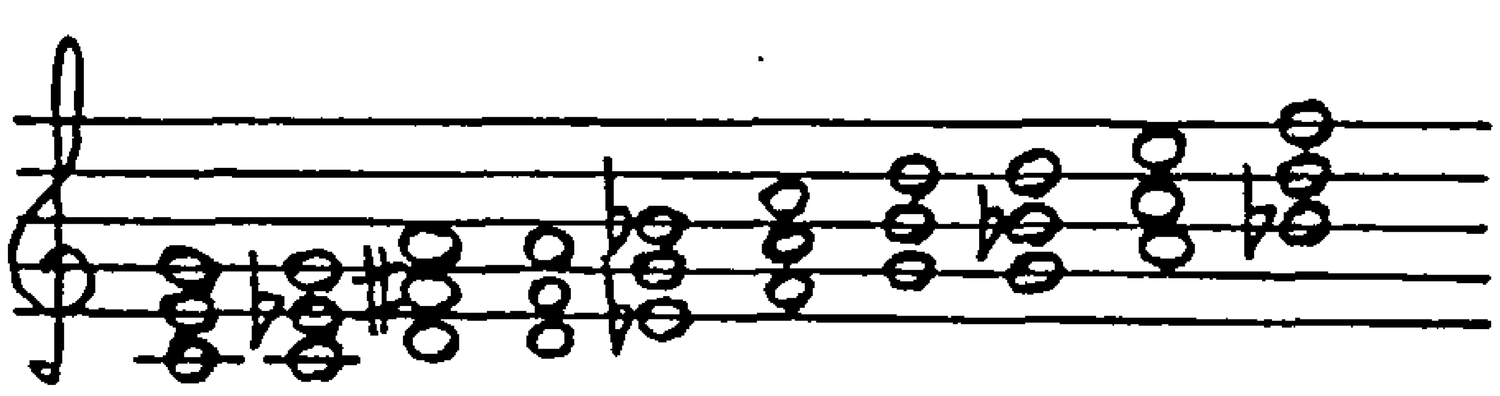
Temperaments available												Total	÷11 D.Q.
Just Py. Ramos	0	22	22	0	22	0	22	44	22	0	0	154	14
" Agricola	22	22	0	22	44	22	22	22	0	22	22	220	20
" Erlangen	0	20	0	20	22	20	20	24	20	40	20	206	19
" Grammateus	22	20	10	22	32	22	32	10	10	22	32	234	21
¼ comma m.tone	5	11	5	11	11	6	11	15	12	14	6	107	10
Schlick	10	22	11	14	21	10	21	15	12	14	10	160	15

Elias Ammerbach (c. 1530 - 1597)

Another sixteenth-century composer who gave a detailed account of how he tuned his keyboard was the Leipzig and Nürnberg organist Ammerbach. From the harmonic vocabulary of his Passamezzo antico (13) and the reconstruction of his temperament on p.73 the following table can be drawn.

Figure 60. Ammerbach: Passamezzo antico.

Temperaments available — chords used



Temperaments available											Total	÷10 D.Q.
Just-Py.Ramos	0	22	22	0	22	0	22	44	0	0	132	13
" Agricola	22	20	0	22	20	22	22	22	22	22	194	19
" Erlangen	0	22	0	20	22	20	2	24	40	20	170	17
" Grammateus	22	10	10	22	10	22	22	10	22	32	182	18
¼ comma m.tone	5	11	5	11	6	6	6	12	12	6	80	8
Schlick	10	16	11	14	11	10	10	15	14	10	121	12
Ammerbach	0	0	0	0	0	0	22	22	0	44	88	9

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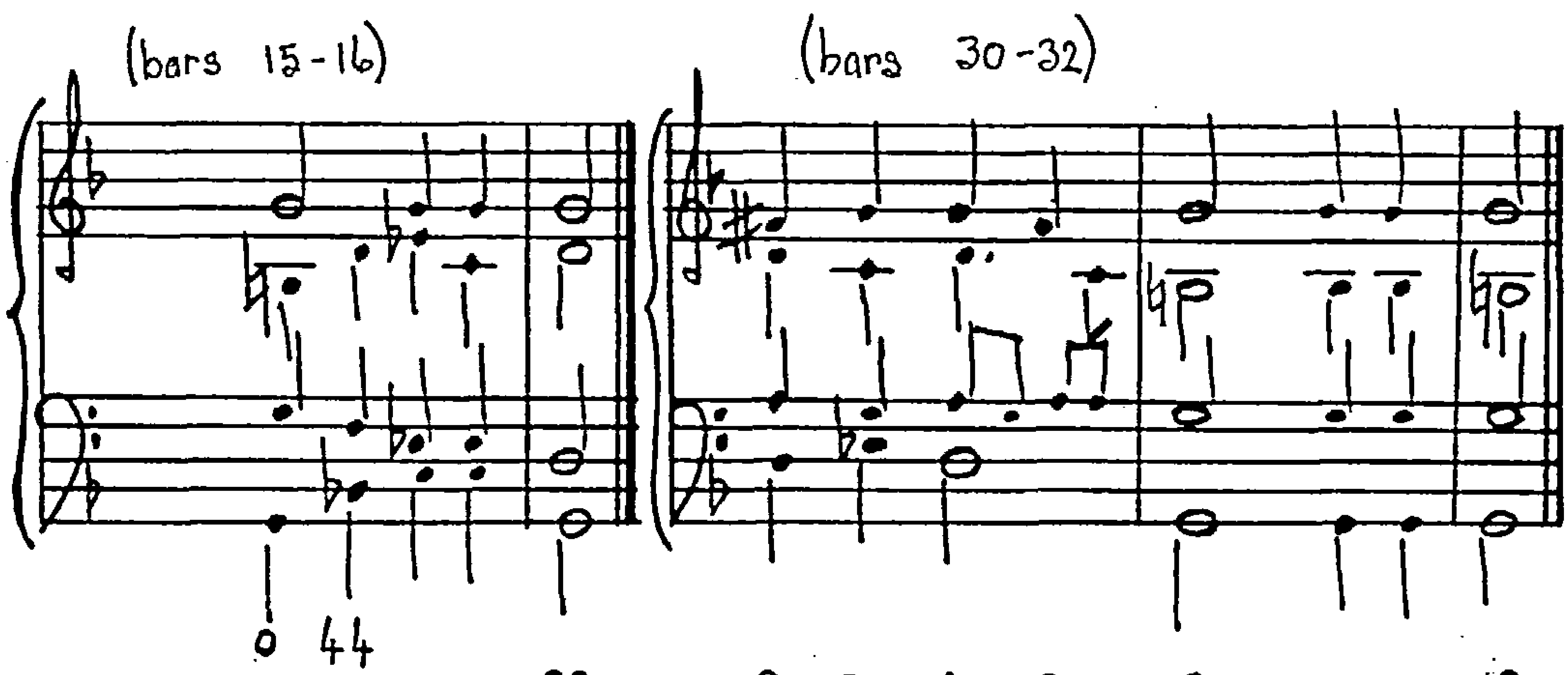
(13) H.A.M. No. 154a.

If the temperament is right, and Fogliano, Kepler and Marpurg found this or something very similar worthy of publication, it may be of value to speculate about aural sensitivity in Renaissance times. The complete dance consists of three repeating sections of which the last is a saltarello. Its modality is transposed dorian, and its strongest harmonic features are firstly, the dominant-tonic relationship of the chords of D major and G major and secondly, the same relationship of the chords F major and B♭ major. Emphasis is given to the purity of the D major chord by its frequent rhythmic repetition, but the B♭ major chord (dissonance level 44) makes frequent distasteful intrusions. Furthermore, the final chords of the sections contain a temperamental anomaly.

Example 5. <u>Passamezzo antico</u>   Example 6. <u>Passamezzo antico</u>



Dissonance levels 0 0 22   0 0 0 0 0 0

End of first section

End of second section.
(End of third section very similar).

The final chord of the first section has a dissonance level of 22 because the fifth alone (680c) supplies the dissonance. The final chords of the second and third sections take advantage of the consonant third (386c) and omit the dissonant fifth, which to present-day ears is far more acceptable and final, thanks to the tièrce, than the wolf fifth.

At this point the method applied so far receives a check. It is clear from the final chords of Examples 5 and 6 that to be faithful to the music and the temperament simultaneously, the method needs to be able to function with incomplete triadic harmony. Query follows query. How will the system deal with a piece of music entirely in two voices, such as a two-part invention ? How will the system deal with four-note chords, for this extension of harmony will shortly be required, if not already encountered ? Perhaps unsupported melody may be more acceptable to the ear in one temperament than another: can provision be made for that ? Music is only sometimes a succession of block harmonies, like a hymn tune sung by a choir. Up to now the system has taken no notice of ornamental notes, and notes outside the justification of the triads, such as suspensions, appoggiaturas and pedals, to mention the more important ones. These notes are not outside the temperament, and so to ignore them is to turn a blind eye to parts of the music.

The inadequacy of the system is also revealed in the explanatory comment on Ammerbach's Passamezzo, where the phrase 'frequent distasteful intrusions' uncovers a gaping hole in the argument. Here is an element of duration which needs to be taken into account. Should a dissonance level occurring for the duration of a semiquaver carry the same weight as a dissonance level lasting the length of a semibreve ?

The work covered in the chapter has not been in vain, however. Its results are neither misleading nor erroneous, but they are inconclusive, incomplete. They lead in the right direction. The reader will not be called upon to unlearn anything. The chapter seeks to give clear indications of the triadic qualities and consequences of using certain temperaments. It is hoped that the correct thought processes have been established, and that eventually this chapter will be seen as a vital step forward towards a comprehensive objective assessment of temperaments applied to music. Chapter 7 contains a complementary analysis. Out of the ideas raised in these two chapters the definitive method of temperament assessment outlined in Part Two comes to fulfilment.

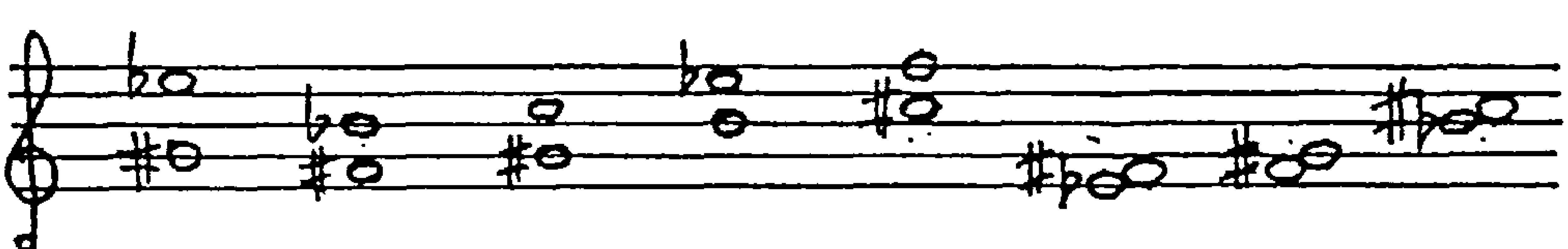
CHAPTER 7

MEANTONE TEMPERAMENT, AND ITS SUITABILITY FOR FROBERGER'S MUSIC.

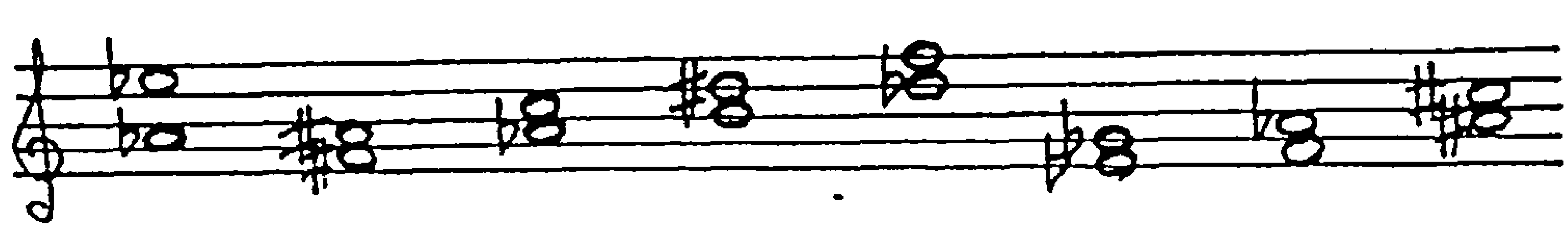
The main concern of the previous chapter was to discover how far certain historical temperaments were appropriate for certain works. The approach in this chapter will somewhat reverse this procedure. Composers would be aware of the limitations of the temperaments of the day, and yet as the seventeenth century progressed, they increasingly refused to confine their music within the safe or consonant limits of these temperaments. The investigation now becomes an attempt to justify the use of certain keyboard procedures whereby weaknesses in temperament might be avoided, disguised or even exploited.

There can be little doubt that meantone temperament was widely used in sixteenth-century Europe, but which divisions of the comma were used apart from the original quarter comma, and where and by whom, are problems still lacking solutions. Quarter comma meantone temperament has many advantages over previous methods. To the Renaissance mind its new and neatly ordered concept of consonance must have seemed attractive. That it was finite in that it had two ends was no deterrent. The modal system was finite. It could be transposed once or twice, but all that had to be said could be said in the system as it stood. The long overdue acceptance of the major third was vindicated. It was the pure fifth that was expendable. Provided that music confined itself to the unequivocal twelve notes produced by the chain of fifths, it was much more euphonious than previously known temperaments. The evidence of the previous chapter confirms this statement. In common with its predecessors, however, it could not take advantage of the tactile and visual ambiguity of the keyboard. Innocent looking fifths and thirds might still be wolves in sheep's clothing. The offence to the ear is not alleviated by notational explanations; see Figure 61.

Figure 61. The Wolves of Meantone Temperament.



The intervals above are unsuitable to be used as substitutes for the intervals below.



A diatonic semitone (117c) was considerably larger than its neighbour, a chromatic semitone (76c), and so a chromatic scale was impossible. Ears accustomed to the leading note qualities, upward and downward, of Pythagorean diatonic semitones (90c) would find meantone's wide diatonic semitones strangely flat and lacking the leading-note quality. Because of the narrow fifths major triads had a perceptible beat. Absolute purity and stillness were possible only by the omission of the fifth. The minor triads were rather less pure (dissonance levels 11 - 12). The temperament was quite adequate for modal music. The fact that there was no D♯ may have helped in the survival of the Phrygian mode, after the other modes had lost their identities in the diatonic system. Only at the third transposition were cadential difficulties encountered.

The temperament was brought to the rest of Europe from Italy in the late fifteenth or early sixteenth century, a period when the court of the Roman Empire was almost as itinerant as the musicians of the time. The Emperor Maximilian I (1459 - 1519) was a champion of the arts, who acquired his taste for music from the Burgundian court. Towards the end of his life his court was constantly on the move, between Italy and as far west as Spain. Resident musicians, many trained in Italy, travelled with the court. Composers attached to the court such as Isaac, Hofhaimer and Sicher wrote keyboard music which fits within the twelve notes of the chain of fifths E♭ - G♯ which defines the temperament. There were many years of consolidation before Calvisius and Praetorius at the end of the sixteenth century documented quarter comma meantone temperament as the one and only temperament for keyboard instruments. It was after this period, extended by the upheaval and devastation of the Thirty Years War, that idiomatic keyboard music with its own distinctive forms developed and prospered in Austria and South Germany. As in earlier times, musicians were often appointed to the Emperor's court, and studied under patronage in Italy.

Froberger's background and personality.

Of these south-German musicians none was more famous at the time, and none had greater influence on musical posterity than Johann Jacob Froberger (1616 - 1667). It may be fruitful to consider his music in the light of the statement, often repeated but rarely substantiated, that meantone temperament was the universal and 'common' temperament of early and middle Baroque keyboard music. Apart from a few insignificant vocal compositions, Froberger was wholly a keyboard composer. The admirable series Denkmäler der Tonkunst in Österreich ed. Guido Adler (hereinafter referred to as D.T.Ö.) provides an urtext of his 104 known compositions. Here is the evidence from which to assess at least how far meantone temperament suited or was adequate for Froberger's music. (1)

If a personality is formed entirely by the interaction of the external forces and influences which besiege a person, then Froberger can doubtlessly be dubbed a cosmopolitan. He often is. He grew up within the staunchly Protestant atmosphere of the Stuttgart Hofkapelle where his father eventually became Kapellmeister. He met, may have been taught by, and certainly heard the music there of the many resident foreign musicians, among whom were the English lutenists Johann and David Morrell, and several eminent Italians and Frenchmen. His musical education continued in the Imperial court in Vienna, noted for its Italian musicians. He was seconded to complete his studies in Rome with Frescobaldi, who is considered to have had the prime influence on his music. After about six years he returned to the Imperial court, converted to Roman Catholicism. At the court he would probably meet Poglietti, J.K.Kerll, F.T.Richter and Athanasius Kircher. He was a friend of Weckmann, the north-German organist, a pupil of Praetorius. Either in the course of his court appointment or as a free-lance musician he visited many parts of Europe, including France, Brussels and London. He became particularly well accepted in Paris, where he was befriended by Chambonnières and Louis Couperin, and the lutenists Denis Gaultier and Blancheroche. Their influence is particularly evident in his suites. It was in Brussels that his links with the Netherlands were forged, mainly through his friendship with Constantin Huyghens. In his formative years he may even have been taught by Samuel Scheidt, to whom, with Frescobaldi, his tendency to write monothematic organ works may be traced. The patterns of the figuration of his variations are similar to those of Scheidt's teacher Sweelinck and even to those of the English virginalists.

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(1) J.J.Froberger: Orgel= und Klavier=Werke, in D.T.Ö. viii and xxi, and Suiten für Klavier, in D.T.Ö. xiii, all ed. G.Adler, (Akademische Druck= und Verlage=Anstalt, 1959).
For the biographical information about Froberger, I am indebted mostly to Adler's prefaces in the above volumes, and to M.Riemann, 'Froberger' in Die Musik in Geschichte und Gegenwart, ed. F.Blume, (Kassel und Basel, 1949) vi. pp.982 - 994.

There is, however, more to personality than an aggregate of external influences. He must also have been a man in his own right. His accepting Catholicism was a most unpopular course to take, as far as his family and background were concerned. Rather than innovative, he was considered of a most conservative nature. It is obvious that a great deal of European music was available to him, and that in his travels he was familiar with the musical thought and attitudes of the day. To the Italianate instrumental forms and the Gallic dance forms he added a mixture of teutonic logic and emotion. The fact that he never stayed in one place for a long time had two results. Firstly, he did not gather around him or train a group of disciples to proclaim a doctrine, and secondly, although many of his works can be dated only roughly, during his travels the harpsichord seems to have become his main means of expression. He left no didactic or theoretical work, and so from the evidence of the music alone must be deduced his attitude to temperament.

He was the first German composer of essentially and idiomatically harpsichord music. It would be to the investigator's advantage if a specific division between organ and harpsichord/clavichord could be made. It is impossible to draw a convincing line for there is little doubt that ricercari, canzonas, capriccios and fantasias were played on both types of instrument, and that even the names were readily interchangeable. A ricercare may appear as a canzona in one collection, a capriccio in another and a fuga in yet another. There are two broad categories of keyboard works, between which stand the toccatas, many of which are more suitable to be played on the clavier. The toccatas headed 'da sonarsi alla levatione' (to be played at the elevation of the host) are expressly for use in the Mass, and so would be for organ.

For organ		For clavier
Canzonas		Suites
Capriccios	Toccatas	Occasional pieces
Ricercari		
Fantasias		

Sideways shift.

The system of quarter comma meantone temperament as described by Praetorius and others is disposed within the limits of a chain of twelve fifths, E♭ - G♯. 48 pieces, 46% of Froberger's total output, are within this range. This number includes the great majority of his organ works. The system, however, is negotiable. Let us imagine that the chain of fifths each a quarter comma narrow extends beyond E♭ on the flat side and beyond G♯ to the sharp side. A chain of any eleven fifths can be tuned in quarter comma meantone temperament to suit any piece with not more than the corresponding twelve notes. In more practical and immediate terms, for a piece requiring D♯ but not E♭, the system can be 'shifted sideways' by one fifth to the disposition B♭ - D♯; for a piece requiring A♭ but not G♯, the system can be shifted sideways by one fifth in the other direction to the A♭ - C♯ disposition. Figure 62 might be called a static slide-rule from which the cent values of any required disposition of the temperament can be immediately obtained.

The harpsichordist whose instrument is tuned in quarter comma meantone temperament and who retunes all the E♭s to D♯s, or G♯s to A♭s is applying the expedient described above. An organ in the same temperament which has alternative pipes for E♭/D♯ and A♭/G♯ similarly applies this expedient. An organ or harpsichord so tuned with split keys for E♭/D♯ and A♭/G♯ extends the range to 14 notes. Froberger would tune his own harpsichord, and at least be familiar with these organ expedients. At the same time, the practice of using nearly related keys, and of confining a set of variations or the numbers of a suite to the same key may have been more of a temperamental necessity, and less of an artistic choice than is realised.

28 pieces, 27% of Froberger's output, can be realised in meantone by the expedient of sideways shift, and most of these 28 pieces can be accommodated by a shift of one place to the right or left. The bulk of the keyboard music of the period can be played in meantone temperament by means of this expedient, but the argument would carry more weight if there were adequate confirmation of the practice being used at the time. Lindley cites the composer Cima as the only Baroque musician to describe this procedure. Praetorius does not go so far as to describe it in detail, but refers to it in a casual manner during a discussion on split keys. Because Praetorius is always painstaking in his descriptions, we may infer from the following

Figure 62. Twelve Dispositions of Quarter Comma Meantone Temperament.

1.	B♭♭ 930	F♭ 427	C♭ 1124	G♭ 621	D♭ 117	A♭ 814	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193
2.	F♭ 427	C♭ 1124	G♭ 621	D♭ 117	A♭ 814	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193	A 890
3.	C♭ 1124	G♭ 621	D♭ 117	A♭ 814	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193	A 890	E 386
4.	G♭ 621	D♭ 117	A♭ 814	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193	A 890	E 386	B 1083
5.	D♭ 117	A♭ 814	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193	A 890	E 386	B 1083	F# 579
6.	A♭ 814	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193	A 890	E 386	B 1083	F# 579	C# 76
7.	E♭ 310	B♭ 1007	F 503	C 00	G 697	D 193	A 890	E 386	B 1083	F# 579	C# 76	G# 773
8.	B♭ 1007	F 503	C 00	G 697	D 193	A 890	E 386	B 1083	F# 579	C# 76	G# 773	D# 269
9.	F 503	C 00	G 697	D 193	A 890	E 386	B 1083	F# 579	C# 76	G# 773	D# 269	A# 965
10.	C 00	G 697	D 193	A 890	E 386	B 1083	F# 579	C# 76	G# 773	D# 269	A# 965	E# 462
11.	G 697	D 193	A 890	E 386	B 1083	F# 579	C# 76	G# 773	D# 269	A# 965	E# 462	B# 1159
12.	D 193	A 890	E 386	B 1083	F# 579	C# 76	G# 773	D# 269	A# 965	E# 462	B# 1159	FX 655

The 'wolf fifth' lies between the extreme notes of each disposition.

passage that retuning was an acceptable and common practice, and Praetorius left it at that.

> "In my humble opinion, this (a divided D♯/E♭ key) would be just as useful and necessary on positives and organs as it is on harpsichords etc., for which one needs only to retune the strings by slackening them off, and later put them to rights." (2)

There is ample confirmation in Renaissance times that Pythagorean tunings were transposed. Quarter comma meantone temperament was easy to tune, easy to change. There can be little doubt that, because of the advantages it offered in extending the note vocabulary flatwards or sharpwards, and the consequences if it were not practised, retuning to accommodate a sideways shift was an accepted expedient for the harpsichord.

<u>Froberger's note vocabulary</u>

Figure 63, subdivided into a, b, c, solely because of the limitations of the size of page, gives details of the note vocabulary of every known keyboard work of Froberger. The works whose three right-hand columns are blank are playable in meantone temperament in the disposition E♭ - G♯. In cases where notes outside this disposition can be substituted for notes within it, a sideways shift will allow meantone temperament to accommodate the work. The two columns farthest to the right interact for this purpose. There occur a few pieces which do not contain more than twelve notes, but which require a chain of twelve fifths (thirteen notes), to define their vocabularies. For instance, Toccata 17 has twelve notes, but requires a chain of twelve fifths because both A♯ and B♭ are required. Although D♯/E♭ is never used, this cannot compensate for either B♭ or A♯. Figure 62 will make this argument clear. Toccata 17 is therefore recorded as requiring thirteen notes.

Apart from the use of mechanical expedients, such as split keys, a sideways shift is an unlikely procedure for the organ music. Therefore discussion of Froberger's use in his organ music of all notes outside the E♭ - G♯ disposition should take place when a note vocabulary of thirteen or more notes is discussed. The organ music shows Froberger at his most conservative, in music in which he respects the modal tradition.

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(2) M.Praetorius: op. cit., See Appendix 1, p.254.

Figure 63a. Froberger's Note Vocabulary

Work	Date, if known.	Final.	Key sig.	No. of bars.	No. of notes if over 12.	Notes needed beyond the E♭–G♯ range.*	Notes NOT needed within E♭–G♯ range.
CANZONA							
1	pre 1650	D		131			
2	"	G	♭	125			
3	"	F		71			
4	"	G		141			
5	"	C		50			
6	"	A		60		D♯1	E♭
CAPRICCIO							
1	post 1658	G		70			
2	"	A		113			
3	"	D		100			
4	"	F		64			
5	"	G	♭	53		A♭1	G♯
6	"	C		94	13	A♭7	
7	1656 or	G		106	13	A♭1	
8	earlier	G	♭	76	13	A♭2	
9	"	G		153			
10	"	D		142		D♯1	E♭
11	"	D		37			
12	"	F	♭	158	13	A♭5	
13	"	E		85		D♯24	E♭
14	1656	E		104		D♯5	E♭
15	"	F	♭	67	14	D♭1 A♭4	
16	"	F		90	14	A♭2 D♯5	
17	"	A		92			
18		C		102			
FANTASIA							
1	pre 1650	C		196	13	D♯3	
2	"	E		99		D♯5	E♭
3	"	F		210			
4	"	G		100			
5	"	A		107			
6	"	A		115			
7		G		160		A♭1	G♯
8		D	♭	53			

* The number to the right of a note indicates the number of times that note is actually played.

The 12 notes of the E♭ – G♯ range are 1) all the natural notes.
2) B♭, E♭, C♯, F♯, G♯.

Figure 63b. Froberger's Note Vocabulary.

Work	Date, if known.	Final	Key sig.	No. of bars.	No. of notes if over 12.	Notes needed beyond the E♭–G♯ range.*	Notes NOT needed within E♭–G♯ range.
RICERCARE							
1	post 1658	C	♭	142			
2	"	G		119			
3	"	F	♭	146		D♭1	C♯
4	"	C		126			
5	"	G	♭	124			
6	"	C♯	♯♯♯♯	92		D♯32 A♯1 E♯5 B♯5	C F B♭ E♭
7		D		104			
8		G	♭	169			
9		E		195		D♯3	E♭
10		G		114			
11		D		94			
12		F♯		84	13	D♯7 A♯4 E♯5 B♯1	F B♭ E♭
13		C		153			
14		D		137			
TOCCATA							
1	pre 1650	A		70		D♯3	E♭
2	"	D		57			
3	"	G		53			
4	"	C		59			
5	"	D		64	13	D♯4	
6	"	G	♭	55	15	D♭1 A♭1 D♯2	
7	pre 1657	G		42			
8	"	E		45		D♯12	E♭
9	"	C		42	13	A♭2	
10	"	F		70	15	D♭1 A♭1 D♯2	
11	"	E		52	13	D♯4	
12	1657	A		61	13	D♯2 E♯1	E♭
13		E		52		D♯12	E♭
14	1650 -53	G		55			
15		G	♭	52			
16/22		C		65	13	A♭1	
17		G		43	13	A♯2	
18		F	♭	63	13	A♭3	
19		D		70	13	D♯1	
20		A		94	13	D♯6	
21		D		45	13	D♯2 A♯1	E♭
23		D		53			
24		A		29		D♯3	E♭
25		F	♭	47			

Toccatas 16 and 22 are identical.

* The number to the right of a note indicates the number of times that note is actually played.

The 12 notes of the E♭ – G♯ range are 1) all the natural notes.
2) B♭, E♭, / C♯, F♯, G♯.

Figure 63c. Froberger's Note Vocabulary.

Work	Date, if known	Key †	Key sig.	No. of bars.	No. of notes if over 12.	Notes needed beyond the E♭-G♯ range.*	Notes NOT needed within E♭-G♯ range.
SUITE							
1	1649	a		52		D♯5	E♭
2	"	d	♭	87			
3	"	G	♯	74			
4	"	F	♭	43			
5	"	C		60			
6	1648-9	G	♯	144	13	D♯9	
7	before 1657	e	♯	87	14	D♯37 A♯9 E♯1	E♭
8	"	A	♯♯♯	59		D♯17	E♭
9	"	g	♭	87		A♭1	
10	"	a		83		D♯4	E♭
11	"	D	♯♯	71		D♯6 A♯3	B♭ E♭
12	1654	C		94	13	D♯1	
13		d	♭	82			
14		g	♭	87	13	D♭1 A♭15	G♯
15		a		126		D♯7	E♭
16		G	♯	83		D♯6	E♭
17	all	F	♭	92			
18		g	♭	67			
19	later	c	♭♭	88	13	G♭1 A♭24	G♯
20		D	♯♯	81	13	D♯8 E♯1	E♭
21	than	F	♭	147			
22		e	♯	73		D♯28 A♯5	E♭ B♭
23	1657	e	♯	181		D♯41 A♯5	E♭ B♭
24		D	♯♯	132			
25		d		113			
26		b	♯♯	84	13	D♯8 A♯33 E♯7	E♭ B♭
27		e	♯	42		D♯16 A♯4	E♭ B♭
28		a		52		D♯6	E♭
29		a		155		D♯11	E♭
30		a		94		D♯9	
Extras							
Sarabande		G	♯	32			
Gigue		D	♯♯	57			
Occasional Pieces							
Tombeau	1650-3	c	♭♭	36	13	D♭2	
Lamentation	1657	f	♭♭	37	13	D♭20 A♭33	G♯

* The number to the right of a note indicates the number of times that note is actually played.

The 12 notes of the E♭ - G♯ range are 1) all the natural notes.
2) B♭, E♭, C♯, F♯, G♯.

† Upper case letters denote major keys.
Lower case letters denote minor keys.

Froberger is very sparing in his transpositions, using only the customary single flat. Of his conservatism and conscientiousness in the matter of accidentals Adler has this to say:

> "His manuscripts give a good indication for learned judgement on the vicissitudes of the mid-seventeenth century... The raising of A, E and B♮ seem to inspire him with awe." (3)

The suites can be regarded as tonal. Each dance has two repeating sections; the leading section usually ends with a close in a related key, a cadence which sometimes oversteps the bounds of the temperament. Froberger's harmonic vocabulary and variety of tonal centre are much greater than those of Schlick and other musicians examined earlier, and yet in no piece does he require more than fifteen notes.

Figure 64. Summary of Froberger's Works.

Canzonas	6	Works within the 12 note range E♭ - G♯	48
Capriccios	18	Works within any 12 note range	28
Fantasias	8	" " " 13 note range	23
Ricercari	14	" " " 14 note range	3
Toccatas	24	" " " 15 note range	2
Suites	30		
Extra movements	2		
Occasional pieces	2		
	104		104

Since the relative merits of different temperaments are not the issue here, comprehensive harmonic analysis of pieces is not required, but the frequency of occurrence, duration and function of notes foreign to the E♭ - G♯ range is of paramount importance. It will be convenient to refer to notes beyond the E♭ - G♯ disposition as 'foreign'. An

(Text continues on p. 132)

(3) G.Adler: D.T.Ö. viii, Comment, tr. J.V.P. (Froberger prefixes these notes not with the usual ♯, but by the double sharp sign x, sic,) pp.123f.

Figure 65a. Notes outside the E♭ - G♯ range.

Numbers of Harmonic and non-Harmonic contexts.

	Final	G♭ non H	G♭ H	D♭ non H	D♭ H	A♭ non H	A♭ H	D♯ non H	D♯ H	A♯ non H	A♯ H	E♯ non H	E♯ H	B♯ non H	B♯ H
Canzona															
6	A								1						
Capriccio															
5	g						1								
6	C					3	4								
7	G						1								
8	g						2								
10	D								1						
12	f					1	3								
13	E								13						
14	E								3						
15	f				1		3								
16	F						2	1	4						
Fantasia															
1	C								3						
2	E								4						
7	G						1								
Ricercare															
3	f			1											
6	C♯	(Key. sig. ♯♯♯♯)						8	20		1		3		4
9	E								3						
12	F♯	(No Key sig.)						1	3		4		2		1
Toccata															
1	A								3						
5	D								2						
6	g			1			2	1	1						
8	E								4						
9	C						1								
10	F				1		1		2						
11	E								4						
12	A								2				1		
13	E								8						
16	C					1									
17	G										1				
18	f						2								
19	D								1						
20	A							4	1						
21	D								2		1				
24	A							3							

All the pieces on this sheet are considered modal. Unless otherwise stated, a capital letter indicates the final of the mode; a lower case letter indicates a single flat transposition.

Figure 65b <u>Notes outside the E♭ - G♯ range.</u>

Numbers of <u>H</u>armonic and <u>non</u>-<u>H</u>armonic contexts.

	Key	G♭ non H	G♭ H	D♭ non H	D♭ H	A♭ non H	A♭ H	D♯ non H	D♯ H	A♯ non H	A♯ H	E♯ non H	E♯ H	B♯ non H	B♯ H
<u>SUITE</u>															
1	a								3						
6	G								8						
7	e							2	25		6		1		
8	A								13						
9	g						1								
10	a								3						
11	D								3		2				
12	C								1						
14	g				1	2	5								
15	a								6						
16	G							2	3						
19	c		1			5	16								
20	D								5				1		
22	e							2	22		3				
23	e							1	34		4				
26	b								7		23		5		
27	e								9	1	2				
28	a								5						
29	a								6						
30	a								7						
<u>Occasional Pieces</u>															
Tombeau	c				2										
Lamentation	f			3	10	4	19								

attempt has been made to analyse the occurrences of foreign notes into their musical functions. The number of times a foreign note occurs, as shown in Figure 63, gives some indication of the freedom with which it is used. If it is used frequently, it is probable that the temperament expected to be used can accommodate it. If it is seldom used, the inference is that the composer was aware of the temperament's inadequacy concerning the note. Figure 65 a, b, increases the significance of the foreign notes by showing them arranged into harmonic and non-harmonic contexts. A 'context' consists of a passage, usually no longer than a bar, in which a foreign note may be used one or more times. It is safe to conclude that retuning or some other adequate expedient can be assumed, if a work contains frequent and uninhibited use of a foreign note, with a complete absence of its familiar 'enharmonic equivalent'; e.g. Suite 8 contains 17 D♯s, but no E♭s. Apart from these obvious cases which occur only in the harpsichord pieces, Froberger uses foreign notes with apparent reluctance, and extremely sparingly. Often a single D♯ or A♯ is sufficient to clinch a harmonic context. In all the long sonorous canzonas he uses only one foreign note, a D♯, and that to define a perfect cadence on E. If then it is conceded that the bulk of Froberger's output can be and probably was played in meantone temperament, it is all the more necessary to examine the contexts where meantone temperament proves inadequate, and see if there are consistent factors.

It is obvious that in these contexts other criteria take precedence over consonance. In these sensitive moments Froberger may have built in, actually or by implication, some means to curtail aural displeasure, or have provided aural titillation or counter-attraction to camouflage weaknesses in the temperament. The first musician to refer to this subject of aural tolerance was probably Schlick. By far the greatest number of meantone infringements in Froberger's music have more harmonic rather than melodic significance. When the notes of a chord are all struck simultaneously the ear has maximum opportunity to experience dissonance, but not necessarily to diagnose what is wrong. A passing note with fewer points of immediate reference may be less critical.

Firstly, Froberger often uses foreign notes to introduce and define a new tonal centre or key, especially at an important cadence. The D♯ of Canzona 6 mentioned above is a case in point. At the end of the middle section, in which the subject has been discussed in compound time, the forward movement is checked by a return to simple time and further to mark the occasion, before the final section, there occurs a cadence on E. Froberger has no desire to introduce an atmosphere of Phrygian austerity at this pivotal point. Therefore D♯ is necessary. (See Example 7.)

Example 7. Canzona 6 (bars 40 - 42)

A single example from the harpsichord music will be sufficient to show Froberger's reticence and economy when the temperament is likely to be overstepped. The D♯ of Suite 20 can be accommodated by sideways shift, but not the E♯. With admirable understatement, which entails leaving the E♯ until the very last moment and supplying only G♯ as a harmonic point of reference, Froberger reaches the necessary related key. (see Example 8)

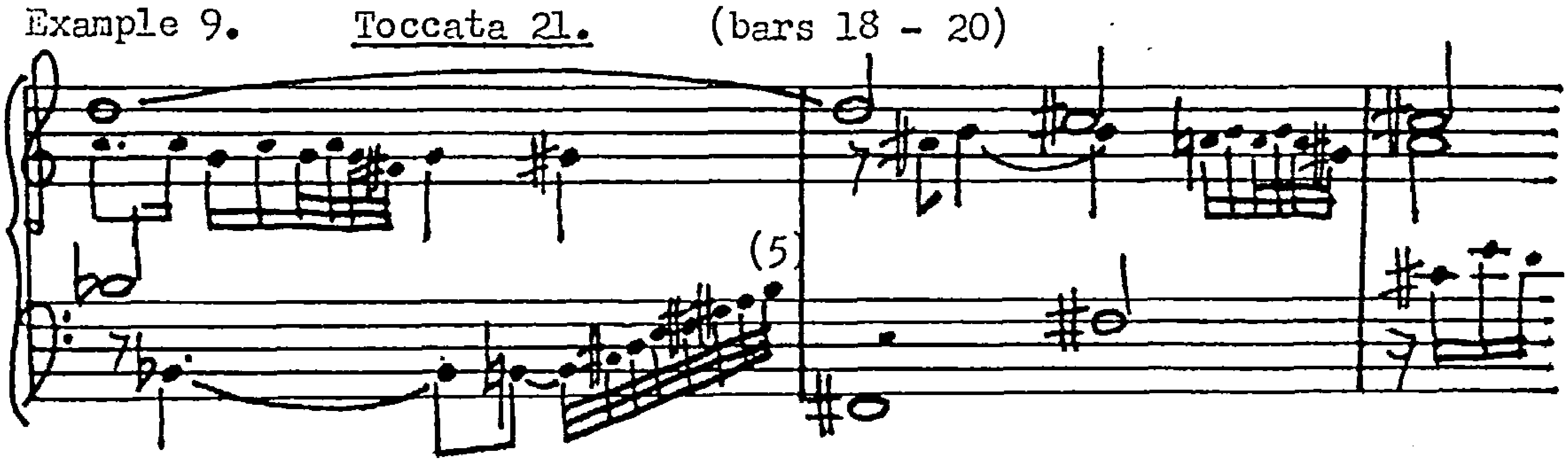
Example 8. Suite 20 in D. Allemande (bars 10 - 11)

In this case the F♮ of the temperament would increase the excitement of the E♯'s leading-note quality. A small ornament on the F♯* would further deceive the ear. In both Examples 7 and 8 Schlick's situational ethics can be taken as a guide, and acted upon:

> "In this form of cadence one can get over this difficulty by a momentary pause, perhaps a diminution, a little decoration or run, hesitation or flourish so that the harshness of the ... cadence is not so obvious." (4)

The single A♯ of Toccata 21 stands in a tonally restless passage. (Example 9). Although its function appears to be more melodic than harmonic, this A♯ could be treated like the E♯ of the previous example, as an anticipated leading-note controlled by the bass's F♯ dominant. In a typical contradiction by a subsequent A♮, Froberger avoids the momentary repose a cadence would provide at this point, but there is just sufficient leading-note quality in the A♯, even if a B♭ is used to beguile, if not delude, the ear.

Example 9. Toccata 21. (bars 18 - 20)



(4) A.Schlick: op. cit., See Appendix 1 , p.252.

(5) D.T.Ö. p.27 prints the last note in the bass of bar 18 sic, but let us assume B♮.

