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Theory Applied to Practice

A Suggested Improvement for the Fisk Organ at Stanford

Mark Lindley

Charles Fisk died before the completion in 1984 of one of his most magnificent organs, a 73-rank instrument at Stanford University designed specially to incorporate two different kinds of unequal temperament.[1]

I was among the hundreds of organists and scholars who attended recitals on this instrument at the 1984 convention of the American Guild of Organists. After one very elegant recital of late-Baroque French music, a few people remarked to me that for all the extraordinary beauty of its voicing and timbres, the instrument sounded out of tune. One person asked me if this was due to the weather, but another, with whom I have worked on 18th century temperaments over the years, recognized the real reason: what was intended to exemplify a late baroque kind of tuning on the Fisk organ is a little too unlike the styles of temperament actually used at that time, and so did not suit the music very well.

Having known in advance the tuning specifications proposed for the organ, I had expressed my concern in a letter to Charles Fisk — which however arrived too late for him to respond to or act upon. I am writing this article in the hope that the misfortune of his untimely death may not

1. The instrument and the history of its making are described in the April 1984 issue of *The American Organist*, 177-79.

be compounded by leaving the instrument tuned in a manner which I think will be more clearly recognized, in the years to come, as unworthy of an organ of this calibre and significance.

The organ's two tunings share the same diatonic notes, but use different pipes for the chromatic notes. The idea was to choose, from amongst the various shades of renaissance-style meantone temperament (where certain keys are very euphonious but others quite sour) one which would also provide a suitable basis, among the diatonic notes, for a late-baroque unequal temperament in which all the keys can be used even though their scales are intoned differently. The player changes from the one style of tuning to the other by moving a single lever.

Before explaining how a single set of diatonic notes can serve for two different styles of historical tuning, it may be of use (at least to some readers) to review some technical rudiments of keyboard temperaments.

On the organ, a tempered harmonic consonance is one which instead of being tuned pure is tuned to beat a certain amount. Why? Because the various basic kinds of pure consonances are not commensurate with one another. A succession of three or four pure 5ths and 4ths (such as G-D-A-E or C-G-D-A-E) makes a major 6th or 3rd that is larger than pure by nearly 1/9 whole-tone; a succession of three pure major 3rds (such as A^b-C-E-G#) makes a very sour octave, smaller than pure by about 1/5 whole-tone; and a succession of twelve pure 5ths and 4ths makes a rather sour octave, larger than pure by about 1/9 whole-tone (or to put it another way: if you tune eleven pure 5ths in succession, the one remaining will be flat by about 1/9 whole-tone and is called a "wolf" 5th). These discrepancies are summarized in Figure 1.

Fig. 1a. The syntonic comma

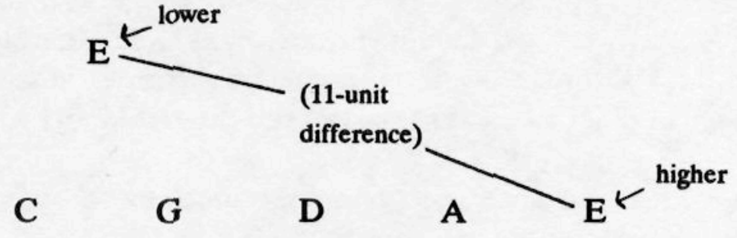


Fig. 1b. The lesser diesis

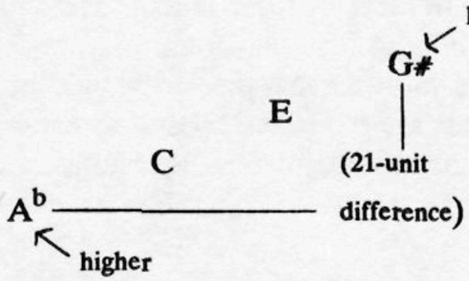
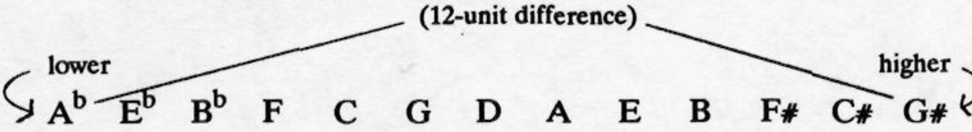
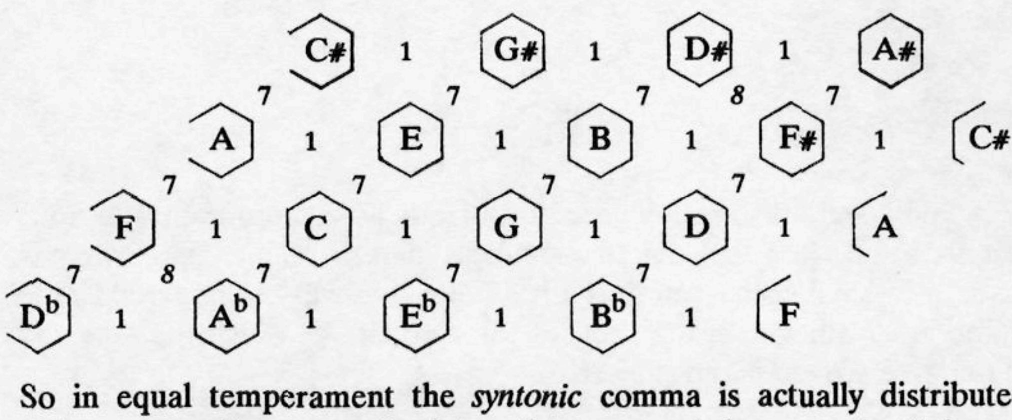


Fig. 1c. The Pythagorean comma



In equal temperament (the normal tuning for a modern piano or organ), two of these discrepancies are distributed equally among the intervals concerned: each 5th is tuned smaller than pure by 1/12 of the pythagorean comma, which is really a very small amount; and each major 3rd is tuned larger than pure by 1/3 of the lesser diesis — which is a more considerable amount. In fact the lesser diesis is almost precisely 21/12 as large as the pythagorean comma, so if we were to take 1/12 of that comma (*the amount by which our 5ths are tuned smaller than pure*) as a unit of measure, we would find that each major 3rd is larger than pure by 1/3 of 21, or 7 units; and each major 6th (amounting to a 4th plus a major 3rd) is larger than pure by 8 units (7 in the major 3rd, plus 1 in the 4th, which is of course larger than pure by the same amount that the 5th is smaller):

Fig. 2. Equal temperament



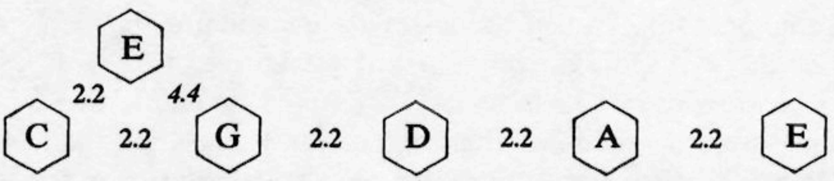
So in equal temperament the *syntonic* comma is actually distributed rather *un*equally among the intervals concerned, because the 3rds and

6ths are tempered seven or eight times as much as the 5ths and 4ths. (Notice, in Figure 2, that since 7 + 4 or 8 + 3 equals 11, it follows that the syntonic comma amounts to eleven of our units.) Most lute players in the 16th century did not mind this,[2] but keyboard players preferred to have the 5ths tempered a little more so that the 3rds would be tempered rather less. If the 5ths and 4ths are tempered by 2 units each, the major 3rds will be tempered by 3 and the major 6ths by 5 units, as shown in Figure 3.

Fig. 3. 1/6-comma meantone temperament

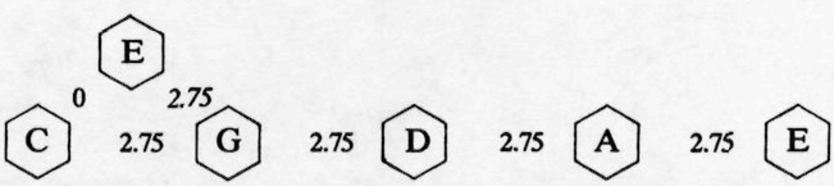
If the 5ths and 4ths are tempered by 2.2 units, the major 3rds will be tempered by the same amount and the major 6ths twice that amount (Figure 4).

