A Passable and Good Temperament

A New Methodology for Studying Tuning and Temperament in Organ Music

JOHAN NORRBACK

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Cover: Anders Bodebeck
Cover Art: The organ in Abbenrode built by Cristoph Contius, 1708 (photo: Reinhard Menger); the manuscript to the Prelude in B minor, BWV 544 (Universal Edition, no. 7005); engraving for a monochord from Andreas Werckmeister's *Musicalische Temperatur,* 1691 (Nederlands Muziek Instituut, The Hague).
Layout: Johan Norrback
Printed by

Göteborg University
Department of Musicology
Box 200
405 30 Göteborg
Sweden

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List of illustrations

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Notes on the text

Abbreviations

BD	Bach Dokumente
BJ	Bach Jahrbuch
BWV	Bach Werke Verzeichnis
NBR	The New Bach Reader

Orthography

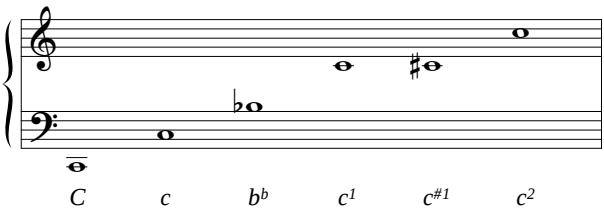
To simplify the identification, names of churches are usually not translated. In cases when a church is designated “Dom” or “Domkirche” it is translated (Cathedral in Freiberg).

References

References are given according to the author-date system, where the full bibliographical information is given in the bibliography. Manuscript sources are referred to with the name of the library and the signum of the source. References to web pages are given with date of download.

Pitch and keys

Note names are given in capital letters when not referring to a specific pitch ($C^{\#}$). When referring to a specific pitch the note name is italicized ($C^{\#}$ and $c^{\#1}$). Keys are referred to as follows: B major and B minor.



Translation of German quotes

All translations of the German quotes are by the author if not otherwise stated. The aim has not been to provide a literal translation, but rather an interpretative translation needed for the present work. The original quote is provided to give the reader a possibility of comparison.

Presentation of Tunings and Temperaments

Temperaments are presented in tables of cents and with a circle of fifths where applicable. A circle of fifths is only provided if it represents the construction of the temperament. Temperaments based on the idea of proportional beating are therefore not provided with a circle of fifths.

The Sound Examples on the CD

The sound examples on the CD are AIF-files (16-bit) which can be played with for example the Quicktime player (freeware available for both PC and Mac from Apple Computer). The CD is not a music CD and can therefore not be played in a normal CD-player. A separate sub-woofer is recommended for the best listening result.

Preface

Towards the end of my studies at the Sibelius-Academy in Helsinki (Finland) I also worked as organist in a parish west of Helsinki. The organ I played on every Sunday was tuned according to John Barnes' temperament.[1] This drew my attention to the question of temperament, and its role in organ music. I noticed that the temperament of the organ had to be taken into account when choosing repertoire for concerts and postludes. I chose to write about this subject in my MA-thesis at the Sibelius-Academy under the supervision of Professor Enzio Forsblom. When I came to Göteborg (Sweden) I was introduced to the Brombaugh organ in the Haga Church, tuned to 1/4-comma mean-tone. The time I spent at the organ was revealing to me, especially for the music from the seventeenth century, which I previously had experienced as flat and rather boring. Against the contrast of the wolf and the expressive semitones the shining pure thirds of the temperament made the music come to life. Since my thesis dealt with the organ music of Johann Sebastian Bach[2] it was natural to continue on that track.

A dissertation is not a result of one person's work. I would first like to thank the Department of Musicology (Göteborg University) and Professor K. Olle Edström for providing the formal context for the present work. I owe much to my advisors: in the first phase, Hans Bernskiöld and Hans Davidsson, and in the final stage, Johannes Landgren as main adviser and Kerala J. Snyder as external adviser. Without my colleagues and friends at GOArt this work could not have been possible. I cannot thank them all, but some of them must be mentioned. Paul Peeters with his deep knowledge about organs and organ literature has been invaluable to my work. Ibo Ortgies, offered his expertise in the field of tuning and temperament, both regarding theory and practice, and I also owe him thanks for helping me with the transcription and translation of the German quotes, as well as to Joel Speerstra who helped me with the English translation. I am also grateful to Sverker Jullander for reading the final text and chasing imperfections. A

1 Barnes 1979.
2 Norrback 1991.

special thank you goes to Karen Speerstra for fast and professional English editing of the text.

Without the assistance and knowledge of Per-Anders Nilsson and Björn Asplind at the Lindblad Studio, School of Music and Musicology, the technical part of the work would not have succeeded. A special thank you goes to Magnus Eldénius who kindly offered to read the manuscript in a rather late stage, providing me with many good thoughts.

Several organ builders have helped me during the years by pointing me to literature, letting me take up their time, teaching me about organs, or sharing their research and experience with me: Helmut Gripentrog, Kalevi Mäkinen, Pentti Pelto, Herwin Troje, Munetaka Yokota, and John Brombaugh.

I am also grateful to Mendel Kleiner, Vincent Rioux, and Pontus Larsson at Chalmers University of Technology (Göteborg), and Anders Friberg and Roberto Bresin at the Royal Institute of Technology (Stockholm) who patiently listened and answered my naïve question on acoustics and technology, and for helping me along.

For help with providing me with photographs I am grateful to Reinhard Menger, Armin Zuckerriedel at Hermann Eule Orgelbau, Ulrich Kneise, Henrik Tobin, and Sandra Petojevic.

The staffs at many libraries have been kind and helpful through the years by providing me with unusual material and rare sources: the Sibelius-Academy (Helsinki), School of Music and Musicology (Göteborg), Göteborg University Library, Lund University Library, Statens musikbibliotek (Stockholm), Staatsbibliothek zu Berlin – Preußischer Kulturbesitz (Berlin), Nederlands Muziek Instituut (The Hague), Altenburg Schloßarchiv, Leipziger Städtische Bibliotheken – Musikbibliothek.

Without the economical support from several foundations, I could not have accomplished this task: Kungl. Musikaliska Akademien (Stockholm), Kungliga Vetenskapsakademin (Stockholm), Filosofiska fakulteternas gemensamma donationsnämd (Göteborg).

Finally, I wish to thank the two people who actually should be heading this list. I look forward to the day when I can spend my time with the ones who are the most important in my life: my wife Benedikta and my son Natanael.

1. Introduction

1.1. Problem and aim

Within historically informed performance practice the context is regarded as very important for the music – both the context in which the music was composed, and the context in which the music was performed. Consequently, the instruments and the performance practice of the past have gained much interest, resulting in recordings and scholarly works. In my opinion the aim has not been to reconstruct the experiences of the listeners during the Baroque, but to use available, historic information with all its deficiency, to inspire and govern a performance today. An interpretation is a temporal act, and thus made in the moment, now. Since the composition is the product of a different historic situation from that of the performance today, it can be said that we actually have two contexts. A historically informed performance can therefore be described as a pendulum between then and now, but never really travelling in time. Information and inspiration is sought from historical sources and applied in the present.

Approaching music under new conditions often raises new questions. An example is playing on an organ tuned in an historic temperament. An illustrative passage with regard to temperament, which exemplifies this, is the last verse of Johann Sebastian Bach's organ chorale *O Lamm Gottes, unschuldig* (see Fig. 1) from the Eighteen Chorales (BWV 656) that corresponds to the text "…sonst müßten wir verzagen…" (otherwise we would be in despair).

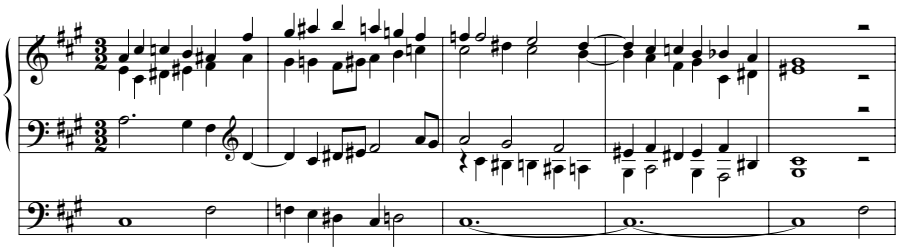


Fig. 1: Excerpt from O Lamm Gottes, unschuldig (BWV 656)

It is quite clear that Bach introduces the chromatic texture to express the words of the text. As an organist I might ask, "What is the role of temperament in this music?"

Except for the unusual chromatic texture, the final chord is crucial from the point of temperament. The C♯ major triad would in itself not stand out in equal temperament. In mean-tone on the other hand, the triad would be a clash of dissonance[3] since the major third *c♯¹–e♯¹* would be extremely out of tune in relation to the pure thirds of the temperament. A well-tempered tuning would, on the other hand, be milder, but still clearly making the passage stand out.

According to di Veroli the most convenient way to analyze temperament is through intervals expressed in cents.[4] Such an analysis would tell us that in 1/4-comma mean-tone the fifth C♯–G♯ is 696,5 cents, and that the wolf-third is 427 cents (actually a diminished fourth)[5] – 27 cents wider than an equal-tempered major third (400), and another 14 cents wider than a pure third (386). It does not say how we might experience this third, and it does not show that the beat rate changes when the interval is transposed. Transposing up or down an octave doubles or halves the beat rate respectively. The musical setting is important, and the placing of a dissonant chord or interval has relevance for the experience of it. Adding information about the beat rate to an analysis based on intervals in cents gives further information and would take the pitch into account; but beat rates for individual intervals does not say much about this context. In 1/4-comma mean-tone and at a¹=440 Hz the major third *c♯¹–e♯¹* in the example would have a beat rate of 33 Hz. The major third in equal temperament has a beat rate of 11 Hz. In a well-tempered tuning such as Neidhardt "for a village" (1732) the interval maintains its dissonance, but remains acceptable as a major third with a beat rate of 14 Hz, and being one of the more dissonant major thirds. Still, after all these numbers an aural impression is lacking.

In the history of temperament the Baroque experienced a transition from mean-tone via well-tempered systems to equal temperament in the tuning of keyboard instruments. There was a very eventful period during Bach's lifetime, with leading figures like Andreas Werckmeister (1645–1706) and Johann Georg Neidhardt (ca. 1680–1739). The issue of temperament was subject to discussion into the nineteenth century, and is even so today. Taking this into consideration, several additional questions are raised. Is it unessential which historic temperament is used, with regard to the acoustical outcome? What is the connection between theory and practice? Do the treatises about, for example, composition

3 In the present work the words "dissonance" and "consonance" are used according to the rules of counterpoint but also referring to the quality of for example a chord. From the context in the text it should be clear which one is referred to.

4 Veroli 1978: 29.

5 A wolf-third in a less strict sense can be any major third with a large enough deviation from the just major third. An example are the thirds on B, F♯, C♯, and G♯ in 1/6-comma mean-tone temperament which are 416 cent.

mention temperament as a factor to take into consideration? Were Werckmeister's or Neidhardt's temperaments applied in practice? How do different temperaments affect organ music, and how can this be described?

Organs with two different temperaments within the same instrument have been constructed, and give the musician the possibility to experience the music in two different sounding contexts.[6] If one would like to involve more temperaments in the comparison, one has to travel, since re-tuning an actual organ takes time and exposes the instrument to unnecessary mechanical wear. Historic organ pipes are not equipped with tuning slides or tuning rolls, but usually cut to the desired length/pitch, and the caps for stopped metal flutes and Quintadenas are often soldered. In the case of an historic instrument, re-tuning is thus out of the question.

Within the frame of the present work it is not possible to address all the questions posed above. Focusing on the problem of comparing temperaments, we can formulate the point of departures of the present work: to investigate the historical background and context of, in the present work, Johann Sebastian Bach's organ music[7] with regard to temperament, and to develop a new methodology to provide means to investigate a temperament's role and effect in organ literature based on the preconditions given by the historical investigation. This approach can be used for studying any composer's organ music where the question of temperament is important.

1.2. Previous research

One of Europe's principal Bach-researchers, Hans-Joachim Schulze, asks for research in the field of temperament in relation to the music. He writes in the article "Zum Themenbereich der neueren Bach-Forschung," after criticizing the adequacy of the research in the field of number-symbolisms by Bach, as follows:

> Gleiches gilt beispielsweise für die Untersuchung der "Wohltemperierung", die ihren Namen zu Recht trug und keine gleichschwebende Temperierung war. Sie war offenbar ein Produkt praktischer Erfahrung und pragmatischen Umgangs mit den Tonarten. Bachs Schüler Kirnberger versuchte jahrzehntelang Bachs "Geheimnis" auf mathematischem Wege zu enträtseln, mancher heutige Forscher tut es ihm nach – und so steckt auch hier die Forschung trotz eines entwaffnenden Aufwandes an mathematischer Spitzfindigkeit und theoretischer Spekulation noch immer in den Kinderschuhen. Bis heute fehlt eine systematische Aufarbeitung des Gebrauchs und der Vermeidung bestimmter Intervalle, Akkorde, harmonischer Abfolgen mit dem Ziel einer Deutung und Bewertung der Tonartencharaktere bei Bach, einschließlich der Toleranz bei Transposi-

6 For example at the Stanford University, USA, the organ built by Charles Fisk, and in Wilschdorf, Dresden, Germany, the organ built by Kristian Wegscheider.

7 The organ in continuo use is not considered in the present work even if the discussions in the sources naturally touch upon the matter, especially when addressing the difference between choir- and chamber-pitch.

> tionen (*es-Moll-Fuge* des *Wohltemperierten Klaviers I* ursprünglich in d-Moll). So ist auch der Weg noch weit bis zur aufführungspraktischen Umsetzung entsprechender Erkenntnisse, etwa in Hinsicht auf die Temperierung von Cembali und Orgeln sowie die Spielweise von Streich- und Blasinstrumenten.[8]
>
> The same applies, for example, in the examination of "well-tempering," which carried its name rightly and was no equal temperament. It apparently was a product of practical experience and pragmatic dealings with the keys. Bach's student Kirnberger tried for decades to solve Bach's "secret" in mathematical ways, as do today's researchers, and the research is still caught in its infancy, despite a disarming expenditure for mathematical hairsplitting and theoretical speculation. Research still lacks a systematic survey of the use and the avoidance of certain intervals, chords, harmonic sequences with the goal of an interpretation and evaluation of the key characteristics by Bach, including the tolerance in transpositions (the E♭ minor fugue of the Well-tempered clavier I was originally in D minor). Performance practice, regarding the tuning and temperament of harpsichords and organs as well as the playing technique of string- and wind instruments, needs further observation.

How have these challenges been met? In his organ method *Orgelschule zur historischen Aufführungspraxis* Jon Laukvik dedicates only two pages to the question of temperament, exemplifying the problem with the chorale *O Lamm Gottes, unschuldig* (BWV 656).[9] In 1997 Mats Åberg's *Orgelskola*[10] was published, but without mentioning temperament.[11] And, in the *The Cambridge Companion to the Organ*[12] we find a good introduction to tuning and temperament, but no musical examples.

In "A Trial of Unequal Temperaments on the Organ"[13] Charles Padgham *et al.* perform an interesting experiment. By choosing historically appropriate temperaments for the repertoire, and re-tuning necessary stops in an instrument (with all the work it carries), they performed a listening test. The results show, among other things, that the reception is clearly affected by the composition of the reference group and their background, telling more about the reference group and their preferences and musical training than the temperaments' effect on the music and eventual appropriateness.

The experiment performed by Padgham *et al.* clearly shows some of the methodological problems of this question. How can one compare different temperaments using the same instrument?

In his dissertation Joseph V. Pollard develops and uses a method to analyze the temperament in Johann Jacob Froberger's music.[14] The method is based on the deviation (in cents) of an interval from just intonation. In a triad the deviation of the separate intervals are added. Consequently the deviation varies with

8 Schulze 1985: 32.
9 Laukvik 1990: 94-95.
10 Åberg 1997.
11 Nor do Kooiman et al. 1992; Newman 1985; or Ritchie and Stauffer 2000.
12 Kent 1998.
13 Padgham et al. 1979.
14 Pollard 1985.

different temperaments. Music with a small deviation is, according to Pollard, a sign that the temperament is more suited for that music. Exploring a temperament's dissonances in a composition for musical reasons, would, with Pollard's method, judge that temperament less appropriate than another temperament. In my opinion, this method cannot account for a performer's intentional use of dissonances to reach a certain expression. It excludes dissonance as a musical expression resulting from a temperament's characteristics. The play between dissonance and consonance with regard both to counterpoint and intonation is of utmost importance to music, and the dissonance cannot be regarded as something primarily negative for the music.

An attempt at analyzing Bach's music with respect to temperament is Franz Josef Ratte's article "Die Temperatur als Mittel der musikalischen Rhetorik am Beispiel des *Orgelbüchleins* von Johann Sebastian Bach".[15] Ratte comes to the conclusion that the wolf-thirds are not used as a rhetorical means, picturing words like "Sünde" and "Kreuze". However, Ratte sees the choice of key as deliberate, and important for the overall affect. This implies that the temperament affects the music in another way, e.g. creating an atmosphere or mood, the rhetorical affect. In his article "Die Temperaturen der Bach-Orgeln und die Konsequenzen für Johann Sebastian Bachs choralgebundene Orgelmusik"[16] the same arguments are used. The analysis is mainly based on the frequency of occurrence of "Wolfterzen", audibility through occurrence in inner or outer voices, and the relative length of the note values in relation to tempo.[17] Such an analysis becomes rather subjective.

In a recent article by one of the leading authorities in the field of tuning and temperament, "A Quest for Bach's Ideal Style of Organ Temperament," Mark Lindley approaches the subject from a stylistic point of view.[18] Stylistic means here the way historic temperaments were described. Here we have mathematical reasoning combined with musical analysis. The temperament that will be chosen as "ideal" will depend heavily on the composition of the reference group or the analyst, and thus we have the same principal problem of reception as with Padgham's experiment mentioned above.

Martin Jira's *Musikalische Temperaturen und musikalischer Satz in der Klaviermusik von J. S. Bach*[19] is of special interest for the present work. In many aspects his work has the same approach as the present study. However, Jira focuses on the keyboard works and not the organ works, and thus encounters problems when it comes to the discussion of relevant historic temperaments.[20] He uses

15 Ratte 1989.
16 Ratte 2000.
17 Ratte 2000: 51f.
18 Lindley 1997.
19 Jira 2000.
20 Re-tuning harpsichords is very easy, and consequently no information about temperaments used can be found in historic instruments. With the organ the situation is different. Jira 2000: 27ff.

temperaments known from historic organs and historic sources.[21] However, some relevant sources are not discussed. Heinrich Gottfried Trost[22] (1681–1759) for example, is not represented. Further, Jira defines four groups of temperaments: major third mean-tone; modified mean-tone; a "good" open temperament; a closed temperament. The first three are "open" temperaments, with at least one fifth considerably too large, and, the last one is a temperament with no fifth so large that it limits its use in a triad. The work is based on analysis of the musical text, where certain criteria indicate the suitability for a specific group of temperaments. An example given is the wolf-fifth, which in "major third mean-tone" usually is avoided, or used as an effect, or by stepwise movement "disguised".[23] The book is accompanied by a compact disc with sound examples from the repertoire under survey, interpreted by the author. This is the strong point of the work. The otherwise, by necessity, very abstract discussion about temperament is exemplified with sounding examples, the actual goal of a temperament. Unfortunately the instrument used is not documented, which is necessary since the sound and the effect of the temperament are greatly influenced by the instrument. Not all of the music in the investigation is recorded, but the music on the compact disc is mostly presented in two different temperaments. Playing and recording, then re-tuning and recording again, limits the amount of material and is a limitation of the method. All known historic temperaments could therefore not be used; consequently Jira decided to use two "working-temperaments" – two temperaments that represent the two different groups of open and closed temperaments.[24] The open temperament contains a wolf, while the closed does not.

