MUSURGIA RECORDS

MEANTONE TEMPERAMENT IN THEORY AND PRACTICE

By J. MURRAY BARBOUR and FRITZ A. KUTTNER

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INTRODUCTORY NOTES

I. DEFINITION OF PITCHES AND INTERVALS IN CENTS

In musical terms an interval is the distance between two tones, or the difference between two pitches, regardless of whether the two tones or pitches are sounded simultaneously (chord) or in sequence (melodic step). In the rather rigid system of modern Western intonations intervals are usually identified by names referring to standardized steps in equal temperament, e. g.: whole tone, semitone, major/minor third, perfect fifth, diminished fifth, etc. Occasionally quartertones may be mentioned, the only deviation from the chromatic series of twelve semitones in equal temperament which form the modern Western tone system.

In acoustical and mathematical terms intervals are defined by the ratio of two figures representative of the two pitches. These figures can be divisions of strings (on a measuring device of ancient origin called monochord), lengths of sonant tubes in wind instruments, or the number of acoustical vibrations (cycles) per second (cps) which produce a given pitch, for example:

Ratio of two string lengths 12 : 18 inches (=2:3, the ratio of the perfect fifth)

Ratio of two vibration numbers 440:880 cycles per second (=1:2, the ratio of the perfect octave).

Unless the numerical ratios are very simple ones—such as above—it is very hard to visualize, without calculations, the size of the intervals thus expressed. The ratios 17:18 (approximately a semitone in equal temperament) or 587:740 cycles (a major third in equal temperament) do not convey any immediate idea of the intervals concerned. Absolutely confusing are ratios such as 524,288 : 531,441. Yet this ratio stands for the Pythagorean comma, one of the most important theoretical and practical problems in Western music for almost two thousand years.

In 1885, Alexander J. Ellis, an English scholar, proposed an improved system of calculation which gives an immediate and clear description of the interval. It is of particular value for the definition of micro-intervals and of intervals deviating from the standard of Western pitches in equal temperament. Today Ellis' system is a generally accepted and indispensable tool for all inquiries into musical acoustics, historical intonations, "exotic", primitive and ancient musical scales.

In Ellis' method of logarithmic calculation the interval of an octave is equal to 1,200 cents; each of the twelve (tempered) semitones measures 100 cents. Thus, the interval c—c♯ equals 100 cents, c—d=200 cents, the major third=400 cents, the fifth c—g, or any fifth for that matter, = 700 cents, etc.

If we are told that the Pythagorean comma measures 24 cents, (cf. Table no. 1, col. 7), we can visualize this small interval immediately as a pitch difference of approximately one quarter of a (tempered) semitone. The information that a perfect acoustical fifth equals 702 cents, makes it immediately clear that in equal temperament the perfect fifth is lowered by the micro-interval of two cents, bringing it down to 700 cents. An interval measuring 911 cents, thus, is easily visualized as being 11 cents sharp as compared with the major sixth in equal temperament.

The above mentioned difference of 24 cents, the Pythagorean or ditonic comma, is an "impurity" and shortcoming of the "Pythagorean" tone system which the theorists of many centuries tried to eliminate or to overcome by all kinds of adjustments and compromises which were called temperaments. The system generally accepted in modern Western music is that of **equal** temperament which sacrifices the perfectly intoned fifth of 702 cents and substitutes twelve equal and slightly flat fifths at 700 cents, resulting in twelve equal semitones of 100 cents each.

Equal temperament has disadvantages, but it made possible the enormous sophistications of modern harmony in Western music, and the modulation from one key into another, without producing dissonances.

Anyone able to handle simple logarithmic calculations and logarithmic tables can learn to calculate intervals in cents. The article on "Intervals, calculation of", in Willi Apel's *Harvard Dictionary of Music,* contains a simplified method and formula for the conversion of interval ratios into cents*). A more detailed discussion of the topic and various methods of calculation are given in the excellent appendices which Alexander J. Ellis wrote for his translation of Helmholtz' work on *The Sensations of Tone.* (A recent reprint of the work was issued by Dover Publications, Inc., New York, 1955. Here Ellis' discussion will be found in Appendix no. xx, Section C, pp. 446 ff.)

The reader is encouraged and urged to try his hand on such calculations; it is much easier than it sounds. One or two hours of practice will make Ellis' method a valuable and ready tool for a lifetime.

II. The "PYTHAGOREAN" TONE SYSTEM IN ANTIQUITY

The "Pythagorean" tone system which formed the fundament and point of departure for most of Greek musical theory, was probably not completely worked out until Euclid, or some disciples of the Pythagorean school shortly before Euclid, closed mathematically the first octave orbit by a succession of acoustically perfect fifths.

The principle of building a tone system within the compass of an octave by a series of successive fifths is a very ancient one. There is sufficient archeological evidence to credit the Sumerian civilization with a pentatonic system derived from **four** upward steps of successive fifths, in the middle of the fourth millennium B. C.

C———G———D———A———E
1 2 3 4

This scale has, as its only intervals, major seconds (c-d, d-e, g-a) and minor thirds (e-g, a-c) at 204 and 294 cents respectively. (cf. Table no. 1, col. 6)

Old Babylonia had a similar system around 2500 B.C.; so had the Egyptians during that same period. There is no doubt that most of the early Greek achievements in musical theory and practice were taken over from sources in Western Asia, among them the series-of-fifths system. When and where any West Asian music civilization first went beyond the fourth step shown above, to create a scale containing semitones, is not known. But we can be sure that in Pythagoras' times, around the middle of the sixth century B.C., a tone system was known within the orbit of Greek civilization that went beyond four cycle steps. It is likely that—by then—six steps had been completed, adding b and f♯ to the above series and producing a scale with two semitonic steps at 90 cents each:

	C		D		E		F♯		G		A		B		C	
Pitches:	0		204		408		612		702		906		1110		1200 cents	
Intervals:		204		204		204		90		204		204		90		

Then, some time in the fifth century B.C., the cycle was closed for the first time **in Mediterranean culture,*)** producing twelve semitones of 90 and 114 cents

*) Useful tables for conversion of frequencies into cents and vice versa have been compiled by Robert W. Young and published by C. G. Conn, Limited, in Elkhart, Indiana, 1939.

*) In Far Eastern civilization the circle had been closed, both in practice and theory, much earlier. Sonorous stones found in the Princes of Han tombs in Lo-Yang, China, have the precise intonation of a complete "Pythagorean" circle. The stones must be dated prior to 550 and possibly as early as 900 B.C.

alternately within the octave and revealing the nature and size of the "Pythagorean" comma. From then on the various keys and modes of the Greek scales could be developed, along with rules for modulation from one key into another. Much thought has been given by scholars to the question as to whether or not the variety of musical *practice* came first, and the mathematical calculations of the tonal material already in actual use followed only as a theoretical rationalization *post factum*. We are inclined to believe that the two processes went on simultaneously all the time: The theoretical discussions and computations of the mathematicians and philosophers must have influenced, ordered and solidified musical practice which, on its part, kept on supplying theory with new problems and techniques to speculate on.

Pythagoras lived and worked in **Tarentum.** The school and religious sect founded by him had its focal point for more than 200 years in the same colonial center of Greek culture. The Pythagorean Archytas of Tarentum discovered, around 380 B.C., that vibrations of air and other sonorous media were the source of sound and tones, thus paving the way for intervals based on acoustical laws rather than arithmetical computations. Another resident of Tarentum, Aristoxenos, wrote exhaustively on melodic and rhythmic problems around 330 B.C. Obviously continuing where Archytas had left off, he stressed the postulates of the *hearing sense* as opposed to the numerical theories of the Pythagoreans.

Hereafter the center of gravity in acoustical and musical scholarship shifts from Tarentum to Alexandria, another important deposit of Greek colonial culture. Around 300 B. C. Euclid may have completed his "systema telaion", the "perfect system" of tetrachords, melodic, scale, and modal structure of music in his time. Around 230 B. C. Eratosthenes of Alexandria contributed further to the tetrachord theory and mathematical scale structure. But then it takes almost 200 years until another great theorist completes a step of lasting importance: Didymos of Alexandria (ca. 30 B. C.). None of his writings are preserved; what we know about his theoretical work, stems from the reports about Didymos in the writings of Ptolemy. Many history and text books credit Didymos with the introduction of the **major third in just** (or natural) **intonation** into Greek tetrachord theory, basing this information on Ptolemy. This is an error. The natural third occurs as early as ca. 380 B. C. in the enharmonic tetrachord of Archytas. Thus Ptolemy's error is being perpetuated in modern texts.

It would appear, however, that Didymos was the first one to realize the superiority of *small* superparticular ratios (explained in column 9) over certain Pythagorean intervals. He may also have been the first theorist who heard or "sensed" a number of harmonics and related them to small superparticular ratios—a consequence which had been prepared by the work of his Tarentian predecessors Archytas and Aristoxenos.

Another major achievement traditionally attributed to Didymos is the discovery of a larger (major) and a smaller (minor) whole tone, and—immediately connected with this discovery—the realization of the pitch difference between the Pythagorean and the natural major third. This difference, 22 cents in size, is called the syntonic (or sometimes the Didymic or Ptolemaic) comma. Again, there is much reasonable doubt that this discovery should have been made as late as in the time of Didymos. It is possible, however, that he was the first to find the mathematical expressions for these differences.

Another 170 years later the last of the great theorists of Greek colonial music culture makes his contribution. Around 140 A. D. Ptolemy of Alexandria gives in three famous books a comprehensive survey of Greek theory on scales and intervals. He stresses the supremacy of the diatonic-syntonic genus with its natural major third 4:5 (386 cents) and the natural minor third 5:6 (316 cents). This sets the stage for the subsequent developments of medieval music theory in Western Europe.

III. METHODS USED FOR THE PREPARATION OF THIS RECORDING

Meantone temperament, in its **practical** application between ca. 1500 and 1750, was exclusively a problem of tuning keyboard instruments. Therefore the decision to use the organ and the harpsichord as the sonant media for our demonstrations was a natural one. The final selection favored a small practice harpsichord with only one string per key, by John Challis. This facilitated the complex tuning processes, as compared with multi-stringed harpsichords. It also eliminated the thick, resonant and reverberating sound characteristics of the oversized modern concert harpsichords.