Secondly, Froberger oversteps the bounds of the temperament when he chromaticises a melody, often with bizarre results. Elaborate chromaticism had become part of the language of the sixteenth-century madrigalists since Willaert, and was often used to express grief and strangeness. Froberger's chromaticism, or more descriptively, chromaticising of diatonic melodies, is rather mechanical and predictable. In no less than six works are complete sections or variations whose primary interest and ploy is consistent chromaticism. These tours de force, sometimes entitled self-consciously 'cromatica', contrast with his otherwise abstemious use of chromaticism. The chromaticism is usually based upon the interval of a perfect 4th, and this interval is so frequently chromaticised in Baroque music that Alan Curtis in Sweelinck's Keyboard music names it 'The chromatic fourth'. Froberger uses it in Toccata 2 between A and E rising and falling, and D and A rising and falling, and the music keeps within the E♭ - G♯ range. Part 6 of Suite 6 'Auff die Mayerin' is a chromaticising of the folk melody. Both E♭ and D♯ are needed. An extension of the chromatic fourth occurs in Fantasia 1, in an independent section in which an entire hexachord, in original and transposed forms, is chromaticised. (Example 10.)

Example 10. Fantasia 1. (bars 146 - 153)

In every case the chromaticism is isolated and contained within the bounds of its own section, which is somewhere in the middle of the piece. The bizarre quality arises first and foremost from the irregular progression of the semitones of the meantone scale, and secondly from occasional temperament infringements. Since such variations merely employ a device and have no organic relevance, it is possible that Froberger used them solely for their strange and sinister effect, and as foils for the more aurally acceptable movements before and after them.

Thirdly, Froberger uses foreign notes for aesthetic, dramatic, whimsical and extra-musical reasons. Whereas foreign sharps are used to extend the harmonic range of a piece towards the dominant side, flats come mostly into this third category. Although few in number, these foreign flats are often long and isolated, and dominate the end of a section. Ricercare 3 has one foreign note, a D♭. (Example 11)

Example 11. Ricercare 3 (bars 116 - 120)

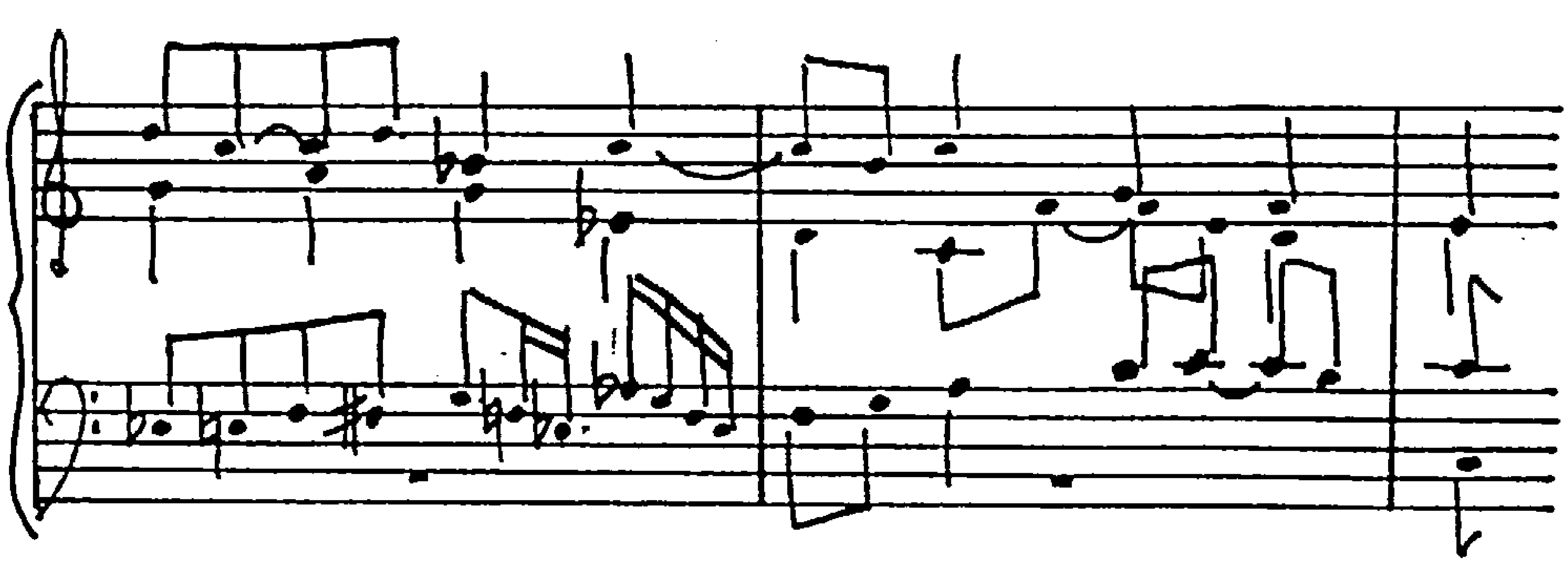
This piece, more tonal than its namesakes, uses the D♭ in a three-bar interlude before the start of its alla breve. It is quite superfluous musically; it is in a position where it is not easy to disguise; it is meant to be heard, savoured and perhaps even lingered over, but in quarter comma meantone temperament the 'tone' E♭ - C♯ is distressingly wide (234c). Froberger marks this important cadence by a threefold surprise; metrical, harmonic and temperamental.

Example 12 demonstrates an even more striking use of a foreign note, in this case A♭, for no apparent musical reason. There are a dozen similar capricious incidents in the organ works involving a foreign note, so that the progression becomes cliché́d. It consists of a major context into which the minor third degree of the scale is introduced, often dramatically and completely without warning, at an important cadence. The passage here consists of a short interlude between two sections of a largely monothematic capriccio, the section following being a polyphonic chromaticising of the theme. It is obvious that Froberger wishes the A♭ to have maximum effect - a heavy landing following a glissando-like take-off. The minor sixth C - A♭ and the minor thirds F - A♭ are each too narrow by a diesis, and there therefore far from consonant. Perhaps this ploy is an attempt in a major key to achieve the finality of a tièrce de Picardie.

Example 12. <u>Capriccio 16.</u> (bars 46 - 49)

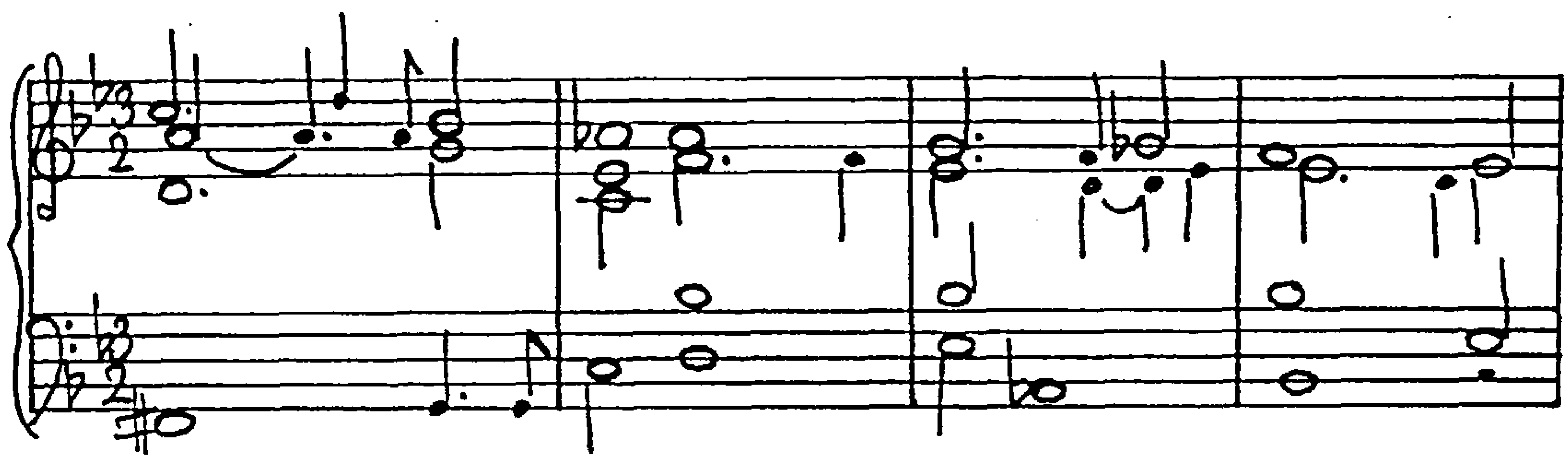
The only other context in this capriccio to use an A♭ occurs at a climax in the chromatic section mentioned earlier. The chromaticised subject is lightly tossed from voice to voice, until an entry rising logically from E♭ to A♭ (Example 13) marks the point of farthest isolation from the tonal centre of the work F, as if to suggest by its momentary discomfort that the temperament can be stretched no farther. There is no caprice or whimsy about this A♭; it is predestinated by any entry started on E♭. The section is liberally sprinkled wuth foreign D♯s, so that there may be justification for wondering whether Froberger has evoked a grotesqueness quite intentionally, the first A♭ acting as a warning of temperamental surprises in store.

Example 13. <u>Capriccio 16.</u> (bars 63 - 65)



The flattest note Froberger ever uses, and then only once, is G♭. In his C minor suite the normal meantone disposition can be moved one place to the flat side, A♭ - C♯. F♯ is needed but G♯ is not. The G♭ comes in a harmonically exciting passage containing an apparent neapolitan sixth in G minor, half a century before A.Scarlatti discovered it. (See Example 14). The G♭ lacks the triadic definition of the A♭ in Example 13. The harmonic ambiguity of the G♭ is such that it might even be written as F♯. The whole passage is dramatic, and the G♭ requires no special feat of aural indulgence, at least to modern ears, in the disposition A♭ - C♯.

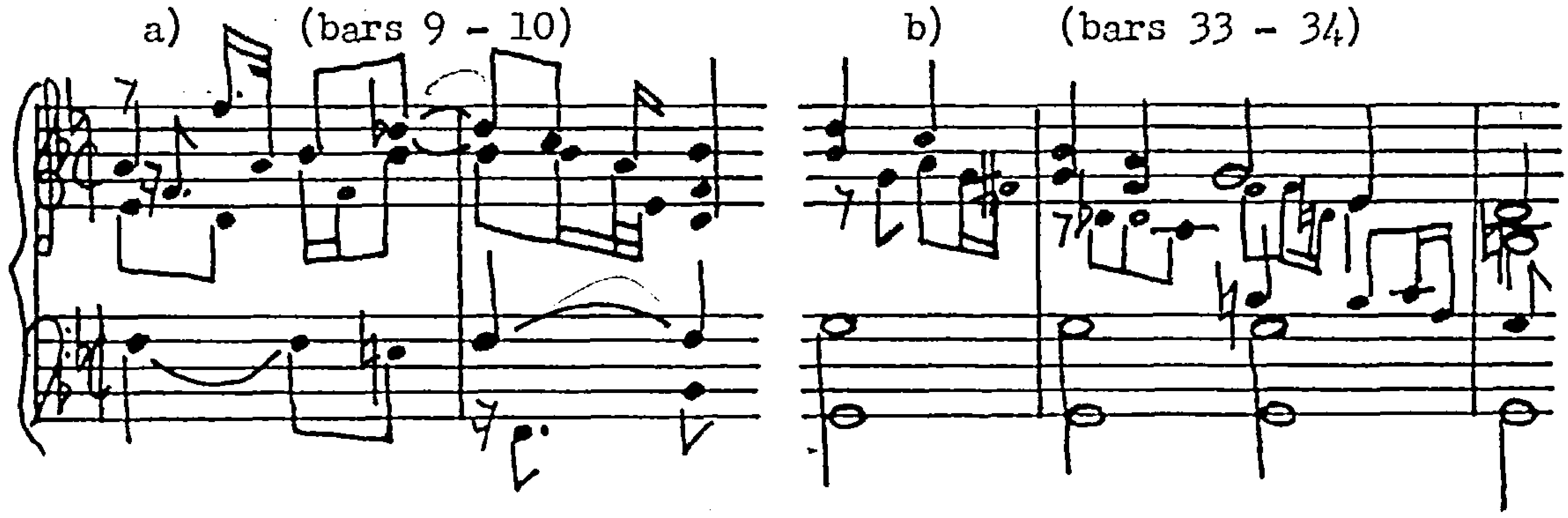
Example 14. <u>Suite 19 in C minor. Sarabande.</u> (bars 4 - 7)



Four allemandes of the suites are headed 'Lamento', with the circumstances of an unhappy event, not necessarily death, outlined below the heading. Together with two laments in the French style. these are overt manifestations of Froberger's extra-musical stimulation. He is too early to be called a Romantic but this tendency is present in his music. His laments are usually marked to be played 'avec discrétion' and with rhythmic licence. It is not impossible that the occasional use of notes outside the temperament had programmatic significance. Froberger and Louis Couperin each wrote a tombeau on the death of their mutual friend Blancheroche. Both composers were known to exploit dissonance for extra-musical reasons. At least in Froberger's case, he may have exploited meantone temperament to produce a melancholy effect in the two contexts in which he uses a D♭. (Example 15)

Example 15 <u>Tombeau in C minor.</u>

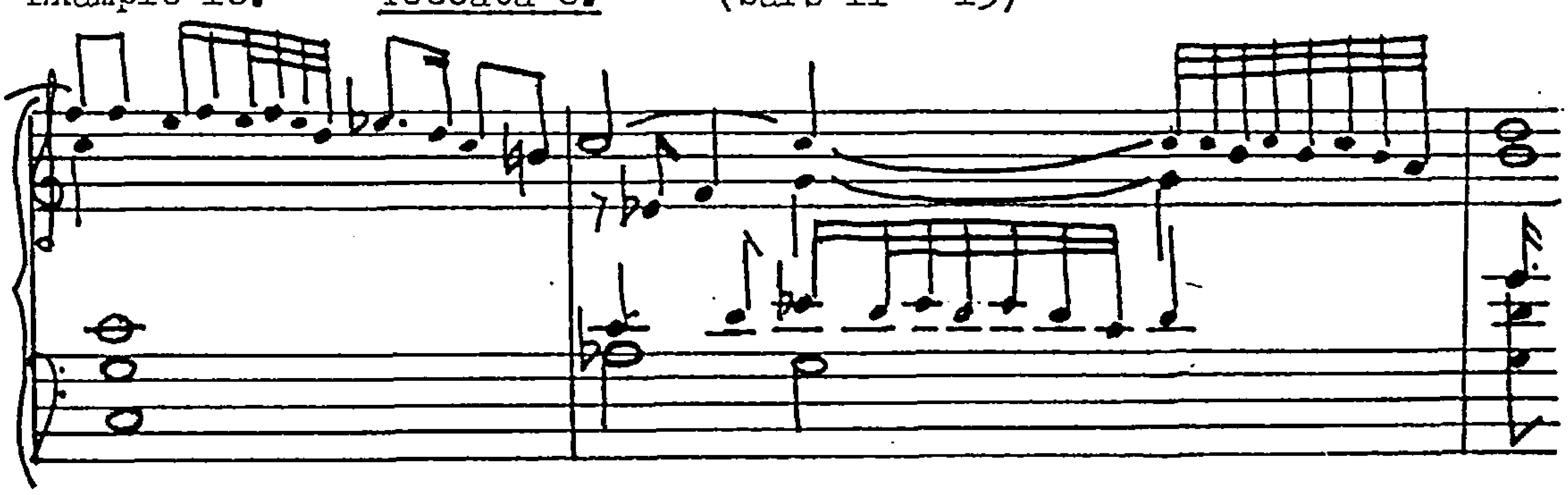
a) (bars 9 - 10) b) (bars 33 - 34)



The two pieces which demonstrate the extremes of Froberger's harmonic vocabulary are both toccatas, nos. 6 and 10. As a genre the toccata is noted for flamboyance rather than restraint, sensation rather than argument, but even so, judged on the grounds of consonance, quarter comma meantone temperament proves quite inadequate for both these pieces. Both require D♭, A♭ and D♯ beyond the E♭ - G♯ range, although in mode and mood they are dissimilar. Both are written in a rich harmonic language, often adding the minor seventh to a triad. Their discords are produced largely by suspension and melodic decoration (6) although occasionally Froberger startles the listener with an unprepared and fortuitous diminished seventh. (7)

Toccata 6 is undoubtedly for organ and headed to be played at the most solemn and ecstatic moment of the mass. It is in the dorian mode and severe in style. The D♯s are transient and may be camouflaged by momentary decoration. The single D♭ is a passing note, apparently gratuitous and whimsical, and therefore used for chromatic effect. To justify the use of A♭ (two contexts) is more difficult. Both A♭s used are long, exposed, placed to gain maximum effect. The wolf fifth cannot be avoided in either case. Example 16 shows the first occurrence.

Example 16. <u>Toccata 6.</u> (bars 11 - 13)



Toccata 10 is more suitable for the harpsichord, forthright and dramatic, and as secular as its lydian mode suggests. All three of its foreign notes are short, transient and might be exploited under the hands of a competent harpsichordist.

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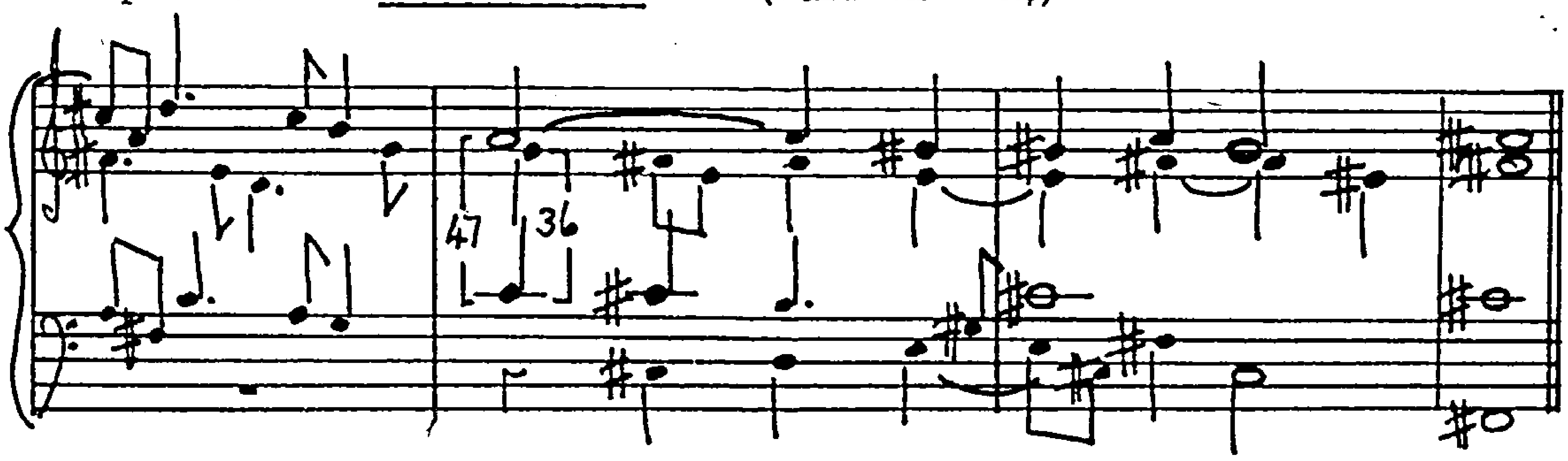
(6) e.g. Toccata 6: an augmented triad in bar 38, and a French augmented sixth in bar 41.

(7) e.g. Toccata 10: bar 45.

But temperamental anomalies persist. For reasons which remain a mystery, Froberger prefixes Ricercare 6 with a key signature of four sharps, and writes in the aeolian mode using twelve notes, requiring a shift to the sharp side of four places. Had the music been written up a diatonic semitone and prefixed by a B♭ key signature, the music would have fitted the E♭ - G♯ range. The idiom and style are those of a sectionalised early fugue, no different from Froberger's other ricercari. For its performance four notes would have to be retuned, which is feasible on the harpsichord, but not on the organ.

The only other work with similar maverick attributes is Ricercare 12, which requires the same meantone disposition as Ricercare 6, G - B♯. Indeed, the only mitigating circumstance common to these two works is that they might be played consecutively with no retuning. In the case of Ricercare 12, however, it is a moot point whether the C♮ is retuned to B♯ or not, because both these notes are required once only. The final bars (Example 17) show the bold style of the work, and also the price to be paid if C♮ is tuned as B♯. The perfect fifth C - G and the major sixth C - A will receive mistuning of 36 and 47 cents respectively. If the work had been written with a tonal centre of E, instead of F♯, temperamentally it would have been unremarkable.

Example 17. Ricercare 12 (bars 81 - 84)



We have covered the ground as far as the evidence of Froberger's note vocabulary goes. Overall, there is not enough significant change in the note vocabulary of the numerical lists of his works to suggest that Froberger ever changed his attitude to temperament. Perhaps the higher-numbered capriccios are less suitable for the organ than for the harpsichord, whose E♭s and B♭s can be quickly retuned to the necessary D♯s and A♯s. There is a reference to an unknown canzona by Froberger, by what might be called an interested party - Werckmeister himself:

> "The world famous Froberger some thirty years ago wrote a canzona in which the theme is gradually transposed through the whole keyboard in all twelve keys, is varied, and cleverly returns, thus going through the cycle of fifths and fourths, until it comes again into the key in which it began." (8)

This is not evidence. No other commentator has a similar reference. The fact that this canzona has never been found is as persuasive an argument that Froberger rejected unlimited modulation as the possibility of such a work being written testifies to Froberger's faith in circulating or equal temperaments. There are other straws in the wind.

Froberger's exposure to Italian and French influence.

During the time that Froberger was in Italy (1637 - 41) there was an acrimonious controversy involving Doni, a champion of just-intonation, and Frescobaldi, fascinated with equal temperament at the time. The argument was over the relative merits of meantone and equal temperaments. The accusation by Doni that Frescobaldi did not know the difference between a major and a minor semitone, and Frescobaldi's subsequent silence on the matter, could be read as rancour on Doni's part and nonchalance on Frescobaldi's. This is evidence only insofar as it assures us that Froberger was aware of temperamental alternatives. The musicians who befriended Froberger during his stay in Paris during the 1650s would be well acquainted with Mersenne's Harmonie Universelle (1636), and may even have known Mersenne. Mersenne puts forward the separate merits of both meantone and equal temperaments: meantone's strength is the purity of its intervals, whereas equal temperament could provide a much needed standard of pitch. Among Froberger's friends were lutenists, for whom the Galilei approximation of equal temperament would be the accepted norm. His other friends were clavecinists, such as Louis Couperin and Chambonnières, for whom the only acceptable temperament was meantone. In 1643 Jean Denis, the most respected of a large family of instrument makers, published in Paris his Traité de l'accord de l'espinette in which he emphatically recommended meantone temperament for harpsichords. His description does not have the precision of Praetorius's 'First and Third Kinds' but there is no doubt that each of the fifths in the chain E♭ - G♯ is to be made narrow by a consistent small amount, and that the thirds should be 'good'. He must be advocating a regular division of the comma, and if not a quarter, then some fraction very near to it. He warns

(8) G. Adler D.T.Ö. xxi Preface refers to A. Werckmeister: Hypomnemata Musica, (Quedlingburg, 1697) p. 37, tr. J.V.P.

organists to avoid the 'premier ton' on E, because of the lack of a D♯. For a similar reason he warns organists against using the 'deuxième ton' on F, although he describes the fault in hexachord terms: E♭ - F - G - G♯ - B♭ - C. He does not suggest to clavecinists that they avoid suites in 'mi' or 'si', which is surely circumstantial evidence in support of the practice of sideways shift. The keys are available by tuning to the ranges F - A♯ and C - E♯ respectively. (See Figure 62.)

The music of Louis Couperin and Chambonnières, and probably that of other French clavecinists, such as d'Anglebert and Henri Dumont, can all be played in meantone temperament with sideways shift. Their choice of keys is similar to that of Froberger, which ranges from A major to C minor in the suites, in which French influence is particularly evident. The modulation facilities which Froberger requires are to nearly-related keys. Sudden modulation to remote keys is not present in his works. He shows greater conservatism in the modal organ works, which, apart from the two ricercari mentioned, require no more than a single transposition.

Apart from his Fantasia 1, founded on the gamut and quoted complete by Kircher in Musurgia as an example of the genre, none of Froberger's works was printed until 1693, long after his death. His music during the seventeenth century cannot have been readily available for performance, study or comment. If it had been available, posterity might now have answers for the few unsolved temperament problems Froberger's music continues to pose, namely the two fifteen-note toccatas, one of them definitely for organ, and the two ricercari, nos.6 and 12. It would be convenient to agree with Mark Lindley that at least in the 'later' works, by which he probably means the suites, Froberger would use equal temperament. (9) But this solution leaves much to be explained; firstly, that nowhere in Europe did equal temperament become accepted for keyboard instruments until long after Froberger's death, and secondly, that apart from the exceptions mentioned, the works of Froberger show no development towards taking advantage of the universal freedom equal temperament offers. It must be admitted that Froberger's works present a strong case for the status quo, a regular meantone temperament. He would not be ignorant about the various divisions of the comma known and used at the time. There is no evidence that he would use any other division apart from quarter-comma, but if he practised sideways shift it is unlikely that

(9) M.Lindley: 'Temperaments', in The New Grove, ed. Sadie, vol. 18 p. 665.

he would choose a division which needed for its application a monochord or variable pitch pipe. A practical advantage of quarter comma meantone temperament is that it is quickly and easily retuned and checked.

Mersenne's temperaments for Froberger's music ?

That is not quite the end of the story, for at this point Mersenne throws a tuning hammer into the works. A short explanation of Mersenne's contribution to temperament's development becomes necessary now, which in Chapter 4 would have been out of place. The three main publications of Mersenne, Harmonie Universelle (1636), its latinised version Harmonicorum libri XII (1648) and Cogitata physico-mathematica (1644) contain certain inconsistent information on one, or perhaps two temperaments, identical with or closely related to quarter comma meantone temperament. This ambiguous situation arises out of equivocal descriptions and diagrams, which suggest that at one time Mersenne himself may not have fully understood tuning procedures, but in any case confusion was the result. (10) Much of this arose over the misunderstanding of the procedure that to obtain narrow fifths on the flat side of the circle, the pitch of the lower note of each fifth must be raised, not lowered. Praetorius took no chances on this vital point. He hammered home the procedure in a lengthy explanation. (11)

The outcome of the confusion was beneficial, in that Mersenne's instructions amount to two meantone modifications, identical in purpose and similar in effect. Figures 66 and 67 give the specifications of Mersenne's modified meantone temperaments nos. 1 and 2.

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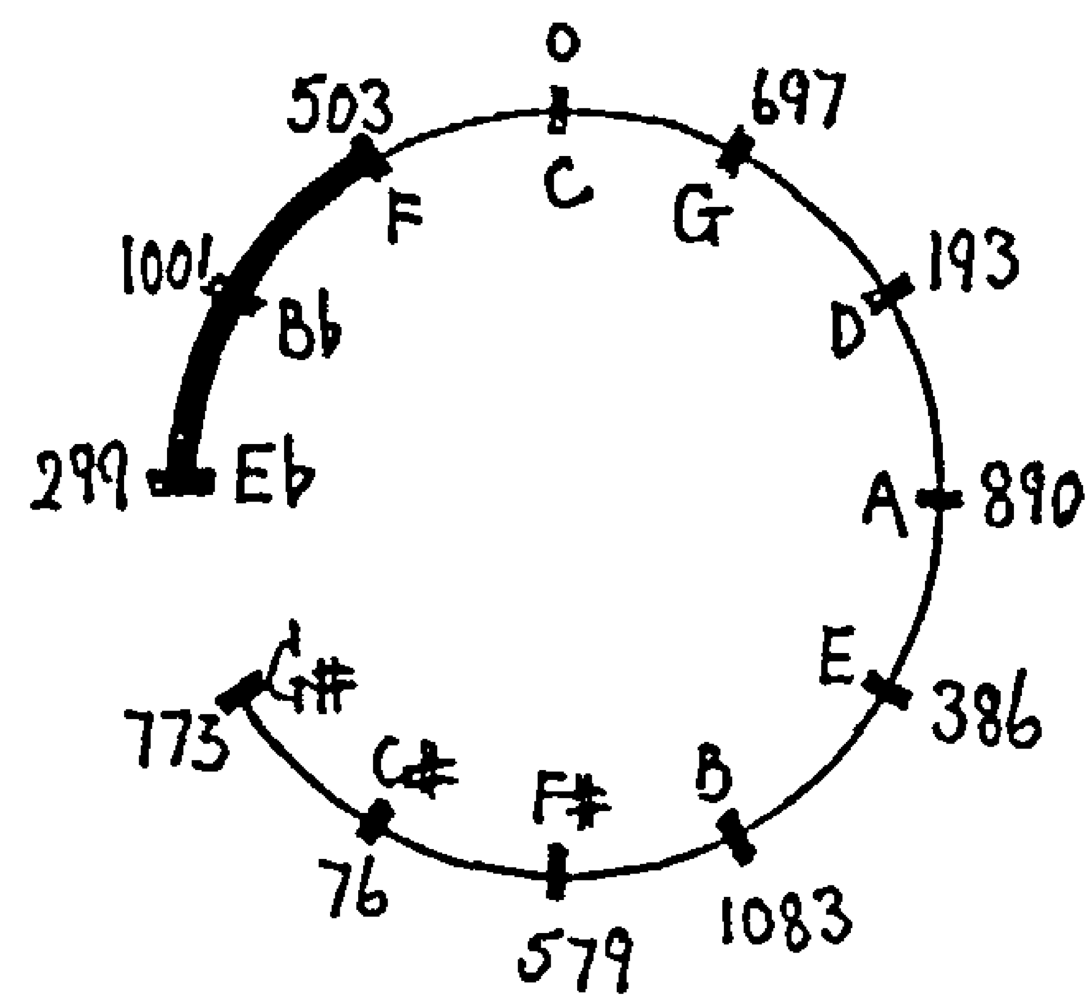
(10) The briefest outline of the circumstances is necessary here. Murray Barbour gives a brief account in Tuning and Temperament pp. 134f. Mark Lindley's unpublished article 'Mersenne and Keyboard tuning' (1974) is much fuller. The results of the confusion is the important thing here.

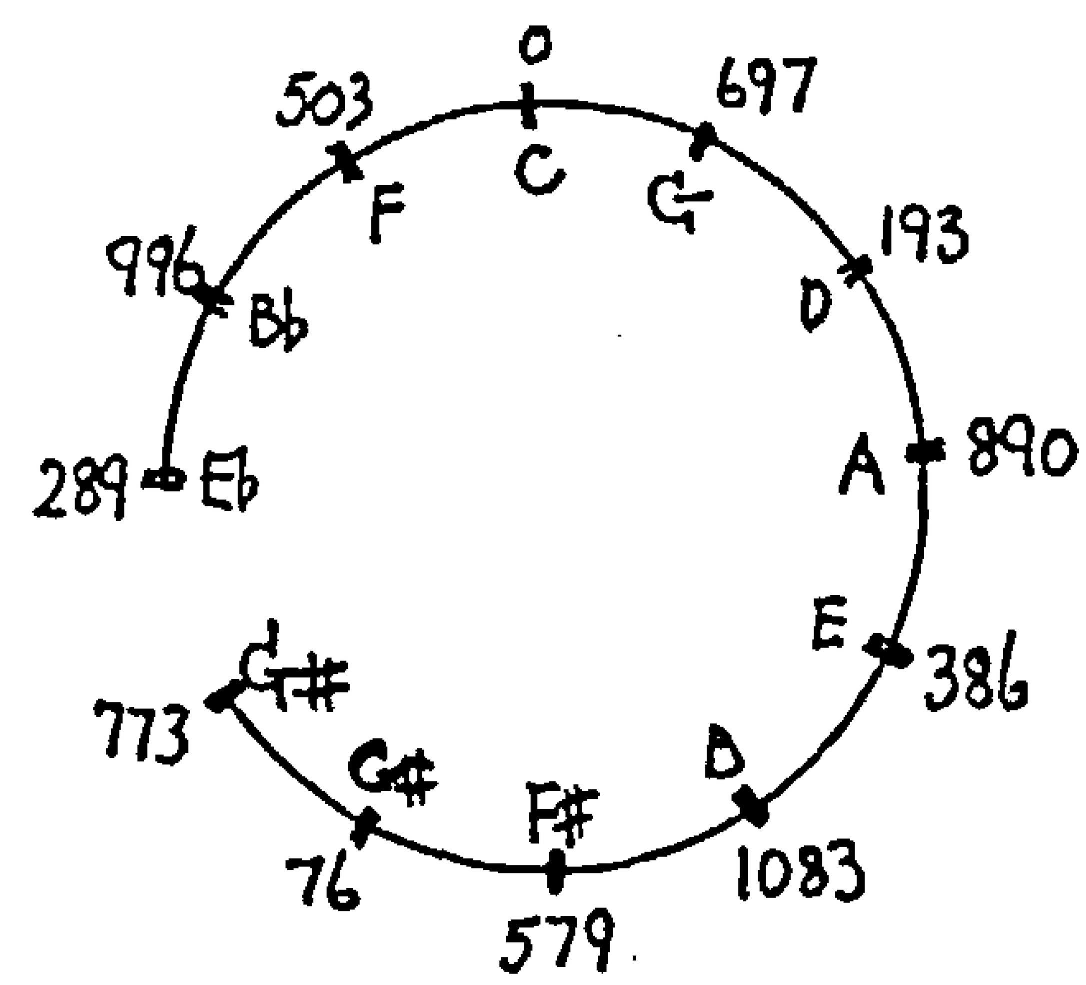
(11) See Appendix 1, p. 262.

Figure 66. Mersenne's Modified Meantone Temperament No. 1.



	m3	M3	5		m3	M3	5		m3	M3	5
C	299	386	697	E	311	387	697	G♯	310	427	726
C♯	310	427	697	F	270	387	697	A	310	386	696
D	310	386	697	F♯	311	422	697	B♭	275	392	696
E♭	280	398	702	G	304	386	696	B	310	416	696

Figure 67. Mersenne's Modified Meantone Temperament No. 2.



	m3	M3	5		m3	M3	5		m3	M3	5
C	289	386	697	E	311	387	697	G♯	310	427	716
C♯	310	427	697	F	270	387	697	A	310	386	696
D	310	386	697	F♯	311	417	697	B♭	280	397	707
E♭	290	408	707	G	299	386	696	B	310	406	696

All the naturals and sharps of both temperaments are tuned as for quarter comma meantone temperament. No. 1 then has two pure fifths on the flat side of the circle, B♭ - F and E♭ - B♭, to complete the temperament. The wolf fifth is reduced by 11 cents to 726 by the lowering of the E♭, but it is still very much of a wolf. In No. 2 Mersenne gives the impression that the two flat-side fifths should be made wider by the same amount as the fifths on the other side of the circle are made narrow. By these adjustments the wolf fifth is further reduced to 716 cents, and the two wide fifths beat at 707 cents. In both temperaments, the aim seems to be to make meantone temperament versatile, by lowering B♭ and E♭ slightly, in order to serve as A♯ and D♯ respectively. Werckmeister scathingly described the organists' practice of lowering the meantone temperament's E♭ for the same purpose as a botched repair.

What has Froberger to do with Mersenne ? He was in the right place at the right time. During the 1650s he made several prolonged visits to Paris. Meantone temperament without sideways shift is grossly inadequate for Froberger's music, but incorporating this expedient there appears to be no temperament superior to it. If, however, sideways shift is discounted, do Mersenne's temperaments make adequate substitutes ? Froberger uses D♯ and A♯ with complete freedom when E♭ and B♭ are not required. This is an argument in favour of sideways shift. He uses D♯ and A♯ more circumspectly when their enharmonic equivalents are needed. It is in these circumstances that Mersenne might be used to advantage. Froberger's music needs a tolerable A♭ for the F minor and A♭ major triads of the C minor suite and the two important occasional pieces. Mersenne's temperaments make no provision for even an emergency A♭, or for the less important C♯/D♭ E♯/F substitutes. As both Praetorius and Werckmeister said, once a temperament is botched, there is no end to the calls to botch it further. Enthusiasm for Mersenne's temperaments for Froberger's music can never be unqualified. The best that can be said of them is this, that if Froberger did not practise sideways shift, then Mersenne's temperaments might have been used, but they provide a safety net with holes.

CHAPTER 8

TEMPERAMENT AND NOTE VOCABULARY TOWARDS THE END OF THE SEVENTEENTH CENTURY.

With the lapse of the modal system as the diatonic system superseded it, it is perhaps surprising that composers' choice of keys and extent of modulation showed few signs of over-indulgence in the new-found tonal freedom of the late-seventeenth century. Gehring mentions in Grove's Dictionary, sixth edition, a 'Missa Nigra' written entirely on the black keys, and a duet for castrati 'O bone Jesu', whose sole accompaniment was a ground bass and which passed through the entire cycle of keys. If these works, reputedly by J.C.Kerll, or other musical milestones like them, were still in existence or had indeed ever been written, they would have been published long ago. Mention of them amounts to little more than musicological hindsight and wishful thinking that composers of the day should have been zealous to extend music's vocabulary. Such works were not held back by inadequate temperament, because the keyboard was not employed, and so concordant performance would be quite feasible. Even in his Ariadne Musica of 1715 (1) Ferdinand Fischer did not discover the remotest recesses of the tonal labyrinth. This sequence of preludes and fugues for four voices, in twenty different major and minor keys, still lacked the keys of F♯/G♭ major and E♭, B♭ and G♯ minors. Fischer never completed the tonal cycle, although he lived for another thirty years. His exact contemporary, J.S.Bach, did this in his Book 1 of The Well-tempered Clavier in 1722.

Allessandro Poglietti (d.1683).

Little is known of the earlier years of Poglietti, who became organist at the Viennese court in 1661. The only claim to Italian origin is his name. Walther's Lexicon described him as a German. He too may have been a pupil of Frescobaldi, and his choice of keyboard genres is similar to that of the rest of the Austrian school. The

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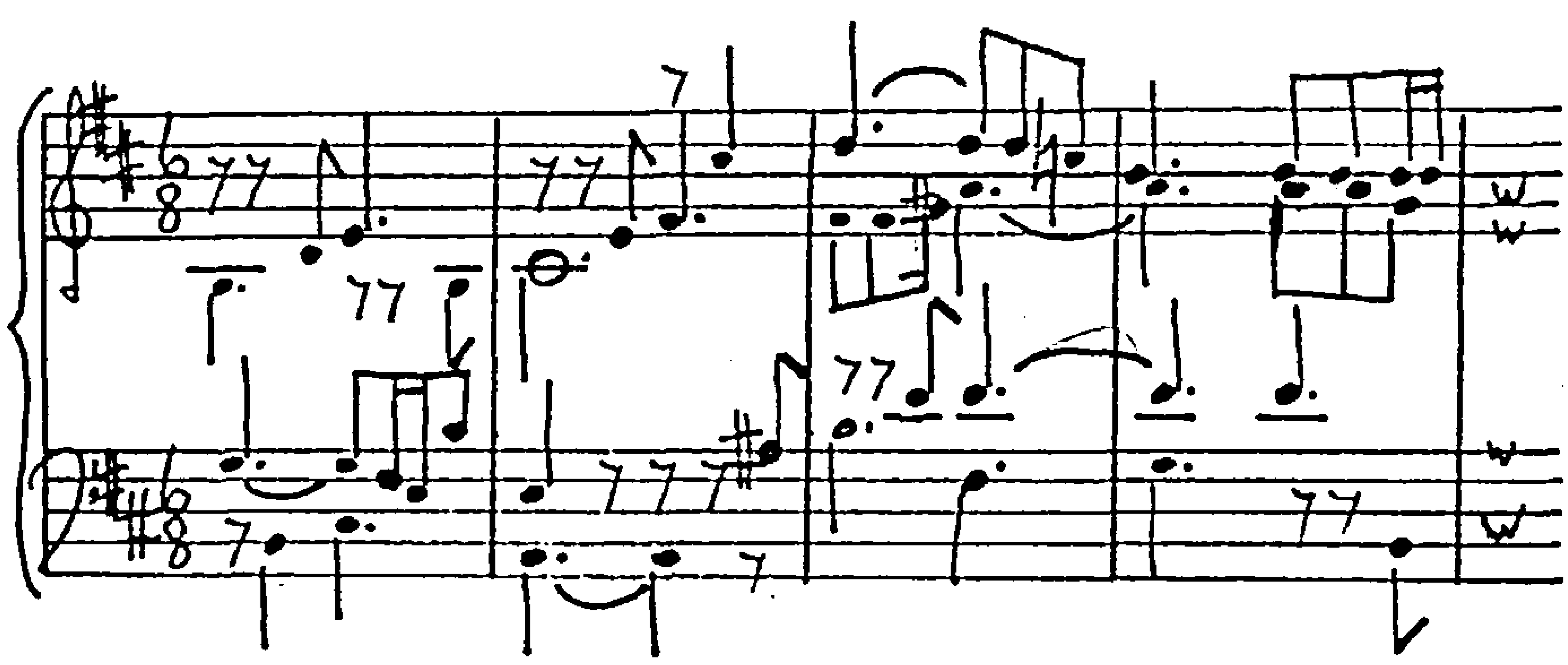
(1) This is the usual date given for publication, but "The first edition is supposed to have appeared in 1702". W.Apel: The History of Keyboard Music, tr. and rev. H.Tischler, (Bloomington/London, 1972) p.591.

twelve note disposition E♭ - G♯ is adequate for his twelve ricercari for organ written in the church modes. His secular music needs sharp much more than flat notes. His suite Rossignolo (1677) is a large collection of keyboard pieces, some in Italian instrumental forms, others in French dance forms, and the rest an elaborate set of variations. (2) The work is monothematic, based on a German folk melody, and never strays far from D major, the tonic key. The title page confirms it is written for harpsichord, although the long bass notes at the beginning of the toccata which opens the suite are a device more suitable for organ pedals. The maximum number of notes required is fourteen, but E♭ and B♭ are of little importance (see below). The entire work can be performed faithfully in a regular meantone temperament in the F - A♯ disposition, which requires a retuning of B♭ and E♭, that is, a shift of two places to the sharp side. Even so, Poglietti uses A♯ in only three contexts throughout the work, and in only one of these (Example 20) is A♯ at all exposed. In the other two contexts (Examples 18 and 19), A♯ is relatively unimportant.