Considering the methodologies reported above, developing a methodology for comparing temperament in music becomes an essential part of the present work. The methodology should facilitate the comparison of several temperaments within actual organ music of, in this case, Johann Sebastian Bach.

1.3. Methodological considerations

The present work is based on source studies of written sources and instruments as sources. The results of the source studies are the points of departure for the investigation of the music.

Since we are dealing with music, the question about reception has to be discussed. As the earlier mentioned experiment performed by Padgham tells us, the use of a reference group does not provide us with more general rules about the

21 Jira 2000: 30ff.
22 Trost's connection to Bach is discussed below, chapter 3.1.4.
23 Jira 2000: 42ff.
24 "Arbeitstemperaturen". Jira 2000: 37ff.

appropriateness of a certain temperament for a particular category of repertoire. The background of the members and their musical training will highly influence their answers. A further question is raised: Is it the general audience and their reception one tries to investigate? There are several groups or categories of listeners. Göran Hermerén structures the event well in his article "The Full Voic'd Quire: Types of Interpretations in Music."[25] Hermerén points out the different agents involved in the process of interpretation: the composer, the musician(s), the conductor/producer, the listener, and the critic/researcher.[26] The process can be outlined as follows:

Composer – Notation – Performer – Instrument – Listener

Fig. 2: The process of interpretation

These all have different functions, and within the category of listeners, critics and researchers listen in a different way compared to the average concert visitor. In addition to the sociological context there are also physical factors between the different agents: between the composer and the musician, the notated music; and between the musician and the listener, the instrument. These two physical factors function in some sense as filters, setting limits for what they can represent and present. In the instrument, the temperament is a kind of filter. The interpretation is always made under differing conditions regarding time and place, naturally giving more or less different results. Furthermore, the performance in itself cannot be repeated exactly from one occasion to another. In the present work, the focus is primarily on the organist of today as agent, and the means for him/her to investigate the significance of the temperament as a part of the instrument, and thus a part of the music.[27] In other words, the focus is on the situation when a performer, in this case the organist, is preparing a piece for a performance. Besides the technical part of the preparations, the organist listens critically to several factors such as registration, touch and articulation, tempo, acoustics of the room. All of these factors are extremely important for the mediation of the music. The result of an interpretation, a performance, is naturally of interest, but in the present work we focus on a specific stage in the process of interpretation.

In this situation the performer is also reacting to the temperament, evaluating consonances and dissonances. Hermeneutically speaking, these matters are experienced differently from person to person, and from time to time. The performer

25 Hermerén 1993.
26 Hermerén 1993: 14.
27 The compositional process during the period under investigation was strongly linked to improvisation which took place at an instrument. Consequently the instrument becomes an integral part of the musical context. The composer did not aim at composing an autonomous composition, but composed music in an existing context with its limitations (instrument idiomatic). The temperament of the instrument should therefore be regarded as a part of the music.

is, in this instant, the only recipient, and it is on these experiences interpretative decisions are made. Evaluating one person's experiences is not useful, since there is no right or wrong answer. A person's perception cannot be wrong. Here musical training in general, and knowledge about temperament in particular are important factors. This subjective part of the situation is important to acknowledge. Brian C. J. Moore formulates the role of the musical training in *The New Grove Dictionary of Music and Musicians*, s. v. "consonance", as follows:

> "Sensory consonance" refers to the immediate perceptual impression of a sound as being pleasant or unpleasant; it may be judged for sounds presented in isolation (without a musical context) and by people without musical training. "Musical consonance" is related to judgments of the pleasantness or unpleasantness of sounds presented in a musical context; it depends strongly on musical experience and training, as well as on sensory consonance. These two aspects of consonance are difficult to separate, and in many situations judgments of consonance depend on an interaction of sensory processes and musical experience.[28]

The most frequent way of comparing and evaluating temperaments in the literature is to create tables with the cent values for the chromatic scale, the fifths, major thirds, and, minor thirds. Very often some kind of graphical representation and a circle of fifths presenting the tempering of the fifths accompany the table.[29] Cents express the relation between frequencies – an interval. The beat rate is relative to the pitch-level, which means that the same interval will beat twice as fast when transposed up an octave. It is the beat rate a listener relates to when judging whether an interval is consonant or dissonant.[30] A table with the beats of the fifths and the major thirds, usually related to the tenor octave or the octave above middle C, is sometimes provided.[31] This gives you the possibility of comparing a certain chord, e.g., the last chord in Fig. 1 ($C^{\#}$ major), in different temperaments. It does not allow you to hear what the differences in the numbers imply, and it does not take into account the different pitch-levels or positioning of the chord. Analyzing music with these means is not very expedient. To my knowledge, there is no methodology that approaches a piece of music taking all these factors into account.

As mentioned above, the basic material for the present work consists of a) the written sources, and the preserved and documented instruments; and b) the music. In the present work, the music is regarded as an equally valuable source since the question of temperament is apparent in the sounding material. To be able to say something about the music, one must investigate the preconditions provided by the context. The following questions define the aim of the different parts of the present work:

28 <http://www.grovemusic.com> (2002-07-24)
29 See for example Padgham 1986.
30 Rasch and Plomp 1999: 108.
31 See for example Ratte 1994a: 409ff.

(1) What do written sources, relevant to the study of Bach's organ music, say about temperament? This gives us information about what temperaments are historically relevant for his music.

(2) What can we find out about tuning and temperament in the organs in the context of Bach? This approach is used to select historic temperaments that actually were applied in practice in Bach's time, and thus were relevant to his music.

(3) How does tuning and temperament affect the organ music of Bach? To provide the means to perform the comparison necessary to answer this question with the limitations imposed by a historical instrument, a new methodology has been developed.

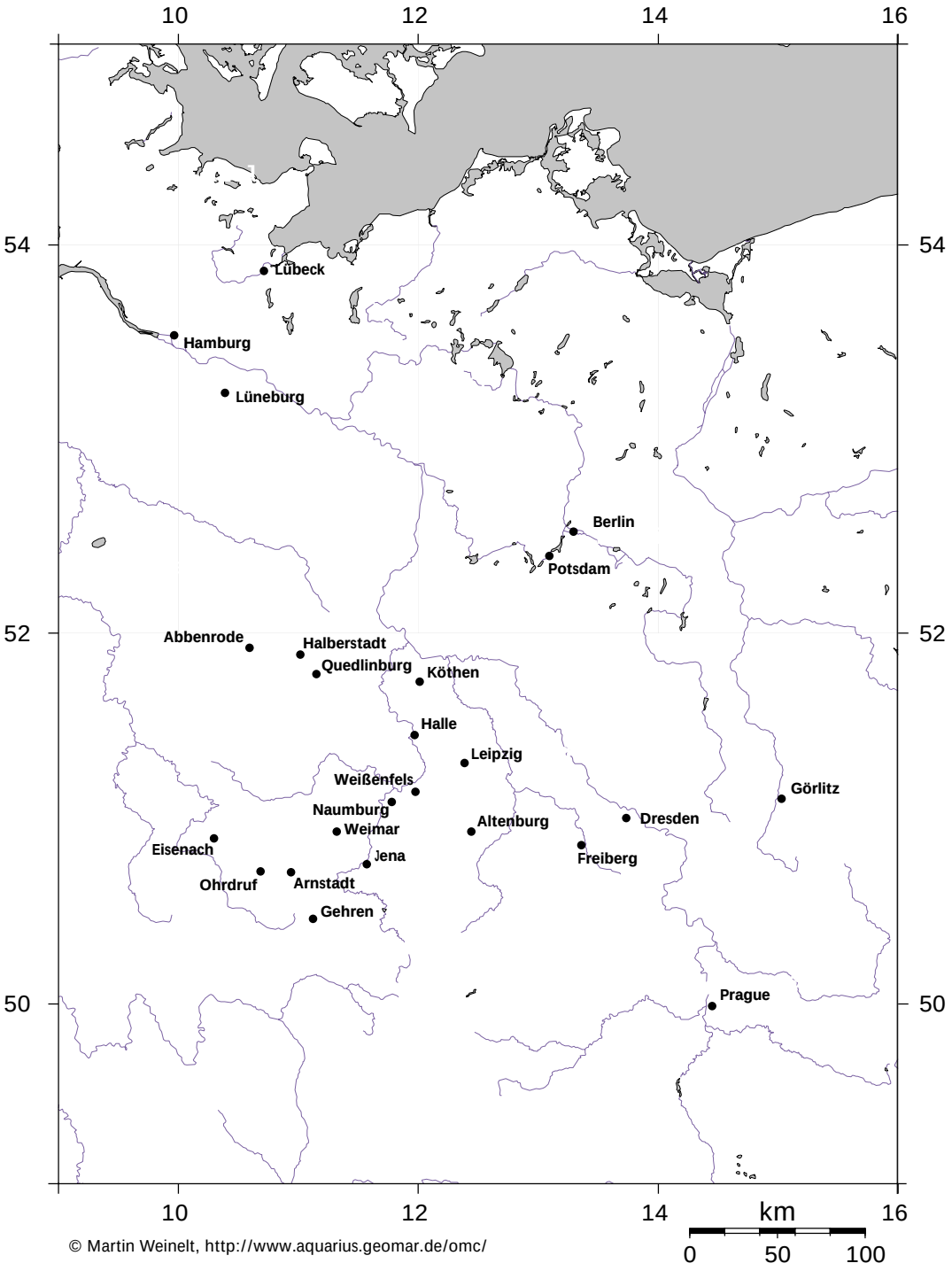


Fig. 3: Map over Bach-related places, places discussed, and, places for reference

2. The Written Sources

As mentioned above, the source material for the present work are: the written sources; the preserved and documented instruments; and, the music. The sources taken together are believed to give a fuller picture than apart. They also balance each other and function as filters. For example, if a writer says that a certain temperament was used all over a region, but we do not find any corroborating evidence in instruments or in other writings, we have to consider whether the writer's statement is an overstatement, or maybe more of a wish or preference. The material we have might also be insufficient for answering the question, and finally the order of events must be taken into account. When Neidhardt promotes equal temperament in 1706 it does not automatically mean that this is the year it was introduced in the region. This is also clear from his later writings, where he continues to argue for equal temperament and discusses its advantages and disadvantages. Equal temperament was not yet generally accepted, so Neidhardt had to continue to argue for the introduction of equal temperament. The discussion about equal temperament in organs started before 1706 (c. f. Werckmeister: 1697 and 1707) and surely continued long after Neidhardt had died.

Traces of the discussions on temperament can be seen in the history of some organs. In cases where we have a thorough documentation of preserved historic instruments we can find information about the instruments' temperament. A good example is the organ in Altenburg, Thuringia. Heinrich Gottfried Trost built the instrument 1735–39.[32] In 1738 there was a lively discussion about the temperament of the organ, which we can follow through the archival material. The arguments were mainly musical and practical, not technical or mathematical. The organists wanted to be able to modulate freely through all keys, and they usually had to transpose when playing with instrumentalists due to the different pitches.

The question of if, and how, the temperament affects the music is addressed through the new methodology. A possibility to compare different temperaments

32 The case is discussed further below, chapter 3.1.4.

and their function in music, and whether it has implications for the organist is sought.

When it comes to Johann Sebastian Bach and theoretical writings most of us are familiar with the following two quotations:

> Bach did not, it is true, occupy himself with deep theoretical speculations on music, but was all the stronger in practice of the art.[33]

> (Bach), like myself or any true musician, was no lover of dry, mathematical stuff.[34]

The first quotation is from the obituary, written by Carl Philipp Emanuel Bach and Johann Friedrich Agricola (with a short passage by Lorenz Christoph Mizler), and the second is from at letter by C. Ph. E. Bach to Johann Nicolaus Forkel while Forkel was working on his biography of J. S. Bach. This issue has been discussed many times.[35] Even if J. S. Bach did not produce any theoretical texts in the strict sense, many of his students did.[36] According to Christoph Wolff, J. S. Bach owned the following theoretical books: Angelo Berardi (c. 1636–1694), *Documenti armonici* from 1687 (a systematic description of contrapuntal composition); Johann Joseph Fux (1660–1741), *Gradus ad Parnassum* from 1725 (and the German edition by Lorenz Christoph Mizler 1742); Johann David Heinichen (1683–1729), *Der General-Bass in der Composition* (1728); Friedrich Erhardt Niedt (1674–1708), *Musicalische Handleitung* (1710); Johann Gottfried Walther (1684–1748), *Musicalisches Lexicon* (both the 1729 and the 1732 version); Andreas Werckmeister (1645–1706), *Orgelprobe* (1698).[37] It comes as no surprise that the field of contrapuntal composition is well represented, considering J. S. Bach's oeuvre. The question of temperament is not the main focus for him as it was, perhaps, for Johann Georg Neidhardt. On the other hand, it cannot be neglected since it was a reality for the sounding music, in particular the organ music. We find in the different manuals for organ examination, by, for example, Andreas Werckmeister and Jakob Adlung, instructions to check the tuning and the temperament. A complete disregard of theory is not likely to have been the standpoint of J. S. Bach. Rather, he was a practical musician, and thus was not primarily interested in highly theoretical reasoning. Still, practice can be described with theory, as the writings on contrapuntal composition prove.

33 David et al. 1998: 307.
34 David et al. 1998: 398.
35 See for example Butt 1997a; Christensen 1998; and, Wolff 2000.
36 Christensen 1998: 23; Wolff 2000: 330f.
37 Wolff 2000: 333f. There is also a possibility that Johann Sebastian Bach was acquainted with Andreas Werckmeister's *Die Nothwendigsten Anmerckungen und Regeln wie der* Bassus Continuus *oder General=Baß wol könne* tract*iret werden* since an edition from 1715 of the publication was in the possession of Johann Christoph Bach, Gehren. The part with tuning instruction, *Kurtzer Unterricht und Zugabe, wie man ein Clavier stimmen und wohl* temperi*ren könne*, was copied into a collection of music (Kobayashi 1983: 168).

The sources on tuning and temperament[38] can be divided into two groups: theoretical descriptions and practical descriptions. A theoretical description contains a description of the distribution of a comma, while the practical description usually does not. The practical description usually gives only an instruction about how to adjust a certain interval, or several. Often the practical descriptions are difficult to interpret, and provide several possible reconstructions.

The present work also includes relevant sources not directly discussing tuning and temperament.

2.1. Descriptions of tunings and temperaments

2.1.1. Michael Praetorius (1571–1621)

Michael Praetorius was born in Creuzburg (Thuringia) in 1571. In the 1590s he went as organist into the service of Duke Heinrich Julius of Braunschweig-Wolfenbüttel. After the death of the Duke he worked at the court in Dresden, as well as in Magdeburg. Praetorius also worked with Esaias Compenius, one of the most famous organ builder of that time.

Michael Praetorius writes rather extensively about subsemitones in the second part of his *Syntagma Musicum: De Organographia* (1619).[39] Therefore it is no surprise when he describes tuning mean-tone with pure thirds and tempered fifths (1/4-comma mean-tone).[40] Subsemitones and mean-tone are strongly connected since the tonal content of 1/4-comma mean-tone can be extended by introducing subsemitones. Praetorius describes three tuning procedures, two of them starting from F and the third starting from C. The criteria for setting a temperament are 1) to choose a key to start from; 2) all octaves and major thirds must be perfectly pure; and 3) all fifths must not be pure but beat somewhat. The tuning procedures include check points where one should check the previously tempered section.

In connection with the second tuning procedure, Praetorius discusses modifying the temperament by adjusting two fifths.

> Die *Quinten "c#–g#"* und *"f#–c#1"*, müssen nicht so gar falsch, und nicht so gar reine seyn, sondern nur etzlicher massen…[41]
>
> The fifths *c#–g#* and *f#–c#1* must not be so much out of tune, and not so pure either, only somewhat [tempered]...

This is an early example of a practical description. The amount of tempering is not defined mathematically; only a practical description of how to proceed is

38 For a general overview of the history of tuning and temperament see Lindley 1987.
39 Praetorius 1619a: 63ff.
40 Praetorius 1619a: 150ff.
41 Praetorius 1619a: 155.

provided. A feasible interpretation would be to try to make the fifths similar, evening out the wolf between G♯–E♭. Praetorius does not change his 1/4 syntonic comma description; he just discusses the possibility to modify the temperament.

In the discussion about the "Clavicymbalum Universale,"[42] a so-called enharmonic instrument with 19 keys per octave, Praetorius notes that viola da gambas and lutes have equal sized semitones.[43] This means that such fretted instruments are tuned according to equal temperament, while most of the organs probably were tuned to 1/4-comma mean-tone.[44]

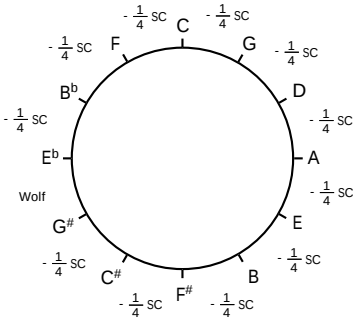


Fig. 4: 1/4-comma mean-tone

Table 1: 1/4-comma mean-tone

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	76,05	193,16	310,26	386,31	503,42	579,47	696,58	772,63	889,74	1006,84	1082,89

2.1.2. Wolffgang Caspar Printz (1641–1717)

An often quoted, and obviously a very important late 17th-century German writer, was Wolffgang Caspar Printz. He was born 1641 in Waldthurn (east of Nuremberg, by the Czech border), Upper Palitanate, and died 1717 in Sorau, Lower Lusatia (now Zary, Poland, northeast of Dresden). Wolffgang Caspar Printz lived a very eventful life, and worked as musician in several places, both as a Kantor and at the court of Promnitz. During his visit to Italy he met Athanasius Kircher, and in Sorau he also met Georg Philipp Telemann.

Printz' most important work is his *Phrynis Mitilenaeus, oder Satyrischer Componist*, published in Quedlinburg (partly 1676–77, complete in 1696). Its three

42 Praetorius 1619a: 63ff.

43 "Dieweil uff den *Violen de Gamba*, und den Lauten die Bünde alle gleich weit (doch je näher dem Steig, je enger, welches sich ohne das verstehet) von einander abgetheilet, und also die *Semitonia*, weder *majora* noch *minora*, sondern vielmehr *intermedia* können und müssen genennet werden." Praetorius 1619a: 65f.

44 Vogel 1986b.

parts contain much information about music theory, and is frequently cited by Johann Gottfried Walther.[45]

When discussing transposition Printz notes that D♯ is missing in organs, which means that the major third on B is not available. To have a pure major third on B and a pure minor third on C you need to virtually split the keys between D and E.[46] This would imply an organ tuned to mean-tone, where the sharps and flats are not enharmonically interchangeable.

Later, when discussing temperament Printz describes only one way of tuning.