Fig. 4. 1/5-comma meantone temperament



If the 5ths and 4ths are tempered by 2.75 units, the major 3rds will be pure and the major 6ths will be tempered by 2.75 units, like the 4ths (Figure 5).

Fig. 5. 1/4-comma meantone temperament



If the 5ths and 4ths are tempered by slightly little more than 2.75 units (let us say 3, just to keep the numbers simple), the major 3rds will actually be smaller than pure, and the major 6ths will be tempered by the difference (rather than the sum) of the amounts by which the 4ths and major 3rds are tempered (Figure 6).

2. See my *Lutes, Viols and Temperaments* (Cambridge, 1984), 19-31.

Fig. 6. 3/11-comma meantone temperament

These models encompass most of the varieties of temperament used on the renaissance organ.[3] They represent various shades of meantone temperament, each of them "regular" inasmuch as it has only one size of tempered 5th. Without going into detail as to how they sound, we should observe that since they all have the 5ths tempered by at least twice as much as in equal temperament — that is, by at least twice as much as will cause a chain of twelve 5ths and 4ths to produce a pure octave — they all contain a wolf 5th at least as bad as the one produced by a chain of eleven untempered 5ths. The wolf 5th in any meantone temperament, however, is larger than pure, not smaller.

Moreover, in all these shades of meantone temperament, the lesser diesis is distributed so unequally that if the sum of two major 3rds (for instance C-E-G#) is subtracted from the octave (C-C), the remaining interval (in this case G#-C) is not serviceable as a major 3rd, except in a rather gingerly kind of way (exactly how gingerly depends on the shade of meantone in question). It is, categorically, a dissonant interval, a diminished 4th.

These two characteristics of any meantone temperament — its very unequal distribution of the pythagorean comma and its very unequal distribution of the lesser dieses — can be summarized, as far as normal keyboard instruments are concerned, by saying that each black key must be tuned either as a sharp or else as a flat. The only way around this in a regular meantone temperament is to divide the key in two and let each half operate a different pipe or string. This has been done for A^b/G# and E^b/D# on the fourth manual of the Fisk organ at Stanford. The division which it applies to, the Brustwerk, has fourteen pipes per octave in each rank, and cannot be switched to a baroque style of tuning. (The other three divisions have a total of seventeen pipes per octave in each rank, for the sake of the two alternative temperaments.)

3. See chapters 2-3 in my "Stimmung und Temperatur," in F. Zaminer, ed., *Geschichte der Musiktheoris*, vol. 6, *Musikalisches Hören und Messen in der frühen Neuzeit* (Berlin, 1987); or part 1 of my "Heinrich Schütz: intonazione della scala e struttura tonale," in *Il Flauto Dolce*, no. 14 (April, 1987); or sections 2-3 in my "Temperaments," in S. Sadie, ed., *The New Grove Dictionary of Musical Instruments* (London: Macmillan, 1985).

I should mention one other feature of any regular meantone tuning: that it has two (and only two) sizes of semitone. Since the major 3rd is tempered rather less than in equal temperament, the diatonic semitone (the difference between a major 3rd and a 4th) is larger than in equal temperament. And so the chromatic semitone (between any natural and its own sharp or flat) is smaller. How much larger or smaller depends upon the shade of meantone.

Among the *irregular* schemes of temperament described in various renaissance treatises (i.e., with different sizes of tempered 5th), two seem to have been put into use. One of them, prescribed by Arnolt Schlick in 1511, is so unlike the regular schemes favored by the Italians and Spaniards that it would have been most unsuitable for the Fisk organ; so it needn't be discussed here.[4] But the other one, for which our source is Michael Praetorius's *De Organographia* (1619), should be described, because Charles Fisk believed that the tuning of the Stanford organ was based on Praetorius's treatise, and indeed the "renaissance" tuning on the Fisk organ is irregular.

Praetorius prescribed a meantone temperament with pure major 3rds, as represented in Figure 5 above. But then he said that although "C#, F# and G# should be quite pure with their (respective) 3rds A, D, and E," nevertheless "the 5ths C#-G# and F#-C#...must not beat as much as (the) other 4ths."[5] Now one might well ask how A-C# can be pure, just like D-F#, even though F#-C# is tempered less than B-F#. That is, if C# makes a higher 5th than F# (in an otherwise regular temperament), *how can it sound just as low as F# does in a harmonic 3rd?* And similarly, how can G# make a higher 5th but still be low enough with E to make a pure harmonic 3rd? The answer lies in the fact that often the pipes for notes a major 3rd apart in any one rank are very near to each other on the soundboard, and so when they are played together they are likely to "draw" pure with one another even if the melodic 3rd which they would make if played separate is a little larger.

Since the irregularity in question was, according to Praetorius, too slight to change the harmonic 3rd, it seems clear that its purpose was to make a difference melodically when the harmonic 3rd was not being played (or at least not played long enough to draw pure). Praetorius evidently

4. See Heinrich Husmann, "Zur Charakteristik der schlickschen Temperatur," in *Archiv für Musikwissenschaft*, vol. 24 (1967); or my "Early Sixteenth-Century Keyboard Temperaments," in *Musica disciplina*, vol. 28 (1974): 129-39.

5. M. Praetorius, *Syntagma musicum*, vol. 2: *De organographia* (Wolfenbüttel, 1619), 155: "cis, fis, gis sollen gegen ihren Tertien als a d e gar rein einstimmen ....die Quinten cis-gis und fis-cis müssen ...nicht so sehr wie andere Quinte schweben."

wanted C#-D and G#-A to be slightly smaller than the other diatonic semitones.

In the "renaissance" tuning on the Fisk organ, however, the chromatic notes are treated in the opposite way: B-F#-C#-G# (and also E^b-B^b-F) are tempered more than the diatonic 5ths, not less; so C#-D and G#-A *et al.* are larger than the E-F and B-C, not smaller. There is no historical warrant for this. I think it represents an approach to tuning analagous to the approach taken, at certain earlier stages of the organ revival, to various other important aspects of historical design. The thinking goes like this: "The 'bad' modern organ has a lot of nicking; earlier organs had less; therefore it would be even better to have none at all. The modern organ has a lot of pipes enclosed in swell boxes; in earlier organs, the pipes spoke more directly to the hearer; therefore it would be even better to have them all out in the open. The modern organ has equal semitones; earlier organs had somewhat unequal ones; therefore it would be even better to make them as unequal as possible...."

What this kind of thinking ignores is that the beauty of the old organs is due to a judicious, balanced and well-seasoned treatment of these matters. I admit that the "renaissance" tuning on the Fisk organ sounds more exotic to us (more "funky," if you like) than a real renaissance tuning would; but the latter would sound better — because C# and G# would not make such dull leading tones (dull in isolation and particularly dull in comparison to the diatonic leading tones). In general, a judiciously chosen shade of meantone temperament is one in which a careful balance is struck between a modicum of conviction in the leading tones and a modicum of euphony in the major 6ths and 3rds. I hope that in the fullness of time the custodians of the Fisk organ will take this into consideration. I think Charles Fisk certainly never intended to have an "anti-Praetorian" tuning for this part of the organ.

* * *

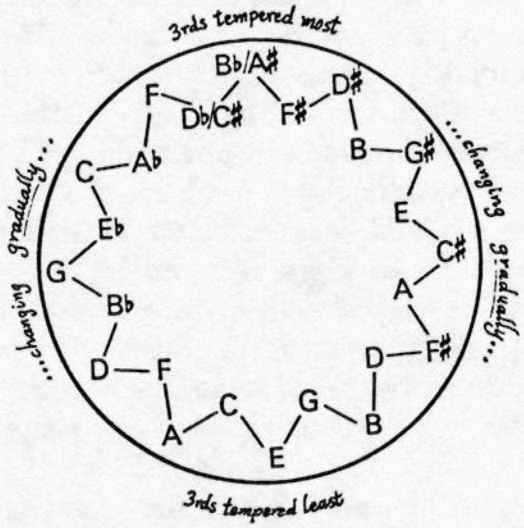
My main criticism, however, has to do with the other temperament. So we should now consider some characteristics of late-baroque keyboard tunings, particularly in France and Germany.[6]

In all these tunings the 5ths were tempered more, on the whole, among the diatonic notes than among the chromatic notes. Hence the 3rds and 6ths among the diatonic notes would be tempered least; those involving

6. For further information see chapters 7-9 in my "Stimmung und Temperatur" (see note 3).

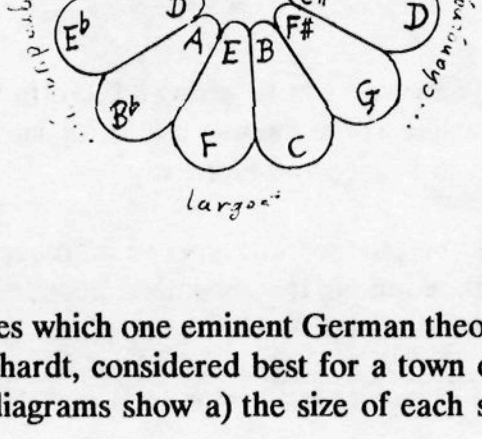
the first or second flat or sharp would be tempered a bit more; and those at the "back" of the circle of 5ths would be tempered most, as shown in Figure 7.