Example 18. <u>Toccata</u> (bars 34 - 37)



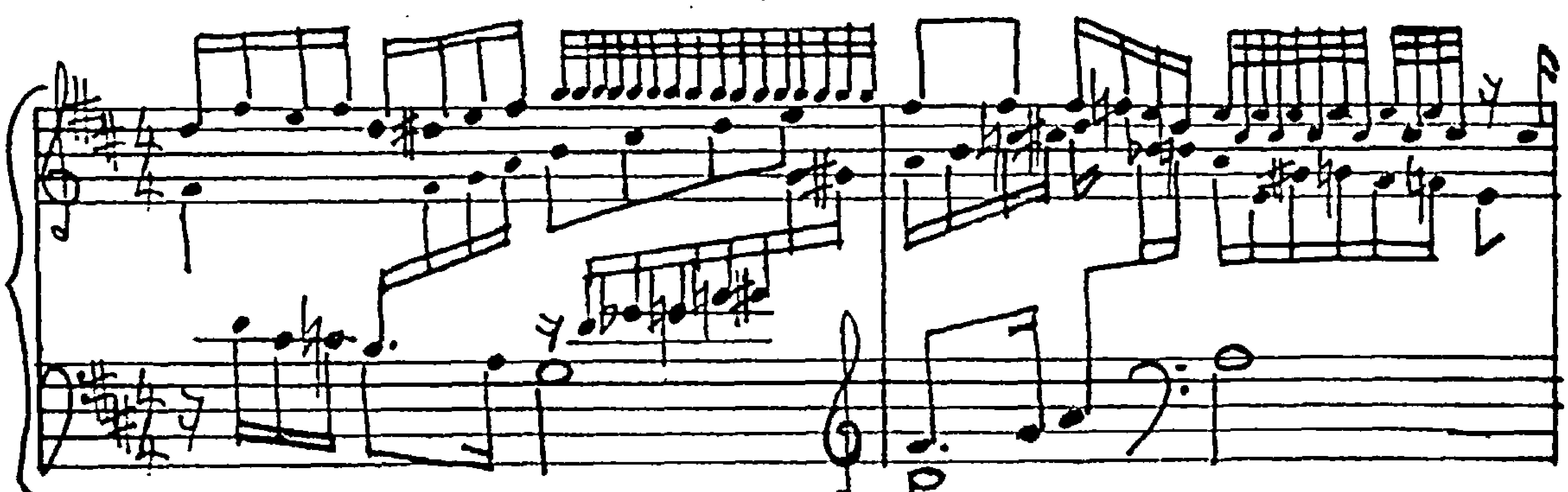
Example 19. <u>Capriccio</u> (bars 9 - 11)

(2) <u>D.T.Ö.</u>, xxvii, ed. Botstiber, pp.1 - 31.

Example 20. <u>Capriccio</u> (bars 37 - 39)

D♮ is used sixteen times, which is scarcely over-using the note in a D major work of this length. It seems as if Poglietti is insuring his work against performers who might ignore the retuning necessary. E♭ and B♭ occur only in a 'cromatica' variation of the theme. Unlike Froberger's 'cromatica' variations, which are mere applications of a device, this variation is integral and justifies the exploitation of the inadequacies of the temperament. It is one of a number of programmatic variations, each given an apt title, such as 'Bohemian bagpipe', and 'Hungarian fiddles'. Poglietti produces an aural analogy or tone picture to suit. The title of Variation 13 is <u>Alter Weiber Conduct</u> (Old wives' procession). The spelling of the raised notes - a chromaticised octave is an early Baroque rarity - is of little consequence, for the irregular steps of the meantone semitonal scale and its grotesque extra-musical association is the important part.

Example 21. <u>Old Wives' Procession</u>. (bars 3 - 4)



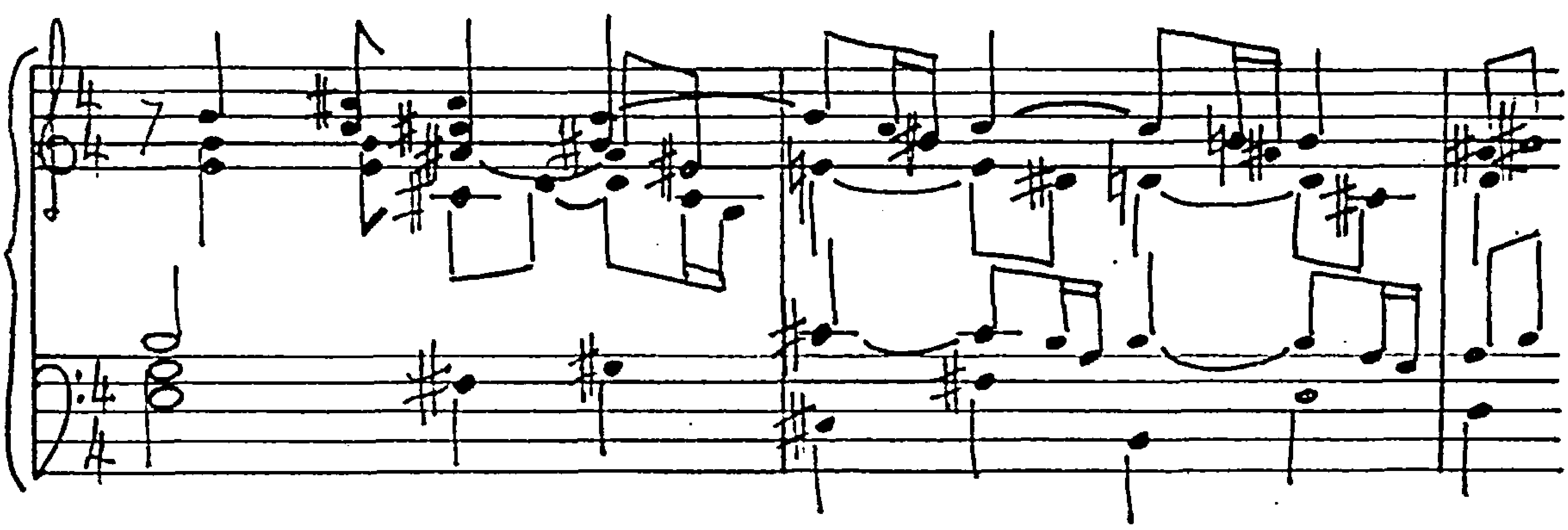
Composers avoided wolves to preserve general euphony. Some must also have deliberately used them to achieve comic and ludicrous effects. (3)

(3) O.Jorgensen: op. cit., p.117 also holds this opinion.

It is quite obvious from his music and choice of titles that Poglietti is one of music's clowns, and this reputation is enhanced by the choice of the right temperament.

The conception of the suite Sopra la ribellione di Ungheria (4) is similar to that of Rossignolo, except that Poglietti substitutes pathos for fun. The sub-titles of the movements of the suite, which include 'Galop', 'Prison', 'Sentence', 'Beheading', 'Requiem', describe the progression of an unsuccessful rebellion. The key chosen, E minor, was even then associated with melancholy, and the first movement, with no key signature, recalls the austerity of the Phrygian mode. With fairly frequent modulations to the dominant minor, A♯ is an integral note of the suite. So is F♮ for a variety of reasons, and the only note to stand beyond the twelve note range F - A♯ is E♯, which is needed twice. The first occurrence happens in the opening movement, a little toccata subtitled 'Galop', where a forceful arpeggio-dominated section suddenly loses confidence and degenerates into a chromatic wandering. (Example 22)

Example 22. Sopra la ribellione: Toccatina (bars 15 - 17)

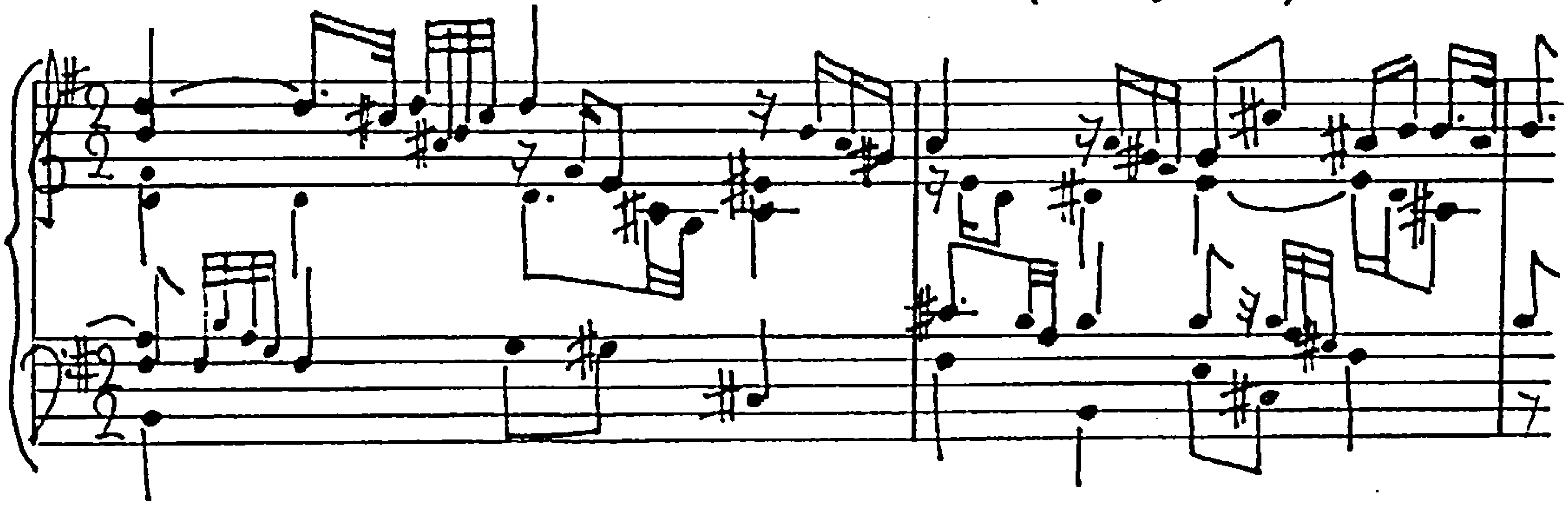


Harmonically, it does not seem to matter a great deal whether F♮ or E♯ is used here. Where harmony becomes more complicated, more integrally discordant, there seems to be greater aural tolerance of temperamental weakness. The second occurence is as a component of a forthright C♯ major triad with momentary seventh. (Example 23) If quarter comma meantone were the chosen temperament, a dissonance level of 47c is registered between the notes of this 'triad' (C♯ - F♮ - G♯), although the former occurrence is more tolerable than the latter. It is impossible from the musical evidence to know whether Poglietti was exploiting the temperament for dramatic effect , but there is extra-musical justification. Perhaps a counter-argument may be found in

(4) D.T.Ö., xxvii , pp. 32 - 36.

Example 23. Sopra la ribellione: Allemande, 'La Prisonnie'

(bars 5 - 6)



Canzon und Capriccio über das Henner und Hännergeschrey (Hens and their cackling), (5) in which Poglietti finds the conventional disposition E♭ - G♯ adequate for his extra-musical intentions.

Nicholas Adam Strunck (1640 - 1700).

Another much travelled musician of the Austrian school was the violinist and organist Strunck. Most of his keyboard music belongs to the mid 1680s, when he lived in Vienna and Rome. Unfortunately confusion can easily arise because many of his keyboard works were originally published under a different composer's name. (6) They are all written in a strict polyphonic style, and with one exception require twelve notes within the ranges of F - A♯ to A♭ - C♯. The pieces are all well suited to the organ, and of their ranges the one least likely to be available is F - A♯, but the capriccio concerned might be played on a regular meantone tuning B♭ - D♯, with an organist's concealing skill. (7) B♭ might make a tolerable substitute for both times the A♯ occurs, if a trill or other expedient ornament were incorporated. Over the second A♯, near the final cadence, a trill is actually indicated, and the A♯ is of such a transitory and gratuitous kind, a B♮/B♭ trill would probably be passed by undetected. (Example 24)

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(5) Ibid., pp.37 - 39.

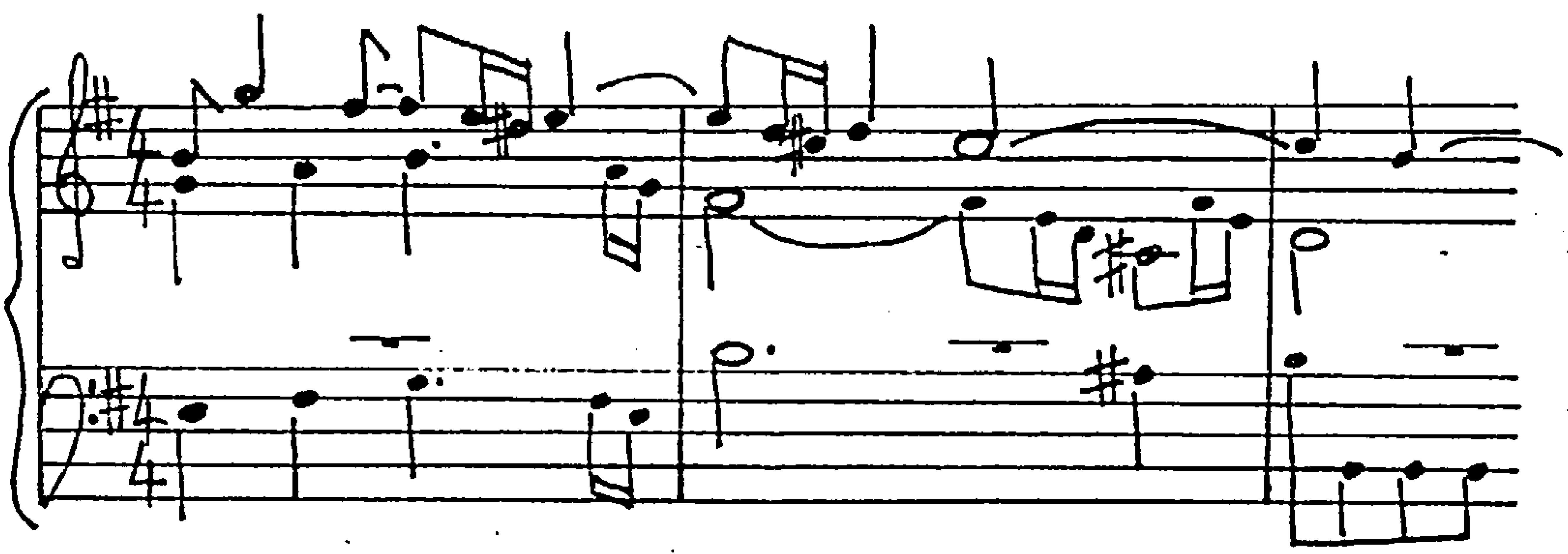
(6) Much of the music published under the name of Georg Reutter der Ältere (D.T.Ö., xxvii, ed. H.Botstiber, 1906) has more recently been found to have been written by Strunck. W.Apel, op. cit., pp. 575f. gives details.

(7) Capriccio in E minor D.T.Ö., xxvii, pp.64 - 66.

Example 24. <u>Capriccio in E minor</u> (bars 71 - end)

The exception mentioned above is a capriccio with thirteen notes. (8) Both A♯ and B♭ are required, with B♭ as the more important of the two, and a note which would be difficult to conceal in the two contexts concerned. The single A♯, however, is offered opportunity of concealment if a B♭ is substituted with a trill. The activity in the alto voice might also assist in the concealment. (Example 25)

Example 25. <u>Capriccio in G major</u> (bars 101 - 103)



Very little of his music remains or is known today, but from what there is it is necessary to face the problem of enharmonic equivalents. It is extremely unlikely that wherever Strunck held organist's appointments, his organ had split keys. If his music is to be played in meantone temperament, A♭/G♯ and E♭/D♯ alternatives are necessary as the overall note vocabulary shows. (Figure 68)

Figure 68. <u>Strunck's Note Vocabulary</u>.

♯		♯	♯	♯	♯	♯
A	B	C	D	E	F	G
♭	♭			♭		

(8) Capriccio in G major <u>D.T.Ö.</u>, xxvii, pp.74 - 77.

On the other hand, in his appointments in southern and central Germany, he came into contact with contemporary temperamental developments. Circulating temperaments were available and required, at least by some organists.

Johann Kaspar Kerll, (1627 - 1693) Franz Matthias Techelmann, (1649 - 1714)
Ferdinand Tobias Richter (1649 - 1711)

In several ways the career of Kerll followed the pattern of that of Froberger. Kerll is said to have been taught by Frescobaldi and even by Froberger. All the organ music studied is written within the twelve-note disposition E♭ - G♯, but the harpsichord music shows more variety. The Gottweig Kerll 2 manuscript contains fourteen keyboard suites which may have been written by Kerll, because his is the signature which follows them, but they may have been written by Techelmann. (9) The suites follow the Froberger pattern but contain additional dances. They require key signatures of up to three flats and three sharps. The necessary and freely used D♯s, A♭s and A♯s can be accommodated as they arise, by sideways shift. Only one of the suites has more than a twelve-note range. Suite 12 in B minor requires both B♯ and C♮, and presents a meantone dilemma; of the two dispositions, C - E♯ and G - B♯, which is the more suitable ? Apart from two C♮ contexts, one in the courante and a very transitory A minor triad in the gigue, the problem is confined to two contexts in the allemande, where both B♯ and C♮ occur.

The B♯ context occurs in a harmonically restless passage. (Example 26) There is little chance of minimising the B♯s' importance, especially that of the B♯ in the bass.

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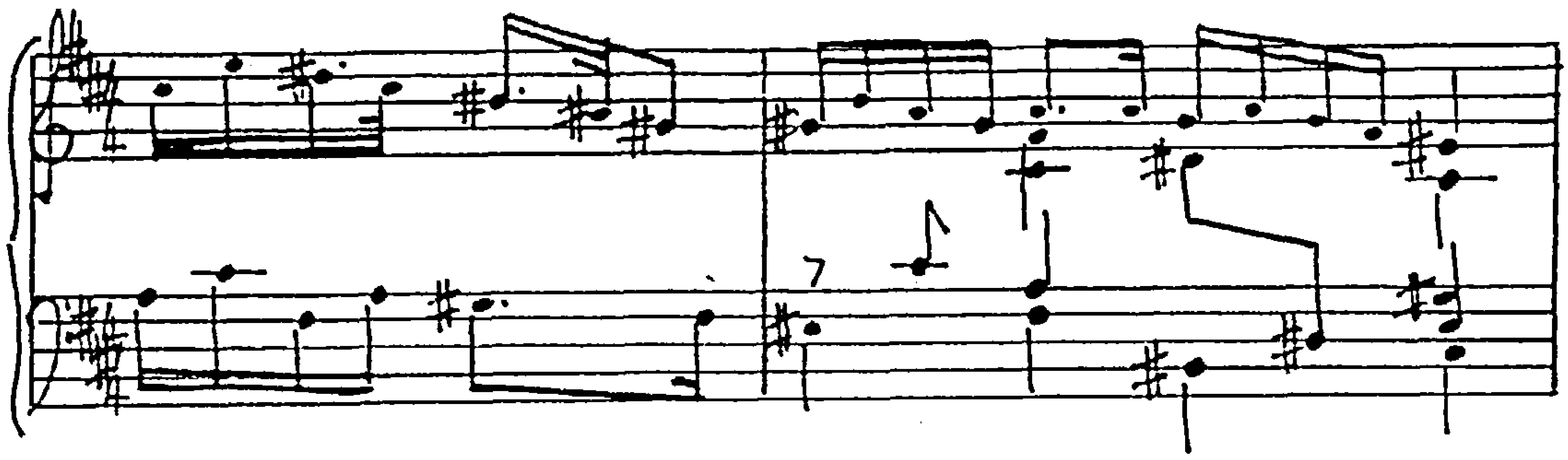
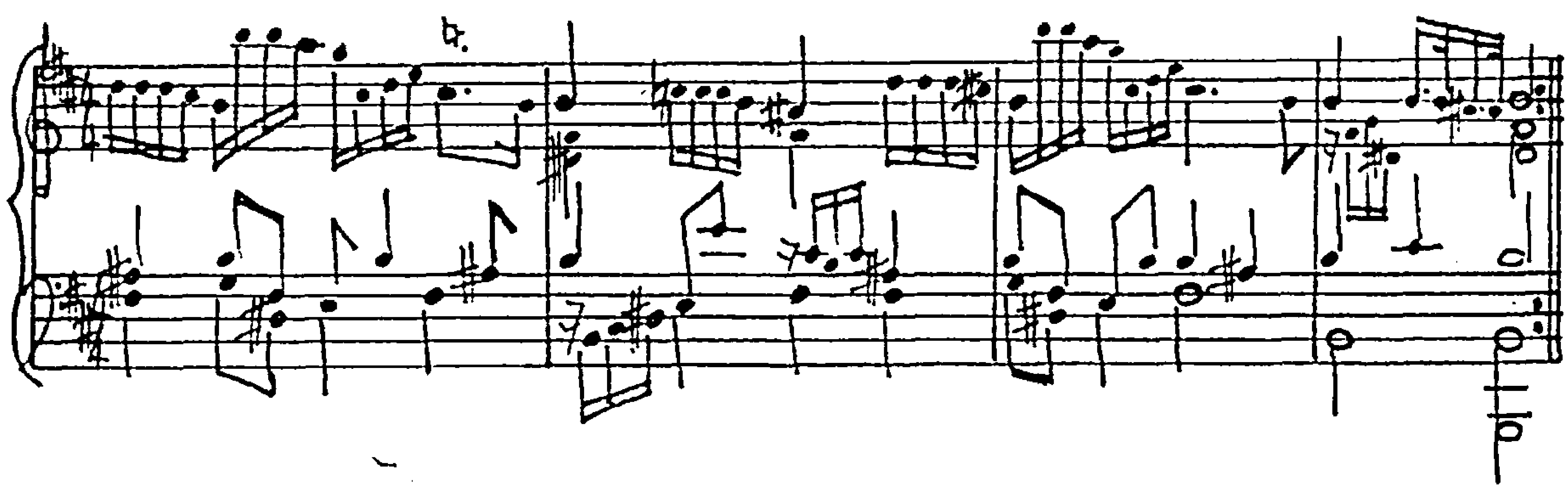
(9) The manuscript was discovered and is kept at the Gottweig monastery in lower Austria. Its title and contents pages have been ripped out. There is little doublt that Techelmann wrote four of the suites. Herweg Knaus asserts that all the suites of the manuscripts were composed by Techelmann. (Foreword, D.T.Ö. cxv, 1966, and her dissertation, Vienna, 1959). Willi Apel (History of Keyboard Music, p.108 note 17) is 'doubtful'. The issue of authorship is not of paramount importance here. The suites are to be found in D.T.Ö. cxv, pp.49 - 100.

Example 26. Suite 12 in B minor. Allemande (bars 17 - 18)



The C♮ (Example 27) is a component of a context involving a neapolitan sixth, in which the repeated C♮ has motivic importance. It might be argued that the neapolitan sixth is not fully defined, lest by adding G♮ to the E and C another point of aural reference would reveal the weakness of a doubtful triad if the harpsichord were tuned with B♯s. Meantone requires a decision. One of these two contexts will contain a note mistuned by 47 cents if the quarter-comma fraction is used.

Example 27. Suite 12 in B minor. Allemande (bars 22 - 25)



A pure C♮ is preferable, not only because it occurs in two other movements and B♯ does not, but neapolitan sixths have a surprising but nevertheless calming effect - this of course is a personal opinion - and since the composer also uses the same neapolitan context two bars previous to Example 27, he is obviously stressing its quality.

Techelmann is the undisputed composer of two other very long suites. (10) Their tonalities of A minor and C major give maximum scope for modulation, within the limits of meantone temperament. The title pages indicate that they are suitable either for the organ or

(10) D.T.Ö., cxv, ed. H.Knaus, pp.3 - 46.

harpsichord. Their note vocabulary requires the disposition B♭ - D♯, but the four D♯s of the A minor suite are not an insuperable obstacle for an organist whose instrument contains only an E♭. The C major suite could be played on an E♭ - G♯ disposition by omitting a sarabande and its four variations.

In 1683 Poglietti met a violent death at the hands of the Turks and was succeeded as court organist by Ferdinand Tobias Richter (1649 - 1711). Of his organ music he wrote a toccata in the first tone with ten versets, which fits the liturgical E♭ - G♯ range. (11) His suites, whose movements are more numerous and of greater variety than Froberger's, are appropriate only for clavier. Suite No. 2 in D minor lies within the E♭ - G♯ range. Suites No. 1 in D minor and No. 3 in F major are substantial works, and include contrapuntal as well as dance forms. Both suites require thirteen notes; the one D♯/E♭ and the other G♯/A♭. A change which seems to have come about towards the turn of the century, is that it is no longer possible to decide which of the alternatives, e.g. D♯ or E♭, has priority, and which note's consonance is expendable or its dissonance concealable. It is becoming plain that more versatile temperaments are needed.

Georg Muffat (1653 - 1704)

Muffat was another of the south-German school of organists to travel extensively in his formative years. He studied under Lully's direction (1663 - 69) and was allowed a later period of study in Italy with Corelli and Pasquini. Apparatus musico-organisticus (1690), his magnum opus for organ, consists of sixteen substantial works, mostly toccatas, and a chaconne and passacaglia. (12) As far as the note vocabulary is concerned, they are suitable also for the harpsichord, because the pedal parts reinforce the bass line. A spectacular independent pedal part is not part of Muffat's utterance. Most of Apparatus has a twelve-note vocabulary, with D♯ appearing more often

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(11) All Richter's music mentioned here is to be found in D.T.Ö. xxvii.

(12) G.Muffat: Apparatus musico-organisticus ed. S. de Lange, (Peters, 1888).

than E♭. Two works require thirteen notes and two works fourteen notes. The remotest note which Muffat uses is G♭, which occurs once only, and then at a dramatic neapolitan moment in the approach to the most important cadence of an adagio section. (Example 28) The chord here is so exposed and unadorned that only a fairly pure G♭ major triad would be aurally acceptable.

Example 28. Toccata in C minor (bars 58 - 62)

His output of music exclusively for keyboard is much smaller than that of Froberger, and is contained in a note vocabulary of seventeen notes.

Figure 69. Muffat's Note Vocabulary.

♯		♯	♯		♯	♯
A	B	C	D	E	F	G
♭	♭		♭	♭		♭

The freedom with which he uses D♯, A♭ and A♯ in his organ music is convincing evidence that meantone temperaments with pure or near pure thirds are unsuitable for his music. The music is suitable and the temperaments are now available for the well-tempered clavier.

Johann Pachelbel. (1653 - 1706)

Pachelbel provides the most important connection between the south-German and the rest of the German keyboard traditions, particularly the link between the Catholic south and the Protestant central Germany. He studied with Kerll in Vienna, and was probably his assistant organist at St. Stephen's for a time, before moving not very far to Thuringia, with its lively tradition of cathedral music, its instrument-building industry and its temperament developers from Schneegass to Werckmeister.

The breadth of Pachelbel's musical outlook is suggested by the dedication of his *Hexachordum Apollinis* (1699), simultaneously to Buxtehüde in Lübeck and Richter in Vienna. During his appointment at Erfurt he was required not only to perform but to write a weekly chorale-prelude on a chorale chosen to be sung during the week. Over seventy of these have survived; they are written in a fairly wide variety of keys, and provide a basic note vocabulary. There are ninety-five 'Magnificat' fugues, composed around the turn of the century, whose modal content consolidates rather than extends the vocabulary. Almost a hundred other works, in Italian instrumental forms and sets of variations, complete a formidable body of evidence. (13) Nearly all of this music has been examined for note vocabulary and Pachelbel's attitude to temperament.

Figure 70. *Pachelbel's Note Vocabulary (organ).*

♯		♯	♯	♯	♯	♯
A	B	C	D	E	F	G
♭	♭	♭	♭	♭		♭

The overall organ note-vocabulary can be seen to be more extensive than any other composer's so far. This is largely because he uses more keys than any other composer studied, for his vocabulary per work seldom goes beyond a twelve-note disposition. He uses every note freely without the slightest inhibition, which of course does not mean that he uses them all the same amount. His flattest note, C♭, is to be

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(13) Most of Pachelbel's works are to be found in the following urtexts:

a) *D.T.Ö.*, xvii, ed. Botstiber and Seiffert.

b) *D.T.Bayern*, ii/1 ed. Seiffert and Sandberger (1901)

c) *D.T.Bayern*, iv/1 ed. Seiffert (1903)

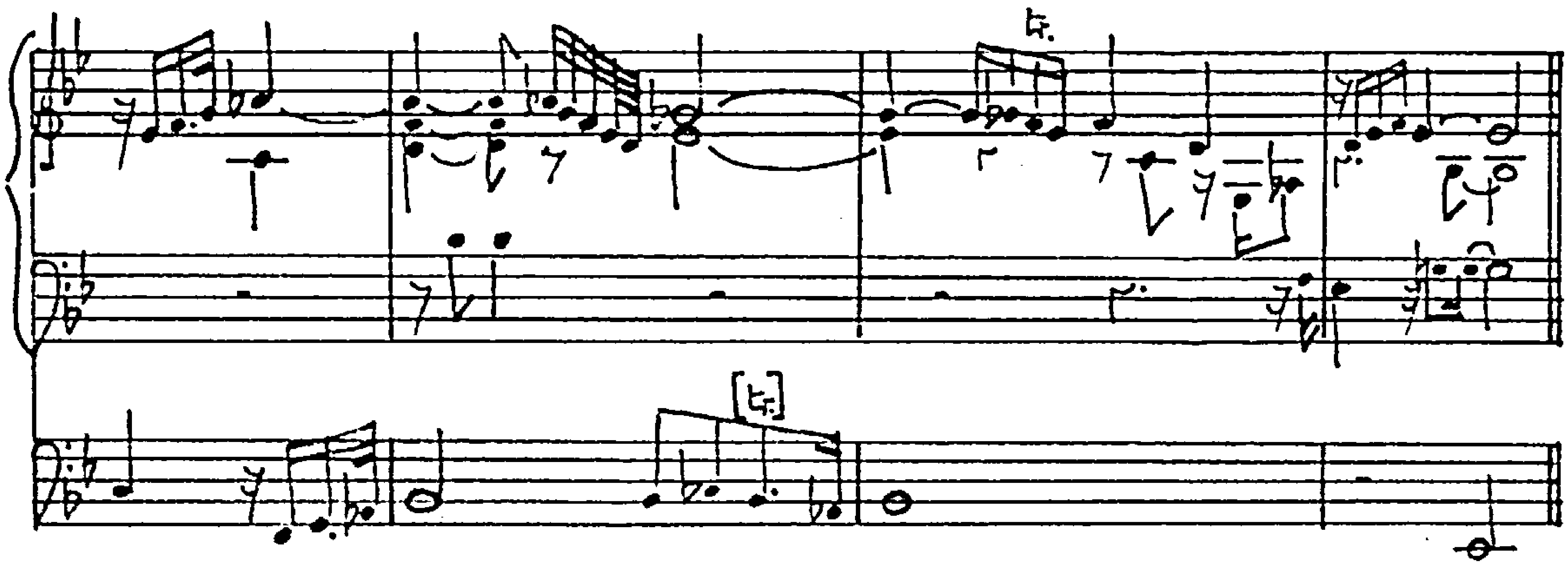
I have examined a) and b) but not c) which contains the choral preludes. These however were made available to me in:

d) J.Pachelbel: *Orgelwerke*, (Belwin/Mills, n.d.), (The 'Kalmus Organ Series' 3760, 3761, 3762)

e) J.Pachelbel: *Orgelwerke*, iv , ed. Traugott Fedke, (Litolff/Peters, n.d.)

found in only two works: firstly, in a fantasia in G (dorian) and secondly, in a fantasia in E♭. Both incidents involve an E♭ minor context. The ending of the E♭ fantasia with its minor third degree (G♭) will come as no surprise to Froberger students; the pedal is technically independent but thematically integral, and perhaps, with its trill, slightly flamboyant. (14)

Example 29. <u>Fantasia in E♭.</u> (bars 32 - end)



His sharpest organ note is E♯, which he uses with complete naturalness. It cannot be otherwise when he chooses fugue subjects like Example 30. (15)

Example 30. <u>Fugue in B minor</u> (beginning)

His chromaticising, which, like Froberger's and Poglietti's, is still something of a <u>tour de force</u>, is only a rare occurrence. The chromatic voice he uses needs fewer harmonic points of reference than that of his predecessors, as if a real chromatic scale, much smoother than the semitonic inequalities of meantone temperament, were to be used. Example 31 is taken from a chromatic variation of a chorale melody. (16)

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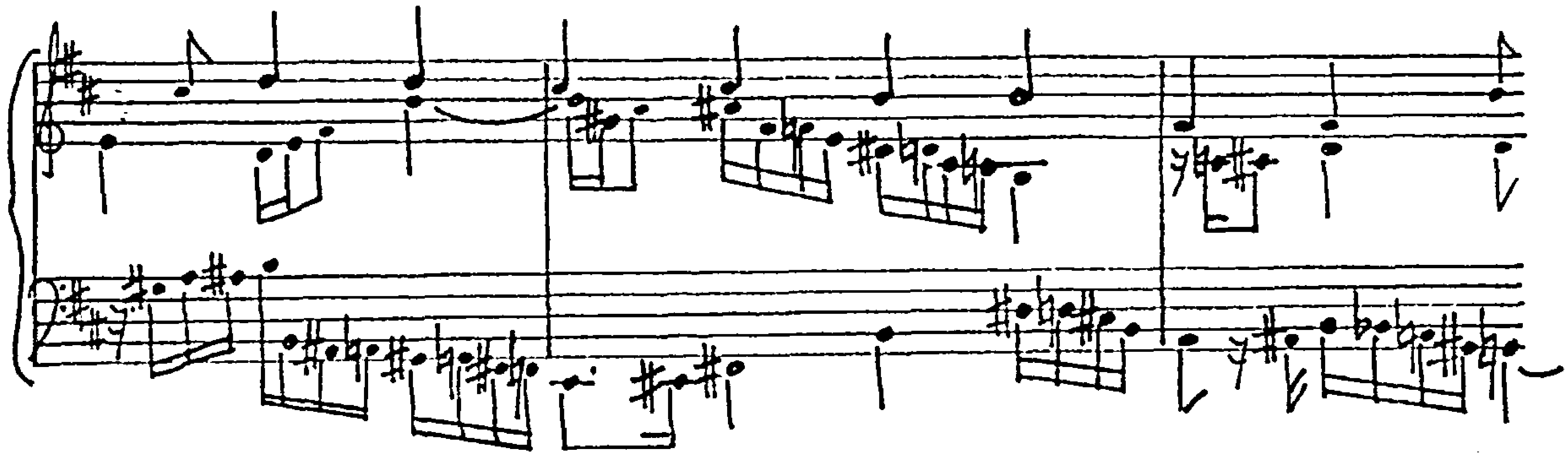
(14) J.Pachelbel: op. cit., ed. T.Fedke, iv pp.50 - 53.

(15) Ibid., pp. 109 - 111.

(16) <u>D.T.B.</u>, ii/1, no. 13.

Example 31. <u>Alle Menschen müssen sterben.</u> var. 7 (bars 7 - 9)



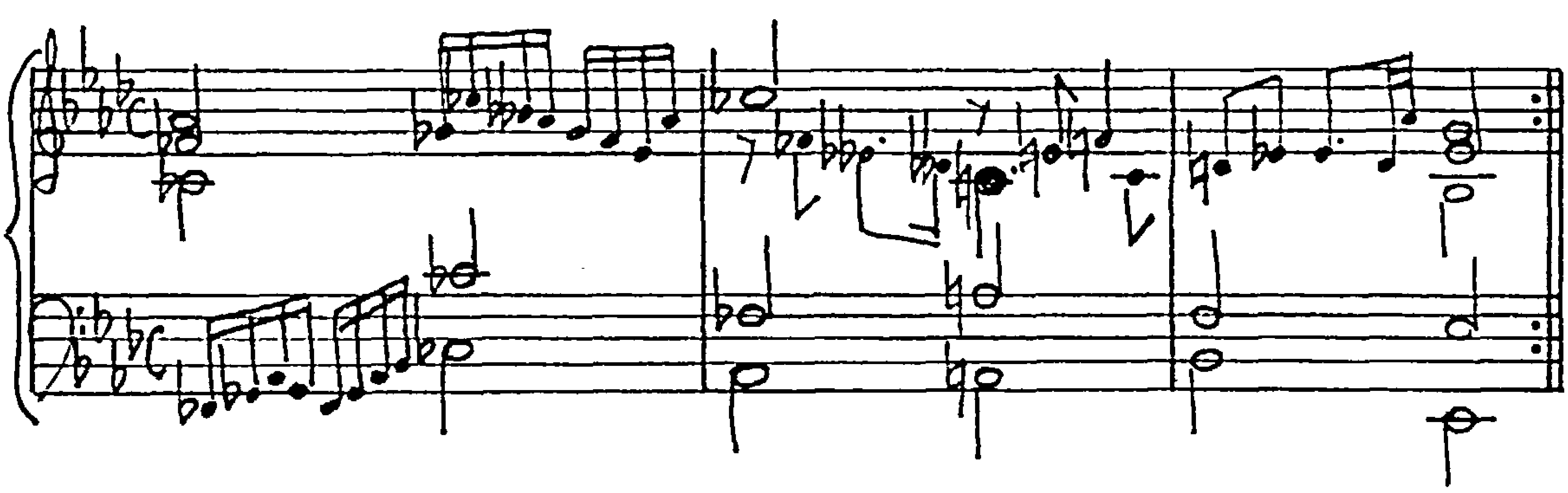
The choice of key in the music for harpsichord is even more adventurous. Apart from one exception, the harpsichord music uses the vocabulary of the organ music plus B♯. This occurs only in the suite in C♯ minor, in which B♯ is the essential and frequently used leading note. It cannot be confirmed that Pachelbel wrote all the suites, because the manuscript, bearing the date 1683, is lost. They are arranged in a logical order, suggesting the availability of all major and minor keys: not quite all, for seven out of twenty four are missing. The way in which Pachelbel names the suites gives us an insight into his concept of the diatonic system. Suites in the keys of the main diatonic notes, including B (the German B♭) come first. He expresses major by ♮, and minor by ♭. Then follow the suites in keys of the raised notes, which have spatial reference for him, because of the ambivalent naming of two of them, Dis and Gis, and yet written with the appropriate flat key signatures in both cases.