> Es werden aber meines Erachtens, die jenigen am besten mit dieser *Temperatur* zu rechte kommen, welche am allerersten *c* und *e²* ganz rein, hernach die *Qvinten*, *c g, g d¹, d a*, niedrig schwebend, daß man es kaum mercke, zusammen stimmen, und so sie dann befinden, daß die *Qvinta a¹ e²* weder mehr noch weniger schwebe, als die vorgemeldeten, welche doch auch gleichmäßig schweben müssen, so wird die *Temperatur* ihre ziemliche Richtigkeit haben. Ferner stimmen sie der erwehneten *Clavium Octaven*, und dann die *Tertias majores*, *fs* zum *d*, *es* zum *g*, *gs* zum *e*, *f* zum *a*, *as* [ais] zum *fs*, *h* zum *g*, *as* zum *c¹*, *cs* zum *a*, *b* zum *d*, und *ds¹* zum *h* rein, und endlich ihre *Octaven* auch gantz rein zusammen, so wird das gantze *Instrument* seine möglichste Reinigkeit haben. Mercket man aber über dieses noch einige Unreinlichkeit, so müssen selbige so lange *corrigiret* werden, biß alles gut und rein scheinet. Denn, wenn einer ieden *Qvinte* nicht mehr als ein Viertheil eines *Commatis* genommen wird, kann das Gehöre solches gar wohl vertragen, und wird es fast gar nicht mercken, wie auff dem *Monochordo* solches klärlich dargethan werden kan.[47]
>
> However, in my opinion, those will do best with this temperament who begin to tune *c* and *e²* pure, and then tune the fifths *c–g, g–d¹, d–a* narrower than pure, so you hardly notice it. They will then find that the fifth *a¹–e²* beats no more or less than the before mentioned, which must beat equally, giving the temperament its fair accuracy. Then you tune the usual octaves to the mentioned keys, and then the major thirds *f♯–d, e♭–g, g♯–e, f–a, a♯–f♯, b–g, a♭–c¹, c♯–a, b♭–d,* and *d♯¹–b* pure, and finally their octaves pure. In this way the instrument will be as pure as possible. If, however, you notice any impurities, they must be corrected until everything seems good and pure. Because if not more than 1/4 of the comma is taken from a fifth, the ear can tolerate it well and will hardly notice it, as can clearly be demonstrated on the monochord.

The tuning procedure has similarities with Praetorius', and is a clear description of 1/4 syntonic comma mean-tone.[48] Since Printz also is distinguishing between E♭–D♯, G♯–A♭, and A♯–B♭, he presupposes subsemitones.

45 Walther 1708.

46 "Es fehlet aber in denen Orgeln das *Ds*, so mit dem *H* eine *Tertiam majorem* macht. Dannenhero muß, im Fall diese *Transposition* recht rein solle seyn, die *Clavis* zwischen dem *D* und *E* gebrochen seyn, daß deren eine mit dem *H* eine reine *Tertiam majorem*, die andere mit dem *C* eine *Tertiam minorem* mache." Printz 1696, part i: 42.

47 Printz 1696, part iii: 68f.

48 Later: 87ff, Printz discusses other divisions of the comma, but issues no new recommendations. See also Lindley 1987: 218.


Orgel-Probe
Oder
Kurtze Beſchreibung
Wie und welcher geſtalt man
Die
Orgel-Wercke
von den Orgelmachern annehmen / probiren / unterſuchen und
den Kirchen liefern könne und
ſolle /
Benebenſt einem kurtzen jedoch gründlichen
Unterricht
Wie durch Anweiß und Hülffe
des Monochordi ein Clavier wohl zu
temperiren und zu ſtimmen ſey / damit man
auch heutiger Manier alle modos fictos in
einer erträglichen und angenehmen harmoni vernehme;
Heraus gegeben und zum Drucke befodert von
Andreâ Werckmeiſter
Hoff-Organiſten zu Quedlinburg.
Franckfurth und Leipzig
Verlegts Theodorus Phil. Calvisius
Buchhändl. in Quedlinburg 1681.

Fig. 5: Title page, *Orgelprobe* (1681). (Nederlands Muziek Instituut, The Hague)

2.1.3. Andreas Werckmeister (1645–1706)

Andreas Werckmeister is a well-known name in the history of temperaments. He was born 1645 in Benneckenstein, Thuringia, and died 1706 in Halberstadt. Werckmeister is best known as a theorist, but he was also an organist and composer. As an organist he worked in Quedlinburg and Halberstadt.

Werckmeister's best-known writings are perhaps *Orgelprobe* (1681)[49] and *Musicalische Temperatur* (1691). His writings were obviously read by other musicians

and theorists. Johann Gottfried Walther and Johann Mattheson, among others, frequently quote Werckmeister's writings in their own works. Even Dieterich Buxtehude was a friend of Werckmeister's, and wrote a dedicatory poem for the "preface" to Werckmeister's *Harmonologia Musica* (1702). Other well-known persons in this context are Arp Schnitger[50] and Johann Philipp Bendeler.[51] It seems that Werckmeister's writings and opinions were rather well known, but it is difficult to judge how influential Werckmeister was. At least he can be said to be one of the authors who started the vast discussion about mean-tone temperament and the different well-tempered tunings, which continued through the eighteenth century.

Werckmeister came forward as a strong opponent to the ruling mean-tone temperament, and presented his own well-tempered tunings in the *Orgelprobe* and the *Musicalische Temperatur*.[52] Today most organists have heard about Werckmeister III, and may have also heard or played an organ tuned to it.

In the *Musicalische Temperatur* (1691) Werckmeister gives his most extensive presentation of his temperaments. In the drawing for the monochord (see Fig. 6) he presents six divisions of the octave, where the first is the just intonation and thus no temperament. Then follows 1/4-comma mean-tone (called the incorrect temperament), and then the correct temperaments. The list is numbered from I to VI, and it is from here the first correct temperament got its name Werckmeister III. In the *Orgelprobe* (1681) Werckmeister gives two definitions, which are the same as numbers III and IV in the *Musicalische Temperatur* (1691).[53]

Werckmeister III and V are divisions based on 1/4 Pythagorean comma, and Werckmeister IV is based on 1/3 Pythagorean comma division. With the introduction of tables in the writings of Werckmeister we get a clearer picture of the structure of the temperaments. Werckmeister VI is not based on the division of a comma, but on the number seven (7). Therefore no circle of fifths are given for Werckmeister VIa and VIb. These temperaments are thus more an approach in the manner of *musica poetica* to the question of temperament. Werckmeister does not give a tuning instruction to these temperaments, strengthening the impression that they are primarily theoretical. The numbers 1, 2, 3, 4, 5, 6 are called "musical numbers"[54] since they represent the octave, fifth, fourth, major third and the minor third (2:1, 3:2, 4:3, 5:4, 6:5). Added together these numbers equal 21, which is 3x7; hence the number 7. Werckmeister continues and gives two tables with string lengths,[55] where the first is 21x7=147 for C. The second is

49 A second edition was the *Erweiterte und verbesserte Orgel=Probe* (1698).
50 Werckmeister 1698, preface.
51 Werckmeister 1697, preface and Werckmeister 1698, preface.
52 Werckmeister 1681 and Werckmeister 1691.
53 Werckmeister 1681: 35.
54 Werckmeister 1691: 69ff.
55 String-length is a common way to define or describe a temperament, directly connected to the use of a monochord. If the length of a string is set to x, then x/2 is the octave.

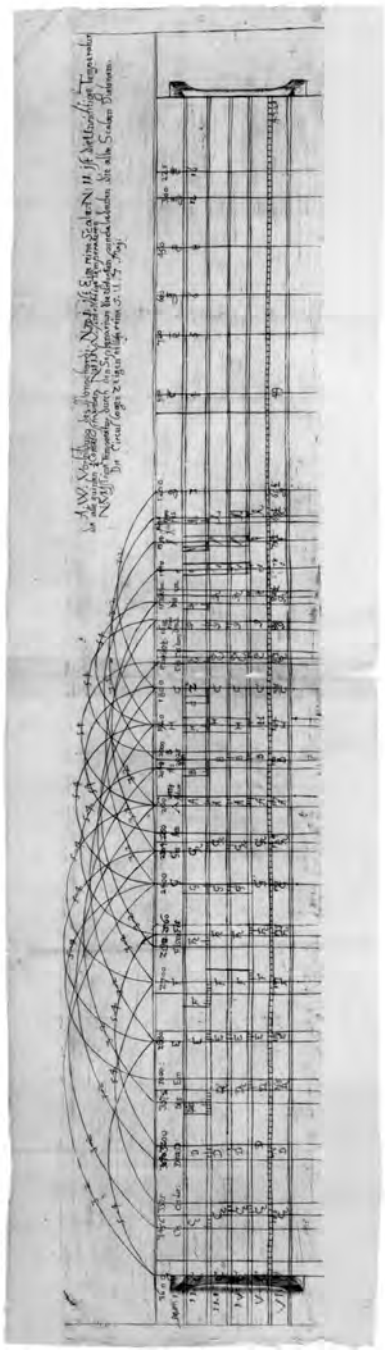


Fig. 6: Division of the monochord, *Musicalische Temperatur* (1691). (Nederlands Muziek Instituut, The Hague)

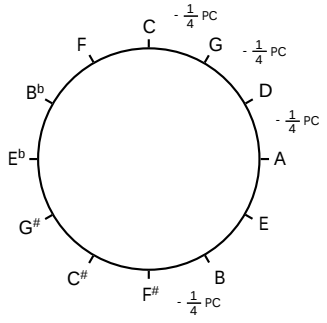


Fig. 7: Werckmeister III

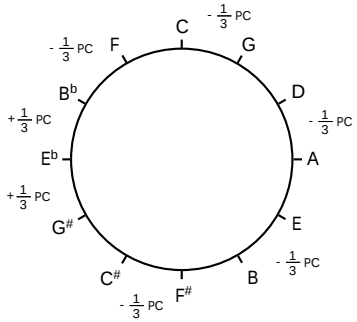


Fig. 8: Werckmeister IV

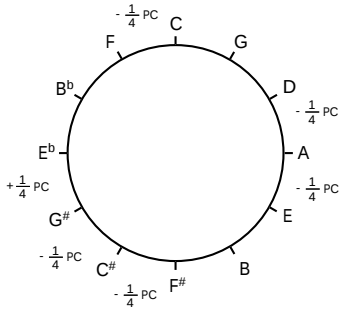


Fig. 9: Werckmeister V

7x7=49, which is further multiplied with 4 (49x4=196 for C). Then follows another table giving the amount by which the fifths are tempered. There are 7 tempered fifths (both wider and narrower than pure), and 5 pure fifths. The tables with string lengths give slightly differing results, and are here labeled Werckmeister VIa and VIb respectively. The only temperaments that Werckmeister actually explained how to tune are the well-tempered tunings, no. III–V.

Table 2: Werckmeister III

C	C#	D	E♭	E	F	F#	G	G#	A	B♭	B
0,00	90,22	192,18	294,13	390,22	498,04	588,27	696,09	792,18	888,27	996,09	1092,18

Table 3: Werckmeister IV

C	C#	D	E♭	E	F	F#	G	G#	A	B♭	B
0,00	82,40	196,09	294,13	392,18	498,04	588,27	694,13	784,36	890,22	1003,91	1086,31

Fig. 10: Description of temperaments, *Orgelprobe* (1681). (Nederlands Muziek Instituut, The Hague)

Table 4: Werckmeister V

C	C#	D	Eb	E	F	F#	G	G#	A	Bb	B
0,00	96,09	203,91	300,00	396,09	503,91	600,00	701,96	792,18	900,00	1001,96	1098,04

Table 5: Werckmeister VIa

C	C#	D	Eb	E	F	F#	G	G#	A	Bb	B
0,00	96,88	199,50	294,57	395,17	501,98	599,08	701,95	792,62	888,29	1000,02	1031,79

Table 6: Werckmeister VIb

C	C#	D	Eb	E	F	F#	G	G#	A	Bb	B
0,00	90,66	186,33	298,07	395,17	498,04	594,92	697,54	792,62	893,21	1000,02	1097,12

It seems from Werckmeister's own writings that he was not always so successful in promoting his new temperaments. He was criticized for his new ideas by, among others, Johann Caspar Trost, who built the organ in the chapel of Weißenfels.[56] Werckmeister tried to meet this critique, which he obviously took very seriously. Throughout his writings he complains about the old-fashioned organ builders who do not want to adopt the new temperament, and how easy it would be to adjust their tuning. Werckmeister writes:

56 See Werckmeister 1691: 82ff, and Rasch 1983: 16.

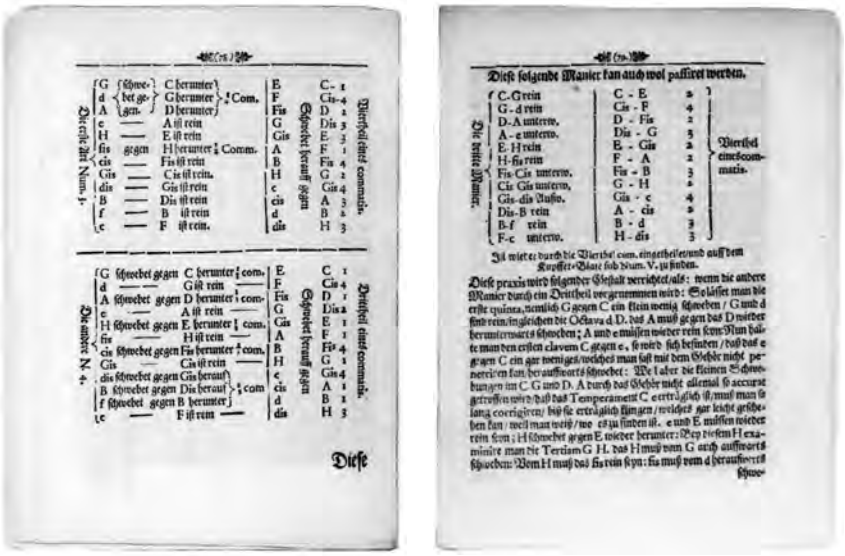


Fig. 11: Description of temperaments, *Musicalische Temperatur* (1691). (Nederlands Muziek Instituut, The Hague)

Oder man könte in der alten *Temperatur* nur das dis etwas niedriger stimmen, so würde gis. dis. etwas reiner, item H. und dis. dis g. und dis b müsten auch in erleidlichem *Temperament* bleiben. Aber etliche Organisten, und Orgelmacher sind durch ihre Gewonheit so eingenommen, daß sie lieber die gräulichen unbrauchbaren *Dissonantien* behalten, alß das sie ihren Sinn ändern solten.[57]

In the old temperament one could lower the d♯ somewhat, making g♯–d♯ more in-tune, and B–d♯, d♯–g and d♯–b♭ would become more tolerably tempered. But many organists and organ builders are so dominated by force of habit, that they prefer to keep the horrible unusable dissonances instead of changing their minds.

Further Werckmeister argues for the new temperament by claiming that it is not so different from the old one, implying that the change would not be that great.

Und unsere *Temperaturen* sind auch von der Alten so sehr nicht entfernet, wie etliche wol meinen.[58]

And our temperaments are not so different from [the temperaments of] the old, as some might say.

57 Werckmeister 1697: 32f.
58 Werckmeister 1698a: 80.

Muſicaliſche Temperatur,
Oder
deutlicher und warer Mathematiſcher Unterricht/
Wie man durch Anweiſung des
MONOCHORDI
Ein Clavier / ſonderlich die Orgel-Wercke/
Poſitive, Regale, Spinetten/ und dergleichen wol tempe-
irt ſtimmen könne/ damit nach heutiger manier alle Modi ſecti
in einer angenehm- und erträglichen Harmonia mögen
genommen werden/
Mit vorhergehender Abhandlung
Von dem Vorzuge/ Vollkommen- und weniger Voll-
kommenheit der Muſicaliſchen Zahlen/ Proportionen/
und Conſonantien,
Welche bey Einrichtung der Temperaturen wohl in
acht zu nehmen ſind:
Benebſt einem darzugehörig-in Kupffer vorgebildeten
deutlichen und völligem
MONOCHORDO
beſchrieben/und an das Tages-Licht gegeben
Durch
Andreas Werckmeiſtern/Stiffts-Hof-Orga-
niſten zu Quedlinburg.
Franckfurt und Leipzig/
In Verlegung Theodori Philippi Calviſii, Buch-Händler
in Quedlinburg/ ANNO 1691.

Fig. 12: Title page, *Musicalische Temperatur* (1691). (Nederlands Muziek Instituut, The Hague)

Werckmeister obviously had great trouble introducing the well-tempered tunings in his day. Today we tend to forget this when we try to date the introduction of equal temperament into organ building earlier and earlier. Changes are not easy to implement.

Why then was Werckmeister opposed to mean-tone temperament? The title of the *Musicalische Temperatur* gives us the answer:

> *Musicali*sche *Temperatur*, Oder deutlicher und warer *Mathemati*scher Unterricht, Wie man durch Anweisung des *MONOCHORDI* Ein Clavier, sonderlich die Orgel=Wercke, *Positive, Regale, Spinett*en, und dergleichen wol temperirt stimmen könne, damit nach

> heutiger *mani*er alle *Modi ficti* in einer angenehm= und erträglichen *Harmonia* mögen genommen werden...[59]

> Musical Temperament, or clear and true mathematical instruction on how to tune a clavier, in particular organs, positivs, regals, spinetts and similar instruments in a well-tempered manner with the help of the monochord whereby in a modern fashion all *modi ficti*, can be used to make a pleasant and tolerable harmony...

"A musical temperament" where all the harmonies would be pleasant and would allow modulations through the circle of fifths was requested. Using more remote keys presupposes another temperament than 1/4-comma mean-tone or many subsemitones. The latter would introduce technical problems in playing on such a keyboard.

Werckmeister is also aware of the fact that people have different opinions about this matter. He says that there are several different ideas about temperament, but he does not mention any specific author or organ builder. The only temperament he mentions, besides his own, is the 1/4-comma mean-tone. This gives the impression that the only other choice is Werckmeister's temperaments.

> Es werden viel und mancherley Meynungen von der *Musicali*schen *Temperatur* auf die Bahne gebracht; Einige bringen vor, es müsten alle *Quin*ten ein Viertel eines *commatis* herunter schweben, so würden hingegen alle *Tertien* gantz rein seyn und bleiben: Dieses scheinet zwar im Anfang des *Processus*, so wohl im *Monochordo*, als auch im Stimmen ganz *favorabel*, allein wenn man durch das gantze *Clavier*, oder durch den Circul der *Quin*ten gehet, befinden sich unterschiedliche *defecta*, daß man ein solch *Temperir*tes *Clav*ier gar nicht gebrauchen kan.[60]

> At the present time there are many different opinions about musical temperaments. Some propose that all fifths must be a 1/4 comma narrower than pure, which would result in pure thirds. Although it seems preferable to begin this way both on the monochord and when tuning, if one goes through the whole keyboard, or through the circle of fifths, there are different defects, so that one can hardly use a keyboard tempered this way.