Fig. 7. 3rds arranged according to the circle of 5ths



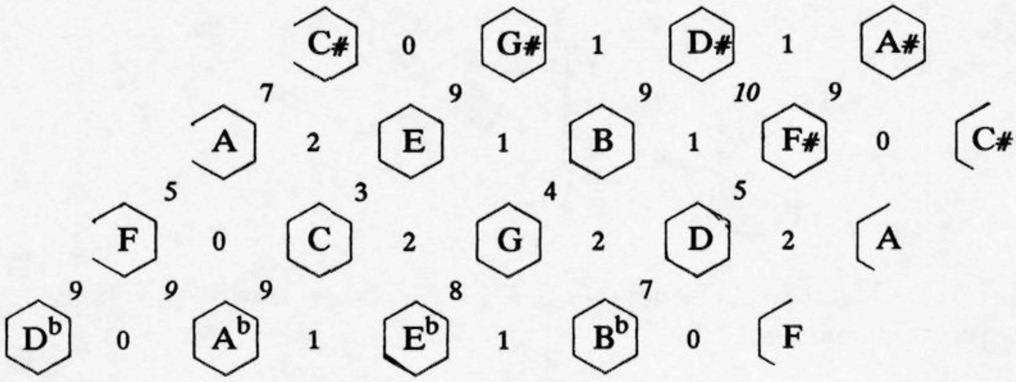
The semitones varied in the same gradual way, the largest being E-F and B-C, the smallest C-D^b, F-G^b (or E#-F#) and A#-B, as shown in Figure 8.

Fig. 8. Semitones arranged according to the circle of 5ths



Here are the schemes which one eminent German theorist of Bach's day, Johann Georg Neidhardt, considered best for a town or city (Figures 9-11). The "flower" diagrams show a) the size of each semitone, in cents (the cent being defined as 1/100 of the uniform semitone of equal temperament), and b) the difference between each pair of semitones adjacent in the circle.

Fig. 9. The scheme Neidhardt recommended in 1724 for villages, but in 1732 for small towns



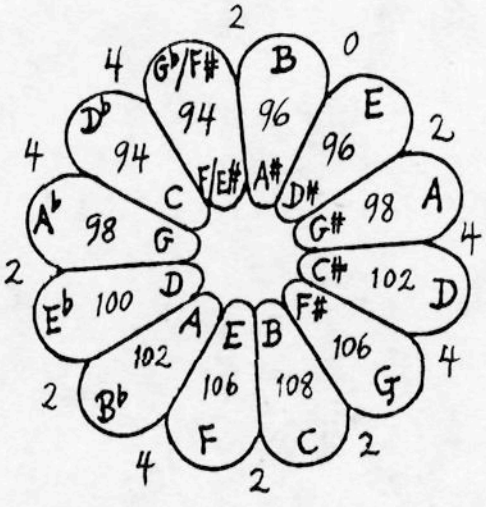
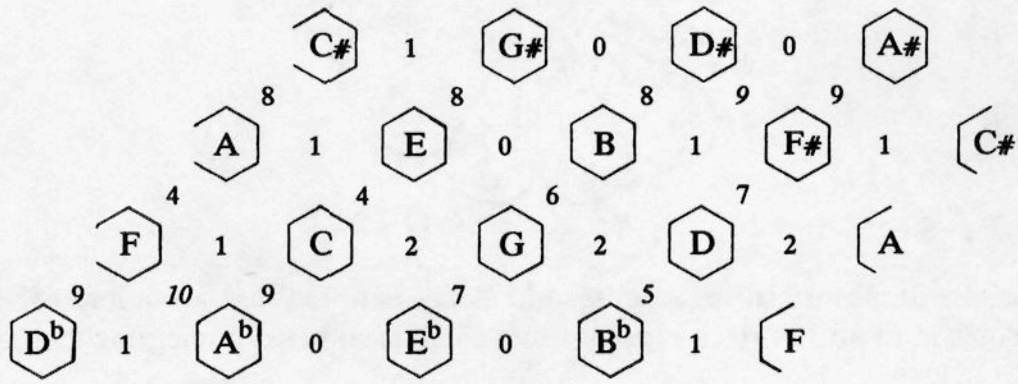


Fig. 10. The scheme Neidhardt recommended in 1724 for small towns, but in 1732 for large towns



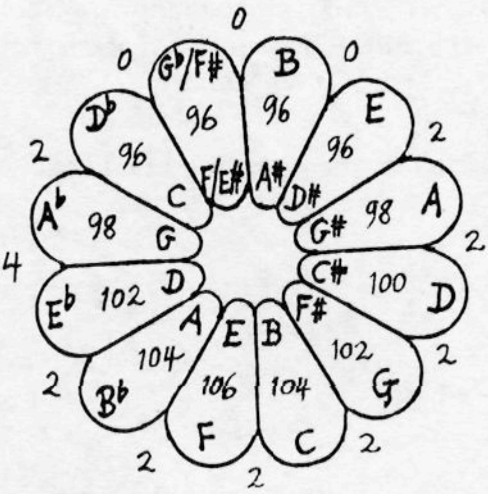
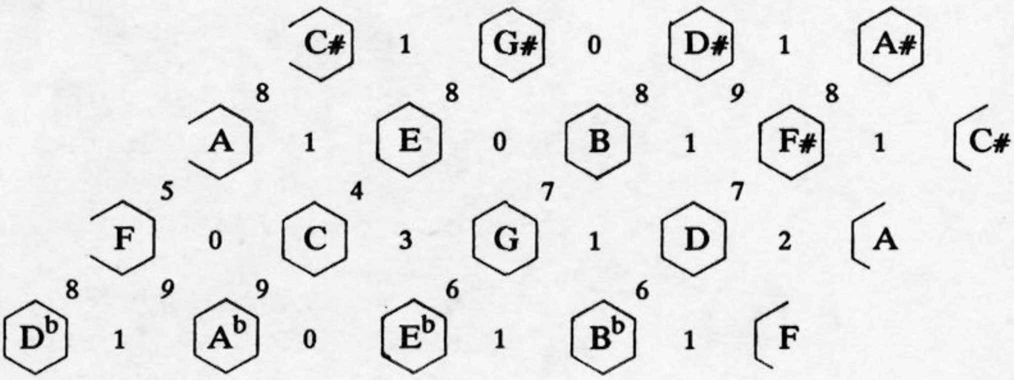
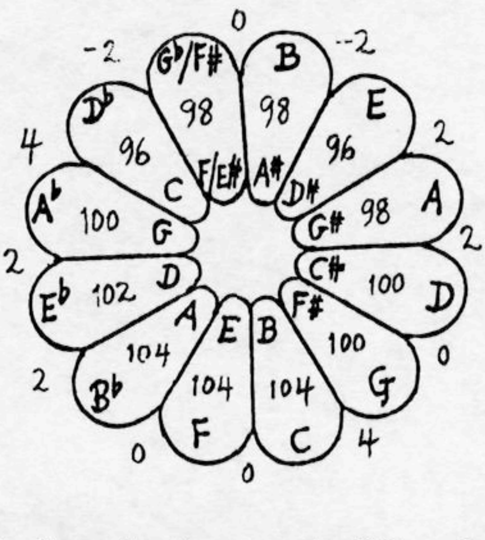


Fig. 11. Neidhardt's scheme of 1724 for large towns (no longer recommended in 1732)





Neidhardt is worth discussing in some detail here because a number of people close to J.S. Bach regarded him as an even better tuning theorist than Andreas Werckmeister. Since we have no explicit opinion from Bach himself we have to make do with theirs; I shall cite three of them here (Mizler, Sorge, Altnikol) and then return to Neidhardt himself.