Figure 71. Pachelbel's suites for harpsichord.

Number	Suite	Key	Key Signature
1	Ex C♭	C minor	♭♭♭
2	" C♯	C major	-
3	" D♭	D minor	♭
4	" D♯	D major	♯♯
5	" E♭	E minor	♯
6	" E♭	E minor	♯
7	" E♯	E major	♯♯♯♯
8	" F	F major	♭
9	" F	F major	♭
10	" G♭	G minor	♭♭
11	" G♭	G minor	♭♭
12	" G♯	G major	♯
13	" A♭	A minor	-
14	" A♯	A major	♯♯♯
15	" B	B♭ major	♭♭
16	" H	B minor	♯♯
17	" Cis	C♯ minor	♯♯♯♯
18	" Dis	E♭ major	♭♭♭
19	" Fis	F♯ minor	♯♯♯
20	" Gis	A♭ major	♭♭♭♭

The exception mentioned above is the allemande of the final suite, Ex Gis. So extreme and uncharacteristic are its modulations that one is tempted to doubt its authenticity, or to dismiss it as insincere or quirkish writing. The modulatory abnormalities occur only in the allemande, mostly in the first repeating section. (See Example 32)

Example 32. Suite Ex Gis: Allemande (bars 5 - 7)



The rest of the suite is remarkable only for its ordinariness. Such inartistic contrast is in itself abnormal. The allemande begins in A♭ minor, and within seven bars passes through C♭ major, D♭ minor, F♭ minor, A minor (which is really B♭♭ minor) and E♭ major. The writer of the suite presents posterity with a rare middle-Baroque enharmonic change. In the decision to include the suite in their Historical Anthology of Music, Davison and Apel illustrate a principle of selection used for their book and cited in the preface: Suite ex Gis is "Something historically or technically important". (17) To Pachelbel's already extensive vocabulary it adds F♭, B♭♭, D♭♭ and E♭♭, giving an overall vocabulary of 24 notes, greater than any other composer up to this time.

Figure 72. Pachelbel's Note Vocabulary (overall)

♯	♯	♯	♯	♯	♯	♯
A	B	C	D	E	F	G
♭	♭	♭	♭	♭	♭	♭
	♭♭		♭♭	♭♭		

It is evident that the temperaments known and used in the first half of the seventeenth century are quite inadequate for Pachelbel. Although he is completely at ease in the modal system, as the 'Magnificat' fugues show, he is otherwise extremely versatile in his choice of keys, using even in his organ music major and minor keys with four sharps or flats. His music must therefore be played using a versatile temperament. The choice is between equal temperament on the one hand, and the group of irregular, circulating temperaments known as 'well-tempered', whose graded amounts of tempering provide different keys with unique acoustic qualities, on the other.

The chorale preludes, based on chorale melodies, each with its own literary and religious associations, offer a limited amount of guidance. Although there are practical considerations to be taken into account for the key choice of the chorale preludes, there are indications that Pachelbel was not insensitive to the Baroque concept of key colour, although less imaginative than J.S.Bach in this respect. Pachelbel pitches Ich ruf' zu dir, with its supplicatory associations, in E minor, and Der Tag der ist so freundlich, a chorale of Christmas celebration, in G major. The church modes were believed to have individual emotive characteristics, although there was considerable divergence of opinion over the specific affections induced by the different modes. Baroque musicians transferred these rather nebulous traditions to the developing tonal system. Baroque

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(17) A.Davison and Willi Apel: op. cit., no. 250.

writings, culminating in those of Mattheson, classified the affective properties of keys. Key characteristics, although a controversial issue, could not be ignored, and were supported by the sensibilities of the musicians of the day. The uniformity of the lack of purity to be heard in equal temperament was to contemporary musicians its great disadvantage. During the half century which followed the death of Pachelbel, Neidhardt and Marpurg continued the development of circulating temperaments, a movement which Bendeler and Werckmeister had begun. Silbermann was considered a reactionary with his continuing promotion of one sixth comma meantone temperament. Recent investigation by John Barnes shows that J.S.Bach probably used an unspecified circulating temperament. Marpurg and Adlung eventually embraced the cause of equal temperament as the simple answer to unlimited tonal freedom. From their publications (18) in which they staunchly defend this temperament against other historical temperaments, they give the impression that the universal acceptance of equal temperament was far from complete in Germany at the time of writing.

The evidence points to circulating temperaments being used for Pachelbel's music, both for organ and harpsichord. Just as in earlier times the fraction of the comma used for regular meantone temperaments was not disclosed from a study of the music alone, so a precise and unequivocal decision cannot be made concerning the actual temperament(s) Pachelbel used, but we can get somewhere near. Both Bendeler and Werckmeister were active and publishing in Thuringia, and both were exactly contemporary with Pachelbel. Their circulating temperaments, whose natural triads had the greatest amount of acoustic concordance and which contained no wolves, were available for Pachelbel's use.

As a postscript to this section of the work, a glance at the ensemble dance and ballet music of the period 1670 - 1700 may help to widen the perspective. It is not the purpose here to justify or condemn certain combinations of instruments which would include a keyboard instrument for support, but rather to observe a practice in

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(18) J.Adlung: Musica Mechanica Organoedi, (Berlin, 1768).
F.W.Marpurg: Anfangsgründe der Theoretischen Musik, (Leipzig, 1757).

order to compare concerted music with solo keyboard music. Poglietti, Johann Josef Hoffer (dates unknown) and Johann Heinrich Schmeltzer (1623 - 1680) wrote ballet and dance music for dramatic musical productions which took place in and around Vienna. The bands which they wrote for, and which invariably required a continuo of a melodic bass instrument and keyboard, ranged from three string parts, sometimes for fretted instruments, to full string orchestra, trumpets and drums. The keyboard part is a bass line, figured often only occasionally, and usually specifies either clavier or organ. Twenty-seven ballets were studied, for which the note vocabulary is as follows: (19)

22 ballets require a 12-note range, usually B♭ - D♯.
2 ballets require a 13-note range, F - E♯ and A♭ - G♯.
2 ballets require a 14-note range, D♭ - G♯ and G♭ - C♯.
1 ballet requires a 15-note range, A♭ - A♯.

Georg Muffat published two sets of suites for five-part strings and continuo (figured) : Florilegium Primum (1695) and Florilegium Secundum (1698). (20) They contain, respectively, seven and eight suites of dances and miscellaneous movements written in the style of his master, Lully. The average number of movements per suite is seven.

14 suites require a 12-note range, usually B♭ - D♯.
1 suite requires a 13-note range, D♭ - C♯.

The conclusions to be drawn from the above sets of figures are as follows. The harpsichordist would be able to play the great majority of the suites in a meantone temperament. He could choose to be silent in movements where, or at precise moments when, a meantone temperament was inadequate. The disposition required was usually B♭ - D♯, but the other dispositions were readily available. A little more weight is added to the argument that the sideways shift was an established harpsichord practice.

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(19) D.T.Ö., lvi. ed. Paul Nettl.
(20) Ibid., ii and iv.

PART II

CHAPTER 9.

AN OBJECTIVE METHOD OF TEMPERAMENT ASSESSMENT.

By the end of the seventeenth century there was not only an extensive repertory of keyboard music, but also a bewildering variety of temperaments to play it in. John Meffen's analyses of temperaments (1) demonstrate the triadic potential of temperaments: they contain the sizes of the intervals of triads on the twelve degrees of the octave and the amounts of deviation from just-intonation. One of their main purposes is cautionary, as if to say, "If you play music in any of these given temperaments, you must anticipate these specified amounts of mistuning". The attempts here in the previous three chapters to assess the effects of some of the temperaments appropriate to the period are only partially successful, for they ignore many acoustic facts and musical considerations. Those attempts, such as they are, are relevant to the issue, because the arguments on which they depend, and the results they achieve, demonstrate an interim stage in my search for an objective means of temperament assessment. Building on previous argument, discarding, confirming and augmenting as required, this chapter aims to put forward a cogent and comprehensive method of temperament assessment. It attempts not only to assess the suitability of any temperament when applied to a piece of music, but also to express in explicit terms merits and weaknesses of one temperament compared with those of other temperaments when presented in a particular musical context. The method described takes a piece of music, dissects its corpus into its intervallic and durational parts, applies to these parts a temperament, and arrives at an ultimate significant figure, which is a succinct declaration of the overall temperamental deviation from acoustic purity of the piece of music concerned.

Following the discussion of note vocabulary in the previous chapters, one must not be lulled into a false sense of security by accepting the erroneous precept that temperaments containing twelve unequivocal notes are inevitably suitable for any piece which matches those twelve notes. This is not necessarily the case; for instance, in Ramos's Just-Pythagorean temperaments the wolf, a perfect fifth minus a comma, lies between two almost indispensible notes, G and D.

(1) See p.109.

Referring to regular meantone temperaments, there are wide differences between the extreme fractions; between adjacent fractions there are subtle differences. Equally subtle are the differences and therefore the appraisal of the circular temperaments whose champions claimed that these temperaments provided a much wider harmonic range, and had affective characteristics implicit in the term 'well-tempered'. The method of assessment can handle wide or subtle differences between one temperament and another.

When one hears a piece of music played in one, or a succession of different temperaments, one immediately makes a value judgement: "I like that", or otherwise. Is this judgement based on a general feeling, of elation or depression, for example, or on the aggregate of a series of moments of pleasure (positive) and pain(negative) ? It is impossible to be sure. Admittedly, the ultimate judgement of a temperament lies in the hearing, because reaction to a work of art is subjective, but it would be satisfying to musicians to have subjective assessment either corroborated or refuted by acoustic fact - "I like that because ..." - and also to be able to consider degrees of temperamental goodness and badness. The pitch components of music are intervals which can be accurately measured. Temperament deals exclusively in intervals which can be just as accurately measured. It should not be impossible to apply the measurements of the latter to the pitch components of a piece of music, so that a rational appraisal of a temperament's quality can be ascertained. There is one aspect of music, however, which must be acknowledged and taken into account besides the physical and acoustic side. In recent years psycho-acoustic investigation has shown that in music, what is heard and received is not necessarily synonymous with and equal in all respects to what is played. Without delving into a profound exposition of the psychology of music, we must be aware of certain aural phenomena, and understand something of the auditory receiving and retention processes. On a knowledge of acoustic fact and auditory perception the objective method of temperament assessment is based.

Psychological considerations.

I should like to submit that the human ear experiences concerted music or harmony as a series of sensations associated with consonance and dissonance. These sensations also have precise measurements of duration. When the human ear registers these sensations and on an imprecise scale makes its own vague assessment of intonation, there must be some standard, albeit unconscious, against which the ear makes its judgement. It is on the assumption that pure consonance represents absolute aural satisfaction, that this method of assessment is based. The justification of this assumption is partly historical, for seventeenth-century musicians were obsessed with temperamental consonance. They accepted pure intervals as their norm. In an era during which the monochord was still used as a teaching aid for musicians it could hardly be otherwise. At a considerably later time Quantz gave the monochord as his remedy for faulty intonation:

> "The best means to escape from this ignorance is the monochord or measurer of sounds. On it you can learn to recognise the ratios of the notes most distinctly. Every singer and instrumentalist should be required to acquaint himself with it. With it he would acquire knowledge of the subsemitone much sooner, and learn earlier that notes marked with a flat must be a comma higher than those that have a sharp before them, for without this knowledge he must rely entirely on the ear, which is deceptive." (2)

The other standard which might have been taken is equal temperament, but there is less historical justification for this choice. In this situation the arbitrariness of equal temperament is its only virtue. If the psychological and acoustic aspects of just-intonation can be seen to be in agreement, then the choice of just-intonation as the standard of measurement is vindicated.

W.Dixon Ward illustrates the two aspects when he refers to our preference for musical intervals with small ratios. When two performers play a consonant interval

> "then many of the partials will coincide. If the frequency changes ever so slightly then beats will appear between the partials that formerly coincided. Therefore in order to minimise these beats, one performer may 'lock into' synchrony with the other, producing just-intonation. Tacit here is the assumption that beats are undesirable.

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(2) J.J.Quantz: On playing the Flute, (Berlin, 1752) tr. E.R.Reilly, (London, 1966), p. 269.

> "The second justification is really not much different, except that the problem has been moved to the receiving organism. It is hypothesised that we prefer pairs of tones for which the frequencies of neural discharge agree." (3)

The system of just-intonation is as elusive as that of equal temperament is cut and dried. The main facts of just-intonation are set out in Chapter 2., but not its implications. The diatonic triads of the system are the most concordant arrangements it is possible to achieve, but they are not all concordant. (4) For instance, the diminished triad on the leading note of a key is discordant: at least one of its intervals, the diminished fifth, is dissonant by definition. The intervals other than triadic, such as major seconds and semitones are all dissonant. Just-intonation is not synonymous with universal consonance. Seventeenth-century musicians neither supported unconditionally nor practised total concordance. Their music was full of dissonant intervals which provided tension, excitement and forward movement. Discordant sound was musically encouraged, justified and legitimised in the form of suspensions, appoggiaturas and pedals. Even the ubiquitous unaccented passing note was harmonically at odds with its immediate environment. Less frequently used was the more abrupt unprepared discord. The human ear receives a kaleidescope of musical sound whose components are intervals, some consonant, the rest dissonant, all of which interact. Every interval of a piece of music generates two series of partials which coincide sooner or later, whose composite sound creates the tonal quality of the interval. Just-intonation implies that every interval should be present in its pure state, where beating is at a minimum.

Where are the purest intervals in musical performance to be found ? Surely in a first-rate madrigal group or small string-ensemble. Even in these apparently ideal situations there are intervallic decisions to be made, which may compromise purity. For example, notice what might happen if a string quartet were to play a diminished triad in root position. Example 33 provides a context.

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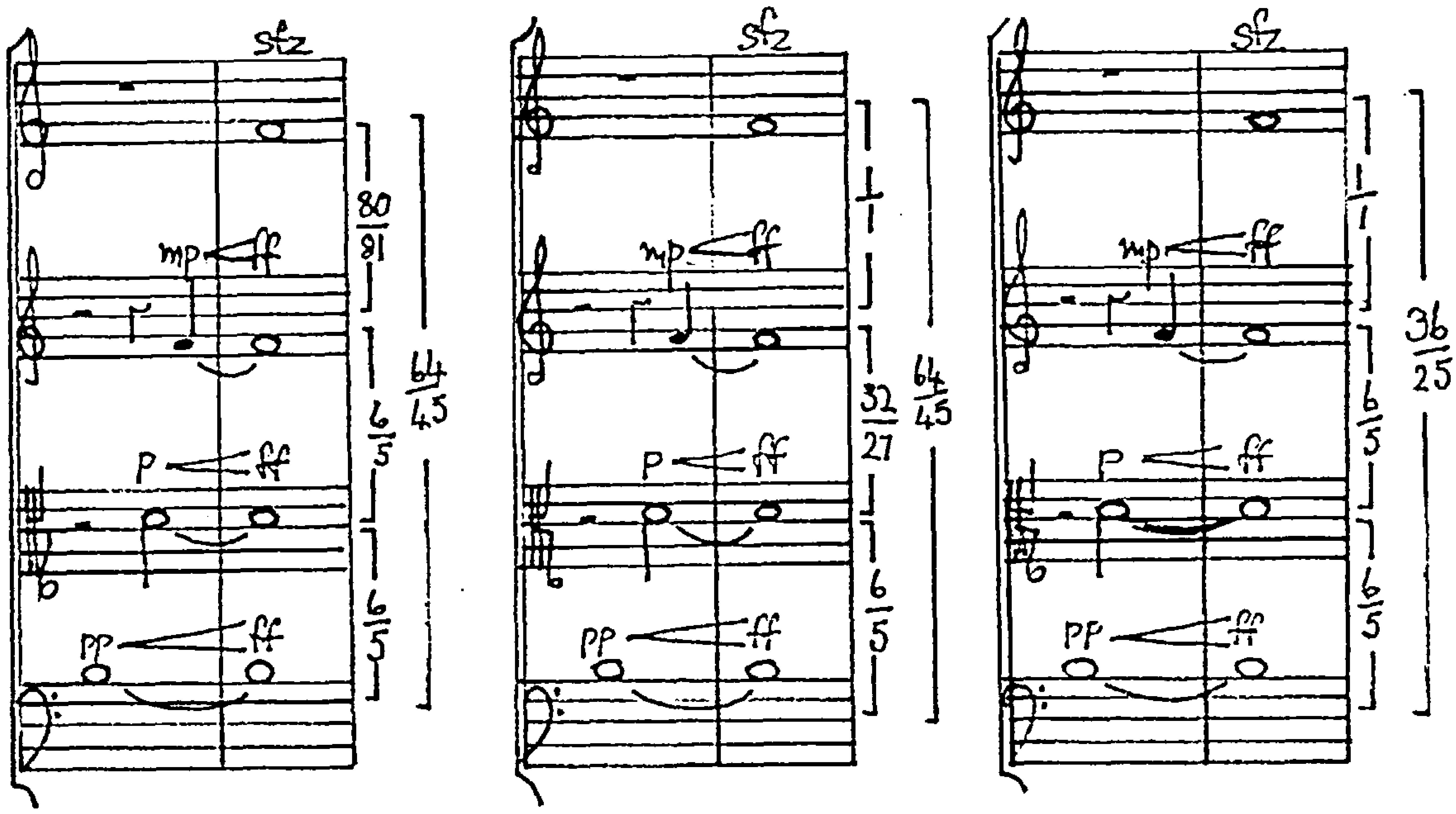
(3) W.Dixon Ward: 'Musical Perception', in J.V.Tobias: <u>Foundations of Modern Auditory Theory</u>, (New York, 1970) vol. 1. pp. 415f.

(4) In <u>An Introduction to the Psychology of Music</u>, Révész applies the terms consonance/dissonance to intervals ('two-note clangs'). The concepts similar to these, but applied to chords, are referred to by the terms concordance/discordance. As an aid to greater clarity, these terms and meanings are adopted here.

Example 33. Intervallic decisions.



a. b. c.

With C as key-note, let us assume that:

'Cello maintains constant pitch throughout.

Viola plays D, a pure minor third from 'cello B.

Second violin plays F, a pure minor third from viola D.

First violin plays F, a pure diminished fifth from 'cello B.

Unhappily, the first violin's F is a comma, ($\frac{36}{25} - \frac{64}{45} = \frac{81}{80}$), below the F of the second violin. The sounds of the violins would be excruciating. (Example 33 a.) What is to be done ? It is of paramount importance to achieve a unison between the violins. The second violin's F may be lowered by a comma to coincide with that of the first violin. By doing this, however, the interval between viola and second violin is reduced from a consonant minor third to a dissonant semiditone. (Example 33 b.) The diminished fifth of just-intonation, which is the interval between a leading-note and a subdominant, has been maintained. Alternatively, the first violin may make a unison with the F of the second violin, whose note lies a comma higher than the just-intonation subdominant of the key-note C. (Example 33 c.) The realisation of just-intonation intervals is full of anomalies such as this one, where one voice must move to make a dissonant interval, or momentarily compromise the overall pitch of the music, in order to accommodate the syntonic comma. In other words performers using so-called just-intonation must apply their own transient temperament where necessary. Pure intervals may have to be flattened or sharpened by the interval of a comma, or complementary partial commas, for expediency's sake.

The intervals of a piece of music do not always occur in their simple state, in size less than an octave. Their notes may be separated by a few octaves. Do simple and compound intervals have similar characteristic ? A musician reduces intervals to their simplest terms, but this may be a result of training and conditioning. Historically the octave was accepted as axiomatic. Helmholtz explained the equivalence of the octave in terms of harmonics. The aural concept of the octave or multiple octaves is accepted by psychologists as a musical phenomenon. Musical training, or lack of it is irrelevant to its perception.

> "A perceptual similarity exists between notes which are separated by an octave or octaves ... Those with absolute pitch may often relegate a note to the wrong octave, even though they name it correctly ... The principle of octave equivalence may be regarded as a universal musical phenomenon." (5)

The acceptance of the equivalence of the octave is a vital step to the declaration that a compound interval has a similar equivalence with its simple counterpart. Révész says that a musical person finds little difference between such intervals:

> "The interval c - e seems to differ far less from the interval c - e' than from the interval c - g. Harmonically it is in fact the same, though in the first the tonal distance is far greater than in the second. (6)

Praetorius uses the equivalence of thirds and tenths as tuning checks.(7) Also arising from the equivalence of the octave comes the acceptance of the equivalence of inversions. Révész explains it in this way:

> "The successive clangs of all c s and all g s can be taken for a fifth just as easily as a fourth (or twelfth or eleventh, etc.). We should really find a new designation for this intervallic quality; for example, fourth-fifth, or fifth-fourth. In the same way the thirds or sixths, in a purely qualitative sense, should be replaced by one common quality, the third-sixth, or sixth-third." (8)

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(5) Diana Deutsch: 'Memory and Attention in Music', in Critchley and Henson: Music and the Brain, (London, 1977) p.109.

(6) G.Révész: op. cit., p. 71.

(7) See Appendix 1. p. 262.

(8) G.Révész: op. cit., p.75.

Diana Deutsch takes a very similar line to Révész in the equivalence of the inversion of intervals issue. She describes briefly the results of specific tests:

> "Experimental evidence for perceptual similarity of inverted note pairs was provided by Plomp et al. (1973). They required subjects to identify the intervals formed by simultaneous pairs of notes and found that confusions occurred between intervals which were musical inversions of each other. For instance, more confusion occurred between fifths and fourths than between either with diminished fifths. Confusions between seconds and sevenths were also common. Further evidence was provided by Deutsch and Roll (1974) who required subjects to make pitch comparison judgements when the notes to be compared were accompanied by other notes of lower pitch. When the test notes differed but formed the same interval, errors in recognition were quite pronounced. A significant increase in errors was also found when the relationship formed by the first test combination (a musical fifth) was an inversion of the relationship formed by the second test combination (a musical fourth). It was concluded that errors were due to the perceptual equivalence of the inverted interval." (9)

In ensemble music the pursuit of purity of interval is all important, but at the same time, the members of the group refer to some standard pitch. The open strings of a string quartet, and the equivalent pitch limits beyond which wind instruments cannot go, help to maintain a standard of pitch. A vocal group lacking a standard of pitch cannot guarantee to hold pitch. In the case of an ensemble the choice of a musical reference point is largely a mutual responsibility. So far, vertical intervals only have been considered, with the implication that at least two simultaneous notes are required for comparison to be made. Voices in unison or octaves and single melodic lines ought not to be ignored. Melody producing musicians, such as singers and trombonists, and also those who listen to them, have a preconceived standard of pitch against which the notes which the musician makes are measured, for here the musician apparently has no simultaneous notes to match, and must rely on pitch memory. The musician's notes relate in theory to the tonal centre of the passage in question, and in practice are produced in reminiscence, where every diatonic note relates to the musician's tonal centre, and each chromatic note relates to the diatonic note which justifies the chromatic note's existence. The nature of a musician's ability to refer to a tonal centre, usually the keynote of the passage,

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(9) Diana Deutsch: op. cit., p. 110.

occasionally the more pervasive sense of absolute pitch, has intrigued psycho-acousticians from Seashore to those of the present day.

> "One of the more important pitch abilities essential to a musician involves not the comparison of consecutive tones, but the comparison of tones with some kind of internal standard ... That such internal standards exist cannot be disputed." (10)

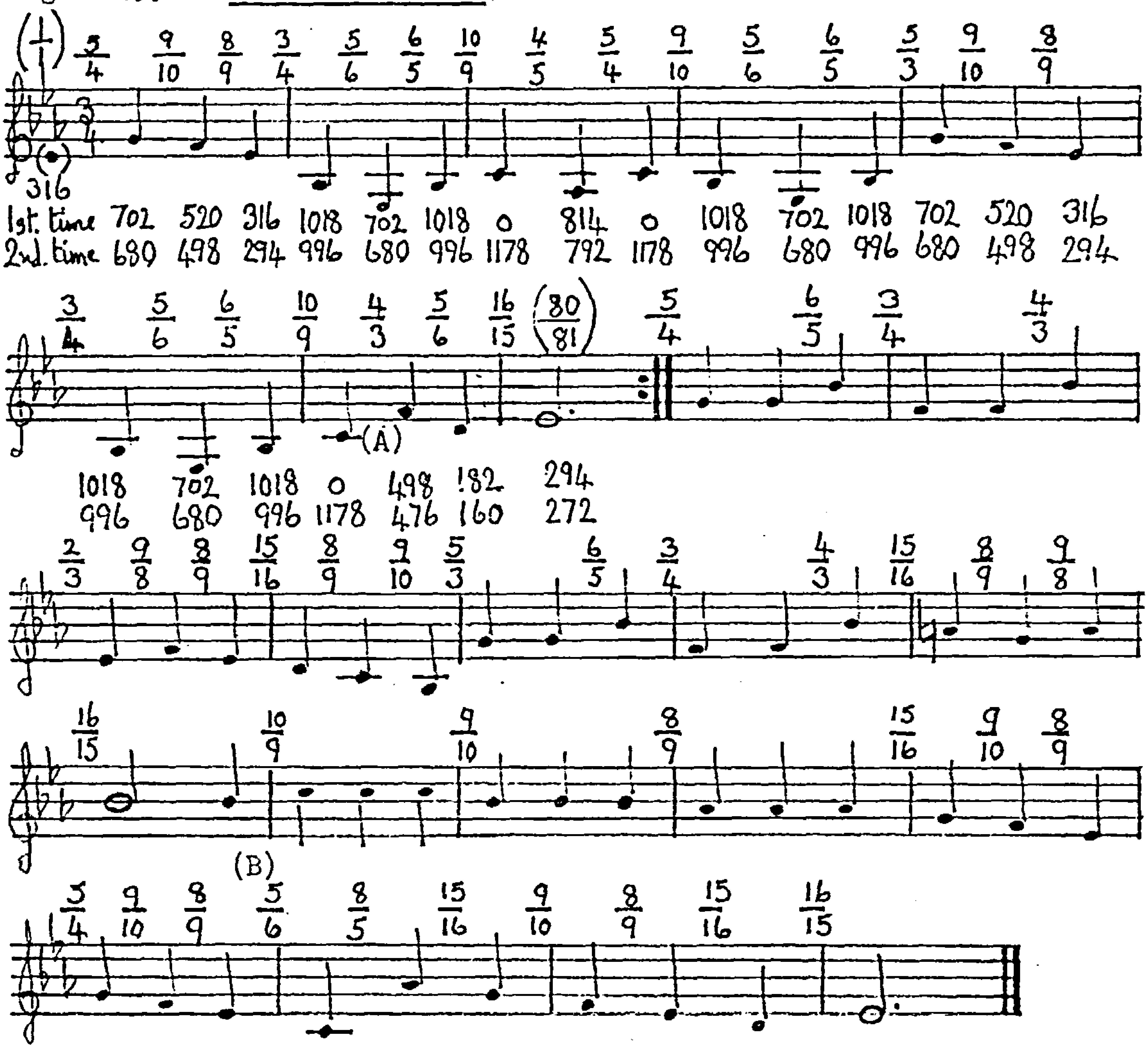
> "In musical performance the musician establishes a standard, usually in the context of a particular key, and all his efforts are then evaluated in terms of that particular key. This sense of tonality or key will underlie all his manipulations, and serve as the basis for his pitch judgements. If, as suggested by existing pitch tests, each note serves as a comparison for the next one, we have a system which is inherently unstable, in so far as any deviations from 'in-tuneness' will proliferate through subsequent notes and produce massive deviations from the tonal basis of the piece being played. In fact, a solo instrumentist may play one particular note out of tune, but play the subsequent ones correctly, an act which is impossible if every note serves as a standard for the next one." (11)

An actual illustration will help to emphasise this point. I made a tape recording from a radio broadcast of Kathleen Ferrier, singing unaccompanied, 'Blow the wind southerly'. She sang the folk song simply, with a minimum of vibrato. E♭ major was the key used. The E♭ of the recording, ascertained by the use of a tone-meter, was 305 cents above C British Standard Pitch, that is, barely perceptibly higher than a pianoforte E♭ at normal pitch. Figure 73 shows the melody as it would be sung entirely as a series of linear intervals, using just-intonation values, and where C = 0 cents at the beginning. The first note G lies a pure major third above the keynote, the second note F lies a minor tone below the previous G, the third note E♭ lies a major tone below the second note, and so on. All goes well until the point (A), where the linear pure fourth lowers the standard pitch by a comma. The first section ends on a tonic a comma lower than that at the beginning of the song. After a repetition of this section the tonic has been lowered by two commas. In Figure 73, the ratios above, and the cent values below the notes, confirm this statement. The rest of the verse will remain at this pitch if all linear intervals are pure. There is one modulatory decision to be

(10) J.Booth Davies: op. cit., p. 132.

(11) Ibid., p. 135.

Figure 73. Linear Intervals.



made: at point (B), provided that the singer not only approaches but quits the C by the interval of a minor tone from a dominant B♭, and not a new tonic B♭ - this would require a major tone - the pitch will remain stable until the end of the verse. However, since there are two complete verses to be sung, the pitch of E♭ at the end of the second verse will be 88 cents lower than the original E♭.

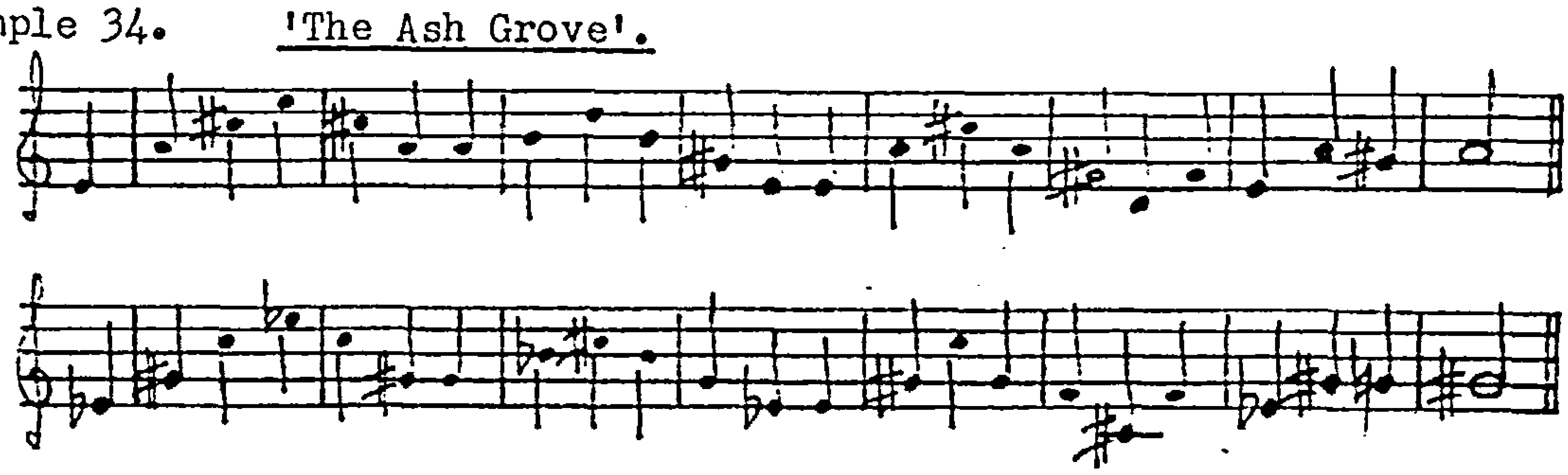
The point of this laboured exercise is, of course, that Miss Ferrier's E♭ remains constant: there is no appreciable fluctuation of pitch standard throughout the song. She must therefore rely on some kind of pitch memory, an ability to recall her own absolute pitches, or, which is more likely, to relate all notes to a memory-stored tonic. To prevent the depression of the standard pitch, and to remain faithful to the tonality, the interval between C and F at (A) must be a pure fourth plus a comma ($\frac{4}{3} \times \frac{81}{80} = \frac{27}{20}$). The idea that in solo melody the performer relates to a tonic, which of course may change through modulation, is more credible than the idea that the performer sings linear intervals and adjusts these pure intervals by a comma when circumstances, such as mutation, require it. Natasha Spender sums up the importance of memory in solo melody thus:

> "Melody perception is not only the recognition of the direction of melodic movement (up or down), nor yet of precise interval steps; it is also the sense of the tonal centre of gravity of a phrase, or the sense that this focal basis has moved, as it does in modulation into a new key. The appropriate tests include not only those of recall or recognition (the memory component) but also those of the ability to predict, for instance, the most suitable end note to a phrase according to its idiom, or to detect a 'wrong note', i.e. one that in a particular idiom makes no 'sense'. In this respect musicality is the implicit grasp of the grammar of one musical language, which an education in that music serves to make explicit." (12)

Tonal memory, and its associated abilities to predict and detect, are relevant to keyboard temperament when a solo passage, such as a fugue subject is played on a keyboard instrument. When only melody is heard, the diagnostic and critical faculty of the human ear is not in a state of suspended animation. It may be even more alert than usual because concentration is not diffused over the perception of several simultaneous notes. To take an extreme example, a musical listener would scarcely react in the same way if the first strain of 'The Ash Grove' were played in quarter-comma meantone temperament, disposition E♭ - G♯, first given the keynote A (Example 34a), and then given the keynote G♯ and played as if in that key. The aural perception tries valiantly to assess the latter, whilst a glance at the actual notation reveals the musical gibberish (Example 34b).

Example 34. 'The Ash Grove'.

a.
b.



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(12) Natasha Spender: 'Psychology of Music', in The New Grove, ed. S.Sadie, vol. 15, p.410.

It must be admitted that solo voices may become so stylised in their own adopted temperament that just-intonation intervals may not be recognised as the norm. The Pythagorean intervals of singers of plainsong, the sharp intervals of string players, (13) or nowadays even the ubiquitous equal temperament may sound to some people more pleasurable and therefore more in tune in unsupported melody than just-intonation, but for the sake of consistency let us assume that the human memory is efficient enough to continue to appreciate and assess melody according to the scale of just-intonation.

The intervals of just-intonation defined.

The first practical step towards objective temperament assessment is to define all the intervals contained in a piece of music. Definition of these intervals is not inhibited by the kind of decisions discussed above, which performers have to make for expediency's sake. In order to maintain theoretical consistency, a vocabulary of all possible pure intervals, with their ratios and cent values, is necessary. The principles governing such a vocabulary are given below; the actual list is given in Figure 74.

(1) The vocabulary of intervals must cover all combinations of two notes, according to the notation they are given in the score.
(2) There should be one ratio only per interval.
(3) Every interval chosen should be in its purest form and simplest ratio.
(4) Each interval should be historically and traditionally acceptable.
(5) Each interval should be consistent with the modal and diatonic systems.
(6) Each interval plus its inversion should coincide with an octave.

The compilation of the list involved consulting the following authorities: H.Helmholtz, W.Pole, C.V.Stanford, C.E.Seashore, Ll.S.Lloyd, W.Dixon Ward.

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(13) "It is now clear that, on average, the internal scale of musical pitch used by musicians corresponds fairly closely to E.T. but with a slight stretch that results in a tendency towards sharpening all tones relative to the tonic." W.Dixon Ward: op. cit., p. 421.

Figure 74. List of Pure Intervals.

Interval		Ratio	Cent Value
UNISON	(per.)	1/1	0
	(aug.)	25/24	71
SECOND	(mi.)	16/15	112
	(maj.)	9/8	204
	(aug.)	75/64	275
THIRD	(dim.)	256/225	224
	(mi.)	6/5	316
	(maj.)	5/4	386
FOURTH	(dim.)	32/25	427
	(per.)	4/3	498
	(aug.)	45/32	590
FIFTH	(dim.)	64/45	610
	(per.)	3/2	702
	(aug.)	25/16	773
SIXTH	(mi.)	8/5	814
	(maj.)	5/3	884
	(aug.)	225/128	976
SEVENTH	(dim.)	128/75	925
	(mi.)	16/9	996
	(maj.)	15/8	1088
OCTAVE	(dim.)	48/25	1129
	(per.)	2/1	1200

Figure 75. List of Inversions

Interval + Inversion = OCTAVE (1200 c.)

UNISON	(per.)	0	1200	(per.)	OCTAVE
	(aug.)	71	1129	(dim.)	
SECOND	(mi.)	112	1088	(maj.)	SEVENTH
	(maj.)	204	996	(mi.)	
	(aug.)	275	925	(dim.)	
THIRD	(dim.)	224	976	(aug.)	SIXTH
	(mi.)	316	884	(maj.)	
	(maj.)	386	814	(mi.)	
FOURTH	(dim.)	427	773	(aug.)	FIFTH
	(per.)	498	702	(per.)	
	(aug.)	590	610	(dim.)	

There may be those who regret various omissions from Figure 74. For instance there is no mention of the minor tone $\frac{10}{9}$, since only one ratio per interval is allowed. The justification of the minor tone's exclusion - for it is certainly a characteristic of just-intonation - is twofold. Firstly, the minor tone is only a residual interval, occurring first of all as a result of accepting the major third as a consonance: $\frac{5}{4} \div \frac{9}{8} = \frac{10}{9}$. Secondly, the minor tone is implicit not only in the pure major third, $\frac{9}{8} \times \frac{10}{9} = \frac{5}{4}$, but also in the pure major sixth $\frac{3}{2} \times \frac{10}{9} = \frac{5}{3}$.

The idea of a templet.

We can now assemble all the intervallic and durational information of a piece of music in processable form. It is assumed that the kaleidoscope of musical emission which constitutes a piece of music is received by the human ear in a series of moments of fixed aural sensations. Natasha Spender confirms and amplifies:

> "All aspects of auditory perception ... are dependent on temporal factors. The problem of how the nervous system organises and integrates large amounts of perceptual information at a given speed has led to 'psychological moment' theories, postulating a central timing mechanism whereby all that is processed in a single micro-unit of time is unchangeable, modification of perceived input having to be processed by the succession of subsequent units." (14)

An accurately notated score allows every moment of fixed aural sensation to be isolated as a finite period in which the ear receives one unchanging, although probably composite and complex, sensation. The first step is to divide the score into these consecutive moments, which are considered as a series of aural time-exposures, to use a photographic analogy, and each time-exposure is called a 'frame'. Any change in pitch or the number of different notes requires a new frame. The intervallic content of every frame can then be accurately assessed as ratios of just-intonation, expressed for convenience in cent values. The duration of each frame is accurately recorded. The detailed information resulting from this dissection of the score is given the name 'templet', an engineering term applied to music.

(14) Natasha Spender: op. cit., p. 403.

A musical templet is an accurate original with which to compare the intervallic deviations of any temperament. Assessment of keyboard music using up to four voices or four simultaneous different notes has been attempted. It is possible to assess music with a greater number of voices, but the calculation of frames containing more than four different notes rapidly becomes complex. (15) The method does not confine itself to contrapuntal forms, but since much of the non-contrapuntal keyboard music of the seventeenth century is expressed in quasi-contrapuntal terms, it has been found convenient to think in terms of voices.

The Construction of a Templet.

The templet may cover a whole piece, or a section of a piece of music. The format of the templet is a succession of frames isolated by vertical lines. Each frame consists of three parts:

(1) The NOTES. These are written on the appropriate staves. Key signatures exert the usual control, but accidentals apply only within the frame concerned. Notes in the score involving several ledger lines may be transferred to equivalent places on the frame stave. Each frame anticipates four voices: soprano, alto, tenor, bass. The absence of a voice is indicated by the symbol which usually denotes a minim rest. Here it has no durational significance.

(2) The DURATION. A unit of duration suitable to the piece is chosen, and the duration of each frame is recorded as a multiple or decimal of the basic unit. This will often be a crotchet or a quaver. Usually it will be more convenient to choose a quaver unit rather than a dotted crotchet unit in compound time, in order to avoid awkward and approximate decimals, such as ·333 and ·666.

(3) The INTERVALS. Every interval within a frame must be accounted for, since every interval is a potential source of

(15) Four-voice frames have up to 6 significant intervals:
Five-voice frames have up to 10 significant intervals:
Six-voice frames have up to 15 significant intervals:

impurity. Therefore:

2-voice frames are defined by 1 interval.
3-voice frames are defined by 3 intervals.
4-voice frames are defined by 6 intervals.

Compound intervals are reduced to their simple equivalents.