One of the defects Werckmeister is talking about is, of course, the wolf. This is one of his strongest arguments against mean-tone temperament. The question of subsemitones is also an argument against the mean-tone temperament. Subsemitones spoil the instrument, making it a patchwork, and confusing many.[61]

Werckmeister also discusses equal temperament and key characteristics. His argument against equal temperament is based on the properties of well-tempered tunings. Werckmeister's first mentioning of equally tempering 12 fifths is in *Hypomnemata Musica* (1697).[62] He refers himself to this in the *Musicalische Paradoxal-Discourse* (1707), published posthumously. Here Werckmeister claims that he knew this temperament already 30 years ago, but the engraver did not manage to do the engraving for his 2-foot monochord.[63] He writes that he is pleased with

59 Werckmeister 1691, title page.
60 Werckmeister 1691: 1.
61 Werckmeister 1698a: 79, and p. "0" [82].
62 Werckmeister 1697: 35f.

the support he received from Johann Georg Neidhardt, who has published a description of equal temperament.[64] However, Werckmeister does not recommend equal temperament even if he judges it to be correct; instead, in his last book, he writes the following:

> Indeßen bin ich doch nicht ungeneigt, und bleibe dabey, daß man die *diatoni*schen *Tertien* etwas reiner laße, als die andern so man selten gebrauchet, es giebet auch gute Veränderung,…[65]
>
> Even so I still remain inclined to leave the diatonic thirds somewhat purer than the others that one rarely uses, which results in good variations…

When it comes to the question whether Werckmeister's ideas were applied in practice, Werckmeister states, himself, in his *Orgelprobe* from 1681 that the organ builder Zacharias Thayßner used his temperament.[66] In 1705 Thayßner received a printed certificate about the organ in St. Wenzel, Naumburg, which, among other things, states that he applied a "musical temperament."[67] The wording is the same Werckmeister uses in the title to his *Musicalische Temperatur* from 1691 implying that one can modulate around the circle of fifths: "musical temperament."

The wolf in the mean-tone temperaments was the main problem for the musicians who wanted to be able to modulate through the circle of fifths. As an example of why one would need a temperament making it possible to play in all keys, Werckmeister mentions in *Hypomnemata Musica* (1697) a Canzona composed 30 years prior by Johann Jacob Froberger going through all the keys.[68]

63 Werckmeister 1707: 111ff.
64 Werckmeister 1707: 112. Neidhardt 1706: 38 (gleich=schwebenden).
65 Werckmeister 1707: 113. A similar statement can be found in Werckmeister's *Die Nothwendigsten Anmerckungen und Regeln wie der Bassus Continuus oder General=Baß wol könne tractiret werden* (1698): "Wir wollen aber in unsern Unterricht keines *Commatis* gedencken, und nur wie gemeldet einfältig verfahren, und dis Werck also beschreiben, daß das *Genus Diatonico-Chromaticum*, welches heutiges Tages am meisten gebrauchet wird, am reinesten bleibe." (Werckmeister 1698b: 64.) Still we find in this book a practical description on how to tune a clavichord, approaching equal temperament. Since the temperament is mainly intended for the clavichord it is omitted from our comparisons. Mark Lindley has made a reconstruction (Lindley 1987: 264. See also Schütz 1988: 137ff.) based on Werckmeister's description *Kurtzer Unterricht und Zugab, wie man ein Clavier stimmen und wohl temperiren könne* (Werckmeister 1698b: 61). Werckmeister describes the different amount of tempering the fifths with formulations like: "ein klein wenig herunter schweben", "ein gar weniges herunter schweben", "gantz *subtil* herunter schweben". The thirds to check the tempering of the fifths are described with: "nicht gar zu stark schweben", "soviel das Gehör ertragen kann", "erleidlich *consonire*". (Werckmeister 1698b: 64ff.) Werckmeister himself approximates the tempering to be between 1/8 and 1/12 of a comma. (Werckmeister 1698b: 69.) Lindley notices correctly in his reconstruction that Werckmeister's approximation cannot be correct, and suggests between 1/6 and 1/8 of a comma. See also Werckmeister 1697: 36, Werckmeister 1698b, s. 63f, and Neidhardt 1706: 39.
66 "…ist auch von *Tit*. Hrn. Z. Thayßner, berühmten Orgelmacher, welcher das Orgelwerck in unser Hoff-Kirchen also *temperir*t und eingerichtet, vor gut erkant, daß man also gar nichts daran zu *desideri*ren hat." Werckmeister 1681: 36.
67 "…und auch zugleich eine accurate musicalische Temperatur gar annehmlich zuhören ist…". Quoted in Dähnert 1962: 73.
68 Werckmeister 1697: 37.

Even if equal temperament is known, it is not yet accepted, probably because it is regarded as "too much" out of tune compared to the pure, or nearly pure, thirds of mean-tone. This is not surprising since some builders and musicians already had problems accepting Werckmeister's well-tempered tuning. Werckmeister accepts equal temperament as correct, but he prefers to have the diatonic thirds purer, since they are more often used. This is the case with, for example, Werckmeister III. Differences in the scales, due to the temperament, give different keys different characteristics, and this quality, according to Andreas Werckmeister, is used and loved by musicians; it possesses a musical quality.

Finally we have some other sources discussing the reception of Werckmeister's temperaments. According to Christoph Albert Sinn in his *Temperatura Practica*,[69] the organ builder Christoph Contius used Werckmeister's temperament. Contius built three instruments before Sinn's book was published: Wernigerode, 1707; Abbenrode, 1708; and Halle, 1716. Contius also restored the organ in the castle of Gröningen, on which Werckmeister wrote the report *Organum Gruningense Redivivum* (1705).[70] In this report Werckmeister writes that the Oberwerck was retuned while the Rückpositiv was still in 1/4-comma mean-tone to enable a comparison.[71] Werckmeister did not, however, succeed in convincing all of the people present about the quality of the "new temperament".

> Ich weiß zwar wohl, daß einige, so noch an der alten, so genanten *Praetorianis*chen *Temperatur* hangen, und nicht weiter kommen sind.[72]
>
> However, I know well that some have not come further, and still keep to the old so called Praetorian temperament.

Werckmeister does not state what the new temperament was, but he refers to his *Musicalische Temperatur* where he tried to prove the 1/4-comma mean-tone to be inferior, or wrong as he put it,[73] and where the equal temperament is not described in the tables but the first correct temperament being Werckmeister III.

Sinn does not specify which of Werckmeister's temperaments Contius used, but he refers to the *Musicalische Temperatur* by Werckmeister. After discussing Praetorius's temperament (1/4-comma mean-tone), Sinn writes:

> §. 6. Es will aber diese *Temperatur* anitzo nicht mehr hinlangen, da die Music zu unseren Zeiten fast den höchsten Gipfel erstiegen, und man aus allen *Semitoniis* zu *Musici*ren angefangen, auch noch immer damit fort fähret; Und ist dahero aufs neue sehr nöthig, daß auch nach solcher Art die *Intervalla* zu einer völligen Richtigkeit gebracht werden, damit die *Harmonie* annehmlich und gefällig sey.

69 Sinn 1717. See also Williams 1984: 189, and, Wegscheider and Schütz 1988: 30.
70 Werckmeister 1705.
71 Werckmeister 1705: §49–52 (no page numbers).
72 Werckmeister 1705: §52.
73 Werckmeister 1705: §58–59. Werckmeister refers to the *Musicalische Temperatur* by using "Monochordo", which is part of the full title.

§. 7. Solches nun ins Werck zu richten, hat sich vor andern der berühmte *Musicus Theoretico-Practicus* Hn. Andreas Werckmeister, Weyland wohlbestalter *Organist* an der Kirche zu *St. Martin* in Halberstatt höchst angelegen seyn lassen, auch mit grosser Mühe und Fleiß es so weit gebracht, daß man aus allen *Semitoniis* spielen kan, was man nur wil, und zwar so, daß es dem Gehör gantz erträglich fället, wie davon in seiner *Musicalischen Temperatur* ausführlich zu lesen ist.

§. 8. Gleich wie nun diese Temperatur seinen grossen Nutzen gefunden, in dem dieselbe durch den berühmten Orgelmacher Hn. Christoph Kuntzen [Contius] in einige Orgelwercke *ad praxin* gebracht worden, so hat sich auch der seel. Mann dadurch einen herrlichen Nach Ruhm erworben, der so lange die Welt stehet nicht vergehen wird.[74]

§. 6. [Praetorius's] temperament is no longer adequate since the music of our time has almost reached its pinnacle, and one has started to play in all semitones, and still does; hence it is again highly necessary to bring the intervals to a full correctness according to such a practice, by which the euphony is pleasing and appealing.

§. 7. More than for others, this was a main concern for the famous musician and theorist Mr. A. Werckmeister, in his lifetime well appointed organist of the St. Martin Church in Halberstadt, and he passed it on with labor and diligence as well, so that one can play anything one likes in all semitones, in such a way that the ear can reasonably well tolerate it, as you can read in detail in his *Musicalische Temperatur.*

§. 8. As this temperament was found to be greatly advantageous when applied in some organs by the famous organ builder Christoph Kunzen [Contius], the late Werckmeister achieved a glorious reputation which will stand as long as the world lasts.

A few pages later Sinn writes that Superintendent Heinrich Neuß discussed the question of equal temperament with some organ builders:

§. 10. Als nun bey vorerwehnten Hn. *Doctori* [Neuß] mit dieser Arbeit beschäfftiget war, und derselbe in meiner Gegenwart mit einigen Orgelmachern davon *discurir*te [*discutir*te], selbige aber vorwendeten, daß solches zwar in Säiten=*Instrumenten* seinen Nutzen hätte, in den Pfeiff=wercken aber keines weges angehen könte, weil es mit denenselben eine gantz andere Beschaffenheit hätte.[75]

§. 10. While [I was] occupied with this work [of calculating equal temperament], at the above-mentioned Doctor Neuß, he discussed it with some organ builders in my presence, but they argued that this is only useful in stringed instruments, and has no place under any circumstance in organs, since they are of a very different nature.

According to Michael Behrens the organ builders could include Contius, who worked in Wernigerode during Neuß' continuance in office.[76] The organ builders clearly did not approve of equal temperament. Based on this, an instrument idiomatic approach regarding temperament is historically justified. Due to the dif-

74 Sinn 1717: 115f.
75 Sinn 1717: 123.
76 Behrens 1988: 13f.

ferent character of the sound production, a temperament might be better suited to a harpsichord than to an organ. Among Werckmeister's temperaments the most likely candidate for an organ is Werckmeister III, since that is the temperament recommended for chromatic music by Werckmeister himself.[77]

2.1.4. Johann Philipp Bendeler (1654–1709)

Johann Philipp Bendeler was a close friend of Andreas Werckmeister's.[78] He was born 1654 in Riethnordhausen, close to Erfurt, and died in Quedlinburg 1709. Bendeler worked as teacher (1681) and Kantor (1687) in Quedlinburg. Bendeler's most important treatise, *Organopoeia* (c. 1690), deals with the construction of the organ, and in the third part of the small book, "Von der Stimmung", Bendeler presents three temperaments.[79]

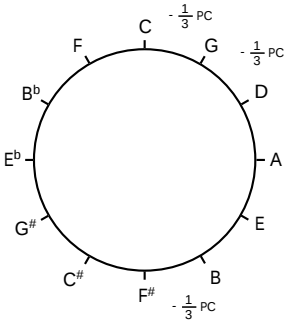


Fig. 13: Bendeler I

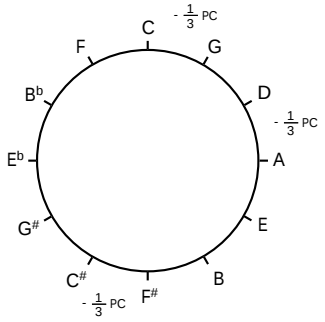


Fig. 14: Bendeler II

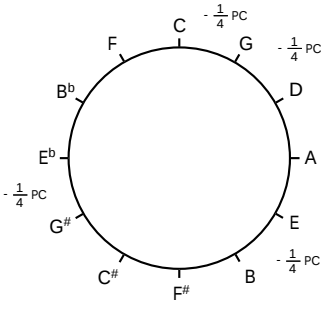
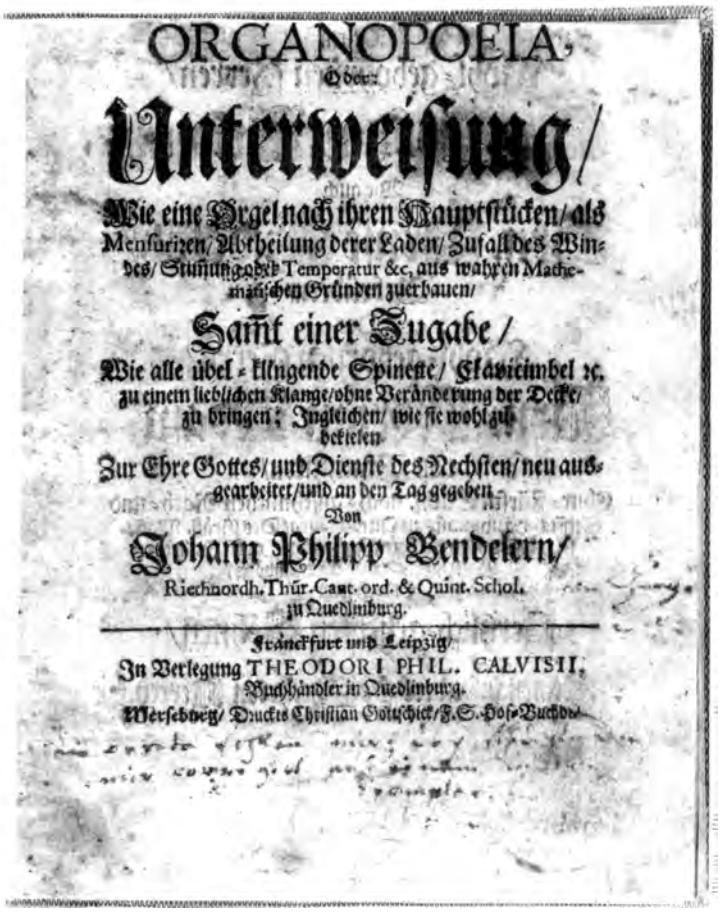


Fig. 15: Bendeler III

77 Werckmeister 1691: 77.
78 See above p. 19.
79 Bendeler 1690: 38ff.



ORGANOPOEIA,
Oder
Unterweisung/
Wie eine Orgel nach ihren Hauptstücken/ als
Mensurirẽ/ Abtheilung derer Laden/ Zufall des Win-
des/ Stimmung/ der Temperatur &c. aus wahren Mathe-
matischen Gründen zuerbauen/
Samt einer Zugabe/
Wie alle übel-klingende Spinette/ Clavicimbel ꝛc.
zu einem lieblichen Klange/ohne Veränderung der Decke/
zu bringen; Ingleichen/ wie sie wohl zu
bekielen.
Zur Ehre Gottes/ und Dienste des Nechsten/ neu aus-
gearbeitet/ und an den Tag gegeben
Von
Johann Philipp Bendelern/
Riechnordh. Thür. Cant. ord. & Quint. Schol.
zu Quedlinburg.
Franckfurt und Leipzig/
In Verlegung THEODORI PHIL. CALVISII,
Buchhändler in Quedlinburg.
Wernsdorff/ Druckts Christian Gottschick/ F. S. Hof-Buchdr.

Fig. 16: Title page, *Organopoeia* (c. 1690). (Staatsbibliothek zu Berlin – Preußischer Kulturbesitz, Musikabteilung mit Mendelssohn-Archiv)

Table 7: Bendeler I

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	90,22	188,27	294,13	392,18	498,04	588,27	694,13	792,18	890,22	996,09	1094,13

Table 8: Bendeler II

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	90,22	196,09	294,13	392,18	498,04	596,09	694,13	792,18	890,22	996,09	1094,13

Table 9: Bendeler III

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	96,09	192,18	294,13	396,09	498,04	594,13	696,09	798,04	894,13	996,09	1092,18

The two first temperaments are based on 1/3 Pythagorean comma. The first tempers the fifths C–G, D–G, and B–F♯, keeping the other fifths pure. The second tempers the fifths C–G, D–A, and, F♯–C♯. The third temperament is similar to Werckmeister III in that it uses 1/4 Pythagorean comma. Bendeler tempers the fifths C–G, G–D, E–H, G♯–D♯, and the other fifths pure. Further information about whether these temperaments were used is lacking.

2.1.5. Johann Georg Neidhardt (c. 1680–1739)

Johann Georg Neidhardt was born c. 1680 in Bernstadt not far from Görlitz, and died 1739 in Königsberg. Since Neidhardt was enrolled at the university in Altdorf already in 1698, one can assume that 1680 is more likely the year of his birth than the more often quoted 1685.[80] He was a theorist, but was also a practicing musician and a poet. Neidhardt studied with Johann Nicolaus Bach, cousin of Johann Sebastian, in Jena, and his writings were referred to by, among others, Andreas Werckmeister.[81] It was Neidhardt who introduced the term "gleichschwebend" in the *Beste und leichteste Temperatur* (1706).[82]

Neidhardt has two arguments for equal temperament. After mentioning the 1/4-comma mean-tone, he comments on Werckmeister by referring to Werckmeister's *Musicalische Temperatur*, saying that the so far prevailing temperaments had differently tempered fifths, making the situation quite complicated:

> Die bisher florirten *Temperatur*en sind so eingerichtet, daß eine *Quinte* rein, die andere über sich schwebend, die dritte unter sich schwebend, und die vierdte ich weiß nicht wie in das Gehöre fället. *Vid. "Werckmeisteri" Music. Temperat: Cap. XX. XXI. XXVII. XXX. XXXI. aliosque.*[83]
>
> Up to now temperaments have been constructed, so that one fifth is pure, the second beat wider than pure, a third beat narrower than pure, and a fourth, who knows how one heard it. See Werckmeister's *Musicalische Temperatur*: chapters. XX. XXI. XXVII. XXX. XXXI. and others.

Now Neidhardt gives his first argument for equal temperament: the use of some keys will not be refined, and they will not be appreciated as would be proper.

> Unterdessen aber bleiben die schweren aber auch schönen *Modi* aus *Cisdur, Disdur, Fisdur, Gisdur, Hdur,* und *Cis moll, Dis moll, F moll, Fis moll, Gis moll, B moll, H moll,* ferner un*excol*iret: indem sie ein verständiger *Componist* aus Vorsatz, und unverständige aus Unwissenheit, weder *fundamentaliter* noch *affinaliter* ihrer Federn werth schätzen.[84]
>
> Besides these [the diatonic keys], the difficult but beautiful keys of C♯ major, D♯ major, F♯ major, G♯ major, B major, and C♯ minor, D♯ minor, F minor, F♯ minor, G♯ minor, B♭ minor, B minor, will not be elaborated: since a competent composer will from prejudice,

80 Ratte1994b: 230.
81 Werckmeister 1707: 112.
82 Neidhardt 1706: 38. Werckmeister uses the word "Gleichheit" when he explains the resulting consonances when tempering all fifths 1/12 of a comma (Werckmeister 1697: 35).
83 Neidhardt 1706: 39.
84 Neidhardt 1706: 39-40.

Johann George Neidhardts/
S.S. Theol. Stud.
Beste und Leichteste
TEMPERATUR
Des
MONOCHORDI,
Vermittelst welcher das heutiges Tages bräuchliche Genus *Diatonico-Chromaticum* also eingerichtet wird/ daß alle Intervalla, nach gehöriger Proportion, einerley Schwebung überkommen/ und sich daher die Modi regulares in alle und iede Claves, in einer angenehmen Gleichheit/ transponiren lassen:
Worbey vorhero
Von dem Ursprunge der Musicalischen Proportionum, den Generibus Musicis, deren Fehlern/ und Unzulänglichkeit anderer Verbesserungen gehandelt wird.
Alles aus Mathematischen Gründen gründlich/ ordentlich/ deutlich und kürtzlich/ bey Academischen Nebenstunden/ aufgesetzt.
Nebst einem darzu gehörigen Kupffer.
JENA/
Bey Johann Bielcken. 1706.