Lorenz Mizler evidently took music lessons from Bach in the early 1730s, and in 1738 (by then he regarded Bach as "a good friend and patron") founded a musicological society in Leipzig, the *Societät der Musicalischen Wissenschaften*, for which Bach composed, when he joined it in 1747, his canonic variations on "Vom Himmel hoch da komm' ich her."[7] In 1737 Mizler reprinted one of Werckmeister's treatises in his own periodical *Musikalische Bibliothek*, and in his introductory essay said of Werckmeister:[8]

Was aber seine	As far as his
Temperatur anbelanget,	temperament is concerned,
so ist selbige zu seiner Zeit	at his time it
die beste gewesen,	was the best,
nach der Zeit aber von Neidhardt	but since the time of Neidhardt
verbessert worden.	it has been improved upon.

Georg Andreas Sorge joined Mizler's society the same year that Bach did, and dedicated one of his books to Bach with some rather friendly and jocular remarks in the dedicatory preface.[9] He invoked Bach in 1748 as a witness that Gottfried Silbermann's use of the regular meantone temperament represented above in Figure 3 was not a satisfactory practice, and he referred to Werckmeister in a way that suggests, clearly though not explicitly, that the best modern tuning was preferable to Werckmeister's:[10]

Die Silbermannische Art zu	Silbermann's kind of
temperiren, kan	tempering is incompatible
bey heutiger Praxi	with modern practice.
nicht bestehen.	
Dass dieses alles	To testify that all this
die lautere Wahrheit sey,	is the pure truth

7. Cf. W. Neumann and H.J. Schulze, *Bach-Dokumente*, vol. 2 (Kassel, 1969), 322; or H.T. David and A. Mendel, *The Bach Reader* (revised edition, New York, 1966), 224.

8. L.C. Mizler, *Musikalische Bibliothek, Dritter Theil* (1737), 55.

9. Cf. Neumann and Schulze, *Bach-Dokumente* 2, 412-23 (see note 7); or for an English translation, David and Mendel, *The Bach Reader*, 235f (see note 7), where Sorge's term "freundlichen Schmunzel-Lachen" is rendered as "friendly smile".

10. G.A. Sorge, *Gespräch zwischen einem musico theoretico und einen studioso musices* (Lobenstein, 1748), 32f.

ruffe ich alle unpartheyische	I call upon all unbiased
und in der Sache erfahrne	and (in this matter) expert
Musicos,	musicians,
sonderlich den Welt-beruhmten	especially the world-famous
Herrn Bach in Leipzig	Mr. Bach in Leipzig.
zu zeugen.	
...Wenn nun mancher	Now if some
Instrument = und Orgelstimmer	harpsichord and organ tuners
nur noch so gut stimmete,	would only tune as well
wie Werckmeister	as Werckmeister
vor 57. Jahren gestimmet hat,	tuned 57 years ago,
so wäre es noch gut.	*that* would be good enough.

On one occasion or another, Sorge recommended equal temperament, Neidhardt's scheme shown in Figure 10 above, or certain schemes of his own that were no less subtly unequal than Neidhardt's.

No one was much closer to Bach in his old age than his only son-in-law (and former pupil) Johann Christoph Altnikol, of whom Forkel said that he took down from dictation Bach's last, uncompleted chorale prelude (BWV 668).[11] With Bach's recommendation Altnikol was chosen organist at the Wenzelkirche in Naumburg in 1748, where the organ had recently been rebuilt by Zacharias Hildebrandt and inspected by Bach to ratify that the contract had been properly fulfilled.[12] (Under the circumstances it would have been very remarkable if Bach had not been consulted during the rebuilding of this instrument.) In describing this organ in 1753, Altnikol said of Hildebrandt:[13]

In der Temperatur gehet er nach	In the temperament he follows
dem Neidhardt, und man kan	Neidhardt, and one can
aus allen Tönen gantz fein	modulate
moduliren,	very nicely into all keys,
ohne dass das Gehör	without giving the ear
wiedriges zu hören	anything unpleasant to hear,
bekomt,	
welches bey heutigen Gusto	which for today's taste
der Music das schönste ist.	in music is the most beautiful.

11. The surviving manuscript is not in Altnikol's hand, however: cf. W. Emery, "Altnikol," in *The New Grove Dictionary of Music and Musicians* (see note 3).

12. Cf. U. Dähnert, *Der Orgel- und Instrumenten-Bauer Zacharias Hildebrand* (Leipzig, 1962), p. 115.

13. Transcribed in Dähnert, *Orgel- und Instrumenten-Bauer*, 112 (see note 12).

Now let us consider Neidhardt's own views. In his first book, *Beste und Leichteste Temperatur des Monochordi* (1706), Neidhardt had championed equal temperament; but in the 1720s he began to change his mind. In 1724 he said that while equal temperament was the best choice for a court, the three schemes shown above in Figures 9-11 were the best, respectively, for a village, a small town, and a large town.[14] There is a clear rationale here, in that the preferred temperaments become less subtly unequal as the ambience becomes more rural. This same rationale is to be found also in Neidhardt's later view (1732) that a large town would really do best with the scheme that he had formerly recommended for a small town; a small town would in turn do best with the one he had formerly recommended for a village; a village wants a scheme slightly more unequal than any of the three shown above; and although equal temperament "cannot easily be given last place" ("nähme wohl nicht gerne den letzten Rang ein"), nevertheless:[15]

die meisten finden doch	most people do not find
an dieser Stimmung nicht,	in this tuning
was sie suchen.	that which they seek.
Es fehlet (heisset es)	*They say it lacks*
ihren Tertiis maioribus an der	variety in the beating
Abwechselung der Schwebungen,	of its major 3rds,
und folglich mehrerer	and consequently a heightening
Gemüths = Bewegungen.	of emotion.

(Many writings from France as well as Germany show that this was a wide-spread view.) From all this it is clear that Neidhardt's distinction as a tuning theorist was that his best schemes had a modicum of variety among the 3rds and semitones (in keeping with the patterns shown above in Figures 7 and 8) without making any of the 24 keys sound harsh.

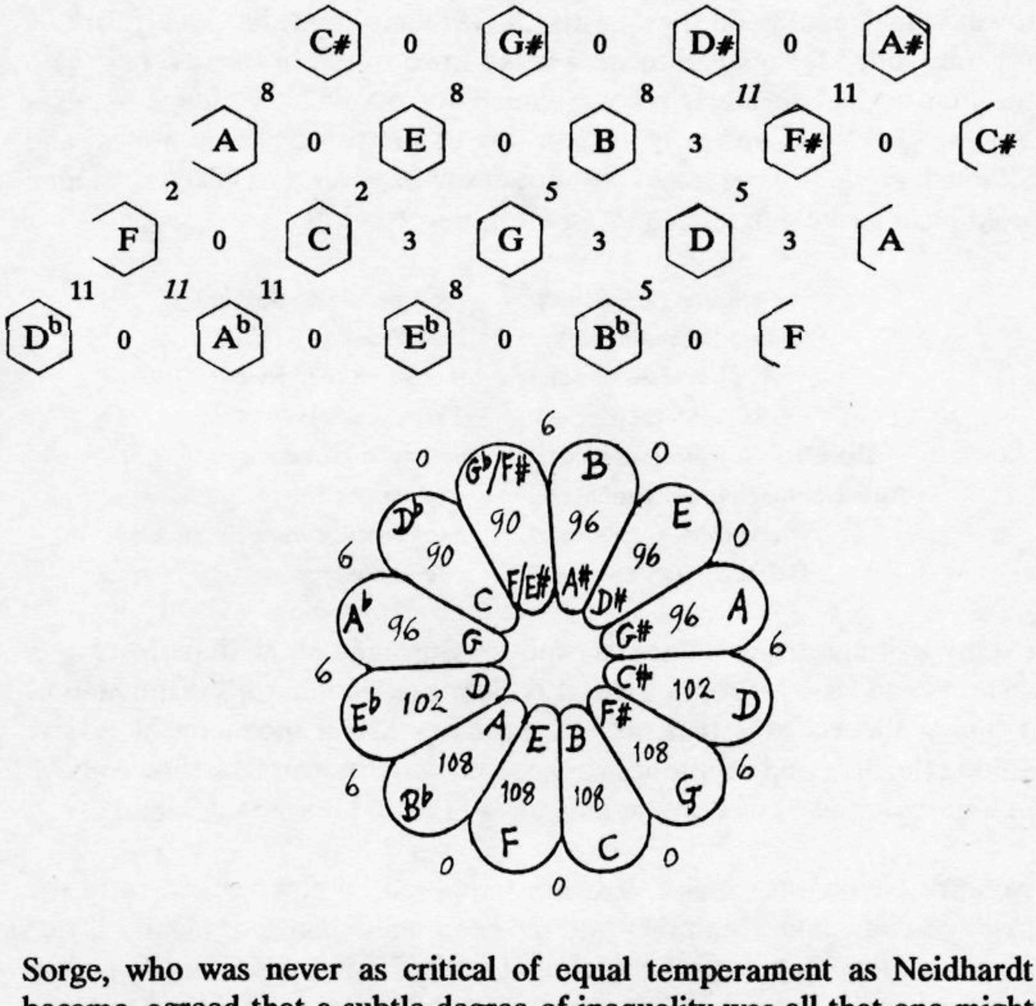
None of Neidhardt's major 3rds are tempered by more than 3/4 of the pythagorean comma, and they and the semitones change gradually as one moves step-by-step around the circle of 5ths. To achieve this he had to temper F-A by at least 1/3-comma; otherwise A-C# would have to be as large as D^b-F (contrary to the pattern shown in Figure 7) if the latter were not to be tempered more than 3/4-comma. Also, the unit of measure for tempering had to be small enough to allow several sizes between the smallest and largest major 3rds (tempered by some 1/4- and