The choice of a suitable organ presented great difficulties. Pipe organs were out of question, because it is impossible to tune them at the great precision required for this type of pitch demonstrations, and to keep them, for any length of time, at such very precise pitches (influences of room temperatures and humidity!). Furthermore, most churches and organists will object to having their instruments brought severely off pitch for experimental and research purposes. This left electronic organs, with all their shortcomings, as the only alternative. Among the many makes and types available only a few met our requirements concerning tuning precision and pitch constancy, together with a sufficient latitude of pitch variation; but none of these organs proved anywhere near satisfactory in their sound qualifications.

There are two ways of recording the sound of electronic organs: from the organ loudspeaker into the microphone, which is one of the worst recording procedures; or to pick up the *electronic signal* from one of the organ's amplification stages and feed it directly into the recording amplifier of the tape recorder. This procedure usually leads to severe distortions, makes true monitoring of the (inaudible) recorded material next to impossible and produces a sterile, dry and unnatural tone quality devoid of all room acoustics and reverberation phenomena commonly associated with the organ. We decided in favor of what was considered the smaller of the two evils, and recorded from the organ's loudspeaker system into the microphones.

The sound technicians and research staff connected with this recording regret the unsatisfactory quality of the organ examples, but are unable to produce anything better as long as the electronic organs available on the market remain as limited in their synthetic sound quality as they are at present. It was for this reason that the number of organ examples offered in this recording was limited to four; most other takes had to be rejected as unacceptable from the viewpoint of sound quality.

All tunings for the recordings were done with the aid of a stroboscopic frequency meter which permits accuracy within one cent. Each individual intonation was double-checked before and after recording to eliminate possible changes of pitch during actual recording. Thus, all pitches and intervals are certain to be precise within a deviation tolerance of $\pm$ 1 cent. This ratio of accuracy will not be influenced by the precision of the turntable used for the playback as far as interval **ratios** are concerned, with the exception of permanent strong fluctuations in the speed of a very inferior turntable producing noticeable flutter or "wow".

An effort has been made to keep a' the center of reference for all intonations at 440 cps for an absolute pitch. Temperature and other influences may change this absolute pitch within $\pm$ 4 cents or $\pm$ 1 cps. Thus playback should produce the reference tone a' always between 439 and 441 cps, i. e. reasonably close to modern standard piano tuning, if the speed of the turntable stays close enough to 33 1/3 rpm. All intervals and *relative pitches,* however, will remain precise within $\pm$ 1 cent, no matter how large deviations from *absolute* pitch should get during playback.

Since the purpose of this recording is the demonstration of sound phenomena uncommon and forgotten in our time, clarity of all demonstrations was a prime consideration. For this reason preference was given to moderate tempi over dazzling concert hall virtuosity, whenever brilliant modern recital speeds tended to obscure significant sound phenomena and pitches. We are confident, however, that all musical examples presented conform to generally accepted views of style and musical performance.

IV. LISTENING TO THE RECORDING

The reader is cautioned that listening to unusual intervals and micro-intervals is a matter of acquired skill and ear training which calls for a certain amount of practice and concentration. Our modern ears have become lazy and indifferent by contemporary listening diet which consists of nothing but equal temperament intonation and its admixtures of "Pythagorean" and natural intonations. These admixtures vary in degree at any moment during performance as we experience it in our concert halls. We do not care very much, nor do we notice consciously, whether we hear a natural, a "Pythagorean" or a tempered interval in actual performance.

This does not mean that a major skill has to be developed to hear and identify micro-intervals, or micro-intervallic deviations from true equal temperament intonation. But a few hours of concentrated listening and many repeated hearings of the demonstrated examples will normally be required, before a clear and sensitive definition of the sound phenomena begins to form. The results of this short period of training and preparation are always gratifying: a new sense of interval and intonation values develops, together with a keenness of discrimination which is very useful to the singer and instrumentalist alike, and highly stimulating to the critical observer and listener. **The net gain produced by one playing of this record will be negligible; ten or more hearings will begin to open a new world of tone sensations.**

Clicking Noises:

Occasionally, there will be heard slight clicking noises in the examples, especially during slow demonstration of single tones. These clicks are caused by the harpsichord's jacks falling back into position after the string is sounded. As great clarity of all sound phenomena was important, the microphone had to be placed close to the strings. Thus it could not be avoided that clicks were occasionally picked up. The alternative—removing the microphone to greater distances—was impractical because this would have impaired the clarity of many sounds. In continuous harpsichord performance at normal speeds the sound of the jacks is covered by the tone volume of the music itself.

V. REFERENCES

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J. Murray Barbour. *Tuning and Temperament. A Historical Survey.* Michigan State University Press, East Lansing, 1953. (Second Edition).

Margaret H. Glyn. *Early English Organ Music.* London 1939.

Luigi Torchi. *L'Arte Musicale in Italia.* Vol III. Milan, post 1897.

I Classici della Musica Italiana. Vol. XXXVI, Milan 1919.

In preparing the commentaries and sound aspects of this recording, the authors leaned heavily on Dr. Barbour's text, which was one of the most important sources used throughout in the planning and completion of this disk.

Personalities

Dr. J. Murray Barbour is Professor of Musicology at Michigan State University, East Lansing. For many years he has specialized in acoustics and in the history of tunings and temperaments. Dr. Barbour is the President of the American Musicological Society for the years 1957-1959.

Dr. F. A. Kuttner was Associate Professor for Oriental Musicology at the Asia Institute, Graduate School for Asiatic Studies, in New York. He specializes in Oriental, comparative, and archeo-musicology.

Robert Conant, harpsichordist, took his Master of Music degree at Yale University where he was a pupil of Ralph Kirkpatrick. He specializes in concert work and has three transcontinental tours to his credit.

Two research assistants aided the authors in the recording stage of this disk:

David Williams who took his Master of Arts degree in composition at Columbia University; and

Cham-Ber Huang, a Chinese musician and graduate of St. John's University, Shanghai, who lives now in Elmont, L. I.

VI. THE "PYTHAGOREAN" TONE SYSTEM TWELVE CYCLIC STEPS UPWARDS

The scale produced by this system uses only two intervals: the perfect octave (ratio 1:2, = 1,200 cents), and the perfect or natural fifth (ratio 2:3, = 702 cents). The twelve semitones within the range of an octave are produced by

twelve steps of consecutive fifths upwards. Whenever a resulting tone exceeds the compass of one octave, it has to be brought back into this compass by octave transposition, i. e. by subtracting 1,200 cents, or by multiplying by 2, the ratio of the octave. The reader is advised to compute these simple arithmetic examples himself to get a clear impression of the acoustical proportions involved in this system.

TABLE 1

Cyclic Step No.	Resulting Tone	Cyclic Ratio	Converted into cents
0	C	1 (see note below)	0
1	G	2 : 3	702
2		(2:3)×(2:3)	+ 702
			1404
2 (a)		(4:9)× 2	− 1200
	D	8 : 9	204
3		(8:9)×(2:3)	+ 702
	A	16 : 27	906
4		(16:27)×(2:3)	+ 702
		32 : 81	1608
4 (a)		(32:81)× 2	− 1200
	E	64 : 81	408
5		(64:81)×(2:3)	+ 702
	B	128 : 243	1110
6		(128:243)×(2:3)	+ 702
		256 : 729	1812
6 (a)		(256:729)× 2	− 1200
	F♯	512 : 729	612
7		(512:729)×(2:3)	+ 702
		1024 : 2187	1314
7 (a)		(1024:2187)× 2	− 1200
	C♯	2048 : 2187	114
8		(2048:2187)×(2:3)	+ 702
	G♯	4096 : 6561	816
9		(4096:6561)×(2:3)	+ 702
		8192 : 19683	1518
9 (a)		(8192:19683)× 2	− 1200
	D♯	16384 : 19683	318
10		(16384:19683)×(2:3)	+ 702
	A♯	32768 : 59049	1020
11		(32768:59049)×(2:3)	+ 702
		65,536 : 177,147	1722
11 (a)		(65,536:177,147)× 2	− 1200
	E♯	131,072 : 177,147	522
12		(131,072:177,147)×(2:3)	+ 702
	B♯	262,144 : 531,441	1224
12 (a)		(262,144:531,441)× 2	− 1200
	C	524,288 : 531,441	24

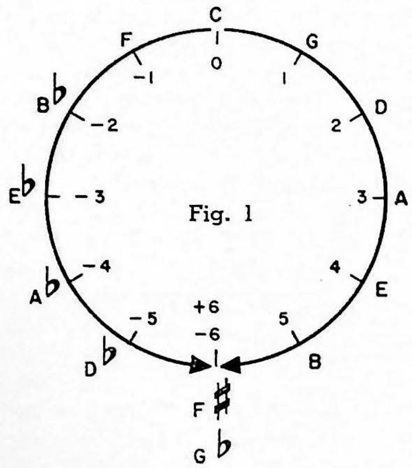


Fig. 1

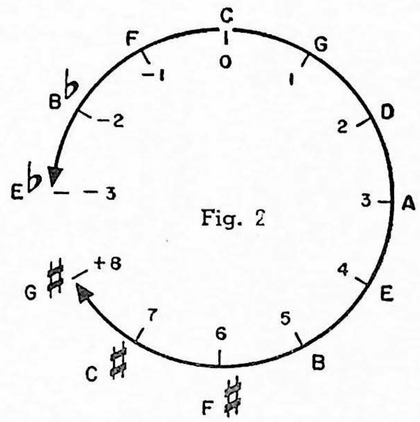


Fig. 2

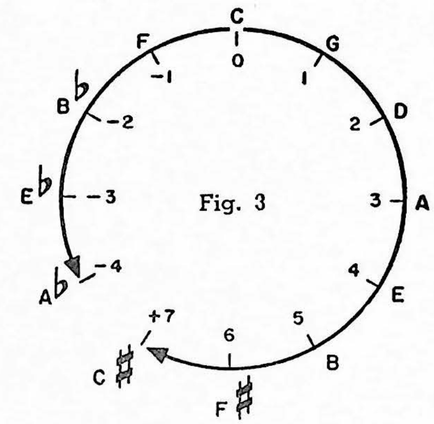


Fig. 3

This last tone C is actually B♯ transposed one octave down. The ratio for C (see above, first step) from which we started out, was 1, (or 1 : 1) while the ratio resulting from step no. 12 (a) is a tiny fraction smaller than 1, hence somewhat sharp (24 cents) as against C. This fraction is the Pythagorean (also called the ditonic) comma. The higher octave C' would have the ratio $1{:}2 = .5$, i. e. half the string length required for sounding the lower octave C. Thus any ratio smaller than 1 represents an interval higher than C, any ratio larger than 1 represents a tone lower than C.