Fig. 17: Title page, *Beste und leichteste Temperatur* (1706). (Staatsbibliothek zu Berlin – Preußischer Kulturbesitz, Musikabteilung mit Mendelssohn-Archiv)

> and an incompetent one will out of ignorance, not bother to learn the basic use [of the key] nor in modulation.

Neidhardt continues with the second argument: when two instruments tuned to different pitch play together, it will result in a wrong depiction of the chosen mood.

> Nebst diesem ist es zärtlichen Ohren ein Greuel, im falle sich ein Instrument zu dem andern *accompagni*ret, wo eines davon im Chor= das andre im Cammer=Thone stehet. Wenn gleich ein guter *Componist* z. e. über die Worte des 147. Psalms *commenti*ret hat: "Er schaffet deinen Gräntzen Friede", so klinget es doch, wenn er dergleichen Instrumente darzu setzt, nicht viel anders, als hätte er den Zanck der Hunde über dem Cörper der abgestürtzen Iesabel vorstellen wollen.[85]

85 Neidhardt 1706: 40.

> Together with this, it is detestable to sensitive ears when one instrument is accompanying another instrument, if one is in choir pitch and the other in chamber pitch. Even if a good composer has glossed the words of the 147th Psalm: "He makes peace in your borders," when using such instruments it sounds as if he was picturing the dogs quarrelling over the fallen Jezebel's corpse.

Here we have to assume that one of the instruments in this example is transposing even if it is not clearly stated. Since Neidhardt is talking about keys in the preceding example the discussion must be about the quality of keys.

Then Neidhardt sets out to define the equal temperament for a monochord, since, to his knowledge this has not been done, and therefore not applied in any other instrument.

> Sie ist aber, meines Wissens, noch bis *dato* auf kein *Monochordum* gekommen (und also noch viel weniger an andern Instrumenten *accurat applici*ret worden.)[86]
>
> To my knowledge [equal temperament] has not until today been defined on a monochord (and so has even less been accurately applied in other instruments.)

The mentioning of the application of equal temperament in other instruments is interesting. According to Neidhardt, an accurate application of equal temperament has so far not been possible, perhaps primarily due to technical problems. There is also a practical problem in using a monochord to set a temperament, namely that the tone fades away too fast. By Jakob Adlung we have a report from an occasion where Neidhardt was supposed to tune an organ stop according to his temperament. This took place in Jena, at Johann Nicolaus Bach's organ. Johann Nicolaus Bach was Neidhardt's opponent, and the result of the tuning should be judged after playing a hymn. According to the report, Neidhardt lost.

> Werckmeister in *Hypomn.* C. 10, S. 30, hält es vor thöricht, Pfeiffen nach dem Monochord zu stimmen. Als die neue Orgel zu Jena fertig war, wollte Neidhardt solche stimmen, und bekam endlich die Erlaubniß, mit einem Gedact die Probe zu machen, da er sich denn die Mühe nahm, solches zu temperiren nach dem Monochord; Herr Bach aber, als Organist, thät dergleichen mit einer gedeckten Stimme ohne Monochord, und am Ende wurde dieses letztern Temperatur jener vorgezogen, wie denn der Organist nachdem sein Werck selbst gestimmt, welches ich aus seinem Munde habe.[87]
>
> Werckmeister writes in *Hypomnemata Musica* chapter 10, p. 30, that tuning pipes with a monochord is foolish. When the new organ in Jena was ready, Neidhardt wanted to tune it, and finally got permission to do the test with a Gedackt which he took the trouble to temper using the monochord; Mr. Bach, as organist, did the same with a stopped register without using a monochord, and in the end the temperament of the latter was preferred by everyone, and later used by him to tune the instrument, as he told me himself.

Neidhardt is perhaps best known today for his pragmatic approach to temperament, first presented in the *Sectio canonis harmonici* (1724). After presenting four temperaments, three unequal and the equal temperament, he evaluates them,

86 Neidhardt 1706: 41.
87 Adlung 1758: 311f, note "y". See also Adlung 1768, vol ii: 54f.


SECTIO
CANONIS
HARMONICI,
zur
völligen Richtigkeit
der
GENERVM MODVLANDI,
herausgegeben
von
Johann George Neidhardt/
Königl. Preußisch. Capellmeister.
Königsberg.
In Verlegung Christ. Gottfr. Eckarts.
MDCCXXIV.

Fig. 18: Title page, *Sectio canonis harmonici* (1724). (Staatsbibliothek zu Berlin – Preußischer Kulturbesitz, Musikabteilung mit Mendelssohn-Archiv)

and gives some recommendations for their use: for a village, a small city, a large city, and the court.

> Meines Erachtens schickt sich die Erste, mehrentheils, am besten vor ein Dorff, die Andre vor eine kleine Stadt, die Dritte vor eine Große, und die Vierdte vor den Hof.[88]
>
> In my opinion the first [temperament] is suitable primarily for a village, the second for a small city, the third for a large city, and the fourth for the court.

Before this categorization, Neidhardt comments on the consequences of unequal temperaments. The unequal temperaments will, through the difference in the intervals and consequently differences in triads, result in different and stronger emotions.

88 Neidhardt 1724: 20.


Gäntzlich erschöpfte,
Mathematische
Abtheilungen
des
Diatonisch-Chromatischen,
temperirten
CANONIS MONOCHORDI,
alwo,
in unwiedersprechlichen Regeln
und handgreiflichen Exempeln,
gezeiget wird,
wie
Alle Temperaturen
zu erfinden,
in Linien und Zahlen
darzustellen,
und aufzutragen seyn.
Den Liebhabern
Gründlicher Stimmung
mitgetheilet,
von
Johann George Neidhardt,
Königl. Preußisch. Capellmeister.
Königsberg.
Bey Christoph Gottfried Eckart.
M DCC XXXII.

Fig. 19: Title page, *Gäntzlich erschöpfte Mathematische Abtheilungen* (1732). (Staatsbibliothek zu Berlin – Preußischer Kulturbesitz, Musikabteilung mit Mendelssohn-Archiv)

> Denn außer dem, daß der *sonus fundamentalis* eines *Modi* bald höher bald tiefer ist, so verändert sich zugleich die *Trias Harmonica*: woraus ohnfehlbar eine mehr als doppelte Gemüths=Bewegung entstehen muß.[89]
>
> Aside from the fact that the tonic note of a key is sometimes higher and sometimes lower, the triads are also changing: which inevitably results in more than a doubling of their emotional impact.

In his *Gäntzlich erschöpfte Mathematische Abtheilungen* (1732), Neidhardt keeps to these same recommendations. A problem is that the definitions of the temperaments he gives are not exactly the same as in *Sectio canonis harmonici* (1724). The definitions are slightly shifted. The greatest difference, though, is Neidhardt's new system of creating temperaments.[90] He defines a frame within which the temper-

89 Neidhardt 1724: 20.

ing of the intervals should stay, and with this system you can go on defining your own temperaments in tables. Neidhardt presents many temperaments created with his new method. Some are symmetrical in their design, with every second fifth tempered equally. Others are practical, with the fifths tempered differently to achieve a sonorous temperament. The system can use either the fifth, which is "die Erste Art," or the third, "die Andre Art," as a point of departure.

Neidhardt defined 17 temperaments according to this method, but only four were chosen: 1/*Erste Art* is equal temperament; 8/*Erste Art* is for a large city; 2/*Andre Art* is for a small city; and, 1/*Andre Art* is for a village.[91] These were further presented with numbers for string lengths.

Table 10: Neidhardt 1732 – Erste Art

No. 1	Equal temp.	No. 8	Large city
Fifths	Beats	Fifths	Beats
c:g	1	c:g	2
g:d	1	g:d	2
d:a	1	d:a	2
a:e	1	a:e	1
e:h	1	e:h	0
h:fs	1	h:fs	1
fs:cs	1	fs:cs	1
cs:gs	1	cs:gs	1
gs:ds	1	gs:ds	0
ds:b	1	ds:b	0
b:f	1	b:f	1
f:c	1	f:c	1

Table 11: Neidhardt 1732 – Andre Art

No. 1	Village	No. 2	Small city
Fifths	Beats	Fifths	Beats
c:g	1	c:g	2
g:d	2	g:d	2
d:a	3	d:a	2
a:e	3	a:e	2
e:h	0	e:h	1
h:fs	1	h:fs	1
fs:cs	0	fs:cs	0
cs:gs	1	cs:gs	0
gs:ds	0	gs:ds	1
ds:b	0	ds:b	1
b:f	1	b:f	0
f:c	0	f:c	0

90 Neidhardt 1732: 26ff.

91 Neidhardt 1732: 40. See Appendix C. No. 12 is of interest for Swedish conditions, since it is referred to and judged the best by Johan Miklin in A. A. Hülphers' *Historisk Afhandling* from 1773 (p. 320, note "y").

A comparison (see table below) of the temperaments in Neidhardt's publications from 1724 and 1732 will reveal the shift that occurred between the two publications. The "kleine Stadt" and "ein Dorf" in 1724 becomes "grosse Stadt" and "kleine Stadt" respectively in 1732. A reference to a temperament by Neidhardt must consequently always be accompanied by the year of publication.

Table 12: Johann Georg Neidhardt 1724

	Hof		Grosse Stadt		Kleine Stadt		Dorf	
	String length	Cents	String length	Cents	String length	Cents	String length	Cents
C	2000	0,00	2000	0,00	2000	0,00	2000	0,00
C$^{\#}$	1887,74	100,01	1892,01	96,10	1892,01	96,10	1894,15	94,14
D	1781,79	200,01	1785,82	196,10	1785,82	196,10	1785,82	196,10
D$^{\#}$	1681,78	300,01	1683,68	298,06	1683,68	298,06	1685,59	296,10
E	1587,39	400,01	1592,78	394,14	1592,78	394,14	1594,58	392,19
F	1498,3	500,01	1500	498,04	1498,3	500,01	1500	498,04
F$^{\#}$	1414,2	600,02	1417,4	596,10	1417,4	596,10	1420,61	592,19
G	1334,83	700,01	1336,34	698,06	1336,34	698,06	1336,34	698,06
G$^{\#}$	1259,91	800,02	1262,76	796,10	1262,76	796,10	1262,76	796,10
A	1189,2	900,01	1193,23	894,15	1193,23	894,15	1193,23	894,15
B^{b}	1122,45	1000,02	1123,72	998,06	1122,45	1000,02	1125	996,09
B	1059,45	1100,02	1061,85	1096,10	1061,85	1096,10	1064,25	1092,20
C	1000	1200,00	1000	1200,00	1000	1200,00	1000	1200,00

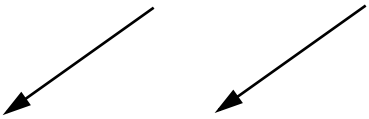


Table 13: Johann Georg Neidhardt 1732

	Hof		Grosse Stadt		Kleine Stadt		Dorf	
	String length	Cents	String length	Cents	String length	Cents	String length	Cents
C	2000	0,00	2000	0,00	2000	0,00	2000	0,00
C$^{\#}$	1887,74	100,01	1892,01	96,10	1894,15	94,14	1894,15	94,14
D	1781,79	200,01	1785,82	196,10	1785,82	196,10	1783,8	198,06
D$^{\#}$	1681,78	300,01	1683,68	298,06	1685,59	296,10	1685,59	296,10
E	1587,39	400,01	1592,78	394,14	1594,58	392,19	1596,38	390,24
F	1498,3	500,01	1498,3	500,01	1500	498,04	1500	498,04
F$^{\#}$	1414,2	600,02	1417,4	596,10	1420,61	592,19	1420,48	592,35
G	1334,83	700,01	1336,34	698,06	1336,34	698,06	1334,83	700,01
G$^{\#}$	1259,91	800,02	1262,76	796,10	1262,76	796,10	1264,19	794,14
A	1189,2	900,01	1193,23	894,15	1193,23	894,15	1193,23	894,15
B^{b}	1122,45	1000,02	1122,45	1000,02	1125	996,09	1123,72	998,06
B	1059,45	1100,02	1061,85	1096,10	1064,25	1092,20	1064,25	1092,20
C	1000	1200,00	1000	1200,00	1000	1200,00	1000	1200,00

For the present work, there is a very important discussion towards the end of Neidhardt's *Gäntzlich erschöpfte Mathematische Abtheilungen* (1732). Neidhardt ad-

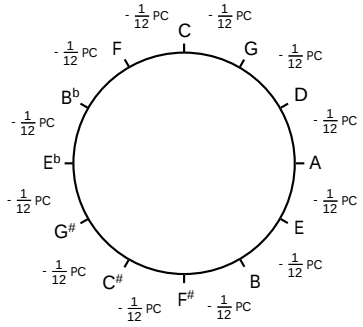


Fig. 20: Neidhardt for the court (1732)

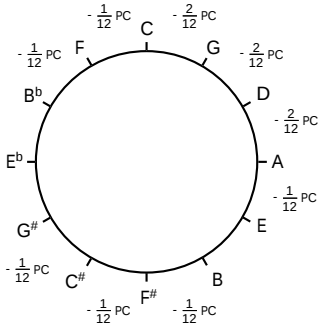


Fig. 21: Neidhardt for a large city (1732)

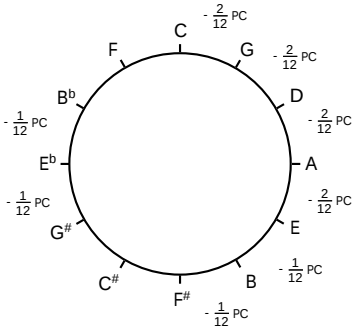


Fig. 22: Neidhardt for a small city (1732)

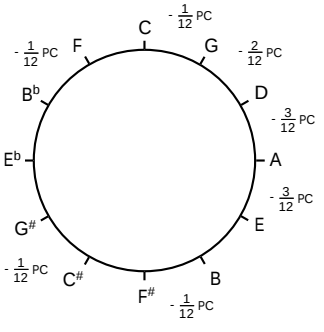


Fig. 23: Neidhardt for a village (1732)

dresses the question of the need for other temperaments than equal temperament. He defines the task as to find the best temperament for the church.

> Es ist nun an dem, daß wir die beste Temperaturen, und und [*sic*] zwar für die Kirchen, aussuchen wollen.[92]
>
> The time has now come to find the best temperaments namely for the churches.

This delimitation is important as an example of a concern for the suitability of a temperament for a specific musical style or environment – church music. Consequently this directly concerns the organ as the principal instrument of the church. Neidhardt continues and writes that even if equal temperament does not readily take the last place, and though it seems the most natural, most people do not find in it what they seek, namely the expression of emotions through the differences in the beats in the major thirds.

92 Neidhardt 1732: 40.

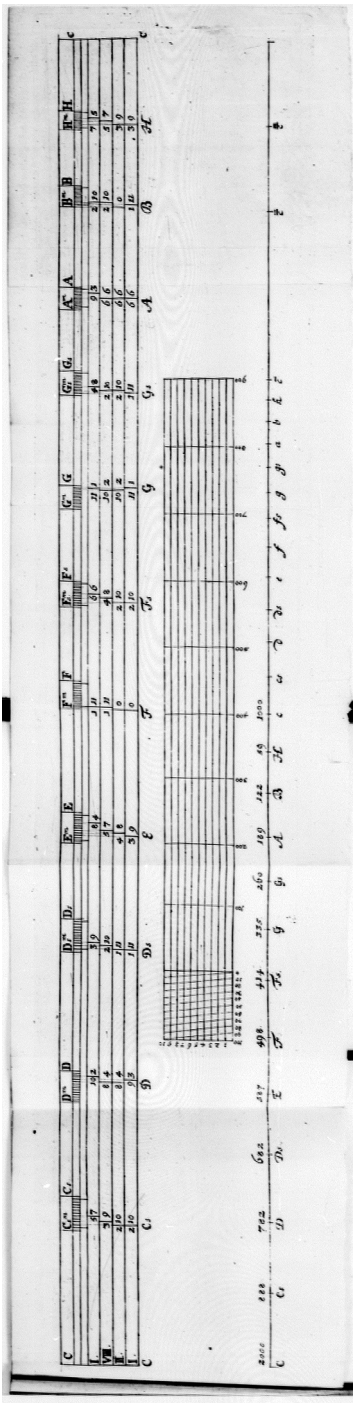


Fig. 24: Division of the monochord, *Gäntzlich erschöpfte Mathematische Abtheilungen* (1732). (Leipziger Städtische Bibliotheken – Musikbibliothek). Compare with Table 10 and 11. See also Werckmeister's similar drawing, Fig. 6.

> Allein die meisten finden doch an dieser Stimmung [die gleich schwebende] nicht, was sie suchen. Es fehlet (heisset es) ihren *Tertiis maioribus* an der Abwechselung der Schwebungen, und folglich mehrerer Gemüths=Bewegungen.[93]
>
> But, most people do not find in this temperament [equal temperament] what they are looking for. The major thirds lack (they say) a variation in their beat [rates], and consequently they lack diverse emotional impact.

Neidhardt refers to the idea about the temperament's role for the expression of emotions, but here he has a more skeptical tone than in 1724. It seems that his personal opinion has slightly changed. He continues, bringing up the problem of playing together with other instruments. The equal temperament is difficult to discern in a triad, but when you hear the thirds by themselves, the difference is clearly audible. The difference in the scale caused by the temperament creates problems with the intonation for the players of wind instruments, and therefore it is not only the organ builders that should be criticized.

> In der *triade harmonica* lässet sich alles leidlich genung hören. Aber wenn die *Tertiae maiores* alleine, und die *Tertiae minores* auch alleine, angegeben werden, so wollen jene alzu hoch, diese alzu niedrig klingen. Ja, so gar die Halbe Tone, hinter einander, weichen sehr viel in die Tiefe ab. Uber dieses finden die Trompeten, nebst den Waldhörnern, auch ihr Theil daran auszusetzen. Es ist also den Orgelbauern eben nicht zu verdencken, daß sie gedachte Stimmung nicht gerne in die Kirche lassen.[94]
>
> In the triads everything is reasonably easy to hear. But when the major thirds or the minor thirds are played alone, then the first will sound way too wide and the other way too narrow. And also the semitones, played one after another are much too flat. Moreover trumpeters and horn players have objected to this. It is, then, not the organ builders one should blame for not willingly using [equal temperament] in the churches.