14. J.G. Neidhardt, *Sectio canonis harmonici, zur volligen Richtigkeit der generum modulandi* (Königsberg, 1724), p. 16.

15. Neidhardt, *Gantzlich ershöpfte mathematische Abtheilungen des diatonisch-chromatischen temperirten canonis monochordi* (Königsberg, 1732), 40f.

3/4-comma respectively). Neidhardt chose 1/12 of the pythagorean comma for his unit of measure; with a larger unit such as 1/4- or 1/5-comma, he could not have obtained a suitable variety of 3rds all tempered by less than a comma (nor indeed a suitable variety of semitones). This was already evident in Werckmeister's schemes,[16] the most important one of which is shown in Figure 12.

Fig. 12. Werckmeister's scheme for chromatic music



Sorge, who was never as critical of equal temperament as Neidhardt became, agreed that a subtle degree of inequality was all that one might want. He said:[17]

Die Diesis 125:128 beträgt 21	The diesis (128:125) is 21
zwölftheile Commatis ditonici	12ths of the pythagorean comma,
diese 21 können nun	and these 21 can

16. A. Werckmeister, *Orgel-Probe...* (Quedlinburg, 1681), 26-40.
17. Sorge, *Der in der Rechen- und Messkunst wohlerfahrne Orgelbaumeister* (Lobenstein, 1773), 56f.

auf verschiedene Art	be parceled out
vertheilet werden,	in various ways
als i) 7,7,7. ii) 6,7,8,	such as 7-7-7, 6-7-8,
iii) 6,8,7. iv) 5,9,7. v) 5,7,9.	6-8-7, 5-9-7, 5-7-9,
etc. Aber in 4,4,13; 4,5,12;	etc. But 4-4-13, 4-5-12,
4,6,11; oder gar 3,3,15;	4-6-11, or even 3-3-15,
3,4,14; 3,5,13; 3,6,12; oder wie	3-4-14, 3-5-13, 2-6-12 or, like
Herr Kirnberger in 0,10,11	Mr. Kirnberger, 0-10-11
thut kein gut.	is no good.

This reference to Kirnberger's manner of tuning, in which C-E is pure,[18] calls to mind Marpurg's point (1776) that:[19]

Der Hr. Kirnberger selbst hat	Mr. Kirnberger himself has
mir und andern mehrmahl erzählet	often told me and others
wie der berühmte Joh. Seb. Bach	how the famous J.S. Bach
ihm, währender Zeit	explained to him, during the time
seines demselben genossen	that he had the privilege
musikalischen Unterrichts,	of studying music with him,
die Stimmung seines Claviers	the tuning of his clavier,
übertragen,	
und wie dieser Meister	and how that master
ausdrücklich von ihm verlanget,	explicitly enjoined him
alle grosse Terzen scharf	to render
zu machen	all the major 3rds sharp.

Werckmeister, Neidhardt and Sorge all agreed with Bach and Marpurg that not even C-E should draw pure. Werckmeister said:[20]

wenn man sich	If you
an keinem Modum im Stimmen	do not want to be bound,
will binden lassen,	to any key in the tuning,
so kan man nur	you can only
alle Tertias majores	let
in die Höhe schweben	all the major 3rds
lassen	beat high.

18. Kirnberger's remarkably crude tunings are so off-target for Bach that they needn't be described further here; they are covered in chapter 8 of my "Stimmung und Temperatur" (see note 3).

19. F.W. Marpurg, *Versuch über die musikalische Temperatur* (Breslau, 1776), 213.

20. Werckmeister, *Musicalische Temperatur* (Quedlinburg, 1691), 75.

Neidhardt would refer succinctly to one or another of his "best" tunings as the one where C-E "beats 4 twelfths" or "beats 3 twelfths" of the pythagorean comma ("4 Zwölftheil schwebt," "3 Zwölftheil schwebt").[21] Sorge would write:[22]

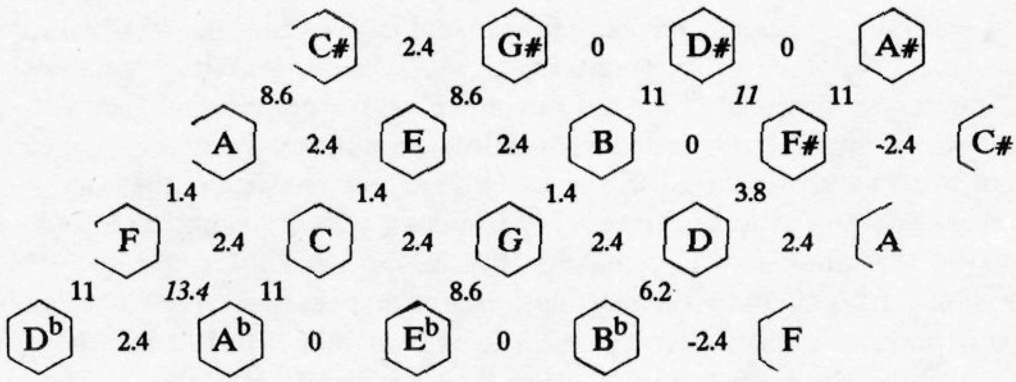
weil man um der Trompeten	Since for the trumpet you
willen dem Modum C dur immer	want always to keep C major,
gern vor den andern	more than the other keys,
so viel wie möglich rein	as pure as possible,
behält...	
Man macht ...wohl c-e erst	you might well first make C-E
ganz rein, hernach das e	quite pure, and then (make) E
ein wenig höher, so dass es	a little higher so that it
erleidlich über sich schwebe.	beats tolerably.
Zu diesem e kan man gis	To this E you can tune G#
erst rein, hernach auch	pure, at first, and then also
ein wenig über sich schwebend	beating a little high,
stimmen,	
alsdenn kan man hören, ob	and then you can hear whether
dieses gs zu c zu erleiden, oder	this G# is tolerable with C, or
noch allzustark ...schwebet;	beats all too strongly (with C);
findet man sich das letztere,	if the latter is the case,
so muss man dem e und	you must help (by making) E and
gs noch ein wenig in die Höhe	G# a little higher,
helfen,	
oder auch dem gs nur allein.	or just G# alone.
Wäre aber gs und c reiner und	But if G#-C is purer and
schwebet weniger als c gs	beats less than E-G#
oder c e, so hat man	or C-E then you have
dem e und gs zu viel gethan.	overdone E and G#.