Note: The starting ratio for the tone from which we set out ($1{:}1 = 1$) stands for ONE unit of whatever medium we choose for measuring pitches, for instance a string 1 yard long, or a sonant tube length of 2 feet, or the standard tone a' =440 cycles per second (cps). If, e. g., we equate 440 cps with this unit 1, the higher octave a" would sound at 880 cps. The major second b' above a' would be computed as follows:

ratio for major second, C-D, as per step no. 2 (a) 8:9

$$\frac{8}{9} = \frac{440}{x}$$

$$x = \frac{9 \times 440}{8} = 495 \text{ cps.}$$

This value b' = 495 cps is, of course, correct only if we wish the tone b' to sound in Pythagorean intonation. In equal temperament tuning the frequency for b' would be 493.88 cps, if the standard tone a' has 440 cps as reference basis.

VII. The "PYTHAGOREAN" TONE SYSTEM IN MEDIEVAL AND RENAISSANCE USAGE

Above computation consisting of twelve consecutive steps upwards is the original system as erroneously ascribed to Pythagoras. It was probably not completed up to the twelfth cyclic step until about 100 years after Pythagoras (see above, col 2). Thereafter, however, a complete cycle of twelve steps upwards was traditional practice for the "Pythagorean" system in Greek theory.

In the Middle Ages and the Renaissance period the system was used in a different way: only seven or eight cyclic steps were computed upwards, and three or four cyclic steps were computed downwards from C. Oddly enough, most textbooks show a "Pythagorean" circle with six steps upwards, and six steps downwards where the Pythagorean comma appears as the difference between the sixth upwards step F♯, and the sixth downward step G♭. It should be noted, however, that this arrangement of six-up, six-down was never used in European practice. (See Fig. 1-3).

The following table shows the computation for six steps downward:

TABLE 2

Cyclic Step No.	Resulting Tone	Cyclic Ratio	Converted into cents
0	C	1	1200
1			− 702
	F	3 : 2	498
2 (a)		(3:2)×(1:2)	+ 1200
		3 : 4	1698
2		(3:4)×(3:2)	− 702
	B♭	9 : 8	996
3		(9:8)×(3:2)	− 702
	E♭	27 : 16	294
4 (a)		(27:16)×(1:2)	+ 1200
		27 : 32	1494
4		(27:32)×(3:2)	− 702
	A♭	81 : 64	792
5		(81:64)×(3:2)	− 702
	D♭	243 : 128	90
6 (a)		(243:128)×(1:2)	+ 1200
		243 : 256	1290
6		(243:256)×(3:2)	− 702
	G♭	729 : 512	588

F♯ = 612 cents
G♭ = 588 cents

Comma = 24 cents

All above ratios are in the octave range **below** our starting tone C. In order to bring the resulting tones into line with the tones gained in the cyclic "upwards series" (Table no. 1), they have to be transposed one octave **up,** by multiplying each of the "downward ratios" by (1:2). Thus the G♭ of the above sixth step would become in the higher octave 729:1024, or converted into cents, = 588 cents. **Note:** All cyclic steps marked (a) in the above two tables indicate that here an octave transposition is taking place. The step numbers without an (a) represent another cyclic step of a perfect fifth.

VIII. THE DIVISIVE SYSTEM

Apart from the cyclic (or "Pythagorean") principle for scale building, there was another method known and used in early Asian and Greek music theory which is usually called the **Divisive Principle.** It is based on the realization that a number of important intervals can be constructed by simple numerical ratios of neighboring figures; e. g. 1:2 = octave; 2:3 = perfect fifth; 3:4 = perfect fourth; 4:5 = major third; 5:6 = minor third; 8:9 = major second, etc. Some of these ratios are identical with the Pythagorean cyclic ratios, viz. 1:2; 2:3; 3:4; 8:9. (See Table No. 1, Col. 6)

Such fractions of neighboring figures are called **superparticular ratios.** They have played an important part in ancient music theory, frequently for reasons of numerical mysticism or superstition. In modern times they continue to influence theoretical thought because these ratios are the mathematical expressions of the series of harmonics sounding in most musical tones besides the frequencies of the fundamental tone. If, e. g., a tone is sounded on any instrument at a frequency of 100 cps, its second, third, fourth, etc. harmonics have the frequencies of 200, 300, 400 etc. cps, and farther up to as much as 1600 or 2000 cycles; sensitive measuring equipment permits to prove occasionally the presence of 16 to 20 harmonics with certain fundamental tones.

The discovery, in modern times, of numerous harmonics and of the fact that their respective frequencies are represented by superparticular ratios, led quite naturally to renewed speculation on the merits of intervals constructed on the basis of such ratios. Especially physicists and mathematicians showed a tendency to overestimate the value of such intervals for *practical musical* purposes. Under normal circumstances the human ear cannot hear and distinguish more than four or five harmonics with any given fundamental, and the audible or perceptible maximum appears to be seven or eight partial tones as a rare exception. Consequently, superparticular ratios beyond the limit of 7:8 cannot have *practical* musical value.

Note: There is some confusion about the order in which interval ratios should be spelled out. Some authors use the order 2:1; 5:4; 81:64. Others prefer it the other way around: 1:2; 4:5; 64:81. There is no real difference between the two spellings; the choice depends on whether we think **first** of the higher or the lower tone of any interval, or whether reference is made to the ratios of string lengths (2:1) or acoustical frequencies (1:2.) These writers prefer to think in terms of acoustical frequencies and therefore set the lower tone first. It should be noted, however, that **for logarithmic conversion of ratios into cents** the higher figure has always to come before the smaller one. In logarithmic procedure, division becomes subtraction; thus the smaller logarithm has to be subtracted from the larger one to avoid negative logarithms which have no meaning in the calculation of intervals in cents.

DISCUSSION OF MEANTONE TEMPERAMENT

The early chants of the Christian church were sung in unison without accompaniment, and presented no particular problems of tuning, save the general problem that singers have in singing together. It is not until the pneumatic organ was introduced into the church that tuning became important. Directions for constructing organ pipes in this period agree that the tuning was "Pythagorean", formed by a series of upward and downward fifths with the pure acoustical ratio 2 : 3 = 702 cents. (Cf. the two tables on "Pythagorean" tunings, up and downward, in columns 6-8.)

This was an excellent tuning for unharmonized music, for its small diatonic semitones (90 cents) are grateful to the singer, and its sharp major thirds (408 cents) were of little consequence. Parallel organum, with perfect fifths and fourths (702 and 498 cents), as used in the earliest stage of polyphony, was of course wholly satisfactory in such tuning. After thirds and sixths began to be employed in discant, they were considered dissonances, to be used sparingly. (In terms of strictly conventional theory, one would have to consider "Pythagorean" thirds and sixths as dissonant even today).

However, the importance of the thirds and sixths gradually increased, especially in the fauxbourdon (faburden) style, which consisted of parallel chords of the third and sixth, such as E-G-C. One might well surmise that the "Pythagorean" tuning was no longer adequate at this time, and the most prominent composer of the English school, **Walter Odington** (ca. 1280), even stated that consonant thirds had (just) ratios of 4:5 (386 cents) and 5:6 (316 cents), and singers intuitively used these ratios instead of those given by the Pythagorean monochord.[1] But Odington did not present a complete tuning system. It was not until **Bartolomeus Ramis de Pareja** offered his monochord directions in 1482 that a system exploiting the just third appeared.[*] It is easy to exaggerate the importance of Ramis' tuning system. He himself presented it as no more but a simplification of the older tuning — something which could be worked out more easily on the monochord. He seemed to have been unaware of the significance of those just major thirds which appeared in his system. The same holds true for the anonymous Erlangen organ tuning (*Erlangen Monochord;* Barbour, page 92, table 82) shown by Wilhelm Dupont.[2]

Of much greater significance than Ramis' monochord was the statement made by **Franchinus Gafurius** in 1496 that organists were accustomed to make slight alterations in the size of the intervals used in tuning; in other words, they were accustomed to **temper.** Nothing definite was said about the sort or amount of the tempering, but without question the cyclic fifths were slightly lowered in order to improve the quality of the major thirds, by reducing their size from 408 cents towards, but not approaching, 386 cents. A somewhat more definite statement was made in 1511 by **Arnold Schlick,** whose tuning system was to be achieved by vague but practical rules the observance of which, he said, would result in major thirds that would all be sharp (as against the just 386 cents), but in varying degree. So, although Schlick's system was **irregular,**[3] it must have been very similar to equal temperament which has flat fifths (700) and sharp thirds (400) also.

However, a little later, in 1523[4] **Pietro Aron** set down in print for the first time the rules for what is now known as the meantone temperament, a tuning system obtained by tuning each of four perfect fifths somewhat flat in order that the major thirds thus formed may have their just values (386 cents). Later writers expressed this temperament with greater precision: each fifth was to be tempered by ¼ comma, so that four fifths less two octaves would yield a major third with ratio 4 : 5 = 386 cents. The comma in question here is the **syntonic comma** (ratio 80:81 = 22 cents), comprising the difference between the "Pythagorean" major third of 408 cents and the major third in just intonation of 386 cents. This comma also appears as the difference between the diatonic and syntonic seconds:

DIATONIC SECONDS (Pythagorean Intonation).

Tones:	C	—	D	—	E
Ratios:	8	:	9		
	64	:	72	:	81
			8	:	9
Pitches:	0		204		408
Intervals:		204		204	

SYNTONIC SECONDS

Tones:	C	—	D	—	E
Ratios:	8	:	9	:	10
	64	:	72	:	80
Pitches:	0		204		386
Intervals:		204		182	

[*] Barbour, Tuning and Temperament, p. 3.
[1] Barbour, pp. 89-92. Table No. 81.
[2] Geschichte der musikalischen Temperatur, Erlangen 1935, pp. 20-22.
[3] An irregular temperament is a scale system built of fifths of unequal size. Equal temperament and the Pythagorean system belong both to the regular category, where all fifths in the cyclic construction measure 700 and 702 cents, respectively.
[4] Pietro Aron (also: AARON); Toscanello in Musica, Venice 1523; revised edition 1529.

This comma, measuring 22 cents (204 - 182, or 408 - 386) is the difference to be overcome in meantone tempering. In Aron's system ¼ comma (= 5.5 cents) is the amount by which each of four fifths is to be lowered: perfect fifth = 702 - 5.5 = 696.5 cents.

TABLE 3

TABULATION OF ARON'S MEANTONE SYSTEM

Cyclic Step No.	Resulting Tone	Cents Value
0	C	0
1	G	696.5
2		+ 696.5
		1393
2 (a)		— 1200
	D	193
3		+ 696.5
	A	889.5
4		+ 696.5
		1586
4 (a)		— 1200
	E	386

(All steps marked (a) indicate that here an octave transposition is taking place.)