But already on the next page, he continues saying that there are people who use the equal temperament. The solution to the problem of intonation and ensemble playing would be to use the same temperament for all instruments, and to have one pitch instead of "Chor= und Kammer=Ton."[95] The situation referred to by Neidhardt is obviously quite complicated. The organ builders prefer a temperament that is easy to set and makes their instruments sound good. The brass instrument players want a temperament that matches their intonation, while the organists want to modulate freely. Still one wants to keep a temperament that better expresses emotions than equal temperament. In 1706 Johann Georg Neidhardt refers to the same theological argument for the justification of the equal temperament as Andreas Werckmeister, an exegesis of the description of the temple of Solomon in 1 Kings 7, especially the twelve oxen mentioned in verse 25.[96] Obviously it was important that one could support and justify one's

93 Neidhardt 1732: 40.
94 Neidhardt 1732: 40.
95 Neidhardt 1732: 41.
96 Neidhardt 1706: 40.

hypothesis with theological argument when discussing temperament for the church. We know that it lasted long before a standard was agreed upon.[97]

A little known source is the undated manuscript *Compositio harmonica problematice tradita*.[98] This is a manuscript in German, not in the hand of Johann Georg Neidhardt, but attributed to him. It deals with the question of composition in a dialogue form. In this source, equal temperament is heavily promoted. The arguments are that instruments would be tuned easier and faster; one could compose and play bearably in all keys; choir and chamber pitch could be used together without offending the ear.[99] If we could date this source we could see how this equal temperament-promoting approach could be fitted in with Johann Georg Neidhardt's other writings. Is this an opinion close to the 1706 writings, or is it a record of how the development turned out, in strong favor of equal temperament?

Further there are some sources dealing with the reception of Neidhardt's writings. Johann Kuhnau, J. S. Bach's predecessor in Leipzig, writes in a letter dated December 1717 to Johann Mattheson

> Diese Meister, wie die andern insgemein noch vielweniger, haben sich doch zu dergleichen Neidhardtischen *exact*en *Temperatur* nicht verstehen wollen;…[100]
>
> These masters [Wender and Silbermann], and many others who have been even less interested, have not wanted to understand Neidhardt's exact temperament [equal temperament]…

Johann Friedrich Wender and Gottfried Silbermann did not, according to Johann Kuhnau, use equal temperament, referred to as Neidhardt's "exacten Temperatur." A problem is that, although the statement clearly points out that they did not use equal temperament, it is not clear what they used instead; it could have been anything from mean-tone to well-tempered tunings like Werckmeister's, and would probably apply to many other organ builders. Already Andreas Werckmeister complained about the old-fashioned organ builders slow to adapt to new ideas on temperament.[101]

A similar case is Johann Christoph Altnickol's statement in a report from 1753 that Zacharias Hildebrandt tuned according to Neidhardt in Naumburg,[102] but this statement is much more specific when addressing one single theorist instead of just saying what it is not.

97 See "pitch", <http://www.grovemusic.com>. It was not until 1939 that the international standard pitch of a'=440 Hz was established.
98 In Lund University Library, Wenster's donation, Lit. G. Nr 1. Johann Mattheson knew this source, since he comments on it in his *Der vollkommene Capellmeister* from 1739 (Mattheson 1739: 352).
99 Neidhardt (s. a.): 6.
100 Mattheson 1722, book 2: 235.
101 See above, p. 23.
102 The organ in Naumburg is discussed in chapter 3.1.5.

> In der Temperatur gehet er nach dem Neidhardt, und man kan aus allen Tonen gantz fein moduliren, ohne daß Gehör etwas wiedriges zu hören bekomt, welches bey heutigen Gusto der Music das schönste ist…[103]
>
> In terms of temperament he follows Neidhardt, and one can readily modulate in all keys without hearing anything dissonant, which is according to the musical taste of today, …

Finally, in Mizler's *Neu eröffnete Musikalische Bibliothek* we find a passage about the reception of Neidhardt's writings. Christoph Gottlieb Schröter (1699–1782), organist in Nordhausen and member no. 4 in the "Societät der musikalischen Wissenschaften," writes that he received the following answer from a traveling able musician to the question why Neidhardt's writings (1706, 1724, 1734 [2nd edition of 1732]) had not been accepted into general use:

> Da die wenigsten ie[t]zt lebenden practischen Musici weder Zeit noch Gelegenheit haben, die Mathematik und die Buchstabrechnungskunst zu erlernen; mithin nicht überzeuget werden können, daß diese oder jene Temperatur richtig sey; so entstehet die Gegenfrage: Ob es nicht möglich u. rathsam, daß die theoretischen Musici in dergleichen Fällen sich einer leichtern Lehrart befleissen möchten? Denn ich halte mit allen Verständigen für billig daß ein Lehrer sich nach der Fähigkeit seiner Schüler richte. u.s.w.[104]
>
> Since very few of today's practicing musicians have neither time nor opportunity to learn mathematics and algebra they cannot be persuaded that this or that temperament is correct. This raises an opposing question: is it not possible and advisable that theoretical musicians in such cases should find a less complicated way of teaching? I, together with all sensible people, think it is reasonable that a teacher should adapt himself according to the ability of his students. Etc.

This critique is valid for more than Johann Georg Neidhardt's writings. All writings on tuning and temperament will necessarily contain mathematical calculations and theoretical reasoning. Maybe this "traveling musician's" comment is echoed in the obituary of J. S. Bach mentioned above, where it is said that Bach "was no lover of dry, mathematical stuff." Nevertheless, Neidhardt has a strong practical approach to temperament, which is mirrored in his categorization of the temperaments – "für den Hof, eine grosse Stadt, eine kleine Stadt, ein Dorf". On a map (see Fig. 25) from the middle of the eighteenth century over the Altenburg area the legend has a similar categorization of the places. This indicates that Neidhardt's categorization had a strong connection to an established practice.

Johann Georg Neidhardt is one of the more important German writers on tuning and temperament in the beginning of the eighteenth century. His pragmatic approach to tuning and temperament, his four tunings from 1724/32, is unique in that he combines theoretical speculations with the demands of organists and organ builders. The musical needs were different in a village, compared to a court. Neidhardt is especially important since we have signs of his tunings

103 Quoted in Dähnert 1962: 115.
104 Mizler 1747, iii/3: 470f.

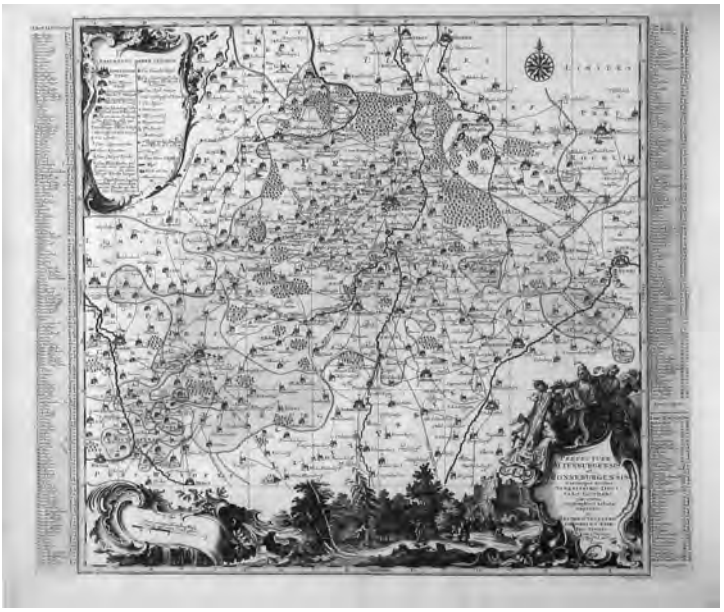


Fig. 25: Map over Altenburg (mid 18th-century). (ThStA Altenburg, Karten- und Plansammlung, Nr. 6413)

Fig. 26: Detail: legend in magnification

actually being applied in practice.[105] We can also see in his writings that the problem with the different pitches is becoming more and more acute.

2.2. Related writings

2.2.1. Johann Gottfried Walther (1684–1748)

Johann Gottfried Walther was born 1684 in Erfurt, and died 1748 in Weimar. He was both a composer and theorist. He was employed at the court as music teacher of Prince Johann Ernst of Weimar, and organist in the church of St. Petri und Pauli. Walther had studied with Johann Heinrich Buttstett, and had frequent contact with Andreas Werckmeister. As a relative and friend of Johann Sebastian Bach's he is particularly important for this study. They both worked in Weimar during Bach's tenure at the court (1708–1717).

Walther's *Praecepta der Musicalischen Composition* (1708) is dedicated to Prince Johann Ernst of Weimar. The unpublished manuscript was a gift for the name-day of Johann Ernst in 1708.[106] The material was obviously not intended for a larger audience, since it was not published during his lifetime, and was most likely adapted to the young prince.

The material consists of two parts, and divides the music into "Theoretica" and "Practica." The latter has a subdivision into "Musica Modulatoria," how to play an instrument, and "Poëtica ... oder die musicalische Composition," which consists of the "invention, thereafter the musical setting on paper, from which one can sing or perform."[107] After this follows the basics of music theory. Here we can see the incitement to *Musicalisches Lexicon* (1732).

Walther does not say anything directly about tunings and composition. Considering that the material was for his tuition of the 12-year old[108] prince, it is likely that some matters were left out, to be dealt with later. But, when discussing *Musica Poëtica,* Walther refers to Werckmeister's *Septenarium* described in *Musicalische Temperatur* from 1691.[109] The point for Walther here is to show that "music is a mathematical science" and not to recommend a temperament.[110]

The *Musicalisches Lexicon* (1732) is one of the most important sources for understanding the aesthetics of the time. It was well known, and also used as source

105 This will be further discussed in connection to the organs in chapters 3.1.4. and 3.1.5.
106 "...wie man eine liebliche und reine zusammenstimmung der Klänge erstlich *inventir*en, und hernach aufsetzen und zu Papier bringen soll, damit selbige hernachmahls kann gesungen oder gespielet werden." Walther 1708: 15.
107 Walther 1708: 14f.
108 Forsblom 1985: 17.
109 Walther 1708: 83. See above p. 19.
110 "...daß die Music eine *Mathemati*sche Wißenschafft sey." Walther 1708: 83. See also Walther 1708: 75.

for some musical articles in Johann Heinrich Zedler's *Grosses vollständiges Universal-Lexicon* (1732–54) in sixty four volumes and four supplements. An author that Walther himself often quotes is Thomas Balthasar Janowka. Janowka's *Clavis ad Thesaurum Magnae Artis Musicae* (Prague, 1701) was probably the source of inspiration and model for the *Musicalisches Lexicon*. For example, under the word "affetto" Walther quotes Janowka. Walther lists only the eight affects, but Janowka continues, and says that the affects are a result of the style, the musical figures, and the differences in the keys.

> Affectus, quos Musica in hominum animis & cordibus excitare solet, potissimùm octo sunt. Primus amoris. Secundus luctûs. seu planctûs. Tertius lætitiæ & exultationis. Quartus furoris & indignationis. Quintus commiserationis & lachrymarum. Sextus Timoris & affectionis. Septimus præsumptionis & audaciæ. Octavus admirationis. Ad quos, si qui præterea sunt, omnes ferè revocari possunt. Hi affectus motuum animi, stylo, figuris seu tropis Musicis, item Tonorum & clavium initiantium diversitati potissimùm adscribuntur.[111]

> The affects, which Music is wont to rouse in the souls and hearts of men, are principally eight in number. The first is that of love, the second of grief or lamentation, the third of joy and exultation, the fourth of rage and indignation, the fifth of pity and tears, the sixth of fear and desire, the seventh of boldness and valor, the eighth of wonder. If there are any others, almost all can be reduced to these. These affects are principally responsible for moving the soul through musical style, figures or modes, likewise through the variety of intervals and key signatures.[112]

In the *Praecepta* (1708) Walther clearly stated that the *modi* results in particular/certain *affects*.[113]

Under "Temperamento" Walther refers again to Andreas Werckmeister's *Musicalische Temperatur*, and to Brossard's dictionary, and Printz' *Satyrischer Componist*. Walther writes:

> ... Temperatur ist in der musicalischen Stimmung, ein kleiner Abschnitt von der Vollkommenheit der musicalischen *Proportio*nen, wodurch die Zusammenbindung der *progress*en füglich geschiehet, und das Gehör vergnüget wird. s. Werckmeisters musicalische *Temperatur*, p[.] 3.[114]

> Temperament within musical tuning is a small segment of the perfection of musical proportions, by which the [chord] progressions conveniently can be performed, pleasing the ear. See page 3 in Werckmeister's *Musicalische Temperatur*.

Again we find Walther referring to Werckmeister's *Musicalische Temperatur* when discussing temperament. This clearly indicates that it was well known to Walther, and most likely that he subscribed to the ideas about tuning and temperament therein.

111 Janowka 1701: 2.
112 English translation by Barbara Gable. I am also grateful to Magnus Wistrand for providing me with a Swedish translation. Several translations are possible. According to Walther 1732 "tropis Musicis" was sometimes used instead of "modi musici", and "tonorum" could mean three different things: note or sound; interval; and scale.
113 "…und die *Modi* verursachen absonderliche *Affectus*." Walther 1708: 17.
114 Walther 1732: 597–98. C.f. Werckmeister 1691: 3.

When writing about *modi* and keys, Walther writes under "Modus Musicus"[115] a lengthy article, with chorales exemplifying the church keys. Towards the end he comes into what he calls the "new way" (neuere Vortrag),[116] i.e. 24 keys, since we have 12 notes, and the third can be either major or minor. At the end Walther keeps a low profile, saying that he just touched upon this matter ("*Moden*-Lehre"), and will not enter into the fight that has arisen about this matter.[117] As we can see, we find a cautious approach in Walter's writings, but clear statements considering key characteristics. The function of music is to govern/direct and move the soul of men. When it comes to tuning there are no elaborate descriptions; instead we find a reference to Andreas Werckmeister. Even if it is not stated, the connection between Walther's key characteristics and his references to Andreas Werckmeister is the temperament. The general opinion among theorists was that the differences between the scales caused by temperaments like Werckmeister III resulted in different key characteristics.[118] However, there was no consensus on this matter, and it could be this debate that Walther did not want to enter into.

2.2.2. Johann Mattheson (1681–1764)

The best-known German author on musical matters during the eighteenth century is probably Johann Mattheson. He was born in Hamburg, 1681, where he also died in 1764. He was a productive opera composer and author of several important books, the most famous being *Der vollkommene Capellmeister* (1739).[119] As an able organist he was invited to apply for the position as organist and successor of both Dieterich Buxtehude and Johann Adam Reincken, but it was mainly in the field of opera that his musical talent was exposed. Mattheson performed in roles at the opera in Hamburg, where he became the friend of Georg Friederich Händel. In 1704 Mattheson was employed as tutor to the son of the English ambassador to Hamburg, Sir John Wich. In 1706 he became the secretary of the same, a post he kept for most of his life, giving him a high social position and status in the society. Mattheson was also music director at the cathedral in Hamburg (1715–1728), and was appointed Kapellmeister to the court of Holstein in 1719.

Mattheson published an extensive discussion of key characteristics, *Das Neu=Eröffnete Orchestre* (1713),[120] which even caused others like Johann Heinrich

115 Walther 1732: 409ff.
116 Walther 1732: 415.
117 Walther 1732: 415. C.L. van Panthaleon van Eck makes a thorough analysis of this article, and concludes that Johann Gottfried Walther refers to a temperament by Johann Philipp Kirnberger (Panthaleon van Eck 1981: 153ff).
118 Steblin 1981: 52f. Rita Steblin has investigated the question in her important study on the history of key characteristics.
119 Mattheson 1739.

Buttstett (*Ut, mi, sol, re, fa, la, Tota Musica et Harmonia Aeterna*, 1716) to write against him.[121] On the other hand, people like Jakob Adlung writes that there is no better manual than *Das Neu=Eröffnete Orchestre.*[122] Mattheson's list of key characteristics was modified and further discussed in his later writings, but as late as 1834 they appear in print, then anonymously.[123]

A general opinion at this time stated one could attribute different characteristics to different keys due to an unequal temperament. Mattheson, on the other hand, claimed that the difference in pitch together with the differences in the intervals of scale were the most important factors.[124] Mattheson has an extensive discussion on the matter in his *Grosse General=Baß=Schule* (1731),[125] where he shows without referring to temperament, that every key consists of different sized intervals. Mattheson is obviously taking just intonation as his point of departure.

Mattheson is at the same time an advocate of equal temperament, but sees some problems in introducing it, since one is so used to the old temperament. He also recognizes that there is resistance against equal temperament from, among others, the "stubborn organ builders."[126] Unfortunately Mattheson did not specify what he meant by "the old temperament." Mattheson's answer to the rhetorical question, "Where can one find this new, so called, equal temperament?" gives us some information about the situation in Hamburg around 1731. Most likely, equal temperament was not used in any organ in Hamburg at this time.

> Hat man schon hie und da ein Paar Orgelwercke und C[l]avicimbel darnach stimmen und einrichten lassen, so machen doch dieselbe, gegen den übrigen in der gantzen Welt, wenig oder nichts, aus: daher ich auch gefragt habe, wenn sie [die gleichschwebende Temperatur] denn in die Welt kommen würde? Hamburg ist eine kleine Welt, und da findet sie sich nicht.[127]
>
> Even if one has here and there tuned a couple of organs and harpsichords to [equal temperament], it does not mean much compared to all the others in the world. I have also asked, "When it will be introduced in the world?" Hamburg is a small world, and here it is not to be found.

In *Der vollkommene Capellmeister* we do not find any new information with regard to temperament, except for the fact that among Andreas Werckmeister, Johann Georg Neidhardt, Johann Arnold Vockerodt, and Christoph Albert Sinn, Neidhardt is singled out by Mattheson and recommended before the others.[128]

120 Mattheson 1713: 231ff.
121 For an overview of Johann Mattheson on the question of key characteristics see Steblin 1981: 43–57.
122 "Kein besser Handbuch." Adlung 1758:12.
123 Steblin 1981: 56, note 33.
124 Steblin 1981: 52f.
125 Mattheson 1731: 104ff.
126 "die eigensinnigen Orgel=Bauer." Mattheson 1731: 144.
127 Mattheson 1731: 143f.

This strengthens Neidhardt's position as perhaps the most important theorist dealing with tuning and temperament in the first half of the eighteenth century.

2.2.3. Jakob Adlung (1699–1762)

Jakob Adlung was born 1699 in Bindersleben (close to Erfurt, Thuringia), and died 1768 in Erfurt, were he served as organist from 1727 to his death. He succeeded J. H. Buttstett. Adlung received musical training already at an early age, and during his studies at the university in Jena, he also studied the organ with Johann Nicolaus Bach. Johann Gottfried Walther came to be a good friend of Adlung's, and it is interesting to see the similarities between the *Musicalisches Lexicon* and the *Anleitung zu der musikalischen Gelahrtheit.* Adlung's *Musica Mechanica Organoedi* (1768) is one of the most important sources when it comes to instrument knowledge from this time.

Jakob Adlung's *Anleitung zu der musikalischen Gelahrtheit* (1758) is a splendid introduction to the musical scene in the beginning of the eighteenth century. It is a survey of the literature known to Adlung, full of comments on the work under discussion.

In chapter four, "Von der neueren Musik," discussing how many keys there are, Adlung refers to the temperament. In a well-tempered tuning you have more reason to talk about different key characteristics as a result of the tuning.