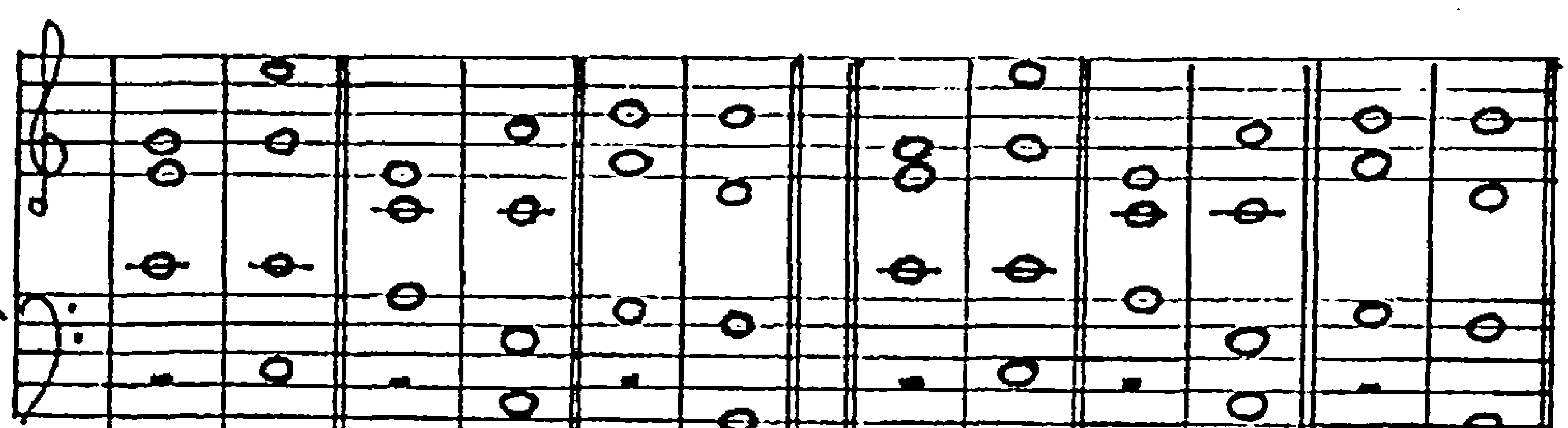
Duplication takes place when an interval between two particular notes occurs more than once in a frame, or when an interval and its inversion occur within a frame. The interval must be recorded the first time it occurs, but not again when it is repeated, nor should its inversion be recorded. Instead, a duplicated interval is indicated by a dash, thus – . At a later stage, this prevents the same interval or its inversion being taken into account more than once in a frame. Duplication occurs when a frame contains more voices than different notes. If a four-voice frame has four different notes, there can be no duplication and all six intervals will have independent significance. If the same interval occurs between different notes, such as c – f, f – b♭, there is no duplication.

Octaves and unisons are indicated in the templet by o . However many times they occur in a frame, they should be indicated each time by o . In historical temperaments, they always remain pure. o indicates not only the presence of an octave, but also an impurity potential of zero. Blank spaces within a frame denote the absence of intervals.

Figure 76. Isolated Frames (without Duration).

NOTES

INTERVALS



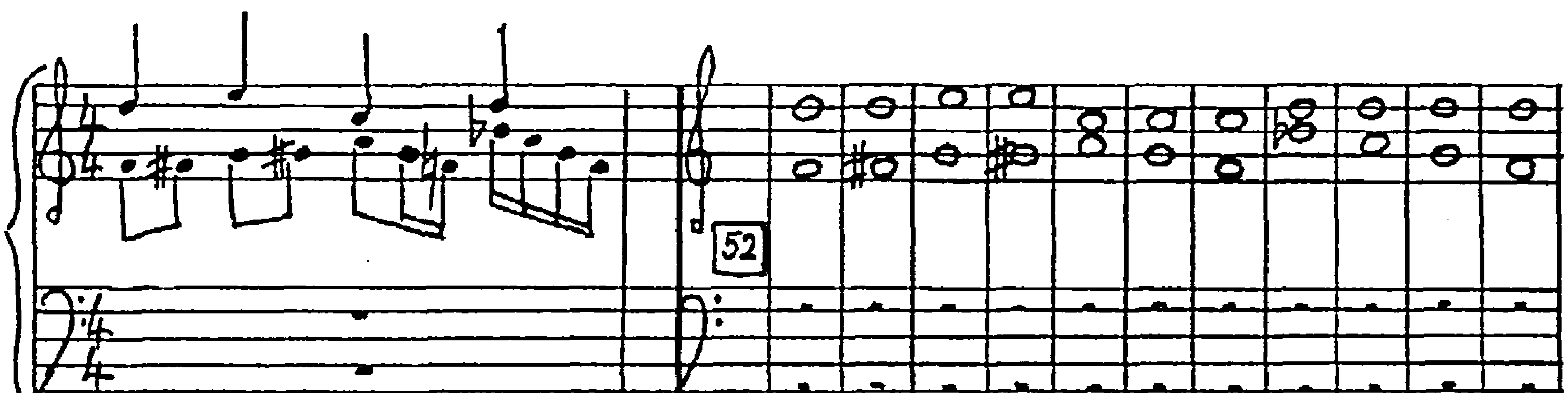
Alto Sop.	6/5	5/3	5/4	5/3	45/32	5/3	316	884	386	884	590	884
Ten. Alto	5/4	3/2	6/5	8/5	16/9	5/3	386	702	316	814	996	884
Bass Ten.		o		3/2		16/9		–		702		996
Bass Alto		–		–		3/2		o		–		702
Bass Sop.		5/4		o		5/4		386		o		386
Ten. Sop.	3/2	–	3/2	–	5/4	45/32	702	–	702	–	386	590

Figure 76 shows isolated frames of the tonic, submediant and dominant seventh chords of C major, both as typical three-voice and four-voice frames.

Although initially just-intonation intervals are thought of as ratios, as in Figure 76(a), it has been found more convenient to change the ratios for cent values at the templet stage, as in Figure 76(b). At a later stage, comparison of pure and tempered intervals will be made using cent values, and so calculations will be simplified.

Figure 77. Two-voice Templet.

Score: Templet:



Froberger: Capriccio 16.
(bar 52)

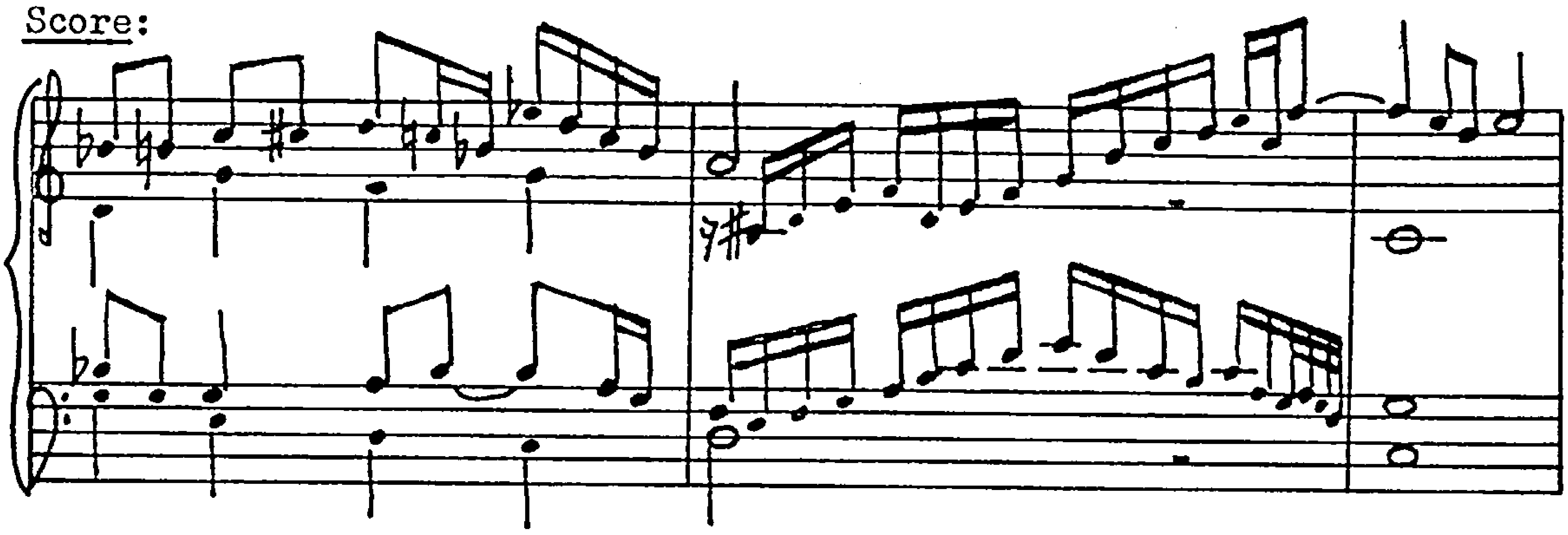
Dur. (♩)	·5	·5	·5	·5	·5	·25	·25	·25	·25	·25	·25
A-S	884	814	884	814	316	498	702	386	498	702	884
T-A											
B-T											
B-A											
B-S											
T-S											

Two voice frames require only the assessment of the interval between them. Figure 77 shows the templet for a chromatic passage in an F major context. The duration of each frame is indicated as a decimal of the basic unit of duration, in this case a crotchet.

Figure 78 shows a templet for three bars ending with an important cadence. Most of the frames are for two or four voices, but the first frame of bar 68 contains three voices. Note the significance of the symbols o and – , and the blank spaces. From this short passage it is amply evident that although the frames of a templet are aural time-exposures, they are not necessarily triads, and that where suspensions, passing notes and other non-harmony notes occur, there will also occur intervals which are emphatically dissonant with one or more of the remaining notes of the frame.

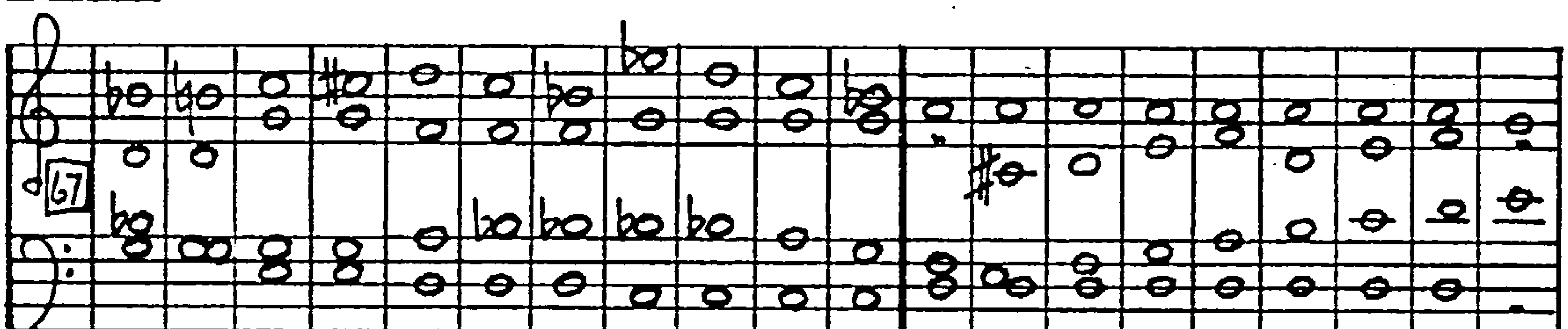
Figure 78. Templet of Two, Three and Four Voices.

Score:

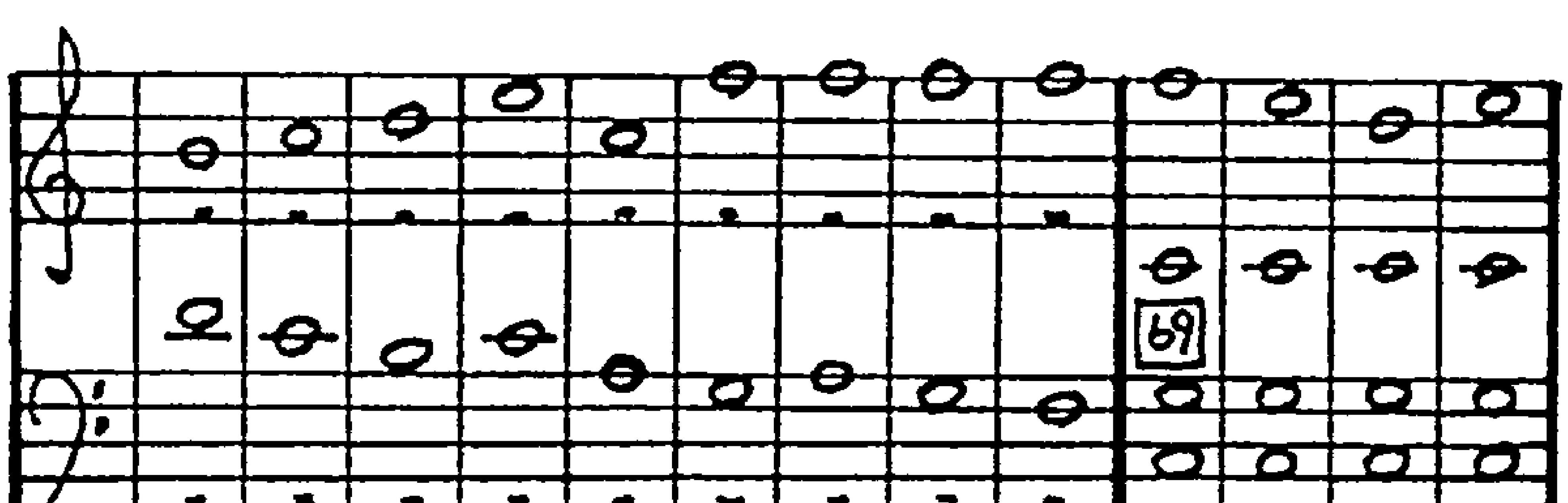


Froberger: Capriccio 16 (bars 67 - 69)

Templet:



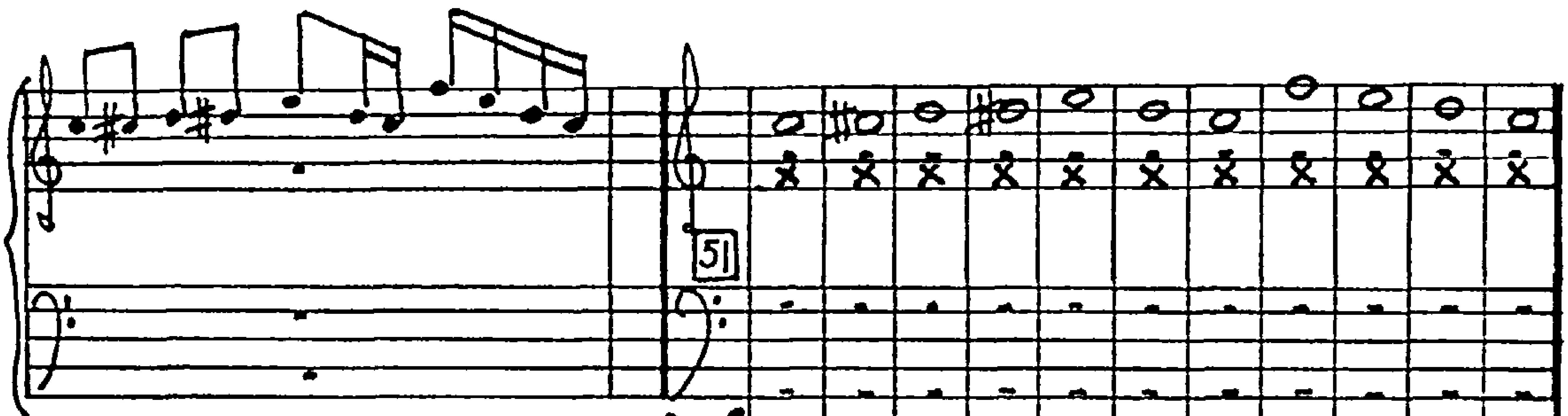
Dur.	·5	·5	·5	·5	·5	·25	·25	·25	·25	·25	·25	·25	·25	·25	·25	·25	·25	·25	·25	·25
A-S	814	884	498	590	884	702	498	814	702	498	316		814	702	498	386	702	498	386	
T-A	-	702	0	0	814	702	-	884	884	996	0		884	884	884	-	316	386	316	
B-T	316	0	316	316	702	814	814	996	996	884	702	316	204	-	498	702	-	996	0	
B-A	702	-	-	-	-	316	316	702	702	-	-		1088	0	204	316	0	204	-	
B-S	-	386	814	884	0	996	-	316	204	0	996	702	702	-	702	-	-	702	702	
T-S	0	-	-	-	-	204	0	498	386	-	-	386	498	386	204	0	996	884	-	316



Dur.	·25	·25	·25	·25	·25	·125	·125	·125	·125	1	·5	·5	2
A-S										498	386	204	386
T-A										498	498	498	498
B-T										-	-	-	-
B-A										0	0	0	0
B-S										-	-	-	-
T-S	884	0	316	386	316	996	814	996	0	996	884	702	884

Figure 79 shows the method whereby the intervals of a melodic passage are assessed according to the tonal centre from which they are derived. This is indicated on the templet by x at the appropriate place below the melody, so that the interval is always measured from the tonal centre below. Since the melody note may occur in any of the four parts and makes an interval with a remembered tonic, none of the interval spaces provided are appropriate for it. Hence it is given its own space.

Figure 79. <u>A Single-Voice Templet</u>.

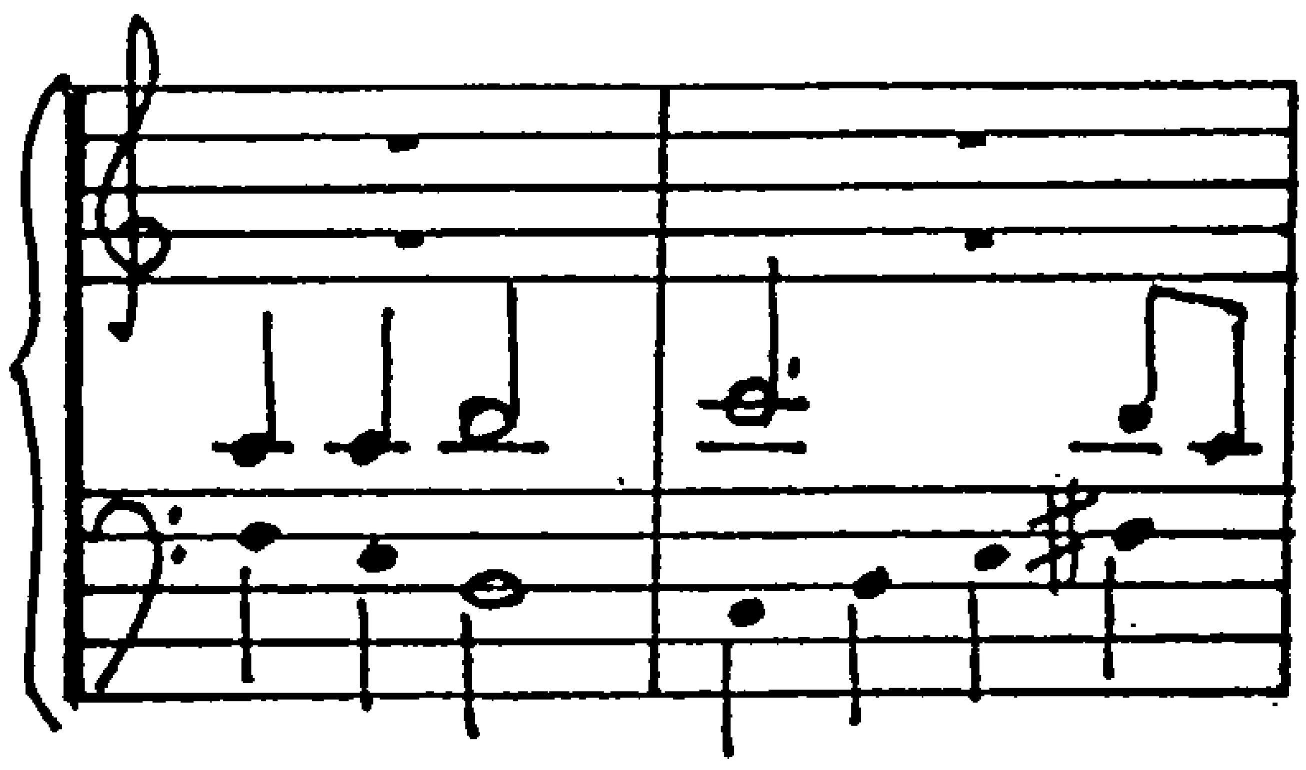


Froberger: Capriccio 16 (bar 51)

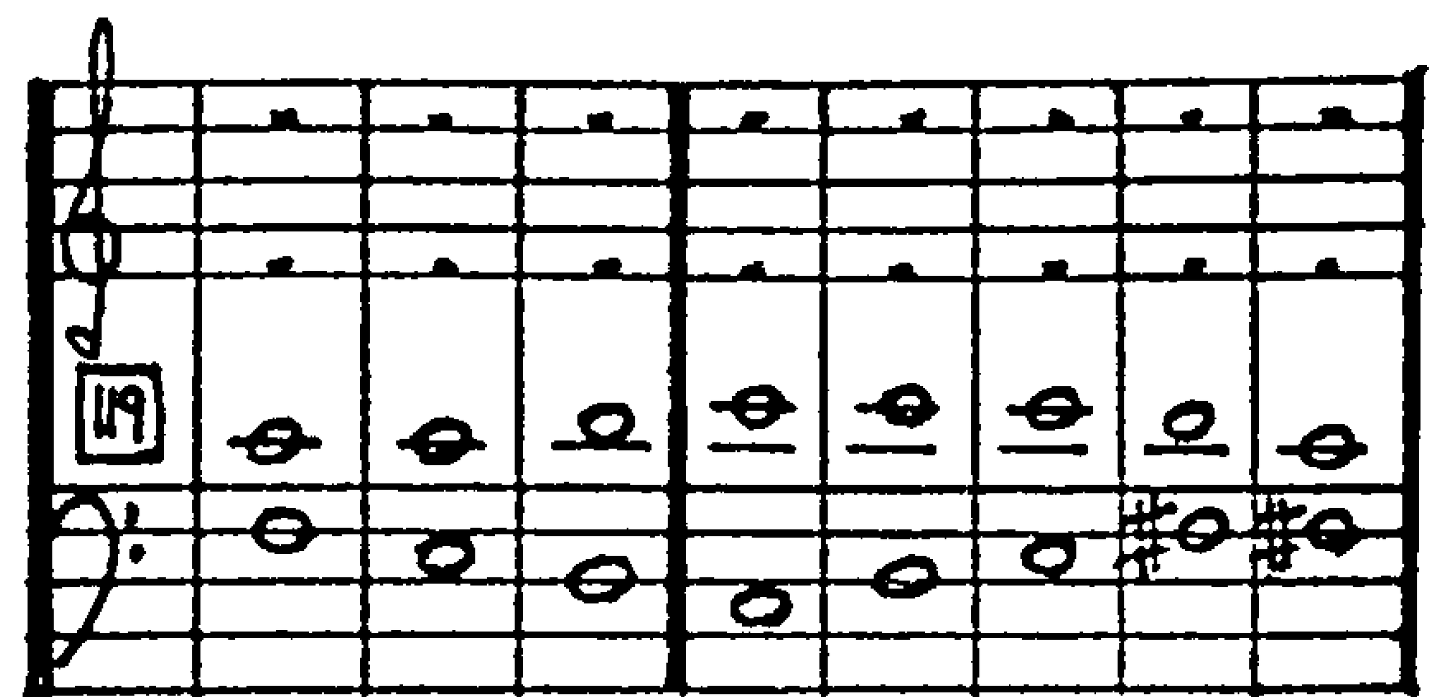
Dur.	·5	·5	·5	·5	·5	·25	·25	·25	·25	·25	·25
A-S											
T-A											
B-T											
B-A											
B-S											
T-S											
Mel.	702	773	884	976	1088	884	702	0	1088	884	702

Occasionally voices may converge on an isolated octave or unison, as in Figure 80. The circumstances are scarcely identical with those of Figure 79. An isolated octave does not constitute a melody. The aural sensation will most probably be perceived as a pure consonance, and so it is listed as an interval between the parts concerned.

Figure 80. Isolated Octaves.



Froberger: Ricercar 4
(bars 119 - 120)



Dur.	1	1	2	1	1	1	·5	·5
A-S								
T-A								
B-T	702	814	0	386	204	0	814	610
B-A								
B-S								
T-S								
Md.								

Crossing of parts is a linear concept; here it is not significant. A frame should be so arranged that the notes are recorded in pitch order from the highest to the lowest note. For instance, if tenor and alto parts cross in the score, the tenor temporarily becomes the alto and vice versa in the templet.

The Application of a Templet.

In historic terms, temperaments are the results of trying to reconcile the twelve notes of the keyboard with the far greater number of the notes of just-intonation. We are going to compare the cent value of every interval of a templet with the corresponding cent value of every interval under keyboard conditions.

When a consonant interval is tempered it becomes impure, and by definition, dissonant. When a pure dissonant interval is tempered it remains dissonant and becomes impure. To avoid the confusion which the inadequacy of the word dissonance may bring, and any distracting associations the word impurity may have, I intend to use the word 'absonance' to describe the deviation from purity or the amount of impurity which any tempered interval contains. The adjectival form 'absonant' has a respectable history, although it may have lapsed from common usage. The English language should not be debased by giving the word new life, by making its meaning harsh, inharmonious a little more specific.

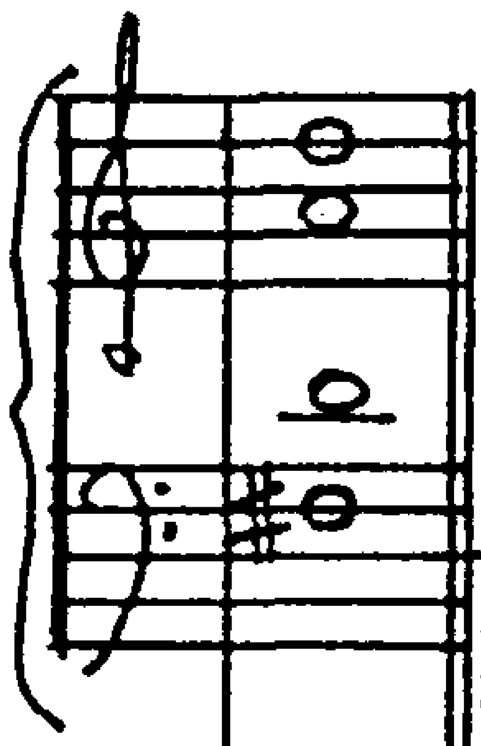
In the only completely regular temperament, equal temperament, all identically named intervals will have the same amount of absonance. For instance, wherever a major third is pitched, an absonance of 14 cents will be present. In all other temperaments, the sizes of their apparently identical intervals may differ, depending on their keyboard location. Therefore their amounts of absonance may differ. Here are the steps which lead to the absonance level of a frame:

(1) Let us imagine that a second templet is prepared, identical with one already to hand, except in one vital respect: the cent values of the second templet record the precise sizes of tempered intervals, specified according to a given temperament.

(2) Any absonance in the intervals of a frame are revealed by comparing the cent values of the pure-interval templet with those of the tempered-interval templet. It does not matter whether a tempered interval is larger or smaller than its corresponding pure interval. The absonance of every interval is calculated by taking the smaller from the larger cent value.

(3) The absonances of a frame are added together to give the total absonance, or to give it a name, the absonance level of a frame.

Figure 81. Isolated Absonance-levels.



T.I.S. = Tempered Interval Size.
Abs. = Absonance.
a.l. = Absonance level.

Templet		$\frac{1}{4}$ comma meantone.		$\frac{1}{5}$ comma meantone.		Reinhard's Temp.	
		T.I.S.	Abs.	T.I.S.	Abs.	T.I.S.	Abs.
AS	498	503	5	502	4	520	22
TA	-	-	-	-	-	-	-
BT	814	814	o	809	5	807	7
BA	316	311	5	307	9	287	29
BS	-	-	-	-	-	-	-
TS	o	o	o	o	o	o	o
			10 a.l.		18 a.l.		58 a.l.

Figure 81 shows the templet for an isolated major triad and the absonance levels of three different temperaments. (Specifications of all temperaments mentioned are to be found in Chapter 4.) In Reinhard's temperament the size of the fourth A - D between alto and soprano is 520 cents (1200 + 204 - 884 = 520). The just-intonation interval between the same notes is 498 cents. There is an absonance or deviation of 22 cents between these two intervals. This absonance, plus those of the other two significant intervals between bass and tenor and bass and alto, are added together to make the absonance level of the frame. For this isolated triad $\frac{1}{4}$ comma meantone has the best performance. Its perfect fourth is not quite as pure as in $\frac{1}{5}$ comma, but its minor sixth is absolutely pure. Reinhard's takes a poor third place. These figures confirm the more general experience of the human ear.

The totals of all the absonance levels of a passage or piece of music might then be presented as a single expression, but this would have little significance per se, because its size would depend largely on the number of frames; the shorter the piece, the smaller the total absonance level. Absonance level and duration must be co-ordinated.

The total duration of a piece of music can be arrived at in two ways. First, the duration units of all the frames can be added together. Secondly, and this serves as a necessary check to the first way, the following formula may be applied:

Number of units per bar x total number of bars = total duration.

The notes of music have perceptible durations. (16) The larger the aural time-exposure the greater is the tolerance needed. The amount of tolerance needed for the D major triad of Figure 81 can be expressed as follows:

Temperament	Duration	♩	♪	𝅝
$\frac{1}{4}$ comma		10	$\frac{10}{2} = 5$	$10 \times 4 = 40$
$\frac{1}{5}$ comma		18	$\frac{18}{2} = 9$	$18 \times 4 = 72$
Reinhard		58	$\frac{58}{2} = 29$	$58 \times 4 = 232$

A new figure emerges here in which both the absonance level and the duration of a single frame are given united significance. Thus:

absonance level x duration = IMPURITY COUNT

But the argument does not finish here. To express the interaction of the total impurity count and the total duration of a passage or piece of music, a new unit of measurement is required. Let it be called the ARP. (17) The quantitive noun derived from arp is arpage. To calculate the arpage of a piece of music, the following formula is applied:

$$\frac{\text{Total impurity count}}{\text{total duration}} = \text{arpage (expressed in arps)}$$

(16) This may not apply to a fast glissando, but the aural effect of a fast glissando is related more to noise than musical sound.

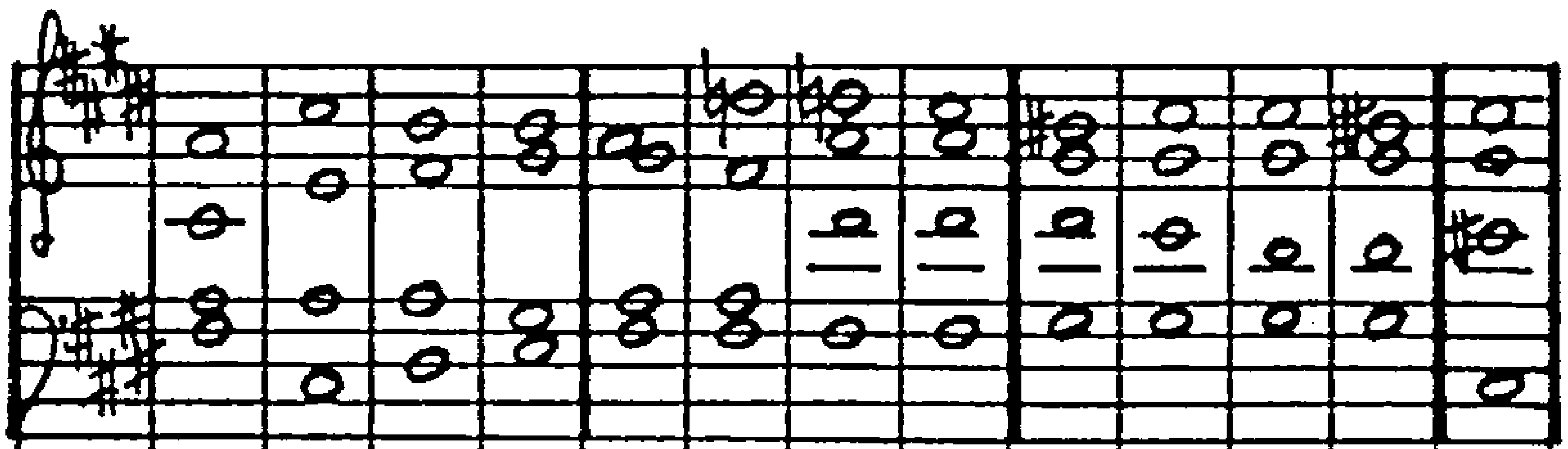
(17) ARP is the acronym for the Rastall-Pollard unit. The arpage of a piece of music is the average count per unit of duration. The arp cannot be an absolute unit of measurement in the scientific sense, but it can be a useful, meaningful term. Arps have the dimension of cents, but for a specific purpose; for example, the expression '16 arps' means an average absonance of 16 cents per duration unit.

0 and Ø ?

Figure 82.

Comparative Arpages.

Froberger: Ricercar 6.
(bars 89 - 92)



Dur.	1	1	1	1	1	1	1	1	1	1	1	1	4
A-S	814	884	498	316	112	814	498	386	386	498	498	386	498
T-A	–	702	884	0	–	884	316	316	204	386	498	498	316
B-T	316	814	610	386	316	–	0	0	–	–	–	–	386
B-A	702	–	316	–	204	0	–	–	0	0	0	0	–
B-S	–	0	814	702	–	–	814	702	–	–	–	–	0
T-S	0	–	204	–	0	498	–	–	590	884	996	884	–
Mel.													

(a) Templet:

$$\frac{\text{impu'ty count}}{\text{duration}} = \text{arpage}$$

(b) Temperaments:

$\frac{1}{4}$ comma meantone, Eb - G♯

A-S	0	6	6	6	5	0	5	0	41	5	5	41	5
T-A	–	6	5	0	–	5	5	5	10	1	35	35	46
B-T	5	0	30	1	5	–	0	0	–	–	–	–	41
B-A	5	–	47	–	10	0	–	–	0	0	0	0	–
B-S	–	0	41	5	–	–	0	5	–	–	–	–	0
T-S	0	–	11	–	0	5	–	–	31	6	30	6	–
Mel.													
a.l.	10	12	140	12	20	10	10	10	82	12	70	82	92

$$\frac{470 + (92 \times 4)}{16} = \frac{838}{16}$$

arpage = 52·375

$\frac{1}{4}$ comma meantone, G - B♯

A-S	0	6	6	6	5	0	5	0	0	5	5	0	5
T-A	–	6	5	0	–	5	5	5	10	1	6	6	5
B-T	5	0	11	1	5	–	0	0	–	–	–	–	0
B-A	5	–	6	–	10	0	–	–	0	0	0	0	–
B-S	–	0	0	5	–	–	0	5	–	–	–	–	0
T-S	0	–	11	–	0	5	–	–	10	6	11	6	–
Mel.													
a.l.	10	12	39	12	20	10	10	10	20	12	22	12	10

$$\frac{189 + (10 \times 4)}{16} = \frac{229}{16}$$

arpage = 14·3125

Werckmeister, Correct No. 1.

A-S	16	16	6	16	16	10	6	16	22	0	0	22	0
T-A	–	0	16	0	–	16	16	16	0	16	0	0	22
B-T	16	16	16	16	16	–	0	0	–	–	–	–	22
B-A	0	–	22	–	0	0	–	–	0	0	0	0	–
B-S	–	0	16	0	–	–	10	0	–	–	–	–	0
T-S	0	–	0	–	0	6	–	–	22	16	0	22	–
Mel.													
a.l.	32	32	76	32	32	32	32	32	44	32	0	44	44

$$\frac{420 + (44 \times 4)}{16} = \frac{596}{16}$$

arpage = 37·25

Werckmeister, Correct No. 2.

A-S	6	6	0	14	6	6	8	6	30	0	0	30	0
T-A	–	0	14	0	–	14	14	14	8	6	8	8	30
B-T	14	6	14	6	14	–	0	0	–	–	–	–	30
B-A	8	–	22	–	8	0	–	–	0	0	0	0	–
B-S	–	0	22	8	–	–	6	8	–	–	–	–	0
T-S	0	–	8	–	0	8	–	–	22	6	8	22	–
Mel.													
a.l.	28	12	80	28	28	28	28	28	60	12	16	60	60

$$\frac{408 + (60 \times 4)}{16} = \frac{648}{16}$$

arpage = 40·5

If it were possible to apply a temperament to a templet and obtain a zero arpage, it would mean that the piece of music concerned could be performed with absolute acoustic purity: $\frac{0}{x} = 0$ arps. It follows that the smaller the arpage, the greater is the suitability of a particular temperament for a particular piece, and musically, the less should be the aural roughness. Figure 82(a) shows a templet of the final bars of Froberger: Ricercar 6. Figure 82(b) shows corresponding absonances, impurity counts and arpages for four different temperaments. It is unnecessary to show the interim stage of the tempered intervals. Quarter comma meantone in the disposition E♭ - G♯ is without question the most unsuitable, for obvious reasons. The temperament does not contain the notes D♯, E♯ and B♯, all of which are required by the music. There is, however, one mitigating factor in the penultimate frame. The major sixth D♯ - B♯ is a sheep in wolf's clothing, none other than E♭ - C of the temperament, and at least as far as that isolated interval is concerned, quite innocuous. If the same temperament is shifted four fifths to the sharp side to the range G - B♯, then all the notes are available with a startling improvement in the arpage. The performances of the two Werckmeister temperaments are much more dissonant than the previous temperament, but consistent with Werckmeister's policy of sacrificing the purity of the less familiar triads for the greater purity of the more familiar triads. When the two Werckmeister temperaments are compared, the arpages in no way contradict Murray Barbour's opinion of 'Correct No.2': "This is the poorest of the three temperaments Werckmeister called 'correct'". (18)

Templets can be prepared, and arpages calculated for complete pieces of music of any length, but a templet for a section may be required, and under certain circumstances may be essential. This is usually the case where the duration unit has to be changed during the course of the piece. Baroque pieces, such as ricercari and canzoni, sometimes have sections of metrical change, such as a change from $\frac{4}{4}$ to $\frac{3}{2}$ or to a compound metre. The templet draughtsman has four courses of action:

(1) To give independent arpages for the new section, and to forego an overall arpage.

(2) To continue with the unit of duration unchanged during the new section.

---

(18) J.M.Barbour: Tuning and Temperament, p. 159.

(3) To adopt a new unit of duration for the new section.

(4) In the case of (a) a change from an undotted to the same unit dotted, or, (b) a metrical change in the ratio 2:3, with no change in the overall duration of a complete bar, then in each case the total duration of the new section should be multiplied by $\frac{2}{3}$, since the section is $\frac{2}{3}$ its nominal length. To choose (1) begs the question. To choose (2) or (3) may lack objectivity. The decision may be unchallengeable. Choice (4) is the only acceptable solution. The mathematical integrity of the method demands numerical compensation for the change of metre. This requires us to know the mathematical relationship between the two metres.