It is thus clear that the objective of meantone tempering was to reduce the size of the Pythagorean major third towards the value of just intonation, by sacrificing the perfect fifth of 702 cents. In order to do so, the value of the syntonic comma has to be distributed, in one way or another, over a number of cyclic steps, if the scale system thus constructed is to be a regular system. As will be seen later, there have been other distributions of the comma, such as 1/3 or 2/7 comma, which lead to different tempering results. Some authors may question the inclusion of such systems in a discussion of meantone tempering, and prefer to have them treated as examples of **regular temperaments.** We believe, however, that their inclusion among the meantone systems is justified in all cases where a regular distribution of comma portions leads as well to the establishment of a **"mean"** tone. Historically, the Aron ¼-comma system came first, and it continued to have somewhat more prestige than the other comma distributions.

The term "meantone" came into existence as follows. The partials of the harmonic series[1] are the basis of all just intervals. The 8th, 9th and 10th partials of the tone C, for example, would be c", d" and e", forming the following intervals:

Tones:	c"——		d"——		e"
Ratios:	8	:	9	:	10
Pitches:	0		204		386
Intervals:		204		182	

Within this diatonic sequence the interval c-d has the ratio 8:9 (204 cents), the interval d-e the smaller ratio 9:10 (182 cents) which would be the theoretical proportions of just intonation.

In the meantone temperament each of these intervals has the ratio $2:\sqrt{5}$ which is the **geometric mean** between the ratios 8:9 and 9:10, and is thus a "mean" tone.

Tones:	c"——		d"——		e"
Ratios: —		$2:\sqrt{5}$		$2:\sqrt{5}$	
Pitches:	0		193		386
Intervals:		193		193	

[1] See the discussion of superparticular ratios in column 9

In terms of cents (a logarithmic unit) the **geometric** mean is reduced to an **arithmetic** mean, and both intervals measure an equal 193 cents. The fifths will be short (702 - 5.5 = 696.5), and the minor thirds will be 310.5 cents wide (696.5 - 386), i. e. they will be flat by the same amount as the fifths, the just minor third being 316 cents.

Thus, the major triad in meantone temperament, with beats[1] on two of its three tones, will have a definite buzz; the minor triad, with the dissonant minor third *below* the pure major third, will be even less satisfactory. Of course, some arrangements of the notes of these triads will sound better than others, as is true of all tunings.

Usually meantone tunings were built in *eight* cyclic *steps upwards,* and *three* steps *downwards,* making G♯ the sharpest note, and E♭ the flattest note of the scale (G♯ - E♭).

TABLE 4

MEANTONE TEMPERAMENT, TUNING OF EIGHT CYCLIC STEPS UPWARDS. AFTER ARON, ¼ COMMA TEMPERING

Cyclic Step No.	Resulting Tone	Cents Value
0	C	0
1	G	696.5
2		696.5
		1393.0
2 (a)		— 1200.0
	D	193.0
3		696.5
	A	889.5
4		696.5
		1586.0
4 (a)		— 1200.0
	E	386.0
5		696.5
	B	1082.5
6		696.5
		1779.0
6 (a)		— 1200.0
	F♯	579.0
7		696.5
		1275.5
7 (a)		— 1200.0
	C♯	75.5
8		696.5
	G♯	772.0

[1] When sounded together for a sufficient length of time, audible beats will develop on all intervals which deviate **by small amounts** from just intonation.

TABLE 5

MEANTONE TEMPERAMENT. TUNING OF THREE CYCLIC STEPS DOWNWARD. AFTER ARON, ¼ COMMA TEMPERING

Cyclic Step No.	Resulting Tone	Cents Value
0	C'	1200.0
1		— 696.5
	F	503.5
2 (a)		1200.0
		1703.5
2		— 696.5
	B♭	1007.0
3		— 696.5
	E♭	310.5

Lining up the twelve resulting tones from the above two tables, we get the following chromatic scale (decimals rounded out to full cents):

Tones:	C	C♯	D	E♭	E	F	F♯	G	G♯	A
Pitches:	0	76	193	310	386	503	579	697	772	890

Tones:	B♭	B	C'
Pitches:	1007	1083	1200

with alternating semitonic steps of 75.5 and 117.5 cents, respectively. In "Pythagorean" tuning the difference between the semitone sizes is much smaller: 90 and 114 cents, respectively. Where the circle steps meet, there was — in "Pythagorean" tuning — a comma clash of 24 cents, the **ditonic** or **Pythagorean comma** which appears as the difference between enharmonic changes, e. g. between G♯ and A♭, C♯ and D♭, etc. In meantone temperament, we get instead the **wolf fifth** G♯ - E♭ which is 36.5 cents sharp against the perfect fifth, and 42 cents sharp against all the other fifths tempered by ¼ comma. (1200 + 310.5 = 1510.5 — 772 = 738.5 cents). (Compute these fifths yourself, in order to confirm the size of the wolf fifth.)

In the major triad on G♯, the **false major third** G♯ — C, has 428 cents, being sharp by the **"great diesis"** against the just third. (Great diesis: 428 — 386 = 42 cents). The minor third, C — E♭, has only its normal meantone distortion of 5.5 cents, while the **false minor third,** B♭ — C♯, measures only 268.5 cents which is 47.5 cents[1] flat as against the just minor third of 316. Other triads with enharmonic makeshifts are fully as bad, such as:

Tones:	C♯————	F————	G♯	
Pitches:	75.5	503.5	772	
Intervals:		428 + 268.5		= 696.5

which is a rather violent distortion of a major triad. The contrast between the good and bad triads is great enough to be easily perceived by the average ear.

(1) Great diesis plus 5.5 cents meantone distortion.

Although the statement is often loosely made that the meantone temperament was the tuning system which was superseded by equal temperament about the time of Bach, this statement has to be strongly qualified to be even approximately correct. In the first place, it must be remembered that the meantone temperament was used primarily *for keyboard instruments* only — lutes and viols had been in equal temperament from at least the beginning of the sixteenth century, and the intonation of other instruments was either elastic (as violins) or imperfect (as the woodwinds).

(Woodwinds of the late Renaissance and early Baroque periods did not have their fingerholes in acoustically correct locations, but they were either bored at places convenient for stopping, or the holes were even placed at equal distances. It is quite possible, however, that woodwind players of this time had considerable skill in adjusting the imperfect intonation of their instruments to the necessities of the moment; unless one is willing to accept this hypothetical skill of intonation, it is hard to imagine how woodwinds of that time could have joined in any decent performance without utterly spoiling it).

Furthermore, even in the sixteenth century, certain other systems of tuning were advocated which were similar in their construction to the meantone temperament, but had their fifths flattened by a fractional part of the comma other than one quarter.

For example, **Gioseffo Zarlino** (1558), the famous theorist, advocated a temperament of 2/7 comma (6.3 cents), in which both the major and minor thirds are 1/7 comma (3 cents) flat. (Barbour, p. 33, table 26). His blind Spanish confrère, **Francisco Salinas** (1557), preferred a system in which the fifths were tempered by 1/3 comma (7.3 cents), with the major thirds 1/3 comma flat and the minor thirds just. (Barbour, p. 35, table 27). Salinas' system, with its very flat major thirds, would be greatly inferior to the ¼-comma temperament were it not that it is a **closed system**[1] like equal temperament. That is, when extended to ten cyclic steps upwards to A♯, and eight cyclic steps downwards to F♭ (to provide two different pitches for such enharmonic pairs as G♯ and A♭), its 19 notes lie equally spaced within the octave, creating no wolves. In order to realize this system on a keyboard instrument, one would need, of course, a keyboard with double (divided) keys for C♯-D♭, D♯-E♭, E-F♭, F♯-G♭, G♯-A♭, A♯-B♭, B-C♭, i. e. a total of 19 keys per octave. Such "divided keyboards" were frequently advocated in theory and occasionally even built during the sixteenth and seventeenth centuries to suit a variety of tempered systems.

The most important variant of the ¼-comma meantone temperament was the 1/6-comma temperament used by **Gottfried Silbermann** (ca. 1740), the famous organ-builder of Bach's day. (1/6 comma = 3.7 cents results in a tempered fifth of 698.3 cents.) In Silbermann's system the major third is 1/3 comma (7.3 cents) sharp, the minor third ½ comma flat (11 cents); but its wolves are still perceptible, since the false fifth, G♯-E♭, has 718 cents; the false thirds, such as G♯-C, have 413 cents. (Barbour, p. 42, table 34. **Verify these figures by computing these false intervals yourself.)**

Because of its importance, several of our examples have been recorded in the Silbermann temperament.

For comparison, several meantone variants are tabulated in Table No. 6 below. At a first glance it may seem as if, chronologically, the various systems proposed by these theorists select smaller and smaller parts of the comma for tempering their fifths, leading finally to a 1/10-comma temperament (2.2 cents) with a fifth of 699.8 cents which is, in effect, almost identical with **equal temperament.** (Fully identical would be a 1/11-comma system.) Unfortunately, this impression is deceptive. The **Schneegass** tuning of 1590 shows a comma part of 4.9 cents, the 1/5-comma distribution by **Verheijen** (1600) and **Rossi** (1666) amounts to 4.4 cents, but that is all until **Silbermann** proposes his 1/6-comma tuning **(3.7 cents)** in 1740 — a very late date for meantone systems. The three tunings mentioned by **Jean B. Romieu** have a purely theoretical character and are listed only for the sake of completeness in our survey of regular systems approaching equal temperament.

(1) A closed system is a regular temperament in which the starting tone is eventually reached again, in a closed circle.

The same goes for a search of evidence that the size of the major third in just intonation begins to approach gradually the equal-temperament size of 400 cents. There is no link between the meantone and equal temperament theories, which seem to run parallel and independent from each other, the same way as the practical applications of the two systems existed side by side, for more than two centuries, without mutual influence. Developments in meantone theory, apparently, had two main objectives: to make the wolf intervals less harsh, and to recognize that the purity of the fifth was *also* worth considering. Up to this day, the just third and the equally tempered third (with shades in between) are still in co-existence in our symphony orchestras, but few people pay any attention to this striking difference in intonation.