> Noch ferner möchte iemand fragen, ob man nicht könne 24 Tonarten (*modos*) zehlen, 12 harte, mit der grossen Terz, und 12 weiche, mit der kleinen? Die Antwort kann seyn: man wird deswegen niemand verkätzern, ob er von 12 oder 24 Arten redet; aber bey jeder Eintheilung pflegt man auch den wesentlichen Unterschied mehr zu betrachten, als Nebenumstände. Folglich wer eine gleichschwebende Temperatur annimmt, nach dem folgenden Capitel, der wird keinen Unterschied unter den 12 harten Arten angeben können, als die verschiedene Höhe, welches aber ihr Wesen nicht ausmacht. So verhält es sich auch mit den 12 weichen. Wer aber eine ungleiche Temperatur annimmt, der findet zugleich einen Unterschied in der Grösse der Intervallen, und hat mehr Ursache von so viel Arten zu reden, als jene.[129]

> Furthermore one might ask, whether we could speak of 24 keys (modos), 12 hard ones, with the major third, and 12 soft, with the minor one? The answer might be: one should not brand anyone a heretic, whether he speaks of 12 or 24 types; but by every categorization one usually looks more at the essential differences, than at peripheral circumstances. Consequently whoever assumes equal temperament, according to the following chapter, will not be able to show any difference between the 12 hard types, except for the tonic pitch, which doesn't describe their essence. The same is valid for the 12 soft types. However, in an unequal temperament, one finds a difference in the size of the intervals, and has more reason than the others to speak of so many different keys.

128 "…absonderlich lasse man sich den zweiten [Neidhardt] wol empfohlen seyn." Mattheson 1739: 55.
129 Adlung 1758: 220f.

Further, Adlung also attributes different affects to different keys, as a result of unequal temperament.

> Wenn wegen der Wirkung der harten und weichen Tonart eine Frage aufgeworfen würde, ob solche bey beyden verschieden sey; so gäbe ich mein Ja darzu, ohne mich lange zu bedenken, weil sie doch wesentlich von einander unterschieden sind (l).[130] Wenn aber von der verschiedenen Höhe beyderley Arten die Rede ist, und eine ungleiche Temperatur angenommen wird; so kann einiger Unterschied geglaubt werden unter den 24 Arten in der Wirkung (m);[131] aber bey der gleichen Stimmung wird kein sonderlicher Unterschied seyn.[132]
>
> If a question were asked whether the effect is different in hard and soft keys, I would have to agree without pause for reflection, because they are essentially different from each other (l). If however the question is about a difference in the pitches [of the tonic note] in either type, and an unequal temperament is assumed, then some differences between the 24 types with regard to effect (m) is likely, but in equal temperament there will still be no particular difference.

Here Adlung describes the complicated situation with regard to key characteristics, before equal temperament became the norm. This happened gradually, and at different times in different places. Adlung recalls that, when he became an organist in 1728, he could not play in B major or in E♭ major, not to mention other keys.[133] This gives us a date with regard to Adlung's context, where equal temperament obviously was not used in the first quarter of the eighteenth century in organs. Adlung was organist in Erfurt until his death.

Chapter Five, "Von den musikalischen Rechnungen," is of special interest for the present work. Adlung gives an important contemporary overview of the writings about tuning and temperament. In the extensive survey of, among other things, Neidhardt's writings and the principles of temperament, Adlung also discusses the use of what could seem like no more than mathematical exercises. He defines two specific advantages of such mathematically defined temperaments: the possibility of transposition and the possibility to modulate through the circle of fifths.

> Es wird mancher noch vor dem Schlusse dieses Capitels wissen wollen, was wir theils von diesem Vortrage, theils von dergleichen Stimmung vor Nutzen haben? Hierauf dient, daß man nicht nur geübte Sinnen bekomme durch solche mathematische Uebungen, sondern daß man sich dadurch wird in den Stand gesetz finden, die mehresten Bücher von der Musik mit mehrerer Einsicht zu lesen, da manche Stelle sonst ohne solche Erkenntniß möchte vorkommen seyn, wie der Kuh ein neues Thor (p).

130 In note "l" Adlung refers to Mizler, writing that there is a difference between major and minor keys when it comes to their suitability to express different affects. See below p. 54.

131 In note "m" Adlung refers to Mattheson's comments in *Das Neu=Eröffnete Orchestre*: 231ff, were Mattheson describes the different key characteristics.

132 Adlung 1758: 223f.

133 "Wo die Temperatur es nicht verträgt, lasse man das Transponiren unterwegens. Als ich Organist wurde 1728, konnte ich ohne Verdruß weder aus H*, noch Es* spielen, mehrerer [Tonarten] nicht zu gedenken." Adlung 1758: 226, note s.

> Sonderlich äussern sich 2 Hauptnutzen solcher gleichen Einrichtung der Tonarten, deren der eine bestehet in der Versetzung der Melodie, (Transposition) der andere in der Verbindung der Tonarten durch die Cirkelgänge.[134]

> Some will still want to know before the end of this chapter what use there might be for us in this presentation or the tuning mentioned in it. Now not only are such mathematical exercises good mental training, but afterwards one will be able to read most of the books on music with better understanding, because without such knowledge some passages would otherwise be like closed doors. (p)

> There are particularly two main advantages in following such an equalization of the keys. One is shifting a melody (transposition), and the other is modulating through the circle of fifths.

Here Adlung is referring to equal temperament. He refers to "tuning," meaning mathematically described. Most of the complicated mathematical presentations are aimed at equal temperament. The main advantages according to Adlung is the freedom of transposition and the modulation through the circle of fifths.

The use of transposition is further, according to Adlung, "pleasant, useful, and necessary."[135] In the following elaboration of why transposition is useful, Adlung writes among other things that it is good to practice on the chromatic keys.[136] But, in note (r) to this passage Adlung writes that it suffices that a temperament makes all the keys usable. A perfect equal temperament is not necessary. The picture, therefore, becomes more complicated.

> r) Hierbey bestehe ich nicht auf einer völlig gleichschwebenden; wenn die Temperatur nur alle Tonarten brauchbar macht.[137]

> r) Here I do not insist on a fully equal [temperament]; as long as the temperament makes all the keys usable.

Adlung himself, Heinichen, Mattheson, Sorge, Mizler, and others have described how to play through the circle of fifths, which is the second advantage of temperament.[138] This corresponds to Andreas Werckmeister's goal stated in the title page to his *Musicalische Temperatur*. But the situation with regard to temperament in organs was anything but uniform. Earlier in the chapter, Adlung mentions subsemitones, and states "such are still frequently found."[139] This would imply that the use of some kind of mean-tone temperament still was frequent. But in

134 Adlung 1758: 324f.26

135 "Es ist dieses Transponiren 1) vergnüglich, 2) nützlich, 3) nöthig." Adlung 1758: 326.

136 "Nützlich ist es ferner zur Uebung der Finger, welche auch müssen lernen hurtig fortzukommen auf den schmalen Schrittsteinen, ich meyne auf den gefährlichen und Trübsals vollen chromatischen Tasten,…". Adlung 1758: 327.

137 Adlung 1758: 327, note "r". This is of interest when Adlung writes about J. S. Bach's "temperirte Clavier in 2 Theilen" that "ein Clavier muß temperirt, oder in allen Tonarten brauchbar seyn, auf welchen man solche spielen soll." Adlung 1758: 707, note "i".

138 Adlung 1758: 329ff.

139 "Man hat sich helfen wollen durch enharmonische Claves, so von einigen *subsemitonia* genannt werden, daher die gebrochenen Claviere entstanden sind, dergleichen man noch viele findet,…"Adlung 1758: 303f.

the chapter on organ building, Adlung clearly states that one should include in the contract for a new organ that equal temperament should be used.[140] This clearly shows the complicated situation in the first half of the eighteenth century with regard to tuning and temperament – mean-tone, well-tempered tunings, and equal temperament side by side.

Jakob Adlung is perhaps best known for his *Musica Mechanica Organoedi* (1768), published six years after his death. According to the biography of Adlung, and the preface by the publisher Johann Lorenz Albrecht in the second volume of the *Musica Mechanica Organoedi*, the manuscript was written when Adlung was a student in Jena (1723–27). The manuscript came into the possession of Albrecht, who writes that many notes were made in the manuscript, and that he thus re-edited the text and printed it in 1768. Albrecht's comments are marked with Arabic numerals. Johann Friedrich Agricola was also asked to read the manuscript, and his comments are marked with asterisks or with Greek letters.[141] The fact that Adlung made additions in the margin makes it difficult to place the information in time. It is not clear in the text what was added later, except for when it is evident from the circumstances, for example, with an instrument such as the organ in Naumburg, which was built by Zacharias Hildebrandt in 1743–46. When Adlung, in the chapter "Von der Temperatur der Orgeln,"[142] promotes equal temperament, it can be noted that he does not mention Neidhardt's *Gäntzlich erschöpfte Mathematische Abtheilungen* from 1732, though he mentions both *Beste und leichteste Temperatur* (1706) and *Sectio canonis harmonici* (1724). This could indicate that the part about temperament is largely written before 1732. Adlung also refers to Andreas Werckmeister, and notes that Werckmeister in his *Die Nothwendigsten Anmerckungen und Regeln wie der Bassus Continuus oder General=Baß wol könne tractiret werden* (1698) still, after approximating an equal temperament, recommends leaving purer the diatonic keys that one uses more often.[143] Adlung himself refers to Neidhardt's *Beste und leichteste Temperatur* (1706), and the description of the monochord for tuning equal temperament.

Further, Adlung notes that there is a core problem with applying a temperament from a monochord to an organ. It is in connection to this discussion that we find the story mentioned earlier about the competition between Johann Georg Neidhardt and Johann Nicolaus Bach (1669–1753) in Jena.[144]

The application and setting of a temperament is a general problem. The degree of precision is unclear in such a process, and would thus be an interesting problem to investigate further. Subjective descriptors such as "as much as the ear

140 "Die gleichschwebende Temperatur wird bey uns vorzuschreiben nie vergessen." Adlung 1758: 526.
141 Adlung 1768, vol ii: XVIff.
142 Adlung 1768, vol ii: 48ff.
143 Adlung 1768, vol ii: 53.
144 See p. 33.

can bear" are difficult to interpret, while using pure intervals such as the major third is safer. None of the sources investigated in the present work describes the tempering of an interval in beat rates, e.g., beats per second.

To conclude, one can say that Adlung is not completely clear on the matter about equal temperament. On the one hand he advocates it, and on the other hand he says it is not necessary to use it, as long as all keys are usable – a very practical approach for a musician.

2.2.3. Lorenz Christoph Mizler (1711–1778)

Lorenz Christoph Mizler was born 1711 in Heidenheim, Franconia, and died 1778 in Warsaw. Mizler moved to Leipzig to study theology in 1731. Later, 1735, in Wittenberg he also studied law and medicine. Mizler was not a professional musician, although he received some musical instruction from Johann Sebastian Bach, but he was regarded as a very important intellectual in Germany during his lifetime. He is best known for his "Sozietät der musikalischen Wissenschaften"[145] which he founded in 1738, and which Bach joined in 1747. Considering the statements about Bach's lack of interest in theoretical writings[146] and the regulations of the society, it is strange that he became a member. According to the second paragraph of the regulations, a mere practical musician was not allowed to join. The third paragraph accepts music theorists without practical knowledge of music, yet it is preferable to be skilled in both practice and theory, since that is of most value to the society.[147] Mizler was proud to be able to call Bach his good friend and patron.[148] Maybe it was in the "Sozietät" that Bach found appreciation of his knowledge of counterpoint in music?

Mizler's important contribution to the theoretical writings in Germany was his *Neu eröffnete Musikalische Bibliothek*. It comprises four books divided into several parts, published between 1736 and 1754. It includes reviews of books such as Johann Mattheson's *Der vollkommene Capellmeister*, and comments on the contemporary musical life. Bach's obituary was published in the last volume of the *Neu eröffnete Musikalische Bibliothek*. Andreas Werckmeister is, alongside with Johann Mattheson and Wolffgang Caspar Printz, one of the most quoted music theorists in the *Neu eröffnete Musikalische Bibliothek*. In Vol. 1, Part 2, we find Werckmeister's tuning instruction from his figured bass treatise (*Die Nothwendigsten Anmerckungen und Regeln wie der* Bassus Continuus *oder General=Baß wol könne* tractir*et werden*, Aschersleben 1698, p. 61–70).[149] In Part 3, Mizler returns to

145 Later "correspondirenden Societät der musikalischen Wissenschaften in Deutschland." Mizler 1746, iii/2: 348.
146 See above p.000.
147 Mizler 1738, i/4: 74. The regulations are reprinted in Mizler 1746, iii/2: 348ff. See paragraphs 3–4.
148 "Bach …, den ich unter meine guten Freunde und Gönner zu zehlen die Ehre habe,…". Mizler 1738, i/4: 61.
149 Mizler 1737, i/2: 58ff.

the question of temperament, this time in connection with Werckmeister's *Hypomnemata Musica* (1697). Mizler notices that Werckmeister argues against the subsemitones, and that his temperament has been criticized.

> Was aber seine Temperatur anbelanget, so ist selbige zu seiner Zeit die beste gewesen, nach der Zeit aber von Neidhardten verbessert worden.[150]
>
> Concerning his temperament it was however the best of its time, but Neidhardt later improved it.

It is not clear if Mizler with the improvement of Werckmeister's temperament by Neidhardt refers to equal temperament. Since both Werckmeister and Neidhardt described well-tempered tunings it could as well refer to them.

After a short explanation of what a temperament is, Mizler continues into a discussion about the relation between theory and practice, and how to convince a practical musician of the usefullness of theory in music. In this discussion Mizler uses the following example:

> Von dem Nutzen aber der Theorie in der Musik etwas weniges zu gedenken, so ist ja handgreifflich, daß die Mathematik einen grosen Einfluß in dieselbe habe. Wie werden denn der Tone Eigenschafften erkannt? nicht wahr, wenn man sie ausmisset, untereinander vergleichet, und ihre Verhältnisse unter einander richtig bestimmet, u. daraus untrügliche Wahrheiten herleitet? allerdings. Wodurch geschiehet denn dieses? etwan nicht durch die Mathematik? ja. Ey nun so sage nicht mehr, daß die Mathematik keinen Nutzen in der Musik habe.[151]
>
> However, to say something about the usefulness of theory in music, it is very clear that mathematics has a great influence on music. How, then, are the properties of the keys to be made known? Is it not when one measures them, compares them and correctly determines their relation to each other, and from this process derives infallible truths? Indeed. How is this done? Is it not with mathematics? Yes. Well, so stop repeating that mathematics has no use in music.

The answer to the question how to investigate the keys and the differences between them is mathematics. From this it seems that Mizler subscribes to the opinion that keys have different properties, which can be shown mathematically. Since this example is put forward in a discussion related to temperament, we can conclude that the cause for these differences between the keys was considered to be the temperament. The argument for convincing a practical musician would then be that it is only with mathematics one can achieve a thorough knowledge about the properties of the keys, for example.

Even if the temperament resulted in differences between keys, Mizler does not ascribe different characteristics to individual keys. It is the modulations, or how the different keys are combined, that expresses the passions. Johann Christoph Gottsched wrote in a text on expressing the affect of a text the following:

150 Mizler 1737, i/3: 55.
151 Mizler 1737, i/3: 57.

> Dadurch hoffte man… iede Zeile …, dem darinn herrschenden Affecte gemäß, auszudrücken; iedem Worte nach seinem rechten Sinne den gehörigen Ton und Nachdruck geben zu können.[152]
>
> By this, one wished to properly express each line according to its dominating *affects*; to be able to give each word the proper key and expression according to its true meaning.

This discussion has relevance for the present work since one of Bach's pupils, Johann Gotthilf Ziegler, commented in 1746 on how he was taught to play chorales.

> As concerns the playing of chorales, I was instructed by my teacher, Capellmeister Bach, who is still living, not to play the songs merely offhand but according to the sense [Affect] of the words.[153]

Expressing the texts of the hymns in the liturgy was asked for, and if we follow Mizler's reasoning, the temperament could be an aid in that. Even if the focus in the present work is on repertoire, this example is important in showing that the temperament had a wider use and function, even if it did cause some problems when playing together with an ensemble.

Mizler further defines the question about a modus' possibility to express affects when he comments on a passage in Johann Adolf Scheibe's *"Critische Musikus"*:

> Wer kan leugnen daß ein Moll Ton, die Liebe, die Traurigkeit, die Demuth zu erregen geschickter als ein Dur Ton ist? Eine geschickte Schreibart, welche freylich noch mehr würket, kan alsdenn gar leicht die völlige Absicht erhalten.[154]
>
> Who could deny that a minor key is better suited to arouse love, sorrow, or humility than a major key? A skilled musical setting, which is indeed even more influential, can then quite easily achieve the whole intent.

Mizler, in other words, holds the view that besides the modulations, there is a difference between minor and major keys when it comes to their suitability to express different affects. Still, it is no automatic system. The musical setting is the main thing.

When it comes to transpositions, caused by the fact that organs were normally tuned to choir pitch and the orchestra in chamber pitch, there has been a discussion whether the temperament was an issue. Mizler published Carl Johann Friedrich Haltmeier's introduction to transposition with comments.[155] Haltmeier writes that one often must transpose because of the pitch of the wind-instruments, or because of the range of a singer's voice.[156] Thereafter he lists how to use

152 Mizler 1738, i/6: 2.
153 NBR, 340, BD II, 542.
154 Mizler 1738, i/6: 69. And "…, daß eine Musik Leiter eine Verbindung vieler Tone zusammen genommen, diese oder iene Leidenschafft auszudrücken geschickter sey, als eine andere. z. E. Ein Moll Ton ist geschickter einen traurigen Affect mit Liebe vermischet auszudrücken, als ein harter Ton." Mizler 1740, ii/1: 64.
155 Mizler 1742, ii/2: 256ff.

accidentals and clefs to transpose. Mizler adds his comments in a note with an interesting remark about the value of transpositions at the end.

> Nun muß ich meine Gedancken von Nutzen der Kunst zu transponiren noch eröfnen. Dieser ist so klein, daß ich noch zweifle ob es überhaupt der Mühe werth sey solche zu erlernen. Denn wenn eine gute Musik, da man zuvor sich deswegen zubereitet, gemacht werden soll, so müssen die Stimmen und Instrumente alle in ihrer natürlichen Ordnung bleiben des Wohlklangs wegen und ist also keine Transposition nöthig. Ja man muß sie, so viel möglich vermeiden; weil leicht in Ansehung der andern Tone durch die Versetzung eine Disharmonie entstehen kan, wenn die Instrumente nicht besonders wohl deswegen gestimmet und temperiret worden. Es ist also nur im Fall der Noth, und wenn es schlechterdings nicht anders angehet. Ob es also gleich ein künstliches Flickwerk ist, so kan es doch zu Zeiten gut, ja unentbehrlich seyn.[157]
>
> Now I also must express my ideas about the usefulness and art of transposing. This [usefulness] is so little, that I still doubt whether it is worth the trouble to learn at all. Because when good music, which has been prepared [for transposition], is to be performed, all the voices and instruments must be kept in their natural order for the sake of the euphony and consequently no transposition is needed. One should avoid it as much as possible since a disharmony can easily result in a transposition with regard to the other keys, when the instruments have not been well tuned and tempered [for transposition]. It is therefore only to be used in emergency, and when there is simply no other way. Even if it is an elaborated patchwork, transposition can now and then be good and even indispensable.

Mizler concludes that sometimes it is necessary to transpose, but it should be avoided if possible. One of the arguments is that a dissonance can be the result of the transposition if the instrument is not properly tuned. Instruments were tuned in choir pitch, and usually not equally tempered. This meant that transposing could really spoil the music with a very dissonant result, depending of the keys. This was a problem addressed already by Neidhardt. Still, properly tuned organs and harpsichords did not cause this problem. If the musical setting is the most important factor, a problem might arise if some of the other instruments would have to play/transpose in a more dissonant key with regard to temperament. Here one has to see what keys are involved. Transposing into a key with few accidentals would not cause a problem. Isolated chords could of course stand out, but omitting the most dissonant notes in the organ part, for example, could solve that problem temporarily.