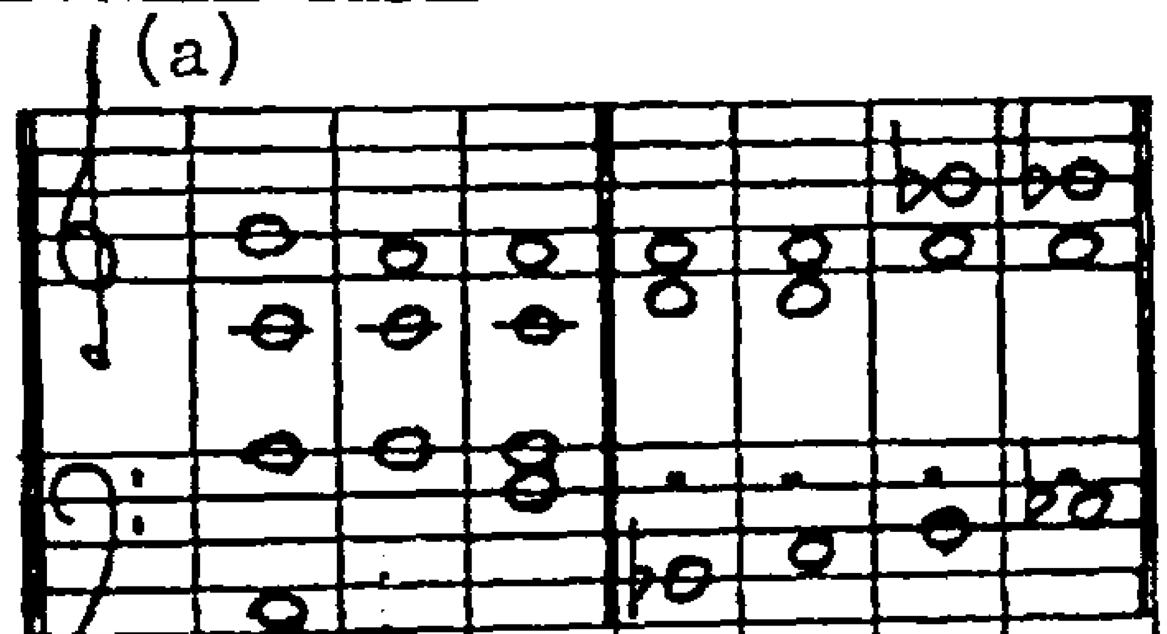
Expedient Templet-Changes.

The factual content of a templet is absolutely explicit, but the visual aspect lacks the contextual clarity and legibility of a score. A blue print is not the finished article. There may be opportunity, where there is a repetition of congruent frames, to compress repeated frames into a single frame of a longer duration. (Congruent frames contain the same notes. The position of the notes and duplication can be ignored.) Figure 83 shows how seven frames over a period of two bars can be compressed into five frames over the same period. The pairs of congruent frames x and y may be entered as single frames x' and y', provided that the duration is adjusted. The templet is shown at (a) strictly in the interval order of the score, and at (b) with templet compression applied. The results of the arpage calculations (in this instance for quarter comma meantones temperament) are identical.

The making of a templet for one of Froberger's ricercari is a comparatively straightforward exercise, because the voices behave like vocal voices. The scores of the toccatas, however, show more idiomatic keyboard writing. Firstly, they contain a considerable amount of written out melodic decoration of a repetitive kind. It is possible to condense the number of alternating identical frames within a beat or a half bar into two frames of duration equal to the total duration of the repeated identical frames. The harmonic progression is still apparent and the result unimpaired. Secondly the toccatas, like the suites, do not keep rigidly to a number of voices, but it is

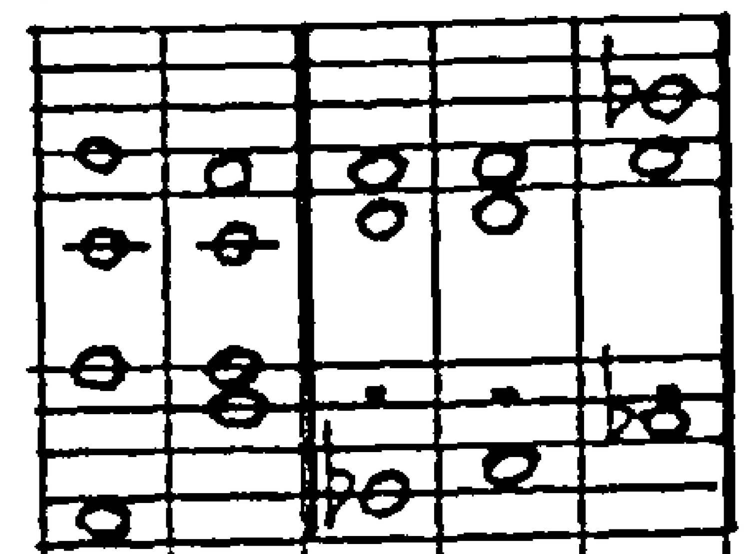
Figure 83. <u>Templet Compression.</u>

(a)



Dur.	2	1	1	1	1	1	1
A-S	702	498	498	316	316	498	498
T-A	316	316	316				
B-T	0		386				
B-A	-		-	386	204	316	204
B-S	996		0	702	498	814	702
T-S	-	814	-				
Mel.							
		x	x	y		y	

(b)



2	2	2	1	1
702	498	316	316	498
316	316			
0	386			
-	-	386	204	204
996	0	702	498	702
-	-			
	x'	y'		

¼ comma meantone

Eb - G#

A-S	5	5	5	6	6	6	6
T-A	6	6	6				
B-T	0		1				
B-A	-		-	0	0	6	11
B-S	11		0	6	11	0	5
T-S	-	1	-				
Mel.							
a.l.	22	12	12	12	17	12	22
		x	x	y		y	

5	5	6	6	6
6	6			
0	1			
-	-	0	0	11
11	0	6	11	5
-	-			
22	12	12	17	22
	x'	y'		

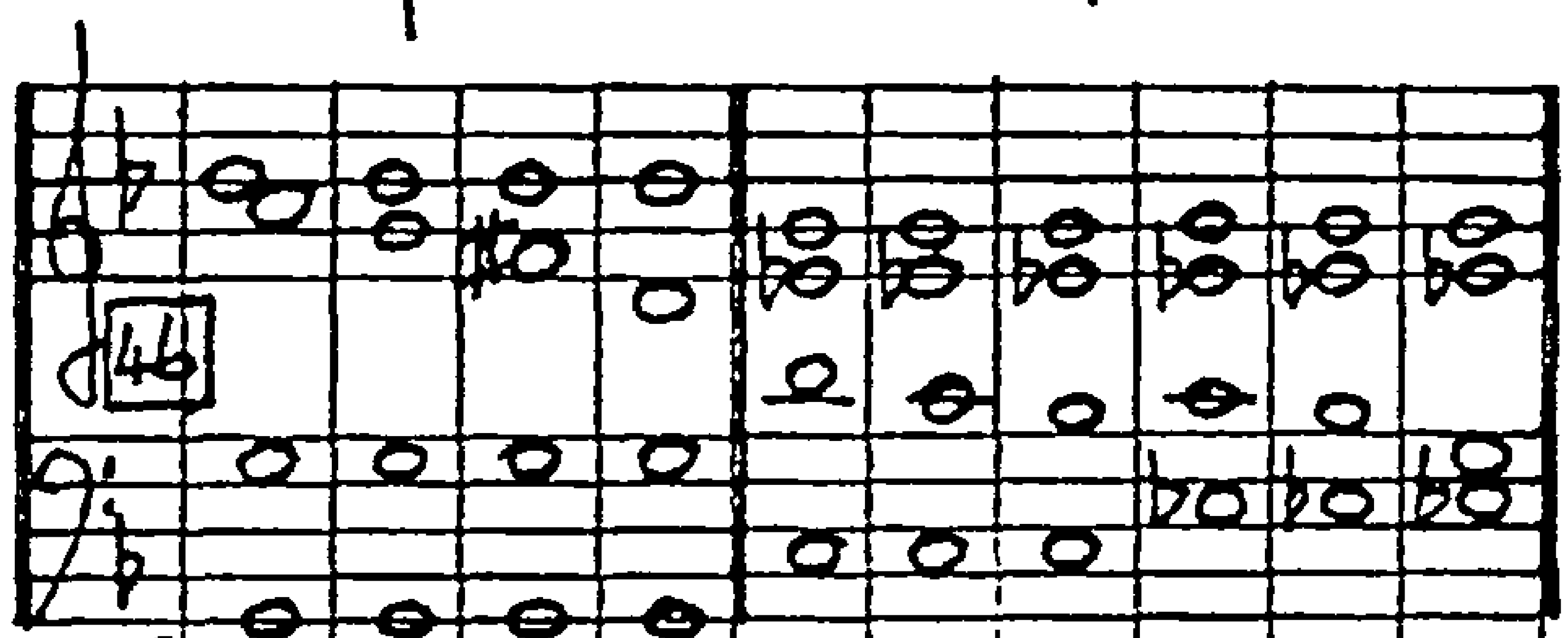
impurity count $44 + 12 + 12 + 12 + 17 + 12 + 22 = 131$ $44 + 24 + 24 + 17 + 22 = 131$

$\frac{131}{8} = 16{\cdot}375$ arpage $\frac{131}{8} = 16{\cdot}375$ arpage

still possible to conceive the score structure in voices for templet purposes. Occasionally five-note (ten-interval) frames are required, but if note doubling occurs, these can be avoided without unfaithfulness to the interval layout by omitting a doubled note and perhaps making an octave adjustment of another. The telescopic effect of the above expediencies is made clear from the following example.

Figure 84. <u>Templet expediencies.</u>

Froberger: Toccata 6.
(bars 46 - 47)



Dur 𝄞	5·5	4	3·5	3	5·5	2	·5	2	3	3
A-S	112	316	427	814	386	386	386	386	386	386
T-A	204	498	1088	702	112	316	498	316	498	-
B-T	0	0	0	0	204	0	996	-	-	-
B-A	-	0	-	-	316	-	316	0	0	0
B-S	316	-	316	316	702	702	702	-	-	-
T-S	-	-	-	-	498	-	884	702	884	0
Mel.										

The over-riding rule of templet compression is that compression should take place only within the bar. To attempt to compress frames from more than one bar at a time - from adjacent bars, for instance - would very quickly create confusion.

Working definitions of the main components of temperament assessment are listed as follows:-

ABSONANCE:	The amount of deviation in a tempered interval from a pure interval, expressed in cents.
ABSONANCE LEVEL:	The sum of the absonance of a frame, without taking duration into account.
IMPURITY COUNT:	Absonance level x duration of frame.
ARP:	A unit used to express $\frac{\text{total impurity count}}{\text{total duration}}$
ARPAGE:	The average amount of absonance per duration unit expressed in arps.

The comma in music is a fact. Just-intonation is an ideal, neither aspired to unreservedly nor attained in performance. The vitality of string quartet sound results partly from judiciously or instinctively exploiting the tension caused by the comma. It may be distributed between a greater or a lesser number of voices, but it is still there. A quartet has the prerogative of placing it where and how it wishes. In a temperament the division of the comma is a fait accompli, and there lies the difference.

Templet construction is uninhibited by intonation problems. An apparent anomaly of two voices in unison plus or minus a comma it takes in its stride. That every frame does not dovetail is a reminder that a templet is a hypothetical arrangement of pure intervals, and not a recipe for consonant performance. It is certainly based on the assumption, however, that pure intervals, consonant or dissonant, are the only pitch standard. It rejects the implication that triads, like oases in a desert of dissonance and extraneous sound, are the only significant aural sensations in a piece of music.

The method of objective assessment cannot be proved, and cannot be proved to be the one and only way. It is not claimed that it is absolutely comprehensive; for instance, the procedure takes no account of the historical and justifiable belief that a struck suspension is more emphatic than a tied suspension or that an appoggiatura is more aurally disconcerting than a prepared discord.

Melodic decorations, indicated in a score by the usual signs and abbreviations, have been ignored. There may be ways of refining the procedure which should reveal themselves as the procedure is used. What is important is that the system works, and is based on logical argument. Perhaps the best that can be said for it is that here is a sensible method of temperament assessment which incorporates a minimum of subjective decision and a maximum of consistency.

The whole process is laborious and painstaking. It was conceived with nothing more than a pocket calculator as an aid. Any wide application was considered impractical because of the great number of calculations involved, even though the arithmetic was simple. My supervisors saw and demonstrated to me that at least after the templet stage, the calculations could all be done by computer. Once the templet information is stored as computer data, any temperament can be applied and results can then be analysed and compared. The computerisation of the process is fully described in Appendix 3.

CHAPTER 10.

AN ANALYSIS OF THE COMPUTER CALCULATIONS.

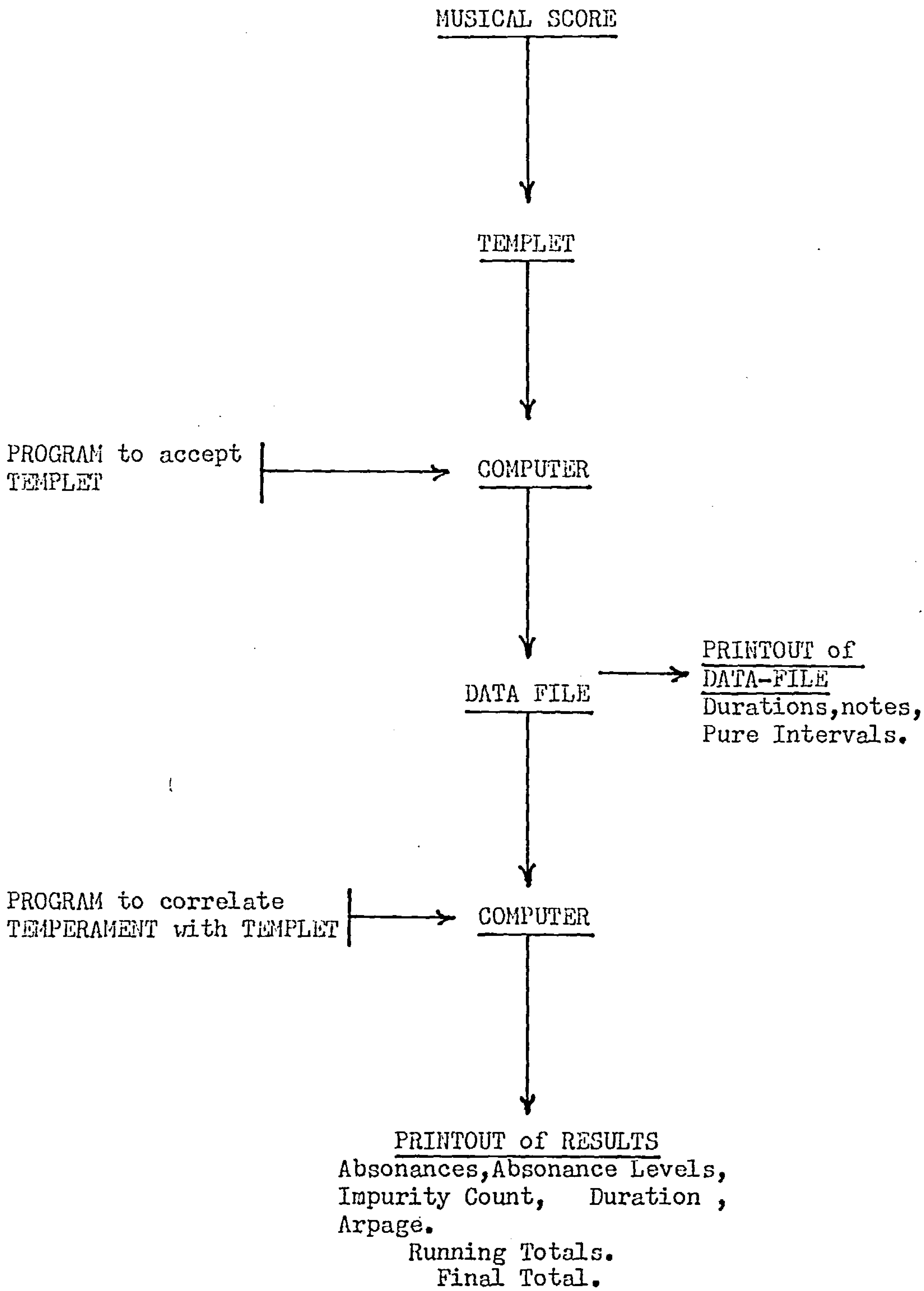
Detailed and specific information on how the results have been and can be obtained is given in Appendix 3, a manual explaining the computer's function and the procedures required. An outline of the basic procedure, however, seems to be called for at this juncture to give credibility to quite a complicated sequence of events. There are three basic stages.

1) Templet. For every musical work or part of a work a templet is prepared from the score, as outlined in Chapter 9. The templet may be complete in itself, or may be divided into sections, which may be necessary because of a change of metre, speed or duration unit. There may be other, non-musical reasons, such as convenience in processing, for dividing a templet into sections. The number of frames in a templet varies greatly; for instance, the templet of the sarabande of Froberger's Suite 26 has only 38 frames and is complete in itself; at the other extreme that of Fantasia 1 has 1007 frames divided into seven sections. The number of frames in a templet does not necessarily indicate the number of consecutive aural time exposures of a score, because of the thrifty expedient of templet compression (see Chapter 9, p. 187), but the number of frames does give an indication of the harmonic activity within a piece of music.

2) Data file of Templet. The templet is then translated in precise and exact detail into a format which the computer accepts and stores in its memory. Given the name 'data file', this templet information is then recorded on cassette tape and retained for the next stage, and future use. Printouts of all data files are retained for reference, although the templet and the original score provide the usual sources of reference at this stage.

3) Temperament applied to data file. The twelve cent-values which specify any required temperament are then fed into the computer. This is followed by the data file of any required templet, which is processed interval by interval, frame by frame, by the computer. The absonance of every interval and the absonance level of every frame is then printed out, corresponding exactly to the format of the (printed) data file and to the templet. Impurity count, duration, and, most important of all, arpage for the piece of music registered in a particular temperament is

Figure 85. The Steps from Musical Score to Arpage.



calculated, followed by running totals which include all previous sections of a piece. The totals of a section of metrical or duration-unit change are standardised to the tactus of the work before being added to the running totals. The ultimate results of impurity count, duration in standard units and overall arpage are printed after the completion of the processing of all the data files of a work. Figure 85 shows this procedure graphically.

The usual computer calculations are printed correct to nine significant figures. All arpages involve a final division calculation which only rarely works out exactly, and so are usually presented by the computer with two figures to the left, and seven figures to the right, of the decimal point, e.g. 14·7238041. In the analysis which follows, for the sake of clarity and memorability arpages will be presented correct to one place of decimals. Thus a computer arpage of 16·2896825 will be shortened to 16·3, with no loss of implication. Where several arpages need to be compared, these will usually be presented in diagrammatic form. Here the overall picture will be far more important than the individual arpages, but nevertheless, arpages can be shown correct to ·2 of an arp in this way. Absonance levels will also be presented in diagrammatic form, correct to one cent.

Froberger's music under scrutiny.

It is assumed that the reader is familiar with the contents of earlier chapters of this dissertation, for constant reference will be made to the temperaments described in Chapter 4, and the music of Chapter 7. We turn again to the music of Froberger to find out, not only how far objective assessment confirms speculation, but whether new light can be shed on a composer whose music was written during a period of temperamental change. The whole of Froberger's known music is available, but a selection has had to be made, although there are no practical reasons against processing the complete works, apart from economy of time and materials. A purposeful, rather than a random, selection has been made in order to cover the extent of Froberger's musical language. All the music selected can first of all be classified unequivocally as either organ music or harpsichord music, but not both. This classification will be helpful when an attempt is made to ascertain the most suitable and likely temperaments for Froberger's music. If the arpages of the organ and harpsichord music show marked differences for the same temperaments, we may conclude that he anticipated the use of different temperaments for the two different instruments. Although it is comparatively quick and easy to change the tuning of a few notes on a harpsichord, this sort of expedient is impossible on an organ without the mechanical contrivances discussed in Chapter 5. From the organ music at least one work in every mode and transposition, and at least one work in each genre - canzona, toccata etc. - has been processed. In order to obtain results from a large and homogenous group of pieces, eight of the fourteen ricercari have been processed. Thus both token and broadly-based evidence is examined. From the harpsichord music, at least one suite in most of the keys in which Froberger wrote has been processed. Suites in D major and G minor have yet to be investigated, although the results of suites in A major, B minor and C minor should partly compensate for these omissions. All the pieces which contain the extremes of Froberger's tonal vocabulary, and pieces which have some consistent unique quality have been processed. For instance, Fantasia 8 is included because it is Froberger's only work written exclusively for two voices. Lastly, although it is usually impossible to date Froberger's work precisely, an attempt has been made to choose works which span his active musical life. Date and locality of a work's first performance may be significant for ascertaining temperaments used.

<u>The arrangement of a printout of results.</u>

The computer calculations are printed frame by frame, in the precise order of the templet. The interval absonances and absonance levels usually show consistent patterns, according to the temperament or type of temperament used. For instance, the figures derived from Pythagorean temperaments show zero absonances, which denote pure intervals, and absonances of 22, the size of the Syntonic comma, which is the difference between a Pythagorean and a pure major or minor third. For Pythagorean temperaments with schisma fifths their absonances will sometimes be modified by 2, the size in cents of the schisma. Probably the commonest absonance level to be found in quarter comma meantone printouts is 11 plus or minus 1, that of a major or a minor triad. The figures of equal temperament printouts abound in absonances of 2, 14 and 16, denoting respectively the equally tempered fifth, major and minor thirds. Irregular temperaments are reflected

Figure 86. Specimen Printout of Results: a Pythagorean Temperament.

FRAME	A - S	T - A	B - T	B - A	B - S	T - S	TOTAL
	0	22	22	0	0	0	44
	22	-	-	0	0	-	22
	0	-	-	22	22	-	44
	0	-	-	22	22	-	44
	22	0	0	0	0	22	44
	22	0	0	0	0	0	22
	22	0	0	0	0	0	22
300	22	-	-	1	22	-	45
	0	0	0	0	22	22	44
	22	0	22	0	0	0	44
	0	22	22	0	22	0	66
360	0	22	22	0	22	22	88
	0	22	22	22	22	0	88
	0	0	0	0	0	0	0
	22	22	0	0	0	0	44
	-	-	-	-	0	-	0
	0	22	22	0	0	0	44

DATAFILE :- SUITE12S STARTING AT FRAME 293
NAME OF TEMPERAMENT :- PYTHAGOREAN, HUGO v REUTLINGEN, 1488

IMPURITY COUNT = 2905
DURATION = 72
ARPAGE = 40.3472222

TOTAL IMPURITY SO FAR = 2905
TOTAL DURATION SO FAR = 72
TOTAL ARPAGE SO FAR = 40.3472222

Figure 87. Specimen Printout of Results: Quarter Comma Meantone Temperament.

FRAME	A - S	T - A	B - T	B - A	B - S	T - S	TOTAL
	5	5	0	0	0	0	10
	0	-	-	0	0	-	0
	5	-	-	0	5	-	10
	6	-	-	0	6	-	12
	1	5	0	0	0	6	12
	6	0	0	0	0	0	6
	1	0	0	0	0	0	1
300	10	-	-	11	0	-	21
	11	6	5	11	0	5	38
	0	5	5	0	0	0	10
	11	6	1	5	6	5	34
360	11	5	10	5	6	6	43
	11	6	5	11	0	5	38
	11	5	0	0	6	0	22
	6	0	0	0	6	0	12
	-	-	-	-	0	-	0
	5	5	0	0	0	0	10

DATAFILE :- SUITE12S STARTING AT FRAME 293
NAME OF TEMPERAMENT :- QUARTER COMMA MEANTONE, Eb - G#

IMPURITY COUNT = 1250.375
DURATION = 72
ARPAGE = 17.3663194

TOTAL IMPURITY SO FAR = 1250.375
TOTAL DURATION SO FAR = 72
TOTAL ARPAGE SO FAR = 17.3663194

Figure 88. Specimen Printout of Results: Equal Temperament.

FRAME	A – S	T – A	B – T	B – A	B – S	T – S	TOTAL
	2	16	14	0	0	0	32
	14	–	–	0	0	–	14
	2	–	–	14	12	–	28
	2	–	–	14	16	–	32
	14	2	0	0	0	16	32
	16	0	0	0	0	0	16
	14	0	0	0	0	0	14
300	10	–	–	5	14	–	29
	4	2	2	4	14	16	42
	14	2	16	0	0	0	32
	4	16	14	2	16	2	54
360	4	12	10	2	16	16	60
	4	16	16	10	14	2	62
	4	2	0	0	2	0	8
	16	14	0	0	2	0	32
	–	–	–	–	0	–	0
	2	16	14	0	0	0	32

DATAFILE :- SUITE12S STARTING AT FRAME 293
NAME OF TEMPERAMENT :- EQUAL TEMPERAMENT

IMPURITY COUNT = 2221.75
DURATION = 72
ARPAGE = 30.8576389

TOTAL IMPURITY SO FAR = 2221.75
TOTAL DURATION SO FAR = 72
TOTAL ARPAGE SO FAR = 30.8576389

in irregular absonances. Figures 86, 87 and 88 show the exact format of the printout, with final results. It is unnecessary to show the entire sarabande of Suite 12 in C major, which begins at frame 293, the suite being numbered from the beginning of the allemande. The characteristic patterns of interval absonances are easily recognisable.

Absonances and absonance levels.

Printouts are cumbersome; they are detailed, and often extend over hundreds of frames. Occasionally it is expedient to condense some particular aspect of the results into graphic form, whereupon they reveal overall significance hitherto unnoticed. Figures 89 (a), (b), (c) and (d) reduce some of the printout results of a Froberger sarabande to histograms showing the absonance level of every frame. Duration is ignored for the moment. In the actual templet (see Appendix 2 pp.440 - 441) the frames of the sarabande of Suite 19 in C minor are numbered from 223 to 299, but here they are numbered 1 to 77 for the sake of clarity. Each histogram has its own characteristic pattern. The absonance levels of most of the frames in each histogram lie below the 40 mark. Referring to Figure 89 (c), which shows the sarabande realised in equal temperament, most of its frames have absonance levels of 32; these show major and minor triads. Let equal temperament, then, be our yardstick. Many of the corresponding frames of Figures 89 (a) and 89 (b) show absonance levels of 11, plus or minus 1. The absonance level of a triad in quarter comma meantone temperament is about one third of that of an equally tempered triad. Many of the absonance levels of (a) and (b) are identical. These are relatively similar to the corresponding absonance levels of (c). These temperaments are regular, and here is visual evidence to prove it. There is regularity even about many of the remaining absonance levels. From a study of templet and absonance levels, most of the frames of (a) and (b) about the 20 cent mark contain three notes, but are not triadic; most of the frames about the 40 cent mark contain four different notes; most of the frames about the 5 cent mark contain two notes and refer either to a perfect fifth or a minor third.

Figure 89. (a) and (b)

Absonance Levels.

Suite in C minor, Sarabande.

77 frames

(a) (left)
Quarter-Comma Meantone,
Eb – G#.

(b) (right)
Quarter Comma Meantone,
Ab – C#.

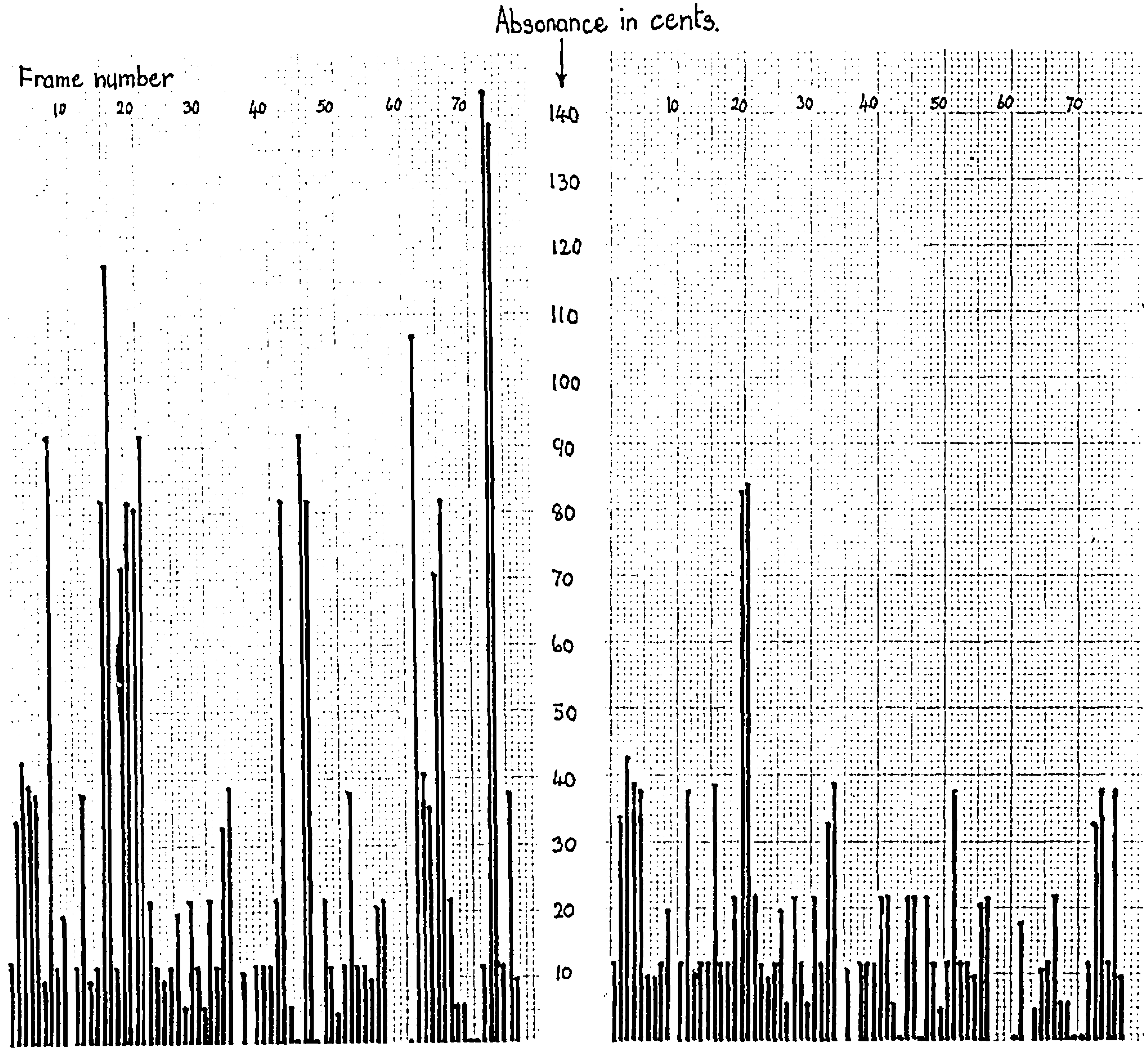


Figure 89. (c) and (d)

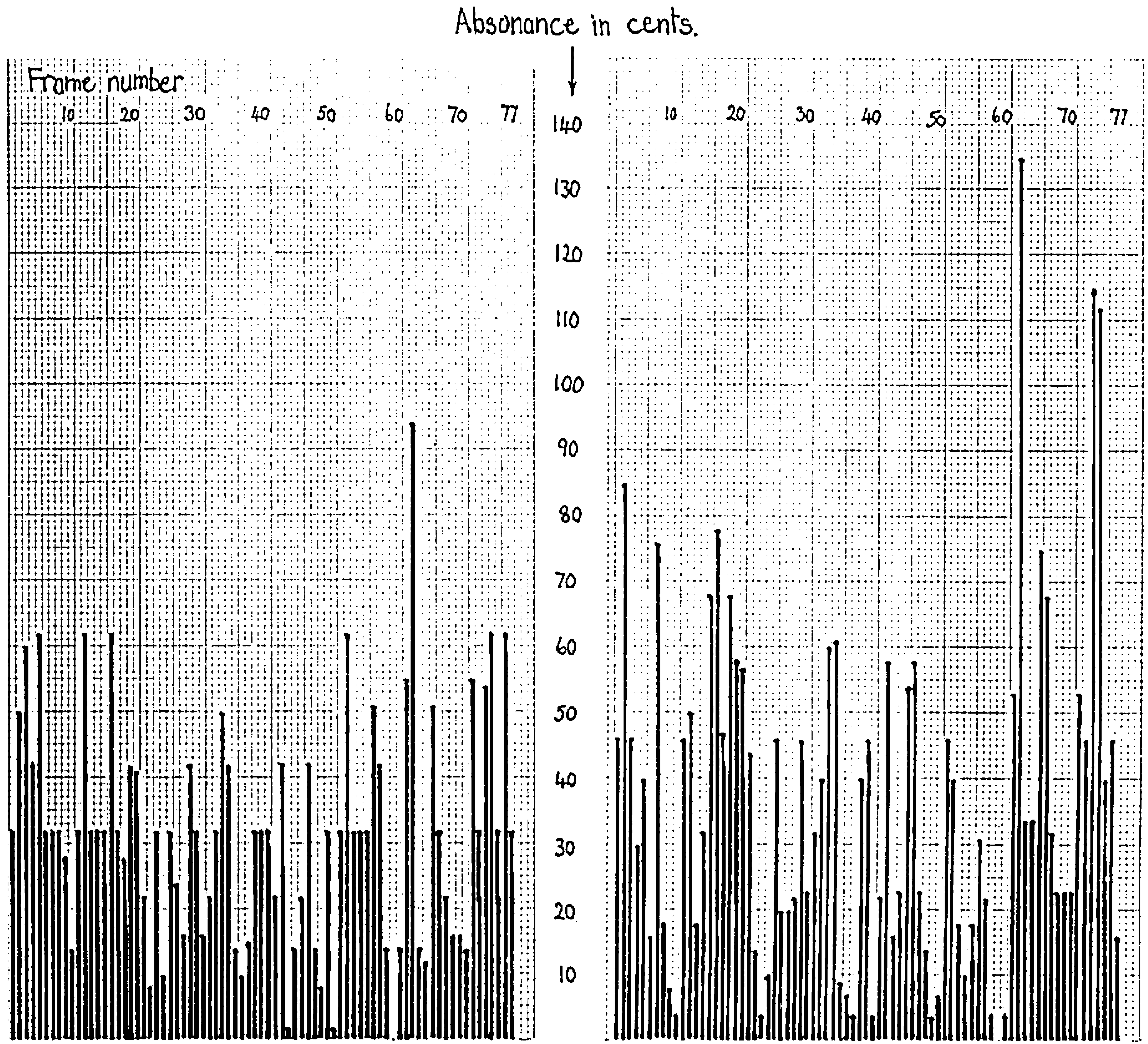
Absonance Levels.

Suite in C minor, Sarabande.

77 frames

(c) (left)
Equal Temperament

(d) (right)
Metius's Monochord.



Quarter comma meantone temperament, A♭ - C♯, covers the vocabulary of this sarabande, except for two frames when G♭ is required. There would be no point in taking the range a fifth further to the flat side, to D♭ - F♯, because that would exclude F♮, which is needed in the sarabande and elsewhere in the suite. Figure 89 (b) immediately reveals the damage done to the sarabande when F♯ has to substitute for G♭ (frames 19 and 20), but this range is the nearest that meantone temperament can get to a satisfactory realisation. Referring again to Figure 89 (a), the reason for the many outstanding frames with absonance levels well beyond the 40 mark is now evident: the disposition E♭ - G♯ has neither A♭ nor G♭. The C minor sarabande requires many A♭s, and the G♯ of the temperament can in no way substitute for this essential component of the tonality. This disposition is demonstrably unsuitable for the piece.

The figures of a printout immediately reveal the presence of a wolf or other interval overstepping the bounds of a regular and comparatively pure temperament, because the nearer the intervals of a temperament approach purity, the more absonance is collected in the wolves. This 'sore-thumb' principle is immediately apparent where, for instance, an 'expedient' diminished fourth, B - E♭ in quarter comma meantone, gives a sore-thumb absonance of 47.

On the positive side, Figures 89 (a) and (b) suggest that ears accustomed to quarter comma meantone temperament would accept absonance levels of up to 40 as normal. Figure 89 (c) shows a considerably higher threshold of toleration, and may indicate the main reason for the general rejection of equal temperament for keyboard instruments in the seventeenth century. The outstanding absonance level of frame 62 is caused by the absonances of six intervals, two of which have the greatest absonances in equal temperament; the augmented second and the diminished fifth, 25 and 27 respectively. The value of Figure 89 (d) is that it provides a contrast to the other three. Metius's monochord is an irregular temperament, published in Amsterdam in 1650. (1) The intervals generated by this

(1) A full description of the Metius system is to be found in Murray Barbour: Tuning and Temperament, pp. 177f.

monochord show great variety, depending on their location in the octave. This is demonstrated in the histogram. The absonance levels of the triads, in and around the key of C minor, show none of the consistency shown in the other diagrams.

In short, certain patterns of absonance occur in the printouts with such regularity that from them a principle can be formulated, axiomatic no doubt, but significant: the more notes of different names a frame contains, the greater will be the absonance level of that frame. A frame with four independent notes has six intervals and therefore six possible absonances. No four-note chord will ever have zero absonance.

Arpage: absonance and duration correlated.

The ground has sufficiently been covered to introduce the element of duration into the analysis, although further discussion of absonance will be undertaken as the need arises. Arpage is a new measure for which guidelines have been given, but as yet there is no conception of normality. Everyone can visualise the size of an average man or woman, and from that assess for themselves the size of any other person. Perhaps the best way to initiate a study of comparative arpages is first to consider those obtained from works run in equal temperament, the universal temperament of today. This is not as abstract and anachronistic as it appears, for Frescobaldi was one of the keyboard composers to advocate equal temperament, at least during part of his lifetime, and Mark Lindley is of the opinion that Froberger used equal temperament, but probably only during his later years. (2) Then having established a familiar base from which to work, we can explore the historical and more esoteric temperaments.

(2) "The influence of Frescobaldi's acceptance of equal temperament is apparent in the later music of Froberger, who was his pupil in Rome when the old Sicilian harpsichodist was there. Froberger was not the first to use equal temperament on keyboard instruments."
M. Lindley: 'Temperaments', The New Grove, vol.18 p.665.

Figure 90. Arpages of Selected Pieces: Equal Temperament.

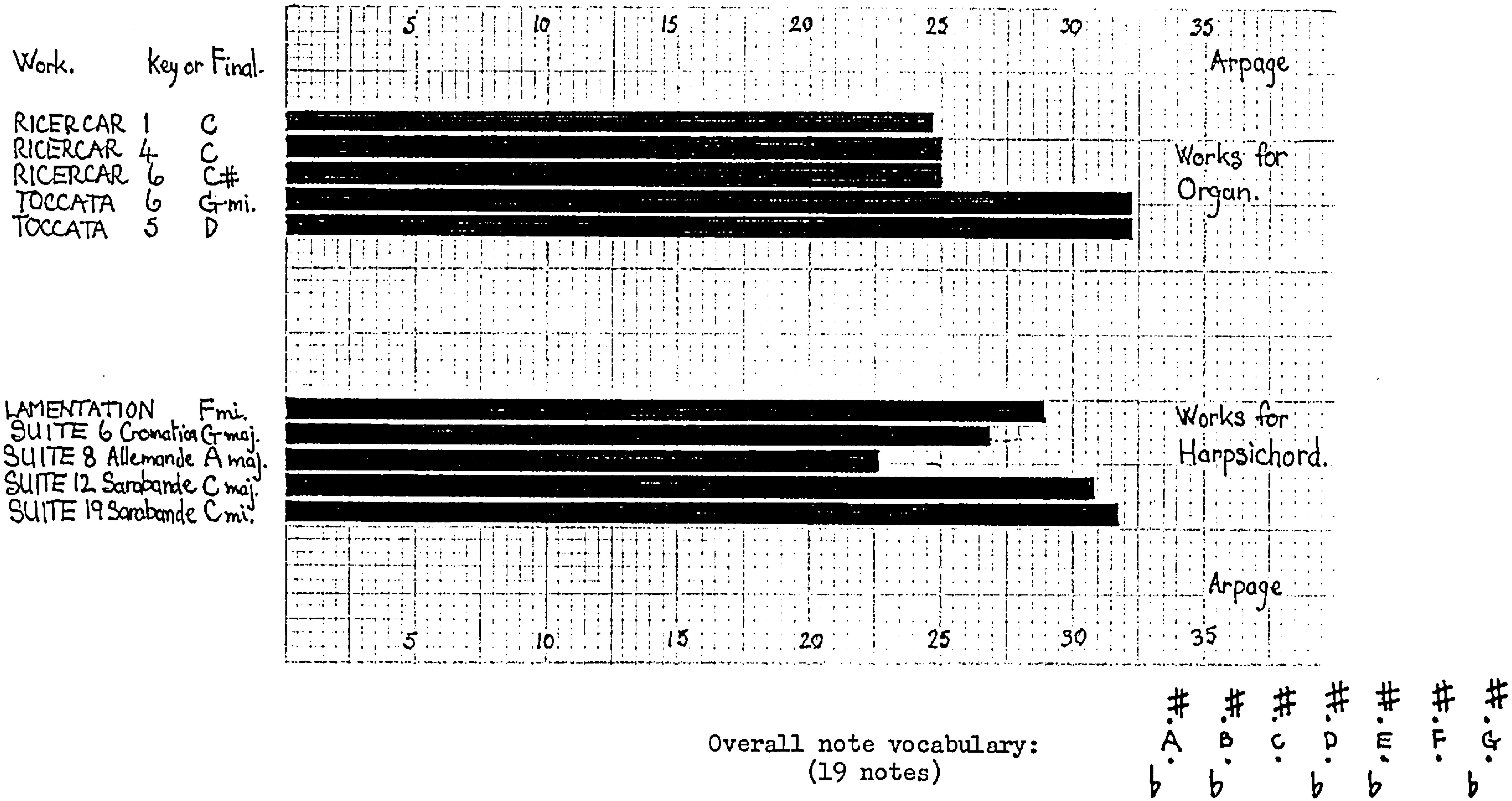


Figure 90 shows the arpages of a selection of Froberger's organ and harpsichord works run in equal temperament. All the works shown here are for four voices, although not all four voices may be sounding throughout. Together with other works and movements not shown here, these results reveal arpages consistently in the middle twenties and lower thirties. Bearing in mind that arpage is an absonance/duration quotient, some people may be surprised that the sophisticated human ear can tolerate the amount of intervallic impurity these figures suggest. Hitherto we have been content with a vague admission that equal temperament sacrifices consonance for versatility. A bargain, we have thought, and Faust-like have had no desire to assess the damage or count the cost. Our aural sensibilities have become blunted by our familiarity with its tonal impurity, but there need be little wonder that musicians of earlier times discounted it. The extent of the sacrifice is shown in Figure 91 which gives a cent value for the absonances of all equally tempered intervals. For this purpose it is immaterial whether any interval is larger or smaller than its pure version.