Since trouble arose with the meantone temperament only when its bounds of two flats and three sharps(1) were exceeded, performers of music written in the more remote keys would often find it necessary to tune their harpsichords to five sharps, for example, or six flats, according to the number of accidentals required in the composition. The recorded examples include such extended tunings to the sharp and flat sides of the circle. In a great many instances, as in the suites of François Couperin, this shift of the **tuning center** was sufficient to make the music wholly acceptable in meantone temperament. An extreme case is the Bach Prelude in E♭-Minor included among the examples.(2)

Extreme chromaticism usually suggests the need for equal temperament or an irregular temperament in which the wolves are less disturbing than in the meantone temperament. But chromaticism alone is no compelling evidence of the failure of meantone temperament, as can be seen in the Toccata by **Michel Angelo Rossi** (Example No. 9), the last part of which is almost wholly chromatic, but which contains no *essential* chord which does not lie within the bounds of normal meantone tuning G♯-E♭. However, some compositions, including many by Bach, were so chromatic that they would have sounded false in any kind of meantone temperament.

COMMENTARIES TO THE RECORDED EXAMPLES

First Group: SOME TYPICAL MEANTONE INTERVALS

There are several intervals which are common to all meantone temperaments. Their typical disadvantages are responsible for the limited usefulness of these tunings in modern Western music history and for the fact that equal temperament has generally replaced meantone systems during the eighteenth century. Among these undesirable intervals are, in particular, the two different sizes of semitones, the wolf fifth, and the major third with diesis error. If the sound phenomena of these intervals are carefully studied in the first three examples, it will be easy to recognize their appearance in the later examples of musical literature.

EXAMPLE NO. 1

¼-comma tuning after Aron, (G♯-E♭).
The two different sizes of semitones.

Tones:	C		C♯		D
Pitches:	0		76		193
Intervals:		76		117	

The semitones throughout any scale in ¼-comma tuning will be alternatingly 76 and 117 cents — a very considerable difference in size of 41 cents (41.5 cents, to be precise) which is, of course, the size of the great diesis. Even untrained ears should have no difficulty in telling these two semitones apart, and the shortcomings of chromatic scales and progressions played in this intonation are evident.

Compared with "Pythagorean" intonation, the Aron tuning, thus, is by far inferior for **chromatic** scales and progressions, since the Pythagorean semitones differ by only 24 cents (90+114 = 204); the 24-cents difference is, of course, identical with the Pythagorean comma. Readers interested in the sound phenomena of the Pythagorean system are referred to the first album of this record series (No. A-1: **The Theory of Classical Greek Music)** which contains numerous examples of Pythagorean intervals.

(1) Confirm this statement by computing the seven triads in the keys of A-Major and B♭-Major.

(2) Example No. 15, in Aron's tuning; example No. 23 in Silbermann's tuning.

An important consequence of any tone system containing widely differing semitones is the coloring influence of the half-tone steps upon modes and modal writing in general. In equal temperament, modes are losing much of their significance and distinctive color because here the various modes of a key are distinguished by but one characteristic: the position of the two semitone steps within the scale. It is thus no mere coincidence but rather a logical development that modal composition gradually disappears during the 2½ centuries in which equal temperament begins to supersede meantone temperament.

EXAMPLE NO. 2

¼-comma tuning after Aron.

The Wolf Fifth of 738 cents, and the major third which Diesis Error at 428 cents, played on the harpsichord.

Tones:	G♯		E♭		G♯'
Pitches:	772		310		772
			(1510)		(1972)
Intervals:		738	+	462	= 1200

The false fifth G♯-E♭ appears here as an interval of 738 cents, or 36 cents sharp as against the perfect fifth of 702 cents. The clash is enormous and truly revolting to our ears which have been used, throughout the centuries, to a pure intonation of the fifth or, in modern times, at least to the slightly compromised fifth of equal temperament (700 cents). Equally bad-sounding is the "wolf fourth" E♭-G♯ at 462 cents which is 36 cents flat against the perfect fourth (498) or 38 cents flat against its equally tempered counterpart (500).

It is, of course, simple to get rid of the false fifth and fourth by replacing the false G♯ with its enharmonic equivalent A♭ (814 cents). The difference between the two tones (814 — 772) is 42 cents, the **great diesis,** which appears whenever an enharmonic change takes place. Such retuning of the G♯ would produce the correct meantone fifth (696.5 cents) in this one location because then the interval becomes A♭-E♭. But then the wolf fifth is shifted to another location and appears between C♯ and A♭ (814 — 76 = 738), and nothing much is achieved except in the one place where one decides in favor of an enharmonic retuning.

The Third With Diesis Error

Tones:	G♯		E♭		G♯'		C'
Pitches:	772		310		772		0
			(1510)		(1972)		(2400)
Intervals:		738		462		428	

Here the false third G♯-C' appears as an interval of 428 cents, i. e. 42 cents sharp against the major third in just (or natural) intonation at 386 cents. This error of 42 cents is the great diesis (Greek, diesis = quarter tone)(1); it will occur at any location where an enharmonic change creates a false interval. What was said above concerning the elimination of wolf fifths by retuning, is valid also for the major third with diesis error. Retuning of G♯ into A♭ will result in a pure major third of 386 cents (1200 — 814 = 386). But again the false third is merely shifted to another location, E-A♭, where it will sound at 814 — 386 = 428 cents while the correct interval would be F♭-A♭.

It is evident, then, that wolf fifths, and thirds with diesis error, are inherent shortcomings of any meantone system; they cannot be eliminated, just as the Pythagorean comma cannot be overcome in the "Pythagorean" tone system.

(1) There is no agreement on the pronunciation of the word *"diesis"*. Philologists pronounce with the accent on the first syllable because the original Greek word was spelled and pronounced that way. Musicians, however, were used for several centuries to pronounce with accent on the second syllable, such as *ut dièse* (French) and *do diesis* (Italian), for the pitch name c♯. We prefer to follow the musical custom and to avoid confusion with the similar-sounding *diocese*.

EXAMPLE NO. 3

¼-comma tuning after Aron.

The Wolf Fifth and the Major Third with Diesis Error, repeated on the organ.

This repetition of Example No. 2 will demonstrate that false intervals sounding bad enough on the harpsichord are even more offensive on the organ whose sustained notes intensify the impression of dissonant sound phenomena.

The regular meantone fifth of 697 (696.5) cents seems quite acceptable on the harpsichord, but it sounds none too good on the organ which makes this narrow fifth beat quite heavily.

The Meantone Fifth

Tones:	D———	———F♯———	———A		
Pitches:	193	579	890		
Intervals:		386	+ 311		= 697

The heavy beat sounds as a slow, intensive tremolo. In this range of the keyboard an interval of 5.5 cents (the difference between 702 and 696.5 cents for the perfect and the meantone fifths) is the equivalent of ca 2.5 cycles per second, and we shall thus hear about 2½ beats per second.

Wolf Fifth and Diesis Error

Tones:	G♯———	———C———	———E♭		
Pitches:	772	0	310		
		(1200)	(1510)		
Intervals:		428	+ 310		= 738

A 36-cents pitch difference (738 — 702) means, in this keyboard range, about 13 cycles per second, and 13 beats per second are too fast to be clearly audible. Thus, the wolf fifth does not produce audible beats any more, it just clashes horribly on the organ. In this triadic combination it is hard to decide which phenomenon sounds worse, the false fifth or the diesis error on the major third.

Second Group: MUSIC EXAMPLES IN ARON'S ¼-COMMA TEMPERAMENT

EXAMPLE NO. 4

Tallis, Organ piece without title, played on the harpsichord.

From Margaret Glyn, *Early English Organ Music,* Vol. I, page 10.

¼-comma tuning, G♯-E♭. (8 cyclic steps upwards, 3 steps downwards).

Thomas Tallis, (ca. 1505-1585), was an outstanding English organist and composer of the early Tudor period, and is known chiefly for his sacred choral music. Thirteen of his little organ pieces are published in vol. I of the above source. The recorded example appears without a title, although like most of the Tallis pieces, it is based upon a plainsong Cantus Firmus in the tenor. The range of accidentals used, taken around the circle of fifths, is from C♯ through E♭. Thus, it lies within the conventional bounds for the meantone temperament, which were from G♯ through E♭.

Since the harmony is essentially triadic, there will be the characteristic smoothness and dullness of the just major thirds (386 cents), as well as the beating of both the minor thirds (310 cents) and the fifths. There are the usual slight clashes from suspensions and passing notes. But in bar 8 there is a harsh dissonance as the F♯ in the alto sounds against the F♮ in the soprano, and in bar 10 the E-flats in the soprano clash badly with the E♮ in the tenor and alto, respectively. (See musical illustration No. 1). Such discords are characteristic

of the English school, and they sounded no better in meantone temperament than in the equal temperament of today.

Tallis

Example no. 4. Illustr. no. 1.

On careful listening, a slight harshness will be noticed on each of the first counts in the sixth and fifth measures from the end. The chord of the sixth, D-D-B♭-F, seems to stress the normal meantone distortion (5.5 cents) by the doubling of the third. In the next measure, the A-Minor chord contains again doubled thirds, a practice which is usually avoided soon after about 1600. It is quite possible that the subsequent ban on doubled thirds in composition theory may have had something to do with the fact that the shortcomings of the meantone triad were particularly exposed by this practice.

EXAMPLE NO. 5

Merula, (17th century), Sonata Cromatica per Organo.

Final Section, played on the harpsichord.

From Torchi, *L'Arte Musicale in Italia,* Vol. 3, pp. 351-352.

¼-comma tuning, G♯-E♭.

Tarquino Merula was born in Cremona or Bergamo in the late 16th century, and served as chapelmaster in both these cities and at the Polish court. His published works include choral and chamber music. His *Sonata Cromatica per Organo* was found in a manuscript collection of keyboard music and is reprinted in Torchi's source quoted above.

Only the final section, pp. 351-352, has been recorded. Here the principal motive is a chromatic scale in quarter notes (often diminished to eighth notes) countered by a motive in sixteenths. With few exceptions the music lies within the ordinary meantone bounds, G♯-E♭. In the last bar of page 351 an essential D♯ (instead of the E♭ tuning) occurs twice, but is not obnoxious in the chromatic context. (See musical illustration No. 2). In the sixth and fifth bars from the end, A♭-F, heard above the subdominant pedal C, would actually be G♯-F, forming a dissonance, and, in the following bar, A♭-C-E♭ does not truly spell out a major triad. (See musical illustration No. 3). Here again, the clashes are minimized by being heard as the result of chromatic passing notes.

Merula.

Example no. 5. Illustr. no. 2.

Illustr. no. 3.

Also in bar 6 from the end, the (incomplete) chord of the seventh, C-B♭-G, sounds dissonant, because the seventh (1007 cents) is 38 cents sharp against the seventh in just intonation (ratio 4 : 7, = 969 cents).