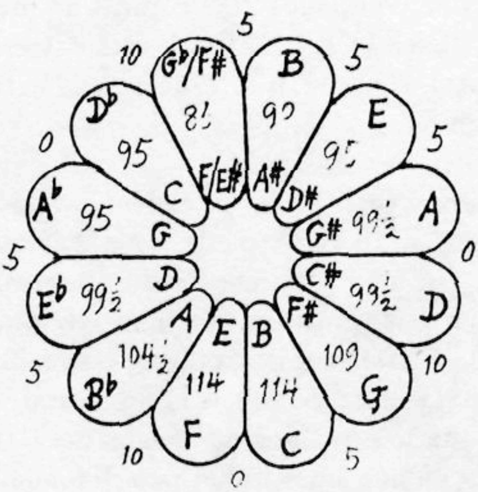
From all this it should be fairly clear that a) the object of Neidhardt's tuning schemes was not that some 5ths should beat exactly twice as much as others and some should be perfectly pure, but rather that the 3rds (and of course the semitones) should vary in a certain way; and b) the "baroque" tuning on the Fisk organ (see Figure 13) is quite different, in as much as its diatonic 3rds are intended to draw pure while four of its major 3rds are tempered by an entire comma (and A^b-F distinctly more). Such a temperament does not really answer to C.P.E. Bach's description of his father's tuning: "so pure and correct... that all the keys sound beautiful and pleasant" ("so rein und richtig... dass alle Tonarten schön

21. Neidhardt, *Gantzlich erschöpfte mathematische Abteilungen* (see note 15).
22. Sorge, *Anweisung zur Stimmung und Temperatur...* (Hamburg, 1744), 30f.

und gefällig klangen").[23] And, no less important, its diatonic leading tones, B and E, are too dull for Bach's music. This cannot be substantiated on the printed page, but I should be happy to demonstrate it at Stanford with comparisons *in vivo*.

Fig. 13. The quasi-baroque tuning on the Fisk organ





* * *

In the contemporary French *tempérament ordinaire*, however, some keys were harsh. Here I would like to describe this style of tuning in just enough detail, citing some representative examples of the various kinds of evidence available to us, to show how it compares with the tuning of the Fisk organ.[24]

23. Mizler, *Musikalische Bibliothek, Vierter Band, Dritter Theyl* (1754), p. 172f; translated in David and Mendel, *The Bach Reader*, 223 (see note 7).

24. See note 6.

We have no mathematical formulations of the *tempérament ordinaire* from before 1750, because the theorists who wrote in French preferred (for reasons which would take us too far afield to explain here) to reckon in multiple divisions of the octave. They knew that the three shades of regular meantone temperament shown above in Figures 3-5 (1/6-comma, 1/5-comma and 1/4-comma) could be matched, for all practical purposes, by dividing the octave into 55, 43 and 31 equal parts respectively.[25] So when Joseph Sauveur said in 1707 that the 55 division was "the one which ordinary musicians use" ("celui dont les Musiciens ordinaires se servent"),[26] he did not mean that everyone had taken to microtonal music, but only that major 3rds were normally intoned larger than pure by some three of our units. He said, however, that organ makers and sophisticated harpsichord makers ("les Facteurs d'Orgues" and "les facteurs de Clavecins du Roy & de Paris") favored the 43 division (i.e., 1/5-comma meantone), except that there were also "some more piquant intervals" ("des accords plus piquants"); I think these involved the chromatic notes, because if they had disrupted the C-major scale it might have been difficult for Sauveur, who measured the intervals from C when he examined a "very exactly tuned harpsichord" (a "Clavecin qu'on avoit accordé très exactement"), to detect that there were only a few such piquant intervals.[27]

There is other evidence that the *tempérament ordinaire* was based (as far as the diatonic notes were concerned) upon 1/5-comma and not 1/4-comma meantone. In 1698 Étienne Loulié described both shades and said that the former was "more in use than any other" ("plus en usage qu'aucun autre").[28] Rameau mistakenly believed in 1726 that although the 5th will always resonate even if it is tempered slightly smaller than pure, nevertheless the major third no longer does so if tempered at all ("la Quinte frémit toujours, quoy qu'un peu diminuee de sa justesse; ...la Tierce majeure ne fremit plus, si peu qu'on l'altère"), so one must reckon on tempering the 5ths by 1/4-comma;[29] but in 1737 he said that in the

25. For example, the major 3rds represented in Figure 4 above are tempered by 4.3 cents (1/5 of the syntonic comma), while in the 43 division they are tempered by 4.4 cents. (On the Fisk organ the 5ths are tempered by 1/5 of the *pythagorean* comma, so the diatonic 3rds are tempered theoretically by 2.7 cents.)

26. J. Sauveur, "Methode générale pour former les systèmes tempérées de musique," *Memoires de mathematique et de physique ...de l'Academie royale des sciences ...m.dcvii* (Paris, 1708), 215.

27. Sauveur, "Table générale des sistèmes temperez de musique," *Memoires de mathematique et de physique ...de l'Academie... m.dccxi* (Paris, 1714), 316f.

28. É. Loulié, *Nouveau sisteme de musique ...par rapport à l'accord du clavecin ordinaire* (Paris, 1698), 28. The text shows clearly that it is a matter of 1/5 syntonic comma.

29. J.-P. Rameau, *Nouveau systeme de musique theorique* (Paris, 1726), 107. "Frémir" (literally, "to quiver") is used here in a rather poetic sense.

tempérament ordinaire the 5ths were "diminished by *nearly* 1/4-comma" ("diminuees d'à peu près un quart de Comma"), which of course is not the same thing.[30] (By then he himself had taken up equal temperament, where the major 3rds are tempered more than twice as much as in 1/6-comma meantone.)

And there is evidence that the chromatic notes were, already before the turn of the century, being tuned differently. In 1691, for example, Jacques Ozanam distinguished between "Les Modes Naturels" (C major, D and E minor, F major, G major and minor, A minor, B^b major and B minor), "Les Modes Naturels par les chromatiques" (C minor, D and E major, F minor, A major, B^b minor and B major), and "Les Modes Transposez" (C#, E^b, F# and G# major and minor). He said the latter were almost never used ("on ne s'en sert presque jamais"), because:[31]

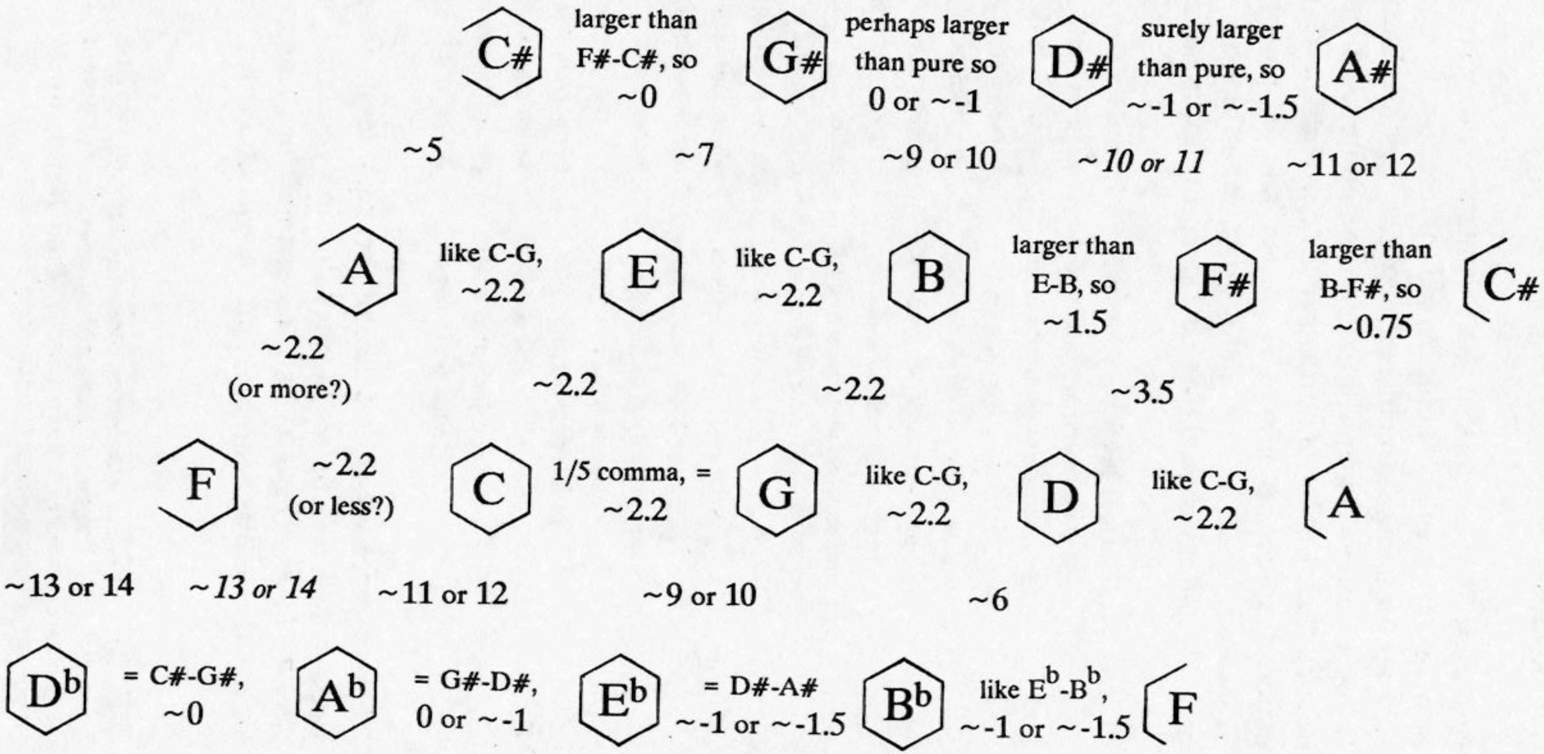
Quelque precaution que nous	Whatever care we
prenions en accordant nos	may take, in tuning our
Instrumens pour en rendre	instruments, to render
tous les Accords egaux,	*all the intervals equal,*
il ne laisse pas de s'y trouver	nevertheless one finds
toujours quelque inégalité:	always some inequality;
et c'est ce qui fait que nous	and it is this which makes us
remarquons un je ne sçai quoi	notice a je-ne-sais-quoi
de triste ou de guay,	of the sad or the gay,
de melodieux ou de dur,	of the melodious or the harsh,
qui nous fait distinguer	which makes us distinguish
un Mode avec l'autre	one key from another
par le secours de l'oreille....	by ear.
C'est la même inégalité	It is the same inequality
des Intervalles semblables,	of equivalent intervals
qui faisoit une des	which may have made one of the
plus differences des	greatest differences among the
Modes des Anciens.	modes of the ancient (Greeks).