Figure 91. <u>Equal Temperament: interval absonances.</u>

INTERVAL	Aug. 1	Mi. 2	Maj. 2	Aug. 2	Dim. 3	Mi. 3	Maj. 3	Dim. 4	Perf. 4	Aug. 4	
<u>ABSONANCE</u>	29	12	4	25	24	16	14	27	2	10	cents ± or
INTERVAL	8 Dim.	7 Maj.	7 Mi.	7 Dim.	6 Aug.	6 Maj.	6 Mi.	5 Aug.	5 Perf.	5 Dim.	

(The list of pure intervals is to be found in Figure 74.) The equally tempered fifth is a mere two cents absonant, but the major and minor thirds are each more than half a comma absonant, so that a major or minor triad in any position in the octave has an absonance level of 32. Figure 90, however, shows the balance redressed by the versatility of equal temperament. The temperament accommodates all nineteen notes required by the pieces in the diagram overall, and more if required. Perhaps chameleon-like is a better description of equal temperament than versatile. It can change its aspect as required to fit into its immediate harmonic environment. If each natural had four other dependent notes, flat, double flat, sharp, double sharp, it would find no difficulty in accommodating these 35 notes. The tonal centre is irrelevant as regards arpage. If a work in the key of C were transposed to any degree within the octave, the arpage would remain constant. Twenty-one templets, covering the whole key structure of Froberger's music were run in equal temperament. The limits of arpage were 23·7 and 33·8, with most of the arpages being between 25 and 30.

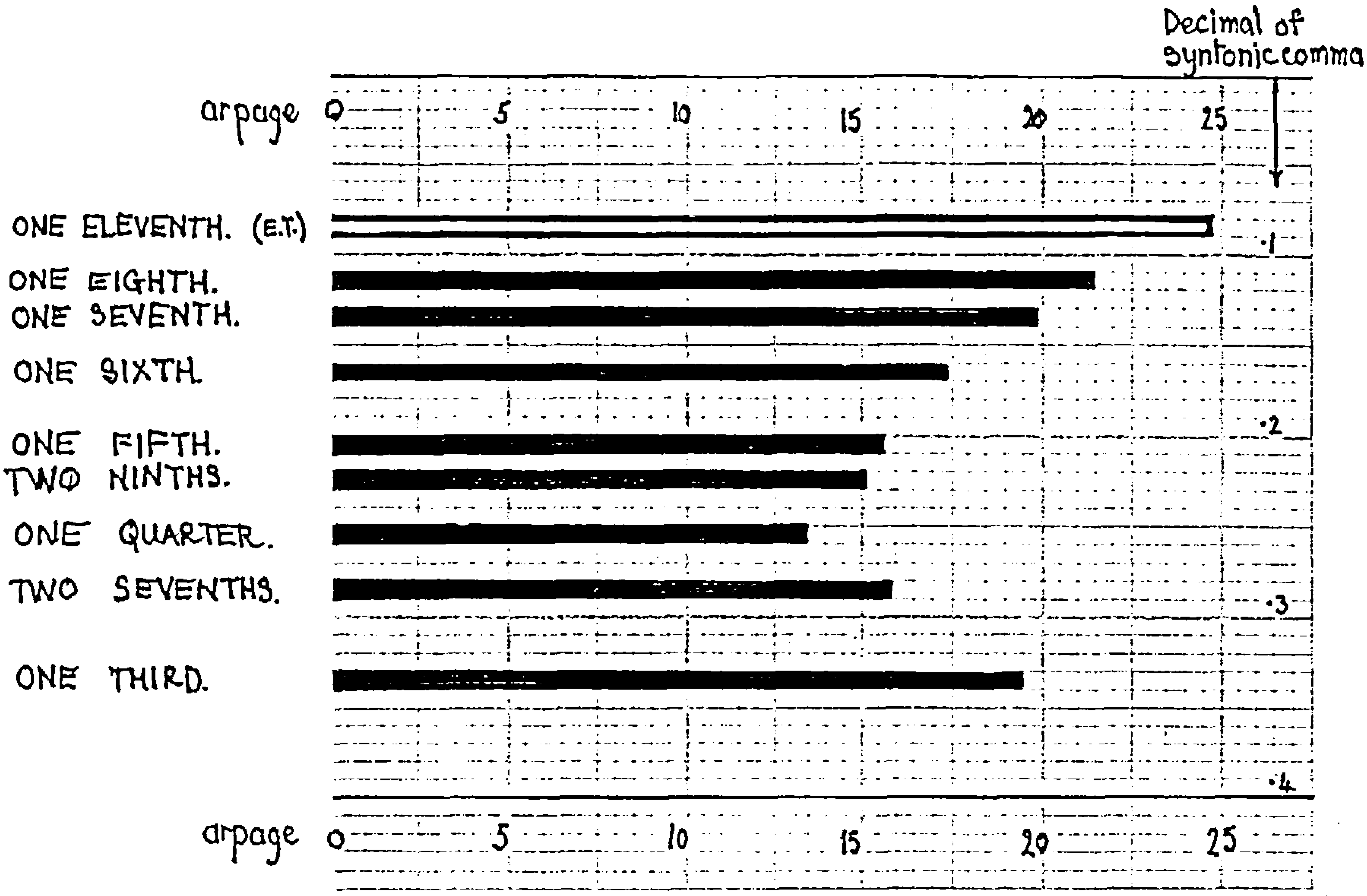
Present day solutions to problems are pragmatic and functional. To arrive is far more important than to travel safely. "Does it work ?" is far more important than "How does it work ?" or "Does it work well ?" This last question was asked by Baroque musicians concerning equal temperament, and because it failed to work very well - the arpages of Figure 90 can be used in evidence - it was set aside until it was really needed, for there were other more satisfactory temperaments for the music of the time. Once again present day musicians tend to think of an arbitrary division of the octave into twelve equal semitones, an immediate solution to an immediate need. That, I suggest, is observing a result, rather than finding a solution.

Arpages of regular meantone temperaments.

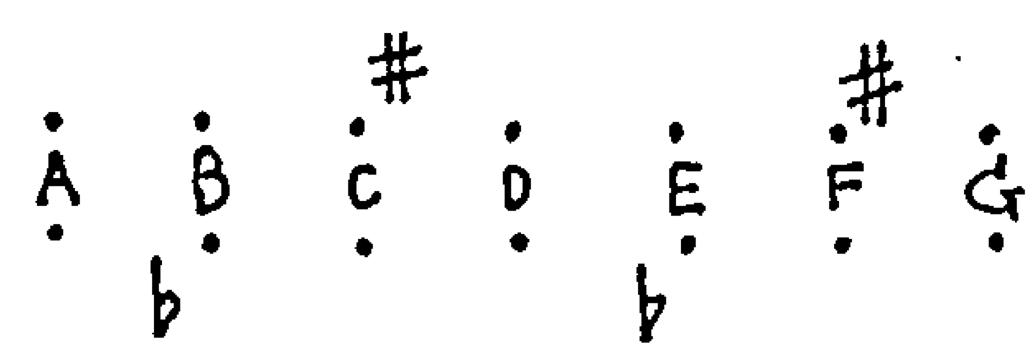
In order to relate the arpages of equal temperament to those of other regular temperaments, let us refer to equal temperament as one eleventh meantone temperament, where the wolf fifth and the rest of the fifths coincide at 700 cents. In each of the historically acceptable meantone temperaments there is always a wolf fifth to be avoided. There are always twelve unequivocal notes. Although their mathematical construction follows the same rules, their musical qualities vary from temperament to temperament. Within any particular temperament, however, all intervals of the same name are identical in size, and therefore identical in tonal quality.

Let us abstract the arpage of Ricercar 1 from Figure 90, and compare it with the arpages for Ricercar 1 in eight historical meantone temperaments. The results are shown in Figure 92.

Figure 92. Arpages of Regular Meantone Temperaments in use as far as the Seventeenth Century.



RICERCAR I.
Final: C
Key sig: ♭
Bars: 142
Duration: 568 ♩
Frames: 533



Note vocabulary: 11 notes.

Moreover, equal temperament is now seen in perspective. The diagram is graduated vertically to show accurately the division of the syntonic comma, from its smallest fraction at the top to its largest fraction at the bottom. It should be borne in mind that the SMALLER the fraction is, the LARGER are the sizes of the major third and perfect fifth. The first thing to notice is that all the arpages are considerably smaller than those of Figure 90. Not far from the middle of the historical fractions lies quarter comma meantone, remarkable in that it registers by a considerable margin the smallest arpage of the complete range. It lies at the nadir of an inverted triangle of absonance. It is here that the major thirds (and minor sixths) are pure, or have zero absonance, and it is this fact more than any other that accounts for the remarkably low arpage recorded. The diminished fourth (and

Figure 93.

Intervals:

MEANTONE ABSONANCES

Fractions of syntonic comma		1/8	1/7	1/6	1/5	2/9	1/4	2/7	1/3
UNISON	perf	0	0	0	0	0	0	0	0
	aug.	+24	+21	+18	+13	+9	+5	0	-7
SECOND	minor	-8	-6	-4	0	+2	+5	+9	+14
	major	-5	-6	-7	-9	-10	-11	-12	-14
	aug.	+18	+15	+10	+4	0	-6	-13	-23
THIRD	dim.	-17	-13	-7	-1	+4	+11	+18	+28
	minor	-14	-13	-11	-9	-8	-6	-3	0
	major	+11	+10	+7	+5	+3	0	-3	-7
FOURTH	dim.	-21	-18	-14	-8	-4	0	+7	+15
	perf.	+3	+3	+4	+4	+5	+5	+6	+7
	aug.	+6	+3	0	-4	-7	-11	-15	-21

correct to ± 1 cent

Inversions:

MEANTONE ABSONANCES

Fractions of syntonic comma		1/8	1/7	1/6	1/5	2/9	1/4	2/7	1/3
FIFTH	dim.	-1	-3	0	+4	+7	+11	+15	+21
	perf.	-2	-3	-4	-4	-5	-5	-6	-7
	aug.	+21	+18	+14	+8	+4	0	-7	-15
SIXTH	minor	-11	-10	-7	-5	-3	0	+3	+7
	major	+14	+13	+11	+9	+8	+6	+3	0
	aug.	+17	+13	+7	+1	-4	-11	-18	-28
SEVENTH	dim.	-18	-15	-10	-4	0	+6	+13	+23
	minor	+5	+6	+7	+9	+10	+11	+12	+14
	major	+8	+6	+4	0	-2	-5	-9	-14
OCTAVE	dim.	-24	-21	-18	-13	-9	-5	0	+7
	perf.	0	0	0	0	0	0	0	0

correct to ± 1 cent.

augmented fifth) also have zero absonance in quarter comma meantone, but that fact is less important because these intervals are met comparatively rarely. Above and below the quarter comma meantone line, the arpages increase regularly as the fraction of the comma becomes either bigger or smaller. As a means of explaining the regular pattern of Figure 92, Figure 93 shows the sizes of all meantone interval absonances, from which, in conjunction with the table of pure intervals, the size of any meantone interval can be worked out. Positive and negative absonance are cited in this instance, partly in order to facilitate the calculation of interval size, but also to show the progression from positive to negative absonance and vice versa, usually passing through absolute purity on the way.

Ricercar 1 is a fairly regular early fugue - some editions actually give it the name of fugue - whose style and treatment are representative of Froberger's contrapuntal organ music. The four voices combine and lapse in the usual manner. When the experiment of Figure 92 was carried out with a similar work, the same pattern of results was obtained, quarter comma meantone producing the lowest arpage (12·0) and one eighth comma meantone the highest (22·0). Equal temperament produced 24·7. On the strength of this evidence, and the arpage pattern of three other works shown below in diagrammatic form (Figures 98, 99, 100), a principle for the comparative arpages of regular meantone temperaments can be extracted: Arpage varies directly with the distance from quarter comma meantone temperament. Apart from any aesthetic considerations therefore, there are adequate factual consonantal grounds for Baroque musicians to use quarter comma meantone temperament in preference to the other regular meantone temperaments.

Meantone arpages of organ works.

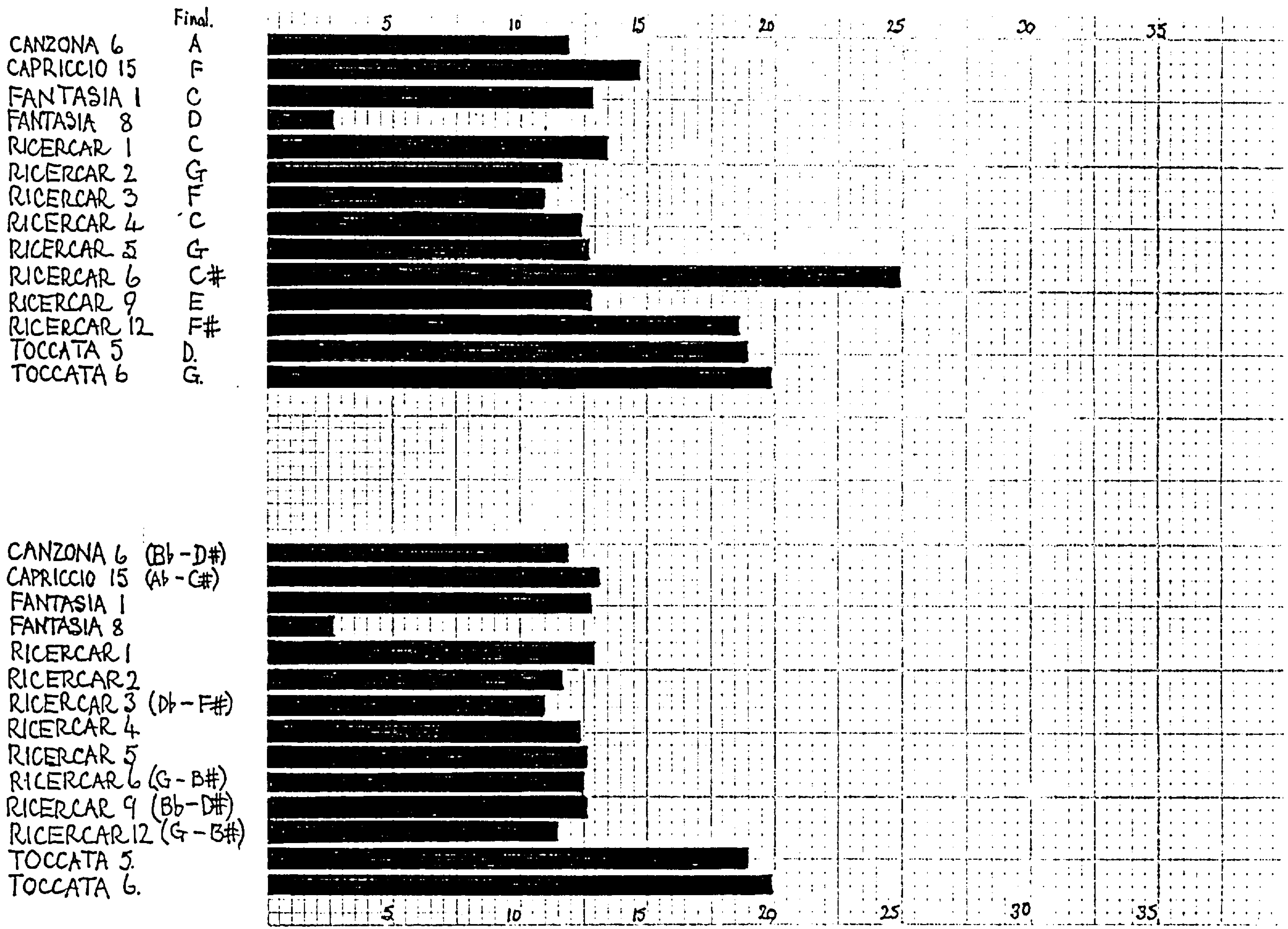
Figure 94 (a) shows the arpages of a selection of organ pieces run in quarter comma meantone, range E♭ - G♯, the range advocated by musicians and theorists of the period. Fantasia 8 can be ignored for the moment, because it contains only two voices, instead of the four of the remaining works. Apart from four other exceptions, the arpages lie consistently between 11 and 15. Of the four exceptions, the two ricercari lie outside usual modal practice; Ricercar 6 is tonally centred on C♯, Ricercar 12 on F♯. These step into line when, for the sake of argument, the meantone range is moved sideways to the G - B♯

Figure 94. Arpages of Organ Works.

(a) Run in Quarter-Comma Meantone, Eb – G#.

(b) Run in Quarter-Comma Meantone. (The most appropriate range)

Eb – G# unless otherwise stated.



position. This shift accommodates their note vocabulary, and consequently establishes their minimum meantone arpage. In Figure 94 (b) six of the works shown in Figure 94 (a) have been rearranged to show their minimum meantone arpage. Not only does it show the consistency of Froberger's musical language, but also suggests what is actually true, that the regular meantone for Froberger's organ music is in the range E♭ - G♮ by a large majority.

Maverick organ works.

Figure 94 (b) conceals the problem of Ricercari 6 and 12, and throws the problem of the two toccatas into sharp relief. The nearest we can get to dating the two ricercari is that they were probably written during the last ten years of Froberger's life, between 1658 and 1667, when he was a revered and much travelled virtuoso. The stylistic idiom of all the ricercari is remarkably consistent. They are obviously written for organ, and equally obviously not written for harpsichord, although a meantone disposition requiring four shifts to the sharp side accommodates them both. They could without difficulty be played on the harpsichord, but it is unlikely that they would be played on an organ with split keys for F/E♮ and C/B♮, besides the more usual ones. They are secular pieces in their own right; transposition would not be required to accommodate another instrument; they are scarcely written to be sandwiched between pieces in similar keys. For the moment they must remain a mystery.

The problem of Toccatas 5 and 6 are more clearly defined, because both toccatas were written expressly for the organ, to be played at the elevation of the host, and so the temperament, whatever it was, was fixed. We may expect their arpages to be on the high side because they require more than the twelve notes meantone temperaments supply, but so do four others of Figure 94, if only momentarily.

In order to discover a more appropriate temperament for the toccatas, a large section of the templet of each work was run in five other temperaments, the arpages of which are shown in Figures 95 (a) and (b). The arpage for these sections in quarter comma meantone temperament remains around the 20 mark, very slightly greater than for the complete works. Figure 95 shows that the arpages of the other

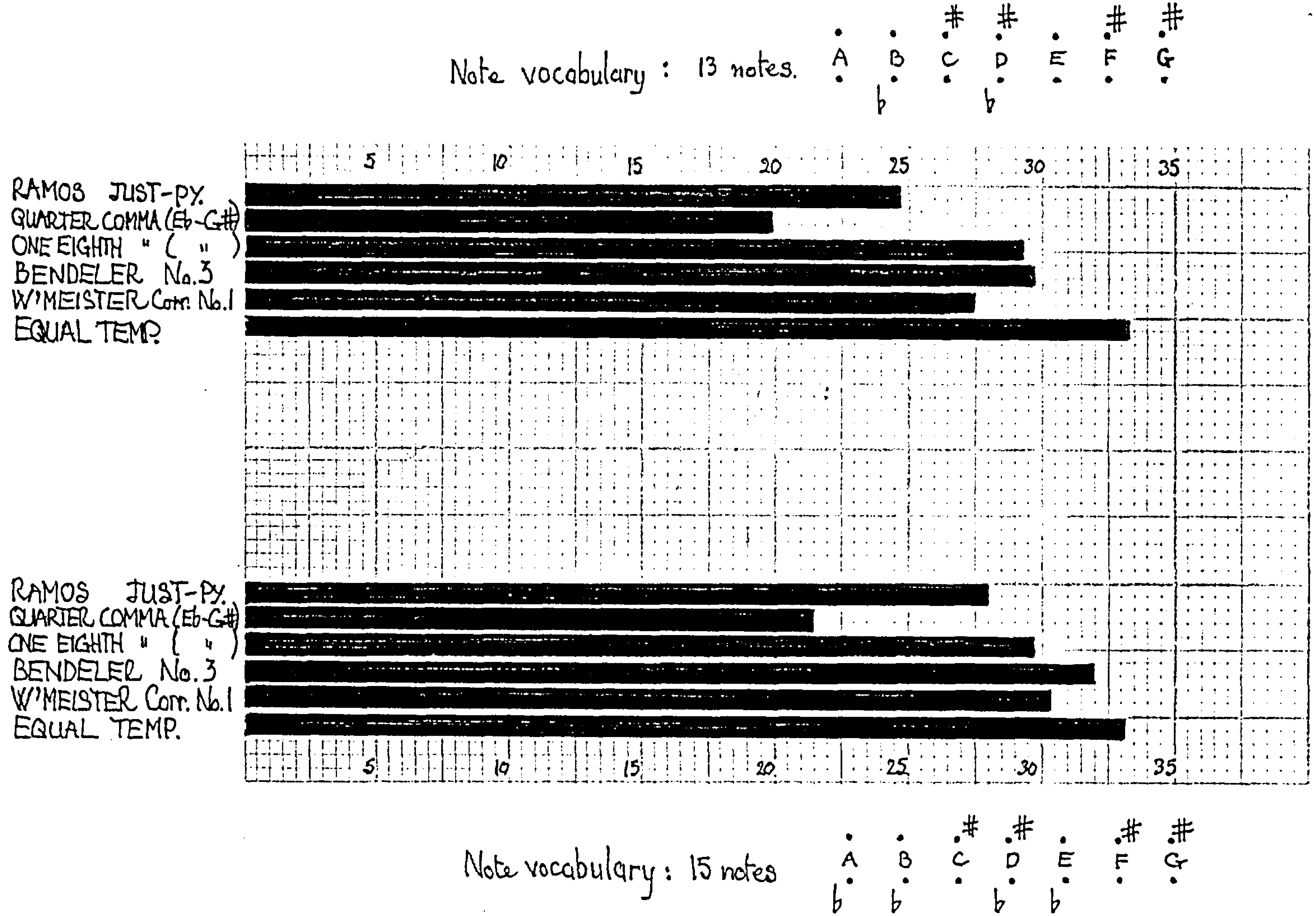
Figure 95. Comparative Arpages: Toccatas 5 and 6.

(a) Toccata 5.

Final: D, no key signature.
A section of 25 bars.
129 frames.

(b) Toccata 6.

Final: G, key signature ♭.
A section of 28 bars.
192 frames.



temperaments are all considerably greater than that of quarter comma meantone temperament. No evidence produced later in the chapter suggests that there is any temperament which, in the circumstances, will produce a lower arpage than this. Evidence of these two toccatas being written for an organ with split keys is not forthcoming. They both were written at the latest by 1649, and quite possibly some years before, during Froberger's years with Frescobaldi, who died in 1643. They may have been intended for an Italian organ which at that time was tuned to equal temperament. This conjecture raises further issues which must be faced later.

Meantone arpages of the harpsichord works.

The problem of changes of tempo, metre and duration unit within a templet (Chapter 9 pp. 186 f.) has been faced and solved in principle. An extended organ work, which contains these changes usually has also an underlying standard measure or tactus, to which temporal matters can be referred, and the computer programs have been made versatile to cope with these situations. On the other hand, it seems impossible to obtain an overall arpage for most of the harpsichord works, namely the suites, without imposing unnecessary and artificial sanctions, leading to dubious results. By nature, the individual movements of a suite are autonomous as far as tempo and metre are concerned, and it is for that reason that arpages are given for individual movements, rather than for suites as a whole. One does not average averages. Nevertheless, an overall picture of the arpages of a suite can be obtained by giving the arpage limits beyond which none of the movements of a suite go. For instance, the arpage limits of Suite 8 in A Major in quarter comma meantone, range B♭ - D♯, are 10·8 and 14·1, lowest and highest.

The arpages of selected harpsichord works run in quarter comma meantone, range E♭ - G♯ are shown in Figure 96 (a). It reveals a similar pattern of arpage diversity to that of Figure 94 (a). Figure 96 (b), which corresponds exactly to Figure 94 (b), shows how the arpage pattern becomes much more uniform, and within similar limits to those of Figure 94 (b), when the meantone range is altered to suit note vocabulary. Figure 96 (b) speaks more loudly than words on behalf of the interim retuning of domestic keyboard instruments.

Figure 96 (a) Arpages of Harpsichord Works: Quarter Comma Meantone Temperament, E♭ - G♯.

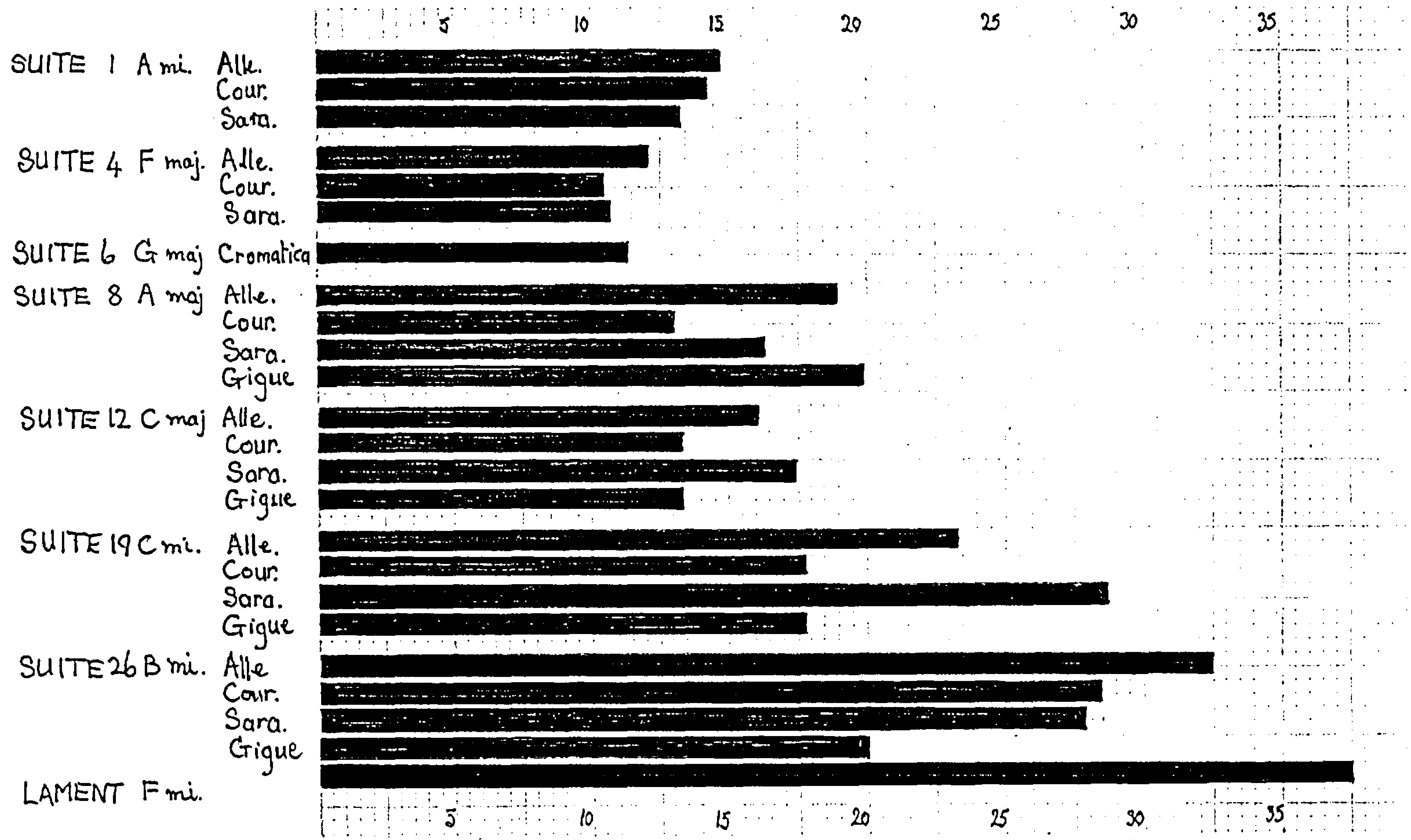
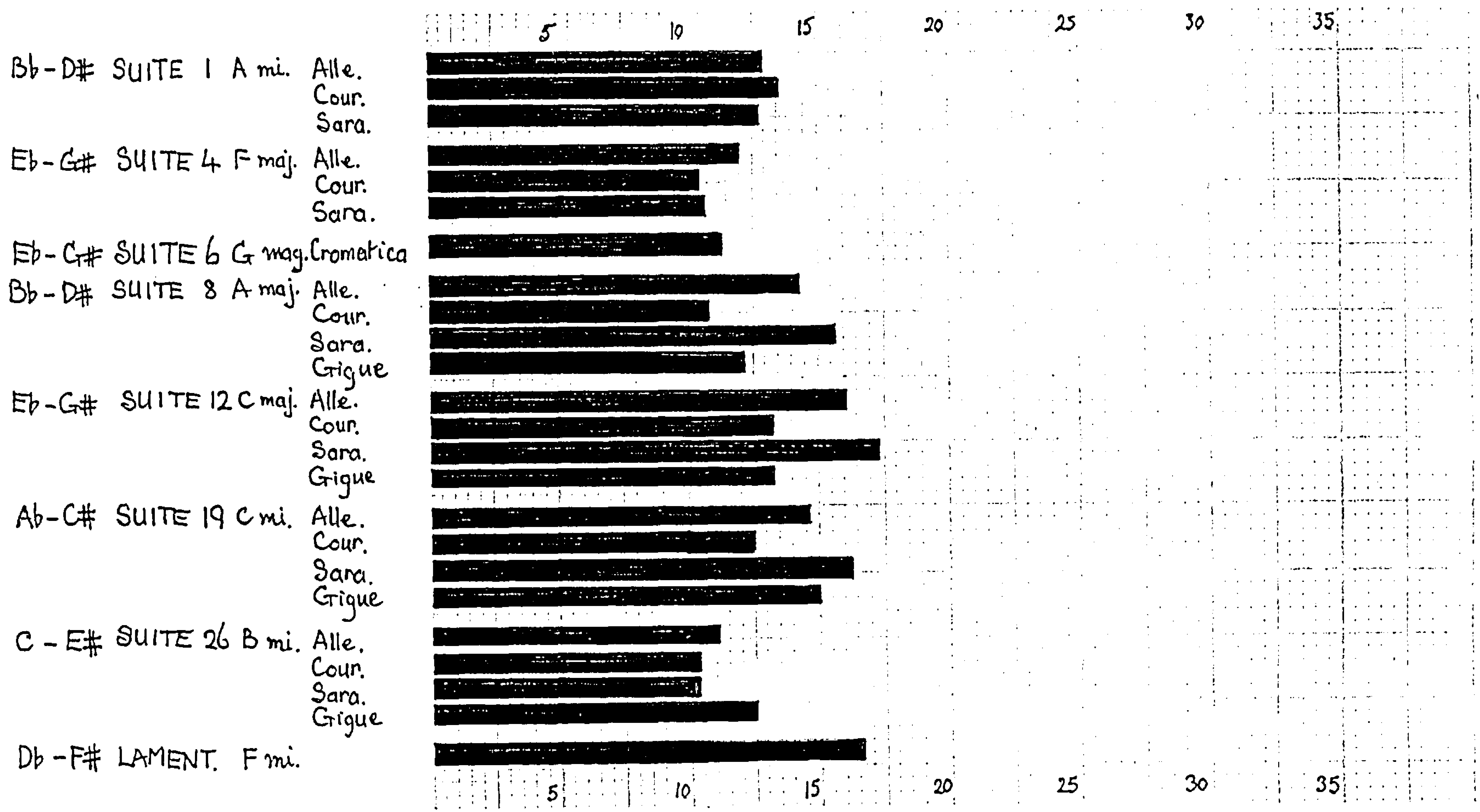


Figure 96 (b) Arpages of Harpsichord Works: Quarter Comma Meantone Temperament, in the most Appropriate Range.



Most harpsichordists tuned their own instruments, and there are strong grounds for thinking that where a regular meantone tuning was required, interim retuning was no less a standard practice than changing of crooks on the horn, or interim retuning of the tympani. (Details of the retuning required is to be found in Figure 62 p.125.)

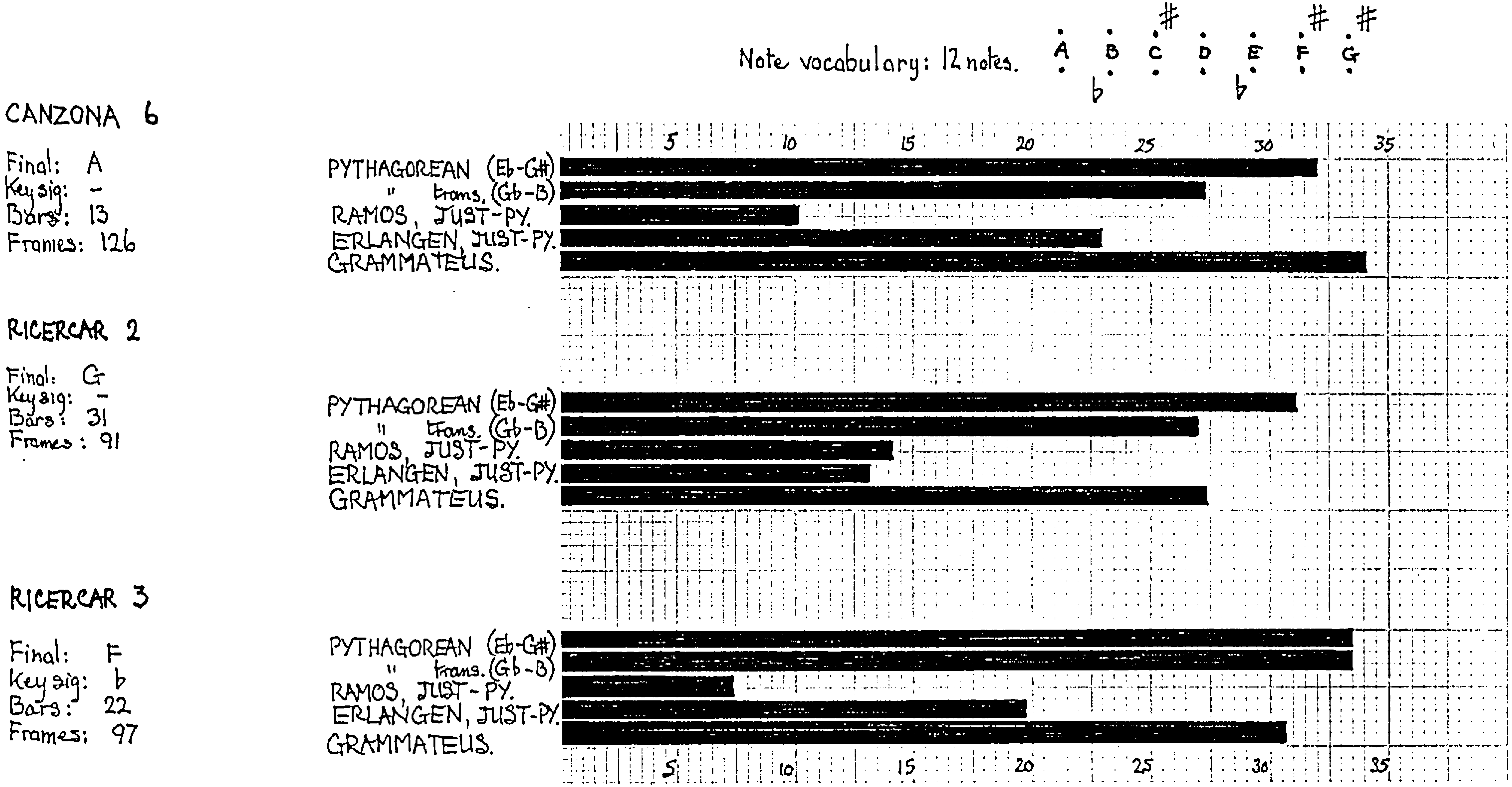
In a comparatively short movement, a foreign note can do more damage to the arpage than in a longer movement. The comprehensive table of Figure 93 fails to show the savage penalties which must be paid in absonance when a foreign note is introduced into meantone reckoning. Since the appropriate quarter comma meantone provides the lowest arpage, we may expect that in this temperament the penalties for stepping outside the twelve-note limit will be the severest. The wolf fifth has an absonance of 35, and any diminished fourth used as a substitute for a major third has an absonance of 41 or 42.

Arpage results of other historical temperaments.

In spite of these limitations, quarter comma meantone provided freedom compared with the Pythagorean-based temperaments it superseded. Its eight pure major thirds are indisputably an improvement over the four pure or near-pure thirds of the Pythagorean temperaments. Seventeenth-century keyboard music needed temperamental freedom to extend its expression beyond the modal system. Figure 97 shows arpages for sections of three Froberger organ works, run in five Pythagorean-based temperaments. Keys and note vocabulary chosen are typical of the organ music of the early Baroque period. With one exception, the arpages are greater than the majority of arpages in Figures 94 (a) and 94 (b). Ramos's temperament performs well here; indeed in comparable sections of other organ works, arpages in this temperament do not rise above 15·2, when the limits of the temperaments are observed. When the limits are overrun, as in Toccata 6 (arpage 26·6), Ramos's temperament can be as damaging as any other.

The erratic performance of Pythagorean-based temperaments is maintained when we consider the harpsichord music. Figures 98,99 and 100 have all the same format. Each diagram gives the arpages for a section of a work; Figures 98 and 99 for suite movements in and around the natural key, and Figure 100 for part of a work in the melancholy and feared key of F minor. Vertically the diagrams are divided very roughly into chronological order, the earliest temperaments at the top.

Figure 97. Arpages of Sections of Three Organ Works: Pythagorean and Just-Pythagorean Temperaments.