EXAMPLE NO. 6.

Gibbons (1583-1625), Almain in C, played on the harpsichord.
From Margaret Glyn, *Early English Organ Music,* p. 8.

¼-comma tuning, D♯-B♭ (9 cyclic steps upwards, 2 steps downwards).

Orlando Gibbons, born in Oxford as the youngest of ten children, is the most important in a family which produced, in several generations, a considerable number of highly competent musicians. He is believed to be the greatest English composer between Byrd and Purcell. Gibbons received a Mus. B. degree in Cambridge, then an A.M. and finally an honorary Doctor of Music degree from Oxford University. He became the organist of the Chapel Royal and of Westminster Abbey; the esteem he enjoyed at the English Court is evidenced by the fact that the title of *"Musician for the Virginalles to attend in his highnes privie chamber"* was conferred upon him.

Gibbons is most noted for his church music and "verse anthems", but also for his madrigal and motet compositions, all of which show his mastership of polyphonic writing. Of his forty-odd keyboard works several are reprinted in the above source.

The Almain played on the harpsichord sounds perfectly smooth, but it should not be regarded as proof for the general usefulness of the Aron temperament. In order to make the modulation to E-Major possible, with the dominant chord B-D♯-F♯ in measure 12, the tone E♭ (310 cents) had to be retuned into D♯ (269 cents). This was a common procedure in meantone tuning to avoid the clash of the great diesis (310.5 — 269 = 41.5 cents) on the harpsichord. On the organ such enharmonic retuning for one particular piece would, of course, have been impossible, which makes it clear that modulations of the above type would have sounded very poor on an **organ** tuned in Aron's system.

EXAMPLE NO. 7.

Trabaci (fl. 1603-1615), Consonanze Stravaganti (published 1603).
From Torchi, *L'Arte Musicale in Italia,* Vol. III, p. 372.

¼-comma tuning, G♯-E♭.

Giovanni Maria Trabaci was born at Montepeloso toward the end of the 16th century. He became organist at the royal chapel of Naples shortly after 1600 and in 1614 became chapelmaster. He died in Naples in 1647. The bulk of his published works consists of choral music. From the first of his two books of organ music (*Ricercate, Canzone Francese, etc.,* Naples, 1603), seven little pieces have been republished in Torchi's work. The most interesting of these is the "Consonanze Stravaganti".

With the exception of bar 8, the music lies within the ordinary meantone bounds, G♯-E♭. (See musical illustration No. 4). Note that in bar 7 there is a very harsh suspension which resolves upon another dissonance, and that in bar 8 the false note D♯ (instead of E♭) first occurs in an augmented triad (B-D♯-G) and only on the fourth beat in the B-Major triad. Thus, although the B-Major triad is false (B-E♭-F♯) in the presently used meantone tuning, the effect is mitigated by the dissonances which precede it.

Trabaci.
Example no. 7. Illustr. no. 4.

EXAMPLE NO. 8.

Trabaci, Consonanze Stravaganti, repeated on the organ.

¼-comma tuning, G♯-E♭.

On the organ, the clash of the triads B-E♭-G and B-E♭-F♯, in bar 8, is much more apparent than on the harpsichord. The diminished triad E-G-B♭ (bar 10, count 4) with its two minor thirds at 310.5 cents each (= 621 cents) stands out unpleasantly. Finally, there is a clearly noticeable beat, in the last four measures, on most of the longer sustained notes; this is caused by the normal meantone distortion of the fifth and minor third. (Cf. the same phenomenon in Example No. 3, part I, above).

EXAMPLE NO. 9.

Rossi (ca. 1600-1660), Toccata No. 7, last page.
From Torchi, *L'Arte Musicale in Italia,* Vol. III, p. 309.

¼-comma tuning, G♯-E♭.

Michel Angelo Rossi, a pupil of Frescobaldi, was a Roman organist. He published a collection called *Toccate e Correnti,* the second edition of which appeared in 1657. These pieces have also been reprinted in Torchi's source, the ten toccate being for cembalo, and the ten correnti for cembalo or organ. The recorded example is the concluding page of Toccata No. 7.

This passage is extremely chromatic. The remarkable thing is that, as notated, all the essential chords lie within the ordinary meantone bounds, G♯-E♭. This is not to say that all of the harmony is smooth. In the course of the chromatic movement several augmented triads occur, such as B♭-D-F♯, and even a pseudo-triad, C-E♭-G♯. (See musical illustration No. 5). Also, just before the final cadence there is an ascending chromatic scale in parallel thirds above a subdominant pedal G. (See musical illustration No. 6). Although three of these thirds are notated as diminished fourths (F♯-B♭; B-E♭; C♯-F), all of these intervals clash with the pedal G, and the clash would still have been present had it been feasible to play these intervals as G♭-B♭; B-D♯; D♭-F. The poor sound of the false thirds stands out clearly among the other thirds; repeated listening to this example will be quite instructive.

Rossi.
Example no. 9. Illustr. no. 5.

Illustr. no. 6.

EXAMPLE NO. 10.

Couperin (1668-1733), L'Epineuse. Vol. V, p. 124, L'Oiseau Lyre Edition.

¼-comma tuning, after Aron. Circle of Fifths starting at E, with 8 cyclic steps upwards to B♯, and 3 steps downwards to G. (B♯-G).

The intonation used for this piece is a rather extreme example of tuning to the sharp side of the circle. In order to make the Couperin piece, with its range of accidentals going as far as B♯, playable in the meantone temperament, one has to use E, rather than C, as the starting point and to build 8 cyclic steps upwards, 3 steps downwards. The resulting scale looks as follows:

Tones:	B♯	C♯	D	D♯	E	E♯	F♯	G	G♯	A	A♯
Pitches:	—41	76	193	269	386	462	579	697	772	890	965

Tones:	B	B♯
Pitches:	1083	1159

(The reader is urged to compute this circle himself, starting at E = 386, to confirm the above scale values.)

François Couperin was the most famous member of the Couperin family which furnished organists to the church of St. Gervais in Paris without interruption for 175 years. He was also organist and harpsichordist to King Louis XV. His twenty-seven charming suites for harpsichord were published in four volumes between 1713 and 1730. *"L'Epineuse"* is an expressive rondeau from *Suite No. 26* in F♯-Minor. As recorded, about half of the first part has been omitted, but the entire section in F♯-Major toward the end is retained. Here the range is only eleven harmonic degrees, from D to B♯ inclusive, such small ranges being rather characteristic of Couperin's works. Thus, the piece can easily and effectively be performed in an extreme sharp meantone temperament, B♯-G. In this tuning, L'Epineuse will be found to sound quite smooth.

EXAMPLE NO. 11

Couperin, L'Epineuse. F♯-Major part repeated on the organ.

1/6-comma tuning after Silbermann, G♯-E♭.

In contrast to the satisfactory performance in Example No. 10, the section in F♯-Major is played again, this time in the Silbermann 1/6-comma meantone temperament, but within the conventional bounds, G♯-E♭. Here the tonic triad sounds as F♯-B♭-C♯, the dominant triad as C♯-F-G♯, and the third on the supertonic as G♯-C.

These false major thirds contain 413 cents and are thus 27 cents sharp against the just major third (386). The performance definitely sounds inferior to the sharp meantone tuning first used.

A computation of the Silbermann tuning G♯-E♭ will be found in Tables No. 7 and 8 and will enable the reader to confirm the size of the false thirds.

EXAMPLE NO. 12.

Zipoli (1688-1726), Preludio from First Suite in B-Minor.

1/4-comma tuning, 11 steps upwards to E♯. (E♯-C)

Domenico Zipoli was born in Prato in Tuscany. In 1716, when his two-volume work, *Sonate d'Intavolatura per Organo o Cembalo,* was published, he was organist at the Jesuit church in Rome. From 1718 until his death in 1726 he was organist at the Jesuit church in Cordoba, Argentina. Most of the compositions in the above collection have been printed in Vol. 3 of Torchi's work and in Vol. 36 of *I Classici della Musica Italiana.*

The Preludio to Zipoli's Suite in B-Minor (Torchi, pp. 396 and 397; also in *I Classici*) is full of lyric simplicity within the framework of binary form. Here the sharpest harmonic degree is B♯ (1158 cents), but this note is used only as a lower neighbor to C♯, and the higher-pitched C (1200 cents) would serve just as well. E♯ is essential in this bar. (See musical illustration No. 7). On the other hand, in bars 34 and 35, the note C occurs in a modulation to G-Major, but might be considered the dominant seventh of that key, in which case the flatter B♯ would not be inappropriate! (See illustration No. 8). In the temperament as played the range is taken from C to E♯ inclusive, upwards.

Zipoli.

Example no. 12. **Illustr. no. 7.**

Illustr. No 8.

Like François Couperin, Zipoli and his contemporaries in Italy seemed to prefer a flat or sharp meantone temperament to the conventional G♯-E♭; but, unlike Couperin, they often exceeded the number of harmonic degrees of the present composition, so that their works would have sounded better in equal temperament.

Here are the pitches of the present 11--step tuning:

Tones:	C	C♯	D	D♯	E	E♯	F♯	G	G♯	A
Pitches:	0	76	193	269	386	462	579	697	772	890

Tones:	A♯	B
Pitches:	965	1083

EXAMPLE NO. 13.

Handel (1685-1759), Allemande from Suite No. 5 in E-Major.

1/4-comma tuning, circle starting at E, with 9 cyclic steps upwards to F double-sharp, and 2 steps downwards to D.

George Frederick Handel was less radical in his modulatory scheme than Bach and some of the Italian composers, but his keyboard music seldom remained within the normal meantone bounds. For example, his *Suite No. 5* in E-Major extends far to the sharp side. In this suite the Allemande has exactly twelve harmonic degrees, F double-sharp to D. Thus, it can and will be played effectively in a meantone temperament transposed to this compass.