There is much other evidence of this kind; let us make do here with only one additional sample: Jacques Boyvin's reference, in the preface of his *Second livre d'Orgue* (1700), to certain "tons transposez" which he said were "the most bearable and the most in use" ("qui sont les plus

30. Rameau, *Génération harmonique* (Paris, 1737), 88.

31. J. Ozanam, *Dictionnaire mathèmatique* (Amsterdam, 1690), 659. According to one recent writer, A. Cohen in *The Music Review*, vol. 36 (1975): 90, this passage is about an "equal-tempered tuning system"!

Fig. 14. Reconstruction of the tempérament ordinaire. The characterizations of the 5ths are from writers like Loulié and Rameau (see above); the numbers, some of which are more vaguely approximate than others, are deduced in light of the information in Figs. 1 and 4 and the text explaining them. Where Rameau says one 5th is slightly larger than another, I have taken 3/4 unit as a fitting estimate of the difference.



supportables, & le plus en usage"), namely C minor, D major, E and F minor and A and B^b major (mostly the same as Ozanam's "Modes Naturels par les chromatiques").

And then there are two other kinds of evidence: tuning instructions and references to certain harsh keys. According to Rameau's instructions for the *tempérament ordinaire*, two or perhaps even three 5ths, namely E^b-B^b-F and perhaps A^b-E^b, were tuned slightly *larger* than pure (just the opposite of the normal kind of tempering), and each 5th in the chain B-F#-C#-G# was slightly larger than the preceding one ("les *Quintes* un peu plus justes, & cela de plus en plus... depuis *Si* a *Fa#*") without any being larger than pure.[32]

So D^b-F had to be, as Figure 14 shows, considerably more than a comma larger than pure, and F#-A# and A^b-C were also probably more than a comma larger than pure. This fits very nicely the contemporary French references to dark or harsh keys, such as Marc Antoine Charpentier's characterization of the minor keys (ca. 1695):[33]

D minor	"Graue et Deuot"
G minor	"Serieux et Magnifique"
C minor	"Obscur et Triste"
F minor	"Obscur et Plaintif"
B^b minor	"Obscur et terrible"
E^b minor	"horrible Affreux"

or the following remarks from Jean-Jacques Rousseau's *Dissertation sur la musique moderne* (1743):[34]

C'est un fait d'experience, que	It is a fact of experience that
les differens tons de la musique	the different musical keys
ont tous certain caractère	all have a certain character
qui leur est propre....	of their own.
Comparons, par exemple, le	Let us compare, for example,
C sol ut mineur et le *D la re*...	C- and D-minor.
Ont trouve ...par	One finds, in
l'accord ordinaire du	the ordinary tuning of the
clavecin, le demi-ton	harpsichord,[35] the semitone

32. Rameau, *Nouveau système*..., 108-110 (see note 29).
33. M.A. Charpentier, "Règles de composition," F-Pn nouv acq fr 6365, 6366.
34. J.-J. Rousseau, *Oeuvres* (Paris, 1864), vol. 3:475-77.
35. I presume Rousseau referred to the harpsichord without meaning to imply that the organ was tuned differently in France; nor have we any evidence that it was.

compris entre le *sol* naturel et	between G and
le *la* bemol un peu plus petit	A^b a little smaller
que celui qui est entre le *la* et	than the one between A and
le *si* bemol. Or, plus les deux	B^b. Now the more (closely) two
sons qui forment un demi-ton	notes forming a semitone
se rapprochent, et plus	approach one another, the more
le passage	tender and touching it is
est tendre et touchant;	to pass (between them).
c'est l'experience qui	Experience
nous l'apprend, et	teaches us this, and
c'est, je crois, la véritable	I think this is the real
raison pour laquelle	reason why
le mode mineur du *C sol ut*	C minor
nous attendrit plus	makes us feel more tender
que celui du *D la re*.	than D minor.
Que si cependant la diminution	But if the diminution
vient jusqu'à causer de	goes so far as to cause some
alteration à l'harmonie, et	alteration to the harmony and
jeter de le durété dans la chant,	bring harshness into the song,
alors le sentiment se change en	then the sentiment changes to
tristesse, et c'est	(deep) sadness, and this is
l'effet que nous érouvons dans	the effect we experience in
l'*F ut fa* mineur....	F minor.
La mécanique du temperament	The nature of (our) temperament
introduit dans la modulation	introduces into harmony
des tons si durs, par exemple	some keys so harsh, for example
le *re* et le *sol* dieses, qu'ils	D# and G# (E^b and A^b) that they
ne sont pas supportables	are intolerable
à l'oreille.	to the ear.

One further point, with regard to the distribution of the lesser diesis amongst D^b-F-A-C#: since D^b-F was tempered by at least (let us say for a round number) 13 of Neidhardt's units, and since F-A was tempered by more than 2 units (for a total of more than 15 in the pair of 3rds D^b-F-A), therefore A-C# must have been tempered by less than 6 units (since 21-15 = 6) — that is, significantly less than in equal temperament where it is tempered 7. When we listen to the repertory in question, we find that this moderation in the tempering of A-C# is quite important musically. One can hardly demonstrate the point in print, as it has to be heard to be understood, but it is no less significant for that.

Some differences between the tuning of the Fisk organ and the French style are that: 1) among the diatonic notes, the major 3rds are tempered distinctly less than 5ths, whereas in the French style they were tempered by about the same amount; 2) A-C# is some three cents larger than in equal temperament, whereas in the French style it was significantly smaller; 3) E^b-B^b is pure, whereas in the French style it was larger than pure; 4) C#-G# is much smaller than F#-C#, whereas in the French style it was larger. The cumulative effect of all the differences is to make the music sound a little out of tune: the diatonic leading tones are too dull, the chromatic ones do not vary smoothly enough, and the A-major triad sounds sour (which I believe Charles Fisk would not have wished it to do!). It is these characteristics that have made the organ sound out of tune to some people. I believe that some others who have not noticed would do so if they heard the music also in a tuning more faithful to the original style of intonation.