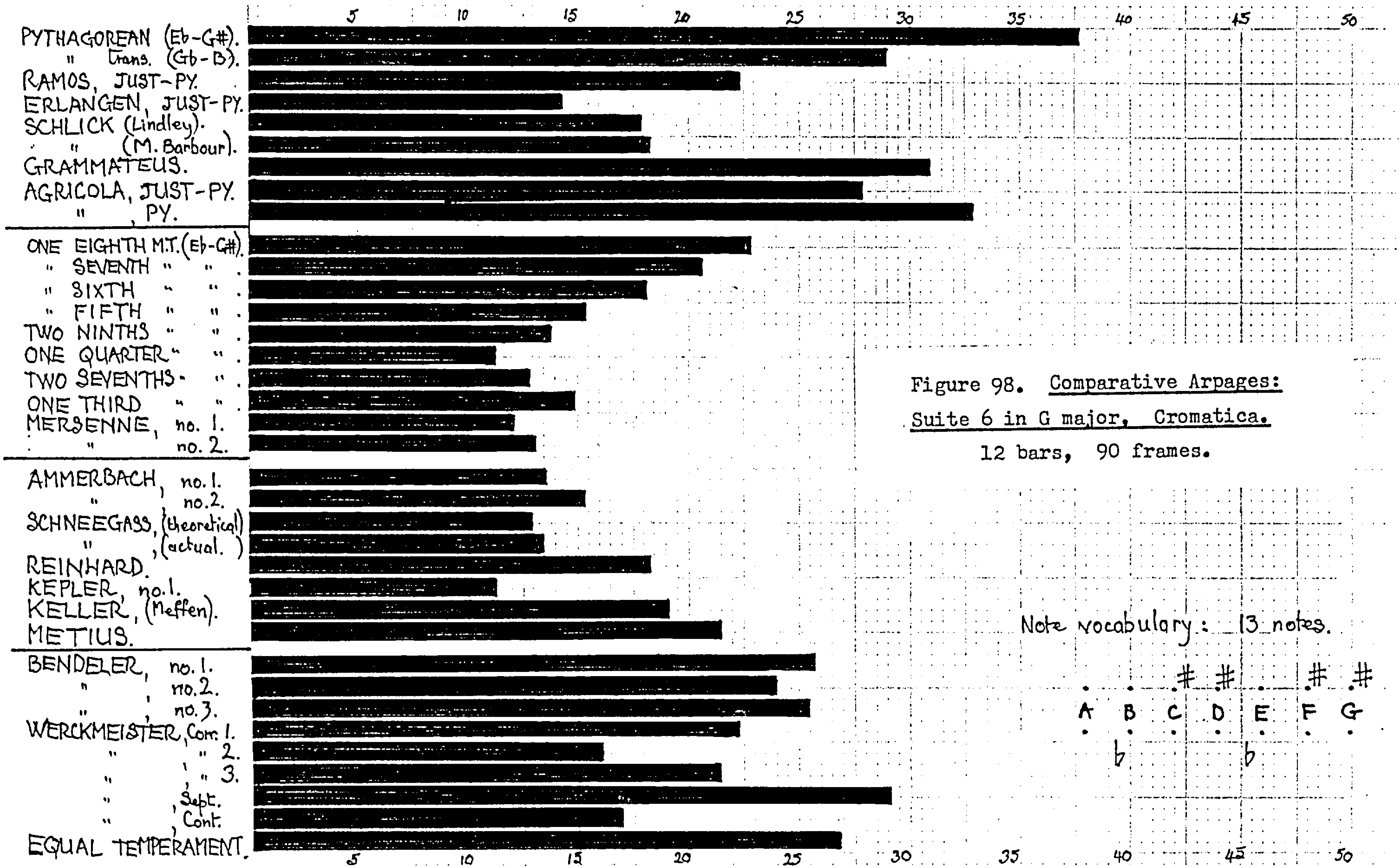


Figure 98. Comparative Arpages: Suite 6 in G major, Cromatica.

12 bars, 90 frames.

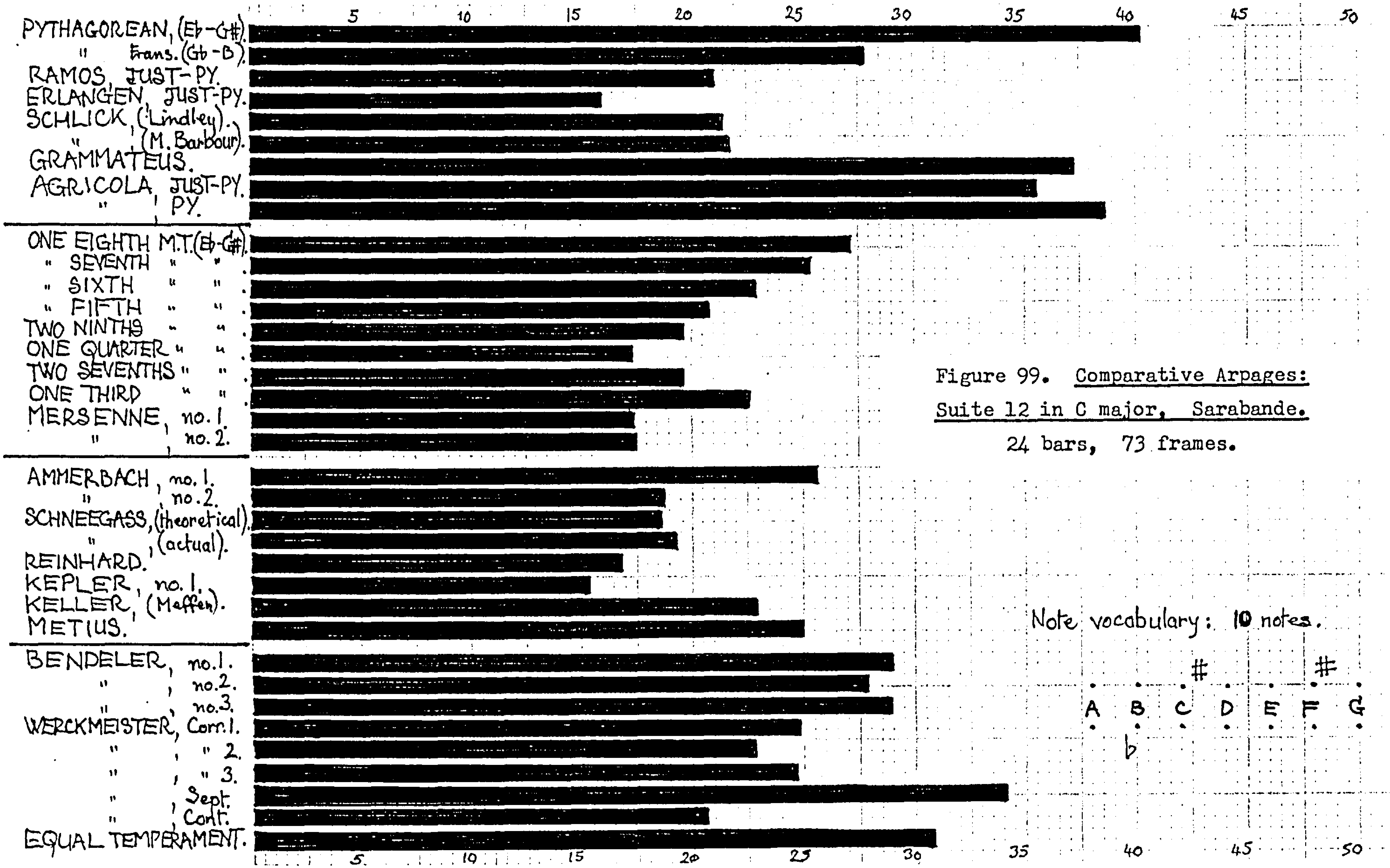


Figure 99. Comparative Arpages: Suite 12 in C major, Sarabande.

24 bars, 73 frames.

Figure 100. Comparative Arpages: Lamentation in F minor.

bars 14 - 24, 73 frames.

It must be emphasised that this order is no more than a general guide, since it has to serve a second purpose, in that the diagrams are also arranged into four categories of temperament, separated by spaces. The top group contains Pythagorean temperaments and Pythagorean/just-intonation hybrids. The arpages are mostly on the high side, but are very much dependent upon the note vocabulary, results which are entirely consistent with those of the organ works shown in Figure 97.

The second group from the top in each case is the only really homogenous group. It represents the arpages of regular quarter comma temperaments ranging from the smallest to the largest division of the syntonic comma. The pattern remains consistent with that seen in Figure 92. Attached to this group, for there is no more appropriate a position, are the two meantone modifications of Mersenne. In the cases of the suite movements, Mersenne's temperaments have very good results. Figures 98 and 99 show the usual note range of meantone temperaments, E♭ - G♯, but the range D♭ - F♯ of Figure 100 is the most appropriate range for the note vocabulary used. This range entails a shift of two fifths to the flat side from E♭ - G♯, and therefore G♯ is retuned to A♭, C♯ to D♭. This diagram presents the meantone temperaments to advantage. If they had been presented in the E♭ - G♯ range, which is the only known range of most of the temperaments shown, the smallest arpage of the group would have been 43·5 for quarter comma meantone, so that the rest of the group would have to be given proportionately greater arpages. Mersenne's temperaments, which are denied the facility of sideways shift, show their inappropriateness in the F minor tonality, and also confirm the previous statement concerning quarter comma meantone temperament.

The third group from the top of these diagrams represents mostly those temperaments whose overriding principle is to achieve the purest harmony, or to put it in our terms, to achieve intervals with minimum absonance. The argument concerning the conjectural Ammerbach temperaments (Chapter 4, pp. 72 f.) seems to be fully confirmed, in that Ammerbach No. 1 appears to be grossly unsuitable for any key apart from G major. The Kepler temperaments make good performances, but here is a case of two temperaments being used. Kepler No. 1 and No. 2 are identical, except they contain G♯ and A♭ respectively. The arpages would change considerably for the worse if the temperaments were reversed. The evidence of Figure 100, although inapplicable for more remote sharp keys, suggests that just-intonation temperaments can be applied to music which has a very limited note-vocabulary which corresponds accurately with the limitations of the temperament.

The last group of this series of three diagrams shows arpages of later temperaments, based mostly on the divisions of the ditonic comma. The music of the later seventeenth century was diatonic rather than modal, and needed access to a greater variety of keys and note vocabulary for expressive and affective reasons. Werckmeister promoted the 'well-tempered' principle of greater consonance in familiar keys, greater absonance being allowed in more distant keys. Of the pieces chosen, the arpages of the Lamentation in F minor are substantially greater in every temperament except equal temperament, which shows least divergence from its norm of about 25 arps. The picture is not complete, however, without equally conclusive evidence on the sharp side, and for this we must return to the organ music. Figure 101 shows arpages for Ricercar 6, whose tonal centre C♯ marks the sharp extremity of Froberger's work. The arpage for quarter comma meantone in the range G – B♯ shows the absonance potential of the work rather than being of practical use.

Figure 101. <u>Comparative Arpages: Ricercar 6.</u>

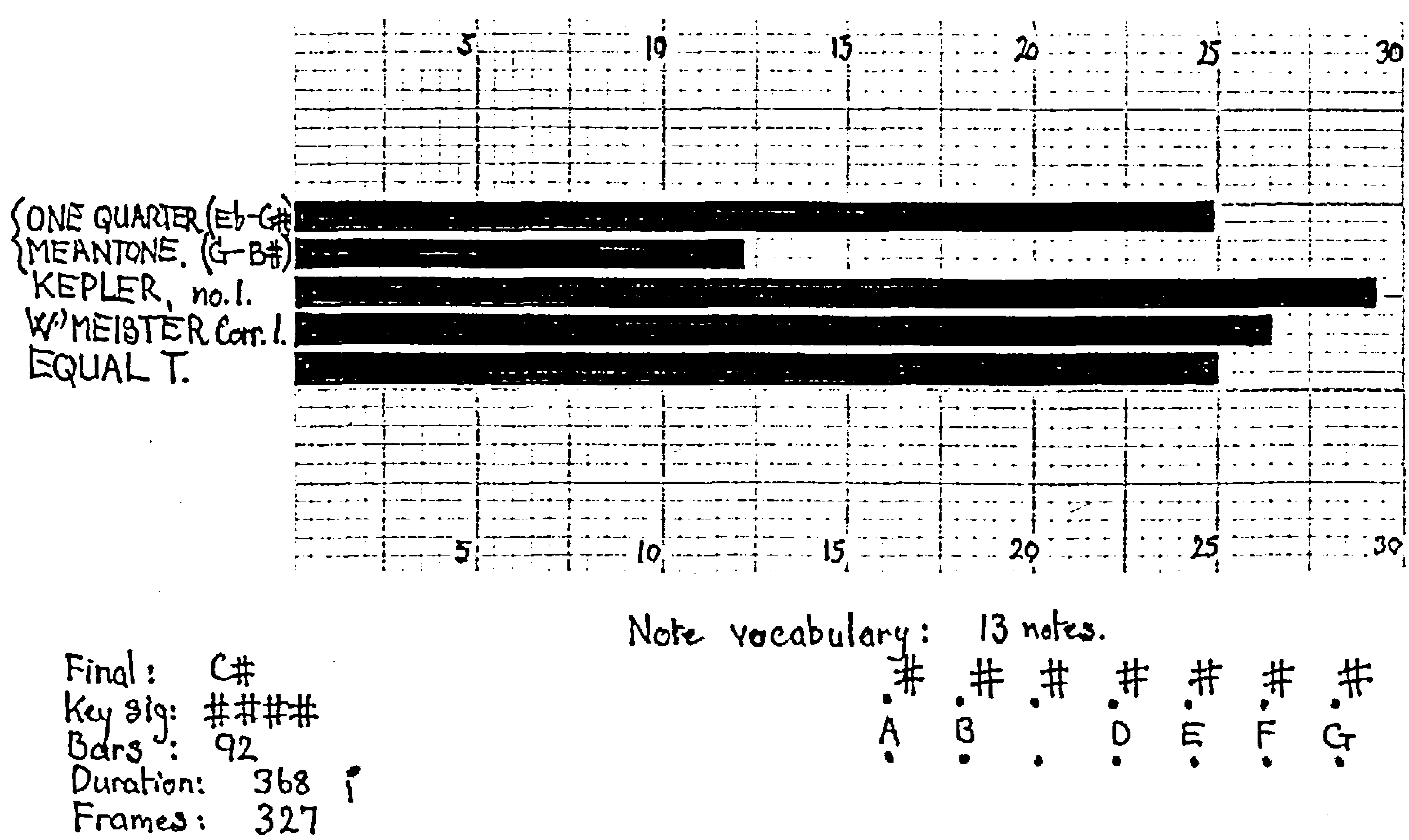


Figure 102. Comparison of Impurity Count with Score: Suite 4 in F major, Sarabande.
Quarter Comma Meantone Temperament, E♭ – G♯.

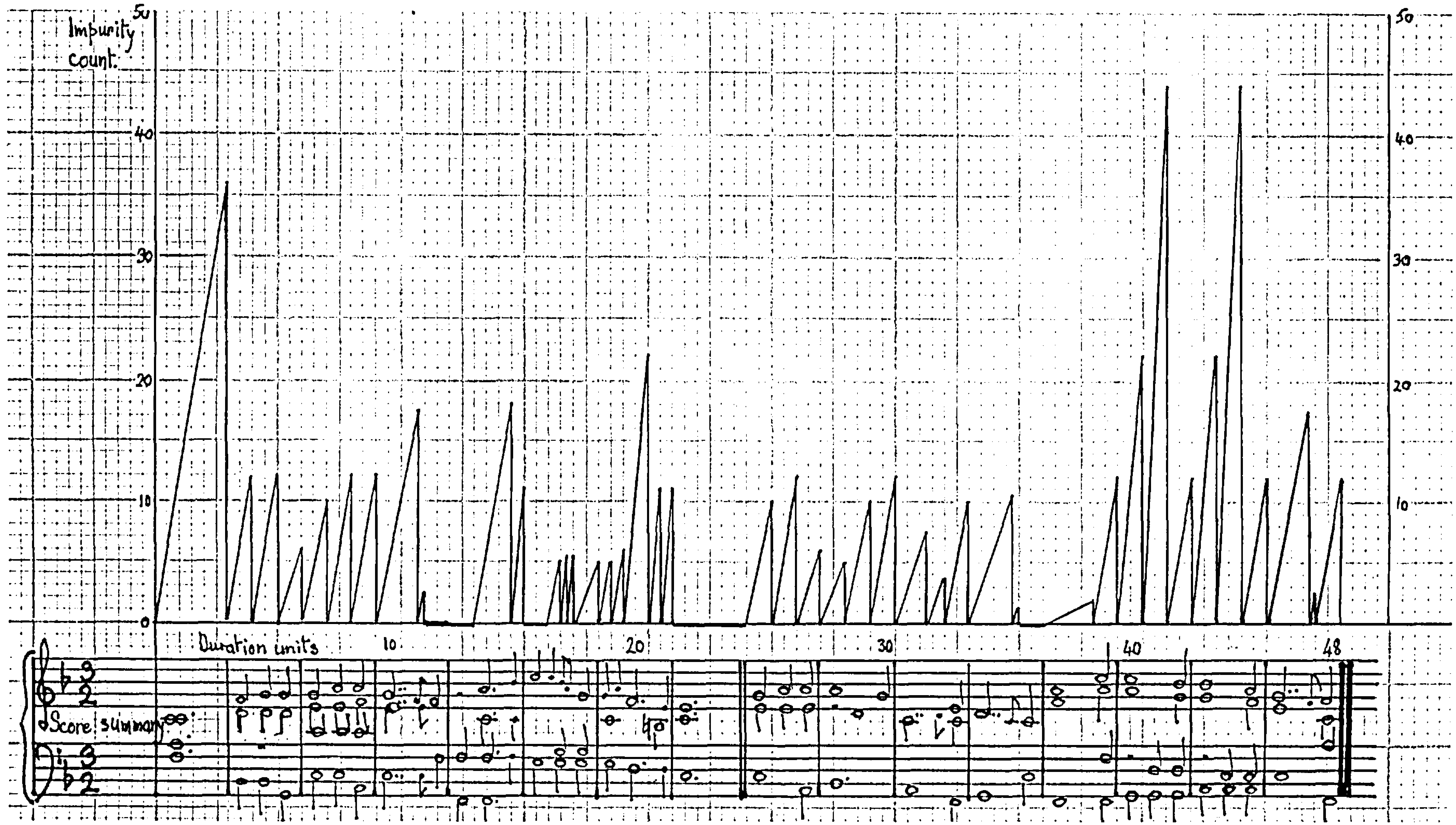


Figure 103. Comparison of Impurity Count with Score: Suite 8 in A major, Sarabande. Quarter Comma Meantone Temperament, B♭ – D♯.

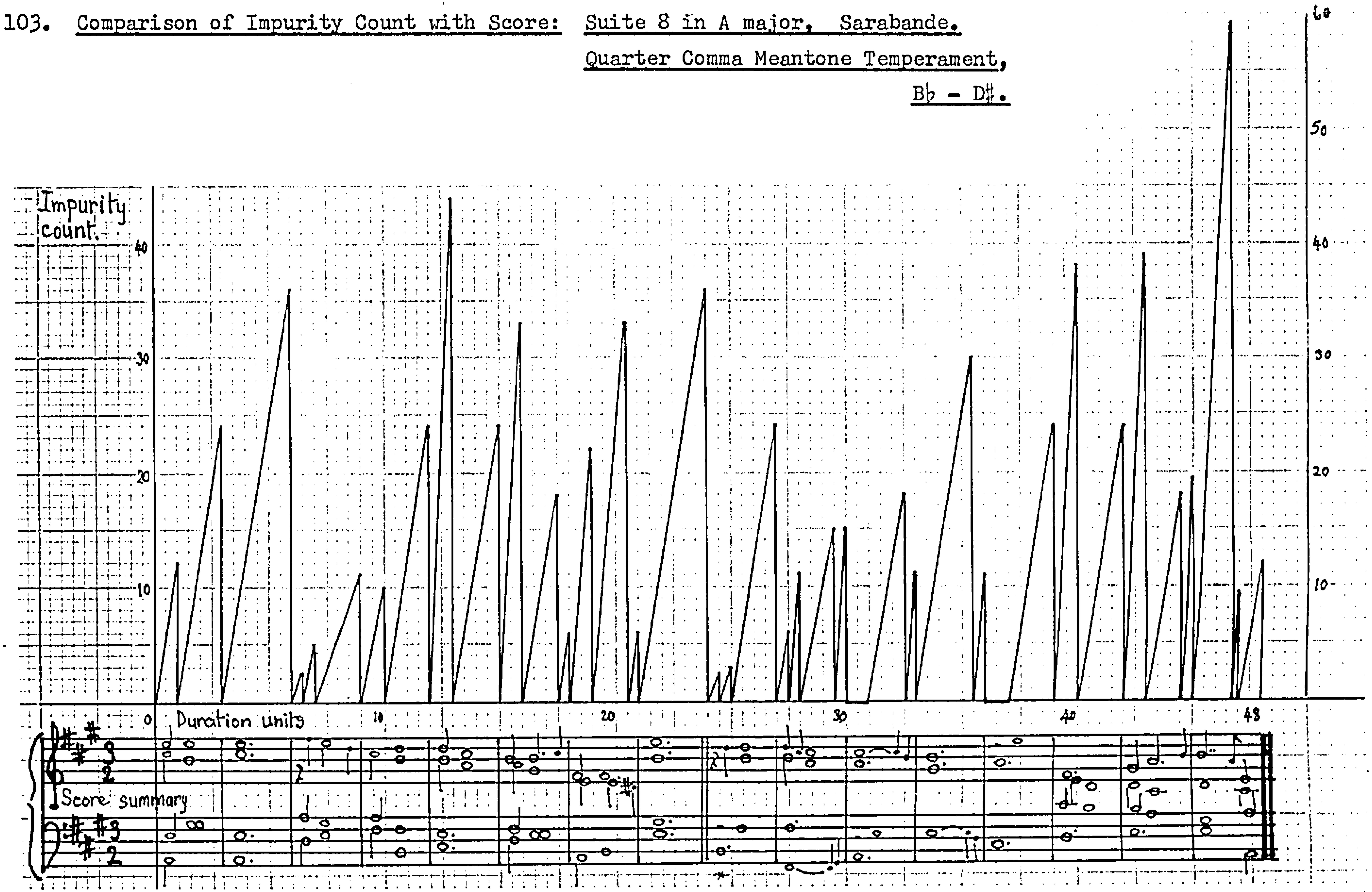
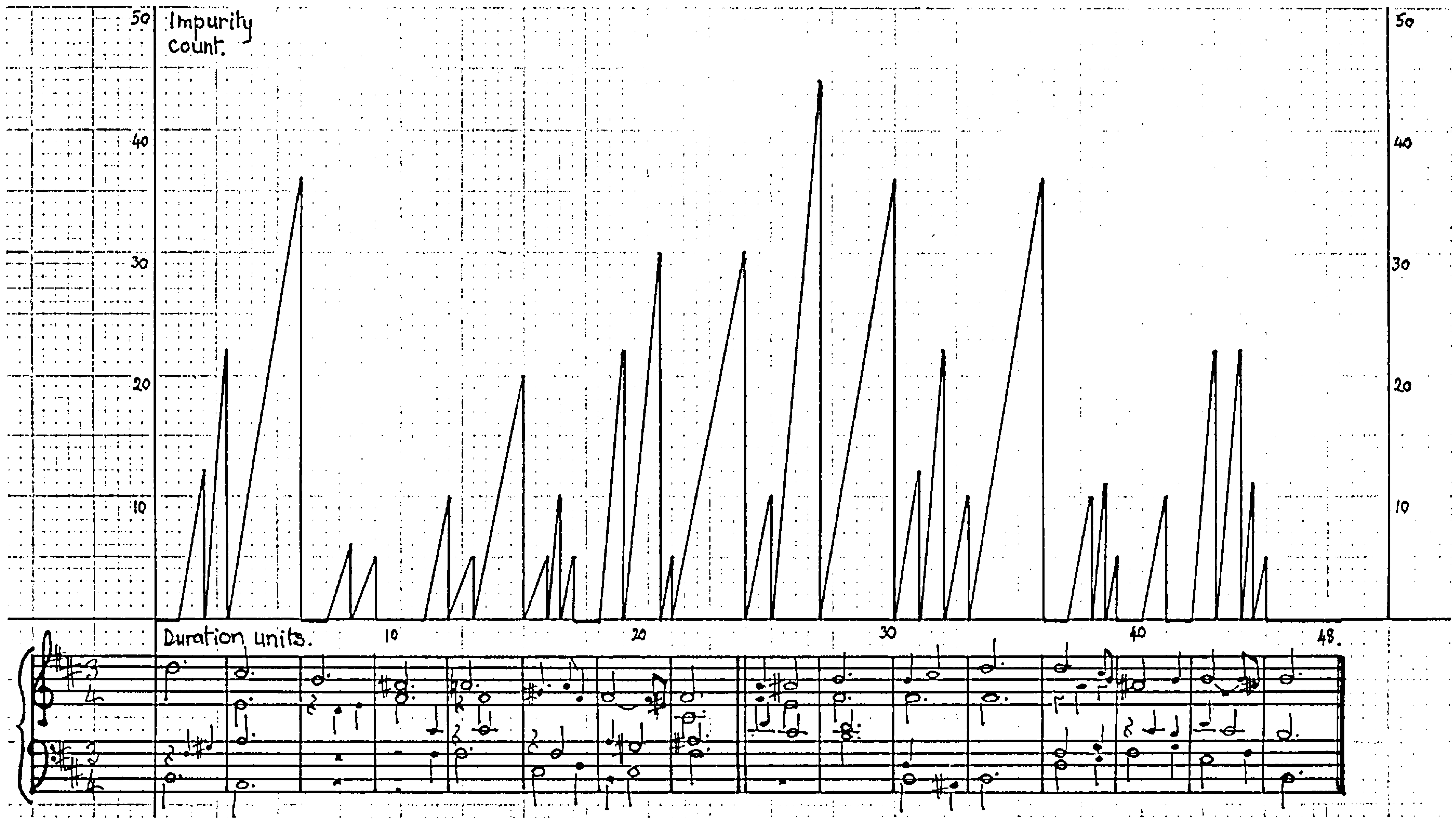


Figure 104. Comparison of Impurity Count with Score: Suite 8 (8n) A major. Sarabande (Second section).

Equal Temperament.

Figure 105. Comparison of Impurity Count with Score: Suite 26 in B minor. Sarabande.
Quarter Comma Meantone Temperament, C - E♮.



Attempts have been made to show the music and the results alongside each other. Short pieces, all sarabandes, have been chosen for this experiment. Figures 102 - 105 display graphically the impurity counts (absonance levels x durations) adjacent to a score summary. A score summary is a reconstruction of the music from the templet; it contains all the notational information, but may ignore ties and repetitions of notes. The order of a bar may be very slightly changed to facilitate templet compression. (see p.187). The number of 'peaks', together with the number of zero impurity counts add up to the number of frames. The format demonstrates how temperamental tension builds up and is released. A meantone frame which consists solely of a pure major third releases all tension, but complete triads in both temperaments build up considerable tension. Equal temperament has moments of comparative relief. In three of the four diagrams tension, both musical and temperamental, builds up and reaches its highest point towards the end of the movement.

Conclusions.

One of the most important principles concerning music and temperament should now be crystal clear; that purity and versatility of temperamental utterance are irreconcilable. Music of a restricted tonal utterance using a maximum of twelve notes in a chain of fifths can achieve low arpages, in the region of 10 to 15 arps. Music which has a large note vocabulary must tolerate high arpages. Music in distant keys may expect high arpages. This applies without qualification for organ. Distant keys can satisfactorily be realised on clavier in meantone temperaments by sideways shift. The inventors of just-intonation temperaments and the musicians who used them were the bespoke tailors of keyboard music: unless the temperament fit the music exactly the result was an ill-fitting performance. Arpage results give the proof. Equal temperament is an off-the-peg garment. It fits any and all music in its fashion of high in-built tolerance. Consequently the arpages, whatever the tonal centre or vocabulary are high, usually between 25 and 30 arps.

There is little doubt that, provided the note vocabulary of a work conforms to the temperament, quarter comma meantone provides the greatest degree of consonance for a keyboard work. To a large extent, the general use of this temperament throughout Europe up to the middle of the seventeenth century is seen to be justified. How far the criterion of excellence in keyboard performance was consonance up to the time of Froberger's death remains to be discussed.

We are now equipped to account for the range in arpage between different pieces run in the same temperament, when the temperament chosen is suitable in each case. First, the number of notes and intervals in the frames affects the results. Figures 94 (a) and (b) show Fantasia 8 with an arpage of 3•6, the lowest arpage on record. This is accounted for simply by the two facts that the work fits exactly its quarter comma meantone, and that it is written for two voices, and therefore every frame contains only one interval. Even in equal temperament the arpage is only 7•5, a record for equal temperament.

Four-note frames with a high absonance level do not necessarily increase the overall arpage greatly. (3) This sort of frame has often a very short time exposure, and consists of three harmony notes plus a transitory melodic note. Frames which appreciably increase the arpage are those with four different notes of long duration, as found in Froberger's use of suspensions and appoggiaturas. It is highly probable that a twelve-note work with a comparatively high arpage will contain a more than usual number of four-note frames of long duration.

There is a fairly consistent similarity among the arpages of pieces of the same genre. Six out of eight ricercar run in quarter comma meantone temperament, E♭ - G♯, have arpages between 11•0 and 13•5. (see Figure 94 (a)). Even more remarkable is the pattern of the differences in arpage between the different movements of a suite. (see Figures 96 (a) and (b)). For instance, Suite 8 in A major requires a temperament to suit the usual twelve notes of the chain of fifths B♭ - D♯. Run in quarter comma meantone the arpages are as follows :

allemande 14•4 : courante 10•8 ; sarabande 15•6 ; gigue 12•2 .

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(3) e.g. In Canzona 6, an organ work 60 bars long, D♯ is needed once only. In quarter-comma meantone, E♭ - G♯, it is a foreign note, and occurs in frames 353 - 4, both of short duration, with absonance levels of 140 and 82. Change the temperament's range to B♭ - D♯; less likely, but more appropriate, and the absonance levels of these frames are reduced to 37 and 17, but the arpages of the complete work are only slightly affected: E♭ - G♯, 11•8; B♭ - D♯, 11•5.

In general, Figure 96 (b) confirms the pattern of higher and lower arpages for the alternate movements, for in the majority of the suites investigated the allemandes and sarabandes have greater arpages than their courantes and gigues. The agility and speed of these two movements resulting in lighter frames, and the slower and richer harmony of the allemandes and sarabandes, co-operate to produce the arpage pattern.

It is now possible to give reasons for the anomalies of the arpages of Toccatas 5 and 6, as shown in Figure 94 (b). These works require note vocabularies of thirteen and fifteen notes respectively. Although this must be taken into account, both toccatas use their foreign notes with great discretion. These 'alla levatione' toccatas contain no fugato sections usually present in other organ works, and therefore the regular give and take of solo, two, three and four voice texture is missing. Instead a greater proportion of four-note frames of long duration (20·7% and 22·3% respectively) increase the arpage significantly. Froberger entitled the allemande of Suite 12 'Lamento' (arpage 16·1). The F minor lamentation (20·6% six-interval frames) has also a comparatively high arpage in quarter comma meantone temperament. We have sufficient evidence to formulate a principle: the more serious the music, the richer the harmony and consequently the higher the arpage.

The circulating temperaments of Werckmeister and Bendeler were published some twenty years after Froberger's death. It was expedient to investigate how far these temperaments suited Froberger's music. There is no evidence that he acknowledged or was interested in the new concept of the well-tempered clavier, although some of his compositions were to some extent stimulated by extra-musical events. Quite apart from Froberger, the transition from low-absonance temperaments through the circulating temperaments, with their fluctuating arpages, to the highly absonant equal temperament can be traced through the computer results. Froberger was less adventurous in his choice of keys than a number of his friends and contemporaries. The number of temperamentally antic pieces is about five. This small number is scarcely sufficient justification for Froberger to transfer his support from the leading temperaments of the day, one quarter and other near divisions of the syntonic comma, to the contrasting and unnecessary equal temperament. It is possible that Ricercari 6 and 12 may have been conceived as experiments in more versatile temperaments. I would rather acknowledge the maverick qualities of a handful of pieces and leave the rest of Froberger's compositions to be played in the less absonant temperaments of his time. Although the aim here has been to cover the whole range of Froberger's musical expression, it must be constantly borne in mind that by far the bulk of Froberger's works lies around convenient and conventional tonal centres. Provided that the expedient of sideways shift is employed in the harpsichord music, there is no more consonant a temperament for his music than quarter comma meantone.

One aim of this chapter has been to establish various techniques in the interpretation of the results. Far from exhausting the method's potential, the results so far may be little more than a beginning of objective temperamental assessment. There is no reason why this tool should not be used on other musicians' music which has a wider tonal and modulatory structure, such as Ferdinand Fischer's and J.S Bach's.

The collected evidence in printout form so far, amounts, in crude but perceptible terms, to a stack of A4 computer paper some 15 cm. tall which, of course, is available for reference. The data files from which this evidence is collected can be used as desired to collate further and re-assess the music of Froberger. (4) The more templets there are, the more consistent and persuasive becomes the argument.

(4) Appendix 2 contains a complete list together with the templets of all the works of Froberger which have been processed. Each work listed has been run in several temperaments.

CHAPTER 11

CONCLUSION: TEMPERAMENT IN PERSPECTIVE.

Temperament in historical perspective.

As part of the summing up of this dissertation the historical attitudes to temperament should be briefly considered. The overall attitude of German theoreticians up to the middle of the sixteenth century may be summed up in this text from the Apocrypha:

> "Thou hast ordered all things in measure and number and weight."
> (Wisdom of Solomon xi. 20)

They believed that music, cosmic and mundane, were integral with, and proof of, this divine order. Pythagoras was God's prophet. His scheme was so logical and simple that it must reflect ultimate truth. Whoever dared to challenge these ideas ran the risk of being declared a heretic. The admission of the pure third into the scheme of things was a vital step towards temperamental emancipation. Neither the acceptance of Pythagorean/just-intonation temperaments, nor the rearguard action of Johannes Kepler with his synthesis of musical and planetary theory could stem the demands for a keyboard freedom similar to that attained for the voice in chromatic counterpoint. The brilliant compromise of quarter comma meantone temperament was a triumph for the major third, but a complete capitulation regarding the purity of the fifth. An absonance of over five cents in every usable fifth was no negligible price to pay. The rift between belief and expediency ever widened. Schlick's attitude to temperament was practical and exploratory. Galilei recognised the diverse tuning needs of voices, keyboard instruments and fretted instruments. The idea which unified musicians and theoreticians, from the tongue-in-cheek acceptance of Pythagoras by Martin Agricola, to the practical and empirical approach of Werckmeister, was the pursuit of consonance, within a system which had been found to be more complicated than was originally acknowledged. It is difficult to decide whether Werckmeister's policy of increasing the absonance levels of triads as their distance from familiar keys increased was a matter of necessity or design. Certainly the well-tempered principle seemed to coincide with the Baroque concept of the doctrine of the affections. It must also be acknowledged that the circulating temperaments of Werckmeister and Bendeler exposed and conditioned the listener to increased amounts of absonance. Once the acceptance of the principle of temperament had been achieved, and the use of different temperaments had gained momentum, it is difficult to imagine anything which could check the progression of temperament to its ultimate end in equal temperament.

If consonance, even in a compromised form, were to be achieved, there were many musical and extra-musical factors to be taken into account. Instruments were being improved. The materials and processes of string making for instruments were far from perfect. Schlick was concerned about obtaining a regular wind supply to the organ. Nearly two centuries later, Werckmeister, even though at that time equipped with a wind gauge, expressed similar concern over the same, and other unsolved problems. The voicing of an organ or harpsichord has always been a matter for human judgement. By the end of the seventeenth century there were still regional deviations in pitch standard. The tuning fork did not appear until 1711. Werckmeister drew attention to the dead-weight of vested interest, especially in the organ-building craft, which resisted vociferously his disseminating of his knowledge and expertise. Those 'braggarts and slanderers' whose calumnies he went to great pains to refute in Musicalische Temperatur, preferred to surround organ building and tuning with a shroud of mystery, which he, in his reasoned explanations and forthright if somewhat repetitive style, sought to dispel. He had something new and exciting to tell. In spite of all these formidable difficulties, temperament was a much debated subject , and a desired temperament on an instrument was considered an achievable goal.

Temperament in psychological perspective.

Present-day musicians sometimes try to reproduce faithfully historical performance. They may reproduce the historical conditions, but have no control of the perception of the listeners. We cannot hear with seventeenth-century ears. We cannot react to musical stimuli nor anticipate musically exactly like our predecessors. Our ears are accustomed to a much greater amount of musical dissonance. We listen to a greater range of musical timbre. Our experience of modulation is so wide, that change of key is a commonplace only the sensitive listener or listener with absolute pitch notices. In our time we have not experienced the changing attitudes to temperament that musicians of Baroque times experienced. Our conditioning to equal temperament since birth has dulled our aural perception of absolute consonance. We like the keyboard sound which is familiar to us. The German writers of the sixteenth and seventeenth centuries kept their readers informed about the dangers of wolves, and comparable potential offences to the ear such as faulty scaling of pipes and strings. They had little to say about the aural effect of spasmodic infringements of temperamental bounds. Schlick was one of the few musicians who admitted that it did take place in performance, and made suggestions about how to disguise such occurrences (See Schlick translation, p.252). Since the earlier temperaments in general were limited in range but comparatively pure, temperament infringement must have been all the more noticeable. To what degree spasmodic infringement was accepted as one of the anticipated hazards of listening to keyboard music there is little or nothing in the writings of the time to tell us.

The human ear perceives mistuned consonances as wayward consonances, not as intervals in their own right. The ear makes allowance for mistuning. A little mistuning may even add excitement or exhilaration to a listener's perception. The nearer a consonant interval is to unity, however, the more sensitive appears to be the aural perception, and the less tolerant the ear to mistuning. For example, the ear is more sensitive to and intolerant of mistuning in a perfect fifth than in a major third, and still more so in an octave than in a perfect fifth. In dissonant intervals the sensitivity of the ear is considerably less acute and the tolerance greater. For instance, the ear will perceive a major tone as very little different from a minor tone. How does this phenomenon affect our perception of different temperaments ? Let us take as examples two so-called regular temperaments. In quarter-comma meantone temperament the fifth is quite small, the major third pure, and among the dissonant intervals the tone is precisely a mean tone, whilst the chromatic and diatonic semitones are fairly pure, but there is greater contrast between these two intervals than even in their pure state. In equal temperament every fifth is nearly pure, the major and minor thirds are very noticeably absonant and contrasting, all the tones are equal in size, a condition which applies also to the chromatic and diatonic semitones. The absonance and arpage results of a piece of music run in these two temperaments will probably show equal temperament as the less suitable temperament for the piece. The listener will certainly hear the differences in temperament when the piece is played in the the two temperaments consecutively. But there is also the subtle issue of relative tolerance which should not be overlooked, even though at present it cannot be measured. It is here that we may be near to a reason why our ears accept the high absonance of equal temperament without what must be referred to subjectively as displeasure. We shall return to this problem in the final section.

We cannot wholly believe our ears. They do not perceive sounds exactly as they are generated. Inharmonicity in piano strings is such that the moment of least roughness or minimum beating does not necessarily coincide with the moment of greatest acoustic consonance. Stretched octaves at the extremes of the piano keyboard may compensate the listener with added brightness instead of temperamental accuracy. No two tuners ever achieve identical tunings by ear. Our perception of the size of consonant intervals may be affected by our physical condition, particularly fatigue.

Temperament: the prospects.

The previous two sections of this chapter raise a number of issues, which either suggest the writer's ignorance, or touch on areas of knowledge which await further research. What are the prospects, or to be more immediate, where do we go from here ?

The necessary but somewhat arbitrary limits imposed on this dissertation leave plenty of room for further research. A similar study to this might be attempted, concentrating on the northern region of Germany and the Netherlands. A difficulty encountered constantly in the research for this dissertation was where to draw the geographical line. The temporal limit imposed stops short of a period of tremendous growth in keyboard music, technique and instrument manufacture in Germany. This coincides with the hey-day of German circulating temperaments which includes particularly the work of Neidhardt and Marpurg. The interdependence of these important factors could be analysed insofar as they influenced the members and generations of the Bach family, for instance.

The objective method of temperament assessment of this dissertation is a faithful way of ascertaining the amount of absonance within all the intervals of a piece of music. The subjective preferences of human ears are outside its province. Relative tolerance, as briefly discussed above, has been recognised for centuries. Tuners make use of it in their general preference for tuning in fifths. No other interval, apart from the octave, affords the aural precision of the fifth. Comparatively little is known about the musical implications of the subject. Here is an area for investigation and experiment. It might need much time, and many people to act as subjects. Its difficulty is not alleviated by the many and controversial facets of the consonance/dissonance phenomenon. How educated musically should the subjects be ? If there were consistent observations to be recorded, then it might be possible to build into the method of temperament assessment a scale of mistuned-interval tolerance, and each interval might then be weighted according to this scale.

Even more immediate, and less controversial, is the need to apply the method as it stands. Results from processing the rest of the music of Froberger should consolidate the present conclusions. The music of different periods and regions might be tackled. To suggest that it would be impossible to refine, adapt or modify the method as opportunities and omissions present themselves, might also suggest that the originator of the method is temperamentally myopic. If, after a further trial period, some researcher produces a superior version of the method, then at least one part of this research has borne fruit.

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