The complete tuning is as follows:

Tones:	B♯	C♯	D	D♯	E	E♯	F♯	Fx	G♯
Pitches:	1159	76	193	269	386	462	579	655	772

Tones:	A	A♯	B	B♯
Pitches:	890	965	1083	1159

TABLE NO. 6

Comparative Table of Various Meantone Tunings in Historical Order

	Pythagorean	Aron 1523 T.22 1/4 comma	Zarlino 1558 T.26 2/7 comma	Salinas 1577 T.27 1/3 comma	Schneegass 1590 T.31 2/9 comma	Verheijen 1600 T.28 1/5 comma	Rossi 1666 T.30 2/9 comma	Silbermann ca. 1740 T.34 1/6 comma	Harrison ca. 1745 T.32 3/10 comma	Smith 1749 T.33 5/18 comma	Mentioned By Jean B. Romieu 1758 T.35 1/7 comma	1758 T.36 1/8 comma	1758 T.37 1/9 comma	1758 T.38 1/10 comma
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C♯	114	76	70	64	79	83	79	89	69	72	92	95	97	99
D	204	193	191.5	189.5	194.5	195	194.5	197	191	192	198	198.5	199	199.5
E♭	294	310	313	316	309	307	308	305	314	312	303	302	301	301
E	408	386	383	379	389	390	389	394	382	384	396	397	398	399
F	498	503	504	505	504	502	503	502	504	504	501	501	500	500
F♯	612	579	574	569	585	586	582	590	573	576	593	596	598	599
G	702	697	696	695	698	698	697	698	696	696	699	699	700	700
G♯	816	772	817[1]	758	812[1]	781	777	787	764	768	791	794	797	798
A	906	890	887	884	892	893	892	895	887	888	897	898	899	899
B♭	996	1007	1008	1010	1005	1005	1006	1003	1009	1008	1002	1001	1001	1000
B	1110	1083	1078	1074	1085	1088	1085	1092	1078	1080	1095	1097	1098	1099
C'	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Size of wolf fifth	(678)[3]	738	747[2]	758	733[2]	726	731	718	750	744	712	708	704	703

(1) This tone is actually A♭, not G♯; the Schneegass scale has been transposed from G-Major to C-Major to make it fit into this table.

(2) The wolf fifth is here C♯-A♭.

(3) 702-24 cents, Pythagorean comma.

NOTE: The T-numbers T.22; T.26 etc. in the column heads refer to the tables in Barbour's *Tuning and Temperament*.

SIDE 2

EXAMPLE NO. 14.

Handel (1685-1759), Prelude to Suite No. 8 in F-Minor.

1/4-comma tuning, 5 cyclic steps up, 6 steps down (B-G♭).

The harmonic compass of this Prelude is strongly on the flat side (G♭-B), but is only twelve degrees also. To make it playable in the 1/4-comma temperament, a tuning to the flat side of the circle is necessary, with the following pitches:

Tones:	C	D♭	D	E♭	E	F	G♭	G
Pitches:	0	117	193	310	386	503	620	696

Tones:	A♭	A	B♭	B
Pitches:	813	890	1007	1083

In this transposed intonation the Prelude sounds quite well indeed, with the exception of bar 13 where a Neapolitan sixth introduces C♭ instead of the present tuning B, resulting in the false fourth G♭-B at 463 cents, an interval that clashes badly.

EXAMPLE NO. 15.

J. S. Bach (1685-1750), Well-Tempered Clavier, Book I; Prelude No. 8 in E♭-Minor.

1/4-comma tuning, 3 cyclic steps upwards, 8 steps down (A-F♭).

Bach has usually been presented as a proponent of equal temperament, because of the title, *The Well-Tempered Clavier,* attached to his first collection of twenty-four preludes in every major and minor key. But "well tempered" does not necessarily mean "equally tempered". It is true that some of these works overlap the circle of fifths to a considerable extent, such as No. 24 in B-Minor, with a compass of seventeen harmonic degrees, from F double-sharp to E♭ inclusive. These must have needed equal temperament. But many of the others barely overlapped the circle, such as No. 12 in F-Minor, with a compass from F♯ to G♭, and could have been played in a sharp or flat meantone temperament. (No. 6 in D-Minor and No. 11 in F-Major lie precisely within the ordinary meantone bounds, G♯-E♭, while No. 2 in C-Minor has only eleven harmonic degrees, F♯-A♭.)

The most remote from C-Major, of these preludes and fugues with limited compass, is No. 8 in E♭-Minor, where the compass is A to B double-flat. Both of these extreme notes are used in the Prelude. The B double-flat occurs in measure 26, but only as a short passing note between C♭ and A♭ where its tuning is unimportant. (See musical illustration No. 9,)

Bach.

Example no. 15. Illustr. no. 9.

The tone A, however, is essential, occurring in bars 11, 14, and 15 as the third of the F-Major triad. For this reason, a flat meantone temperament (A-F♭) was selected for our performance of the *Prelude in E♭-Minor,* with the following intonations:

Tones:	C	D♭	D	E♭	F♭	F	G♭
Pitches:	0	117	193	310	427	503	620

Tones:	G	A♭	A	B♭	C'♭
Pitches:	696	813	890	1007	1124

Third Group: MUSIC EXAMPLES IN SILBERMANN'S 1/6-COMMA TEMPERAMENT.

Gottfried Silbermann (1683-1753) was one of the great German organ builders of his generation; he created 47 organs, among them two famous instruments: at Freiburg Cathedral and at the Dresden Court Church. He was equally admired for his harpsichords and clavichords and had the distinction of being the first German piano maker. Several of his harpsichords were built for Frederick the Great of Prussia, for use at his Sanssouci concerts.

Like most organ and harpsichord builders of his time, Silbermann was a good mathematician and a competent musical theorist; his most important theoretical contribution was a meantone temperament in which the circle fifth is lowered by 1/6 comma. From contemporary reports[1] it is apparent that he used this tuning for his organs and claviers. The quoted source does not make it clear whether Silbermann divided the ditonic (Pythagorean) comma of 24 cents or the syntonic comma of 22 cents. Since the results of either method would be identical for *all practical purposes* (1/6 of 2 cents = 1/3 cent would be an inaudible pitch difference), we present Silbermann's temperament as a distribution of the syntonic comma.

1/6 comma, or 3.67 cents, will reduce the perfect fifth (702) to 698.33 cents. The following tabulation shows the construction of a conventional meantone circle, 8 steps up, 3 steps down (G♯-E♭).

TABLE 7

1/6-Comma Meantone Temperament after Silbermann, Eight steps upwards.

Cyclic Step No.	Resulting Tone	Cents Value
0	C	0
1	G	698.33
2		+ 698.33
		1396.67
2(a)		− 1200.00
	D	196.67
3		+ 698.33
	A	895.00
4		+ 698.33
		1593.33
4(a)		− 1200.00
	E	393.33
5		+ 698.33

[1] George Andreas Sorge, *Gespraech zwischen einem Musico theoretico und einem Studioso musices,* 1748.

	B	1091.67
6		+ 698.33
		1790.00
6(a)		− 1200.00
	F♯	590.00
7		+ 698.33
		1288.33
7(a)		− 1200.00
	C♯	88.33
8		+ 698.33
	G♯	786.67

TABLE 8

1/6-Comma Tuning after Silbermann. Three cyclic steps downwards.

Cyclic Step No.	Resulting Tone	Cents Value
0	C'	1200.00
1		− 698.33
	F	501.66
2(a)		+ 1200.00
		1701.66
2		− 698.33
	B♭	1003.33
3		− 698.33
	E♭	305.00

Lining up the values of these two tables, we arrive at the following chromatic scale for the Silbermann temperament G♯-E♭:

Tones:	C	C♯	D	E♭	E	F	F♯	G
Pitches:	0	88	197	305	393	502	590	698

Tones:	G♯	A	B♭	B	C'
Pitches:	787	895	1003	1092	1200

Like the Pythagorean, and like all other meantone tunings, the Silbermann scale also shows two alternating sizes of semitones: 88.33 and 108.33 cents, the difference between being 20 cents. This compares favorably with the Aron temperament where the cleavage amounts to 42 cents, and is better than the Pythagorean difference of 24 cents. Accordingly, the Silbermann diesis for enharmonic changes will also be 20 cents only, and the wolf fifth G♯-E♭ (1505-787) will measure no more that 718 cents, i. e. 20 cents sharp against Silbermann's tempered fifth of 698 cents.

EXAMPLE NO. 16.

1/6-comma tuning after Silbermann. (G♯-E♭)

The two different sizes of semitones.

Tones:	C——C♯——D
Pitches:	0 88 197
Intervals:	88 109

This demonstration is an analogy to Example No. 1; a listening comparison of the semitone sizes in the Aron and Silbermann temperaments will be useful and help to sharpen the hearing sense for micro-intervals. It is quite easy to tell the two Silbermann semitones apart, but a comparison between the corresponding 1/4-comma and 1/6-comma semitones calls for concentrated listening and an effort at memorizing the four different intervals.

There is a theory in the field of musical esthetics and psychology which believes in "semitonic tensions" between neighboring tones, and holds that these "natural" tensions furnish the explanation for such phenomena as the leading tone (French: *note sensible!*). The seventh degree of modern diatonic scales has, in triadic harmony, a "strong tendency to lead upward" into the tonic and the same is true of all harmonic schemes which use half-tone steps for the purpose of modulation. The underlying idea of this theory is that "natural" melodic flow prefers the smallest interval step possible under given circumstances of voice-leading, very much like lightning and other electric discharges which are supposed to seek automatically the shortest distance between existing potentials or tensions.

It is unfortunate that none of the tunings which were important in the 17th to 19th centuries, seem to support this theory. All semitonic steps with the character of leading tones (C♯-D; D-E♭; E-F; F♯-G, etc.) have the larger size of the two semitones, and so far no tuning system has been proposed which tries to make use of the smaller half-tone step for leading-tone "tensions". In the musical developments of the twentieth century, however, questions of leading tones and semitonic tensions have lost much of their previous significance.

EXAMPLE NO. 17

1/6-comma tuning after Silbermann. (G♯-E♭).

The wolf fifth of 718 cents, and the major third with diesis error at 413 cents.

Tones:	G♯——E♭——G'♯
Pitches:	787 305 (1505) 787 (1987)
Intervals:	718 + 482 = 1200

The wolf fifth, 16 cents sharp as against perfect intonation, is still unpleasantly audible, and the same is true of the false fourth which is 16 cents flat as against the perfect fourth (498). The marked improvement over the Aron wolf, however, is immediately evident.

Tones:	G♯——C'——E'♯——G'♯
Pitches:	787 1200 305 (1505) 787 (1987)
Intervals:	$\underbrace{413 + 305}_{718}$ + 482 = 1200

The wide major third with diesis error, sounding alone by itself, is not very offensive to our contemporary ears. The reason, probably, is that it is only 5 cents wider than the Pythagorean third of 408 cents, and that contemporary string instruments show a tendency to intone wide thirds exceeding the size of the equally tempered interval. Thus we are quite accustomed to hearing oversized major thirds in daily performance. The moment the wolf fifth is added, however, the combined triad becomes definitely unpleasant; in fact the listener will find that the ear becomes more aware of the fifth being too wide when this fifth follows the oversized third. Oddly enough, the triad alone is still bearable, but when the higher octave G♯ comes in, the chord suddenly sounds revolting. Apparently the ear distinguishes clearly between two and three dissonant intervals; although the two tonics are tuned as perfect octaves, the highest tone adds the sensation of one more dissonance, the false fourth, while the consonant octave does not help to alleviate the cumulative effect of these dissonances.