* * *

To summarize this rather intricate argument as succinctly as possible, we might say that the underlying defects of the tuning of the Fisk organ at Stanford are that:

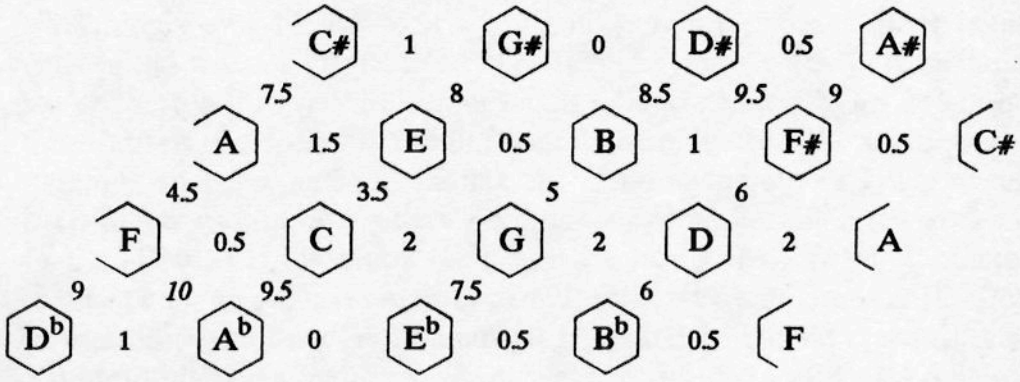
1) the diatonic major 3rds are too small to make a proper basis for any kind of late-baroque temperament;

2) in the "renaissance" scheme the chromatic notes are tuned irregularly in a way that no one at the time would have wished;

3) in the "baroque" tuning only one unit of tempering has been used for the 5ths, whereas in both the French and the German late-baroque styles some 5ths were tempered less than others for a more subtle variety among the 3rds and semitones.

Figure 15 shows that it is possible to design a temperament midway in character between the French and German styles. The differences between the tuning of the Fisk organ and a proper tuning are quantitatively subtle, but musically more telling than one might imagine without hearing them. I urge the custodians of the Fisk organ to consider these points, to listen to some better tunings, and not to be unduly embarrassed should they decide to have the organ retuned. It merits better because it is in so many ways an instrument of extraordinary beauty, and superbly placed; and Mr. Fisk cannot, unfortunately, give us another one.

Fig. 15a. Average between Figs. 9 and 10



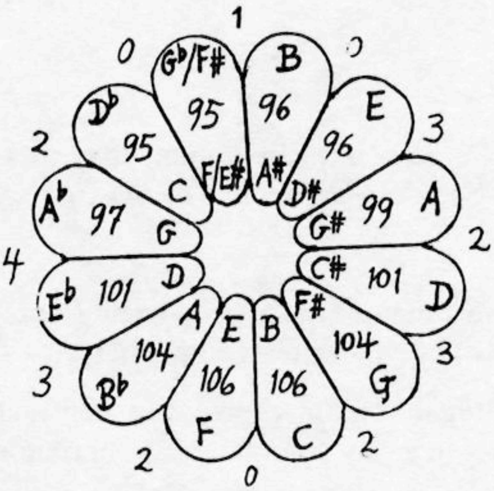
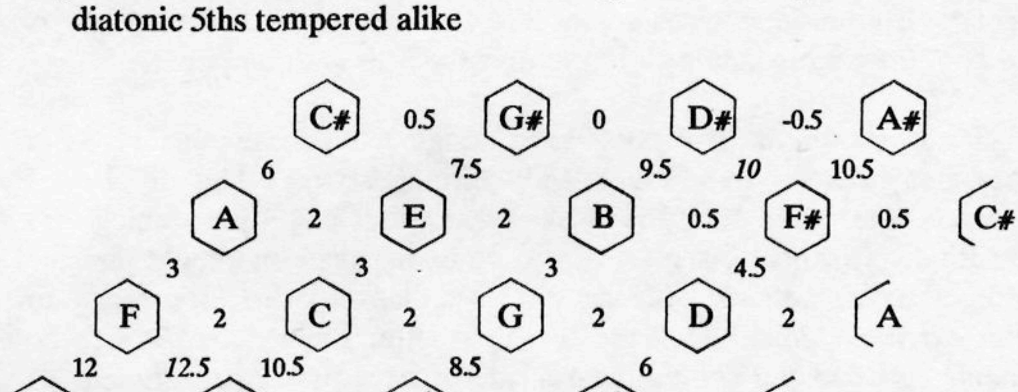
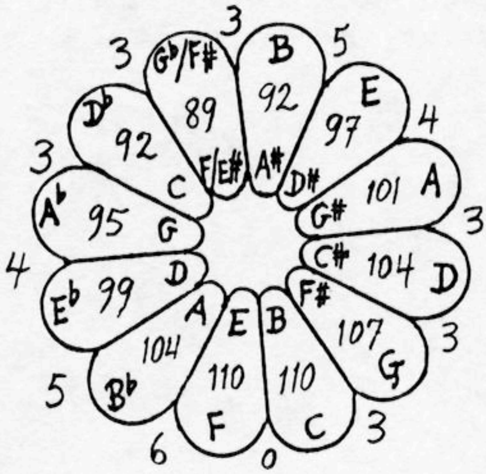
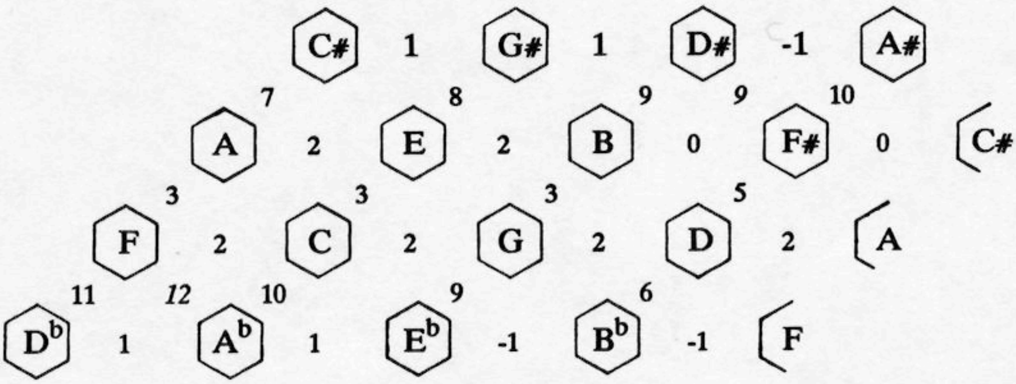


Fig. 15b. Two schemes intermediate to Figs. 14 and 15a, and with all the diatonic 5ths tempered alike




G♭/F♯ 89 F/E♯
B 92 A♯
E 97 D♯
A 101 G♯
D 104 C♯
G 107 F♯
C 110 B
F 110 E
B♭ 104 A
E♭ 99 D
A♭ 95 G
D♭ 92 C
3 3 5 4 3 3 3 0 6 5 4 3


C♯ 1 G♯ 1 D♯ -1 A♯
7 8 9 9 10
A 2 E 2 B 0 F♯ 0 C♯
3 3 3 5
F 2 C 2 G 2 D 2 A
11 12 10 9 6
D♭ 1 A♭ 1 E♭ -1 B♭ -1 F

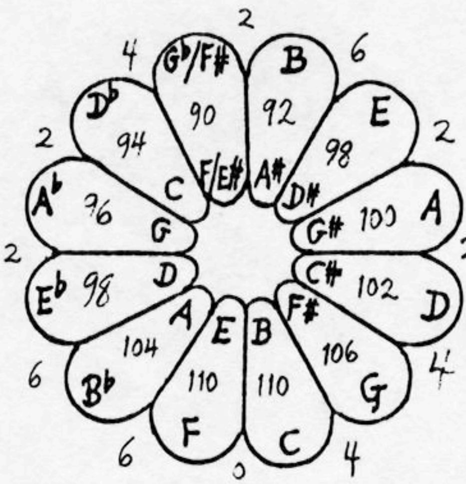

G♭/F♯ 90 F/E♯
B 92 A♯
E 98 D♯
A 100 G♯
D 102 C♯
G 106 F♯
C 110 B
F 110 E
B♭ 104 A
E♭ 98 D
A♭ 96 G
D♭ 94 C
2 6 2 2 4 4 0 6 6 2 2 4

Fig. 15c. How to convert to them from the tuning of the Fisk organ (keeping G the same to minimize the changes)

	C	x	D	x	E	F	x	G	x	A	x	B	
	-1	-4	-0.5	0	+2	-2	+2	0	0	+1.5	+1	+3	
or													cents
	-1	-2	-0.5	-1	+2	-2	+3	0	+1	+1.5	+1	+3	