EXAMPLE NO. 18

J. S. Bach, Sarabande from French Suite in D-Minor.

1/6-comma tuning, G♯-E♭.

The *French Suite No. 1* in D-Minor is one of the few large works by this composer that not only keep within the bounds of twelve harmonic degrees, but also lie wholly within the conventional meantone compass, G♯-E♭. Therefore it is a suitable work with which to illustrate the Silbermann temperament. The resulting major thirds are sharp by 1/3 comma (7.33 cents, = 393) instead of being pure as in the Aron temperament. Beyond the limits of the given compass the wolves are still present, although they have been tamed to an extent. The recorded Sarabande from the *D-Minor Suite* is full of polyphonically conceived dissonance which will be harsh in any tuning. It is interesting to note that Bach has used the note E♭ here only in diminished seventh chords and other somewhat dissonant functions for which a D♯ would not have been really disturbing. Even when the E♭ occurs in the chord of the sixth and fourth in bar 7, it is heard together with the C♯ as a chromatic appoggiatura to the D in the following measure and not primarily as a chord tone. (See musical illustration.)

Bach.

Example no. 18. Illustr. no. 10.

EXAMPLE No. 19

J. S. Bach, Well-Tempered Clavier, Book I. Prelude No. 6 in D-Minor.

1/6-comma tuning after Silbermann, G♯-E♭.

The Prelude and Fugue No. 6 in D-Minor have already been mentioned as lying completely within the G♯-E♭ bounds. The Prelude has relatively mild dissonances, as well as a constant rhythm of fast-moving triplet sixteenths in the treble, both of which features add to the smoothness of its harmony when performed in this tuning.

It seems that D-Minor is a particularly suitable key for the Silbermann temperament. In fact, this Prelude sounds magnificent in the 1/6-comma tuning where it is enhanced by a poignancy and beauty of interval coloration that cannot easily be duplicated in equal temperament. The conclusion is fully justified that equal temperament need not always be superior to Silbermann's meantone system. It was for good reasons that this tuning enjoyed popularity in the middle of the eighteenth century.

EXAMPLE NO. 20

J. S. Bach, Well-Tempered Clavier, Book I. Excerpt from Prelude No. 17 in A♭-Major.

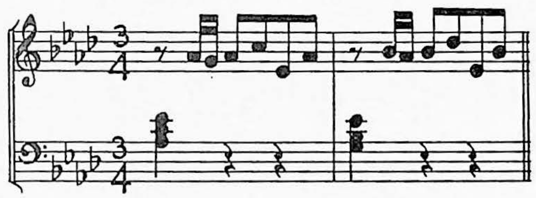
1/6-comma tuning, G♯-E♭.

In its normal range, G♯-E♭, the Silbermann temperament served well enough for most of the music written at the time of its use. Even if an occasional A♭ or D♯ did appear in the music, its false tuning would not matter too much if there were many polyphonic dissonances present, such as suspensions, or, conversely, if the texture were thin and the melodic movement rapid. It was in sustained triads containing the dangerous notes that the tuning errors were most marked. Thus, in Bach's *Prelude No. 17* the A♭ triad is struck as an accompanying chord in bars 1, 3, and 5 (see the musical illustration), and the falseness of the A♭ is apparent in the Silbermann temperament. (The dissonant D♭ occurs in bars 2 and 4, but only in the dominant seventh chord.) A few bars later, with a thinner texture and many sixteenths, the frequent A-flats (instead of G♯) cause little trouble.

However, the E♭ at the end of this example sounds clearly off pitch after the modulation into the dominant key. Hearing the low G♯ intonation all the time, the ear expects a correspondingly low D♯ tuning at 285 cents; instead there comes a high E♭ (305 cents) which sounds 20 cents higher than we anticipate. This goes to show that a wolf can become apparent, by its context, even on a single tone.

Bach.

Example no. 20. Illustr. no. 11.



EXAMPLE NO. 21

J. S. Bach, Fantasia for Organ in B-Minor. (B. G. XXXVIII, pp. 59-60)

1/6-comma tuning, G♯-E♭.

B-Minor is a very critical key in meantone temperament, for not only does its dominant triad contain two false thirds (F♯-B♭-C♯), but the dominant triads in the nearly related keys of E-Minor and F♯-Minor (B-E♭-F♯ and C♯-F-G♯) are also false. Thus an attempt to play an organ continuo part in meantone temperament for Bach's *Mass in B-Minor* would have been hazardous indeed. The same holds true of Bach's short organ piece in B-Minor, *Fantasia con Imitatione*. In the prelude-like Fantasia, essential E-sharps occur in bars 7, 8, 9, and 13. However, the polyphonic movement of the parts prevents the baldness of the false C♯-Major triad from becoming very evident except possibly on the first beat of bar 9. (See musical illustration.) In the three-and-a-half bars with dominant pedal before the cadential chord there are six essential A-sharps — all being too short to clash much. But the Picardy D♯[1] in the sustained final triad does beat badly in the organ recording.

Bach.

Example no. 21. Illustr. no. 12. (Bar 8 and 9)

EXAMPLE NO. 22

J. S. Bach, Imitatio for Organ in B-Minor. (B.G. XXXVIII, pp. 60-61.) Excerpt played on the harpsichord.

1/6-comma tuning after Silbermann, G♯-E♭.

[1] A Picardy third is the major third as used in the final chord of a piece written in a minor key.

In the first forty-seven bars of the *Imitatio* (the part that is played here) there are twelve A-sharps. But almost all of these are on weak beats, the only disturbing place before the final cadence occurring in bar 8 where the accented F♯ triad is heard. (See musical illustration.) Note in the excerpt performed that Bach keeps shifting away from the dangerous tonic key to the safer realm of the relative key of D-Major. On the harpsichord, used in this example, all of the clashes are of course less evident than on the organ. Yet, on keen listening, the false B♭ tuning (instead of A♯) will be clearly discernible, very much the way we can spot a sour note on a poorly tuned piano.

Bach.

Example no. 22 Illustr. no. 13. (Bar 5 - 9).

EXAMPLE NO. 23

J. S. Bach, Well-Tempered Clavier, Book 1. Excerpt from Prelude No. 8 in E♭-Minor.

1/6-comma tuning, G♯-E♭.

In very remote keys (as already noted in the F♯-Major section of the Couperin rondeau), the Silbermann temperament would have been excruciating without a shift of tonal center. For example, in E♭-Minor, the tonic triad must be played as E♭-F♯-B♭, the subdominant as G♯-B-E♭, the mediant as F♯-B♭-C♯. The beginning of *Prelude No. 8* in E♭-Minor, so pleasing in the flat Aron meantone temperament, is here played in the Silbermann temperament in the normal range, G♯-E♭.

The effect is that of a harpsichord appreciably out of tune. It is evident that Bach would have tuned his instrument at least five more steps to the flat side of the circle (A-F♭), if he had wished to play this Prelude in the Silbermann temperament.

EXAMPLE NO. 24

J. S. Bach, Well-Tempered Clavier, Book I. Excerpt from Prelude No. 3 in C♯-Major.

1/6-comma tuning, G♯-E♭.

The key of D♭-Major is one of the worst when played within the ordinary meantone bounds, for all three of its principal triads are false (C♯-F-G♯, F♯-B♭-C♯, G♯-C-E♭) and so are its secondary triads. An excellent example of the distressing sound of this key in meantone temperament is *Prelude No. 3* in C♯-Major — enharmonically D♭-Major. In the performed part of this Prelude there is not even one consonant triad. And yet the effect upon the harpsichord is not completely unpleasant — partly because of the percussive nature of the

instrument, partly because there is constant motion with no points of repose. But the main reason why the piece is not wholly unacceptable in the Silbermann temperament G♯-E♭ seems to be that there are no really good triads with which to compare the clashing triads; the tuning is *uniformly* poor, and that makes it almost listenable.

Conclusions:

The recorded examples indicate that Bach and several of his predecessors and contemporaries must have had meantone temperaments in their minds when they composed certain keyboard works, particularly because of certain precautions taken that would have been unnecessary with equal temperament.

It is hoped that the studies undertaken in this recording will inspire investigations into a question that has never been asked: to which degree did methods of tuning and tempering influence the rules of musical composition as they were developed during the Renaissance and Baroque era?

Engineer's Report:

For best results phono equalization should be set for the RIAA curve (bass turnover frequency 500 cps, treble attenuation 14 db at 10,000 cps). Playback is recommended at moderate volume levels whenever possible. These disks are pressed of 100% pure vinylite.

TUNING RECORDS:

Numerous users of the present record series "The History of the Theory of Music" have requested advice on the tuning of keyboard instruments for experimentation with a variety of tunings. The most precise method of tuning keyboard and other instruments is to measure and check tunings, with a stroboscopic frequency meter. This is an expensive instrument normally beyond the means of musicians, teachers and students. It is, however, quite possible to tune keyboard instruments by ear in comparison with given tuning standards or pitches. If carefully done, this method is sufficiently accurate for most musical experimentation.

In order to meet the requests for tuning standards, MUSURGIA RECORDS has provided a number of tuning records the first of which are now available.

Tuning Series No. T-1.	1/4-Comma Meantone Tunings
Tuning Series No. T-2.	1/6-Comma Meantone Tunings
Tuning Series No. T-3.	Just Intonation Tunings
Tuning Series No. T-4.	Pythagorean Tunings

Further MUSURGIA RECORDS releases completed or in preparation:

- No. A-1. THE THEORY OF CLASSICAL GREEK MUSIC
- No. A-3. THE THEORY AND PRACTICE OF JUST INTONATION
- No. A-4. THE HISTORY OF UNEQUAL TEMPERAMENTS
- No. A-5. CHINESE MUSIC THEORY AND ACOUSTICS
- No. A-6. ARABIC MUSIC THEORY AND ACOUSTICS
- No. A-7. INDIAN MUSIC THEORY AND ACOUSTICS
- No. A-8. THE SOUND PHENOMENA OF QUARTERTONE MUSIC AND OTHER MODERN EXPERIMENTAL SCALES