When commenting on Mattheson's *Der vollkommene Capellmeister*, Mizler discusses the role of temperament in music:

> Der Herr Verfasser [Mattheson] sagt ferner: "Wenn die Temperaturkunst auch bey allen Instrumenten nöthig oder nützlich wäre, so machte doch ihre richtige Stimmung eben so wenig eine Musik aus, als ein feingedeckter Tisch ohne Speisen eine Mahlzeit seyn kann." Es heisset hier, wie bey den meisten Gleichnissen: *omne simile claudicat*, alle Gleichnisse hinken. Denn die Temperatur gehört zum Wesen der Musik, weil ohne rich-

156 "Denn wie offt träget es sich zu, daß blase=Instrumente zum vorhandenen Claviere nicht stimmen, oder daß ein Sänger nicht hinlängliche Tone hat, die Höhe oder Tiefe einer Cantata zu erreichen?" in Mizler 1742, ii/2: 256f.

157 Mizler 1742, ii/2: 268f.

> tige Stimmung der Instrumenten gar keine Musik gemacht werden kann; Ein feingedeckter Tisch aber ist bey einer Mahlzeit nur was zufälliges, indem solche statt findet, wenn auch der Tisch gar nicht gedecket ist. Fleisch, Brodt, Wein, Wasser u. Bier u. verschiedene Erdgewächse geben den Stoff zu einer Mahlzeit. Soll diese nun vor sich gehen, so muß der Stoff erst zubereitet u. auch wirklich gegessen werden, so ist es eine wirkliche Mahlzeit gewesen. Eben so bestehet der Stoff einer Musik aus verschiedenen Größen u. Verhältnissen, diese müssen durch die Temperatur erst zubereitet, u. alsdenn auch wirklich abgespielt werden, so ist es alsdenn eine wirkliche Musik gewesen. Wer siehet nicht, daß die Temperatur ganz was anders ist, als ein feingedeckter Tisch ohne Speisen, u. also übel damit verglichen worden.[158]
>
> The author [Mattheson] says: "Even if the art of temperament in all instruments would be necessary and useful, a correct temperament no more makes a piece of music, than a nicely laid table without courses makes a meal." Here we have, as with most similies, *omne simile claudicat*, all comparisons limp. Temperament is a part of the essence of music, because without the proper tuning of instruments, no music can be made; a nicely laid table, however, is unessential for a meal, since a meal can happen even when the table is not laid at all. Meat, bread, wine, water and beer and fruits of the earth provide the elements of a meal. If it is to take place, the ingredients must be prepared and also really eaten to be a real meal. Similarly the elements of music have different sizes and ratios; these must first be prepared by the temperament, and then really played to be real music. Is it not obvious to everyone that temperament in music is completely different from a nicely laid table without courses, and is therefore a bad comparison?

These two views are quite different. Mizler considers the temperament in music equal to that of cooking in cookery – it is a part of its nature and essence. Mattheson on the other hand holds temperament as something that is *ad libitum*, and not a part of the composition. Consequently we have to take into account these two different views on the role of temperament in music during the first half of the eighteenth century. Mizler, and probably the group around him, gave temperament an important role and function in music.[159]

2.2.4. Carl Philipp Emanuel Bach (1714–1788)

Johann Sebastian Bach's son, Carl Philipp Emanuel, was born 1714 in Weimar, and died 1788 in Hamburg. He was well known as a keyboard player, teacher and composer. C. Ph. E. Bach's *Versuch über die wahre Art das Clavier zu spielen* (1753/I, 1762/II)[160] stands as one of the most important sources to historical information on the playing technique of the clavichord. The focus is not on the organ, but he made two comments that are of interest for the present work.

After discussing the clavichord and the harpsichord, C. Ph. E. Bach writes that when it comes to the temperament, one tempers most of the fifths ("...den meisten Qvinten...").[161] Interestingly, Bach does not recommend tempering all of the fifths, which then excludes equal temperament. But, one can play in all 24 keys

158 Mizler 1747, iii/3: 519f.
159 A parallel case is the discussion about key characteristics. See Steblin 1981.
160 Bach 1753/62.
161 Bach 1753/62, I: 10.

("...spielet man aus allen vier und zwantzig Tonarten gleich rein...").[162] He continues:

> Durch diese neue Art zu temperiren sind wir weiter gekommen als vor dem, obschon die alte Temperatur so beschaffen war, daß einige Ton=Arten reiner waren als man noch jetzo bey vielen Instrumenten antrift.[163]
>
> Through this new type of tempering, we have come further from when the old temperament was constructed in such a way that some keys were purer, which can still be found in many instruments.

The crucial point here is, of course, the evaluation of the words "some keys were purer." Today this is how we would characterize a well-tempered tuning; some keys are purer than others. On the other hand this can be valid for modified mean-tone depending on how one defines the words *modified*, *keys* and *purer*. A key is not simply a scale or triads on the steps of that scale. It is more a tonal area with a content of triads a composer can use. In a regular temperament like 1/4-comma mean-tone there are only two categories of tempered fifths, and consequently the same with regard to major thirds. The question is then, what makes up a key? If we make the simplest possible comparison, triads on I and V, we can see that there is already a difference in 1/4-comma mean-tone between the keys C major, F♯ major, and E Major. C major would have two pure thirds (C–E, G–B), F♯ major would include two unusable major thirds (F♯–A♯, C♯–E♯), and E major one pure (E–G♯) and one unusable (B–D♯). When Bach writes "that some keys were purer" in "the old temperament," it is hardly these differences he is referring to. There is a difference between these keys with regard to the number of pure and poor (unusable) thirds. The point is that the definition of key is crucial. If considering a modified mean-tone temperament such as VOSCH, the situation is much more complicated since the temperament is not regularly constructed, involving fifths of two or more sizes. In mean-tone there is a wolf, which actually is not tempered but resulting from the eleven tempered fifths. Regular in the strictest sense is only EQ since this is the only temperament where all fifths are tempered equally. The "old temperament" probably meant some mean-tone temperament, perhaps modified, as discussed earlier, and "many instruments" probably includes organs. Andreas Werckmeister called mean-tone the old temperament, and Adlung said that one still finds organs tuned in the old way. It is not very likely that Bach would have referred to a well-tempered temperament by calling it the old temperament opposed to the "new type of tempering." In the second part of the *Versuch* C. Ph. E. Bach again refers to organs being tuned differently from other keyboard instruments, stating that one should restrain oneself in modulations when making a fantasia on the organ, since it is usually not tempered in a good way (well-tempered).[164]

162 Bach 1753/62, I: 10.
163 Bach 1753/62, I: 10.

C. Ph. E. Bach clearly has an instrument idiomatic approach to playing when it comes to temperament, giving the temperament a function in the interpretative process. This might be a good example of how practical musicians in general approached the problem. Avoiding when necessary, and using when suitable. A picture used by Wolffgang Caspar Printz when describing dissonances in counterpoint can be used with regard to temperament as well:

> Ein Componist soll die Natur und Wesen der *Dissonan*tien billig rechtschaffen wissen, nicht nur allein daß er sie vermeiden, sondern auch, daß er sie zu rechter Zeit setzen könne: Denn ihr Gebrauch ist nicht gering in der *Composition*, sintemal ein *musicali*sches Stück dadurch nicht wenig gezieret wird. Sie seyn die Finstermis [Finsternis], die *Consonantiae* das Licht: Das Licht würde uns so angenehm nicht seyn, wenn es immer Tag, und niemahls Nacht wäre. Sie seyn das Bittere, die *Consonantiae* das Süsse; Das Süsse würde uns nimmermehr so wohl schmecken, wenn wir das Bittere nicht gekostet hätten. Sie seyn das Schwarze, die *Consonantiae* das Weisse; Nimmermehr ist die blosse weisse Farbe denen Augen so angenehm, als wenn sie mit der schwartzen schattiret ist.[165]

> A composer must be able to thoroughly know the nature and essence of the dissonances, not only when to avoid them but also when to use them, since they are not seldomly used in composing, because a piece of music is more than a little decorated with them. They are the darkness, the consonances, the light: the light would not be so pleasing to us if it were day all the time and never night. They are the bitter, the consonances the sweet; the sweet would never taste so good again if we had not tasted the bitter. They are the black, the consonances the white; nevermore is the plain white color so pleasant for the eyes as when it is shadowed with the black.

2.3. Discussion

From the sources it is quite clear that the authors have different personalities and ways of expressing their ideas. Simply put, there are cautious writers such as Johann Gottfried Walther and more fearless molders of public opinion such as Johann Mattheson. Walther clearly writes in his *Musicalisches Lexicon* that he does not want to take part in the fight that has arisen concerning the question of "Moden-Lehre."[166] This cautiousness does not mean that the writer did not have an opinion in the matter. Another good example is Johann Kuhnau. In the preface to his *Musicalische Vorstellung einiger Biblischer Historien* he praises Zarlino's wise and cautious approach to the question of key characteristics, not denying that there is such a thing as key characteristics, but being cautious and less categorical in stating what properties they have.

> Der berühmte *Zarlino* hat in seinen so genannten *Istitutioni Harmoniche, parte 4. Cap. 5*. meines Erachtens am besten gethan, wenn er, da er der *Proprie*tät der *Tonorum* gedacht,

164 "…, weil die Orgeln selten gut temperirt sind." Bach 1753/62, II: 326f.
165 Printz 1696: 92.
166 See above p. 46.

> sich immer dieser oder dergleichen Worte bedienet: *Si dice, dicono, referiscono,* man saget, es wird erzehlet, und so fort.[167]
>
> In my opinion, the famous Zarlino has made a wise choice when, in discussing the properties of the keys in his so called *Istitutioni Harmoniche;* Part 4 and Chapter 5, he always uses words like: *Si dice, dicono, referiscono,* one says, it is told, and so forth.

Taking this into account, the writer expressing the strongest opinions does not necessarily have to be the one who describes the prevailing situation.

It is clear that theorists, for example Johann Georg Neidhardt, assign the cause of key characteristics to the temperament, caused by the differences in the scales due to it. Both Johann Georg Neidhardt and Andreas Werckmeister write that many prefer a temperament that gives purer triads to the more often used keys. This is quite understandable from the background that the pure thirds of mean-tone, the dominating temperament in the organs, sound more consonant than the tempered thirds. Even if the theorists regarded equal temperament as acceptable from a theoretical and theological point of view, some organists and, above all, organ builders, did not appreciate equal temperament. Organ builders came to be seen as old-fashioned. Later, with Adlung, equal temperament was seen as a requirement when building a new organ.

None of the authors presented here has listed key characteristics as Mattheson did in *Das Neu=Eröffnete Orchestre* (1713), but most of them refer to Andreas Werckmeister's writings. His role in the discussion of temperament should therefore not be neglected, but alongside him Johann Georg Neidhardt has gained a strong position as a leading theorist in the beginning of the eighteenth century.

During the Baroque the compositional process was primarily seen as a handicraft. The autonomous work of art, and the composition as a primarily subjective expression was not a part of the aesthetics, and the concept of composing for a specific instrument was yet not fully established. *Clavier* could refer to several different keyboard instruments. This could explain why there is no clear connection in the literature between the composition and the instrument. A handicraft was learned from a teacher, not from reading treatises. Even if there is a huge bulk of treatises appearing at this time dealing with figured bass, a specific treatise for how to compose for the organ did not exist. Temperament is usually mentioned only in connection with the usability of specific keys, or other factors of practical quality. A polarized example is the discussion between Mattheson and Mizler about the role and function of temperament, being either an essential integral part of the music or a peripheral factor.

167 Kuhnau 1700/10, preface: §.

3. Instrument Sources

Over the years much has been written about temperament in general and Johann Sebastian Bach in particular.[168] In the field of temperament, the writings have usually aimed at defining what temperament Bach had in mind when composing, or his preferred temperament for tuning his harpsichord. Considering the harpsichord and the clavichord, we have to say that we will not be able to establish Bach's way of tuning the instrument without written evidence. When it comes to the organ, the situation is different. The organ cannot be re-tuned as often and as easily as a harpsichord or a clavichord without suffering some damage. This means that the temperament cannot easily be changed according to the wishes of, say, the organist. Furthermore it is possible in some cases to measure the length of historic pipes and draw some conclusions about the temperament used. Furthermore, the role of temperament is greater in the organ than in, for example, the harpsichord due to the sustained and dynamically stable tone of the organ.[169] Focusing on temperament in the organ is thus an important delimitation for the present work and an important instrument idiomatic factor.

3.1. The "Bach organ"

The organ of Johann Sebastian Bach has been the subject of many writings.[170] Many different organs have been called "the Bach organ." Albert Schweitzer mentions the organs of Andreas and Gottfried Silbermann as the ideal ones.[171]

168 An extensive bibliography, created and maintained by Brian McLaren, Manuel Op de Coul, Franck Jedrzejewski and Dominique Devie can be found on Internet at <http://www.xs4all.nl/~huygensf/doc/bib.html> (2002-07-24), and on the CD-ROM.

169 According to Parncutt 1989: 66, the organ is perhaps the instrument that is most susceptible to beats that occur in intervals not perfectly pure. (See also Hall 1980: 448.) One needs to be aware that a stopped pipe (Gedackt) has a different content of harmonics from a principal pipe. A stopped pipe has very weak even numbered harmonics, and thus there are fewer harmonics interacting in creating beats (Andersen 1955: 30. See also Vos 1986: 252).

170 In later times see for example Bicknell 2000; Blanchard 1985; Busch 1995; Dähnert 1986; Edwards 1991; Friedrich 1983; Haupt 1986; Sumner 1985; Towe 1985. See also Friedrich 1983, footnote 19: 104.

Hermann Keller recommended the organs of Arp Schnitger for Bach's early works and Gottfried Silbermann for the later.[172] Ulrich Dähnert showed the important connection between Bach and Zacharias Hildebrandt;[173] and, Felix Friedrich added Heinrich Gottfried Trost to the list.[174] As Bach worked in many places during his career, both as organist and organ consultant, we cannot say that there is one single Bach organ. Also, the organ building style in northern Germany and of Arp Schnitger was very different from that of central Germany and builders like Heinrich Gottfried Trost, Gottfried Silbermann, or Zacharias Hildebrandt, who even among themselves are very different. Instead, one could say that there are several Bach organs, not only one.

Depending on the criteria they have defined, different authors have come up with a varying number of Bach organs. Homer D. Blanchard presents stop lists for 63 organs. His criteria are "organs that Bach certainly, probably, or possibly a) heard, b) played casually, c) practiced on, d) played as official organist, e) played as a recitalist, f) examined officially."[175] Werner David discusses 47 organs,[176] and Ulrich Dähnert discusses more than 30 organs that Bach played and tested.[177]

The organ expert and organist at the Trost organ in the Altenburg Castle, Felix Friedrich, has suggested a more concise definition of the criteria for a Bach organ. He lists three criteria for a Bach organ. They are: (1) an instrument Bach played through an employment; (2) an instrument Bach himself knew, played, inspected or had influence on the specification; (3) an instrument suited to the performance of Bach's organ works through historical, scientific and organological findings, especially with regard to the first two criteria.[178] Friedrich's definition is, in my opinion, the best since it also addresses and includes the instruments that are very interesting and important for the understanding of Bach's organ music, but on which he, as far as we know today, never played. An example is the organ in Abbenrode (Contius 1708). According to Felix Friedrich's definition this would be an organ in the third category. Since the focus of the present work is tuning and temperament there must be information available about the temperament used in the organ. This can be contemporary information about the temperament, or, information about a tuning actually applied in an instrument found through documentation of organs in connection with restorations. It is important that the instruments are extant to be able to have an aural impression.

171 Schweitzer 1908: 174. See also 258.
172 Keller 1948: 12f.
173 Dähnert 1962: 151.
174 Friedrich 1989: 74.
175 Blanchard 1985: xi.
176 David 1951.
177 Dähnert 1986.
178 Friedrich 1983: 101f, and Friedrich 1989: 72.

The following table gives an overview of relevant organs (see Table 14 below). The table is based on the information we have about Bach’s tenures and travels. Only organs or churches that are referred to in sources are included. Consequently some instruments that, for example, Blanchard included are not in the table because of insufficient information. A comment on the content of the table follows.

Johann Sebastian Bach had a good opportunity to learn about organ building while living with his older brother Johann Christoph Bach in Ohrdruf, since the organ was then being rebuilt. Meanwhile a new organ was also being built in Eisenach. It could have been in these years that J. S. Bach learned the basics of organ building. The organ in Ohrdruf is included since the obituary states that J. S. Bach received tuition from his elder brother.[179] The instruments in Eisenach and Lüneburg have been omitted, since it is impossible to evaluate their relevance for the present work with the available information. There is no evidence of contacts between Georg Böhm, organist of the St. Johannis church in Lüneburg, and Bach, even if it is likely that they knew each other.

The obituary further says that Bach traveled from Lüneburg to Hamburg to hear the famous Johann Adam Reincken.[180] This means that Bach knew the organ in St. Katharinen, which is important when considering his application to the post as organist of St. Jacobi, Hamburg, in 1720. This visit, together with his visit to Lübeck from October 1705 to January 1706, shows his interest in the music by the famous musicians in Hamburg and Lübeck. The aim of Bach’s visit was to “comprehend one thing and another about his art.”[181] The organs are included in the table even if it is difficult to fully evaluate their influence on Bach.

In 1702 Bach successfully applied for the position as organist in the St. Jacobi church in Sangerhausen. However, he did not acceed the job owing to interference by the Duke Johann Georg of Saxe-Weißenfels.[182] The organ was rebuilt by Zacharias Hildebrandt and inaugurated in 1728.[183] Information about the organ when Bach was in Sangerhausen is lacking, and consequently it has been omitted from the table.

179 NBR 306.

180 NBR: 300. In connection with this passage, it also states that Johann Sebastian Bach had the opportunity to hear the band kept by the Duke of Celle, consisting mostly of French musicians. This most likely took place in the second castle of the Duke, in Lüneburg. Sometimes it is assumed that Bach had to go to Celle to hear the band, a trip twice as long as the one to Hamburg.

181 NBR 20. On the basis of his new archival research Ibo Ortgies is of the opinion that changes of temperament in St. Marien in Lübeck during Buxtehude’s tenure cannot be concluded safely. He suggests 1701 for the Totentanz-organ and 1704 for the main organ as more probable dates for a possible change of the temperaments than 1683 for both organs. Ortgies points out that, if these dates are correct, new temperaments in St. Marien could have been one reason for J. S. Bach’s travel to Lübeck in 1705. The information will be presented and discussed in a forthcoming dissertation.

182 Wolff 2000: 67f.

183 Dähnert 1962: 49ff.

Table 14: “Bach organs”

Location	Building	Builder	Year	Size	Organist	Examined	Recital	Visits	Category	Temperament
Altenburg	Schloßkapelle[a]	H.G. Trost	1735–39	ii/p/36(42)			1739		2	x
Ammern	Church[b]	Wender	1708/12 ?	?		1708/12 ?			2	x
Arnstadt	Neue Kirche or Bonifatiuskirche[c]	Wender	1699–1703	ii/p/23	1703–07	1703			1	x
Bad Berka	Church[d]	Trebs	1742–43	ii/p/28		design			2	
Dresden	Sophienkirche[e]	Silbermann	1718–20	ii/p/31			1725/31		2	x
Dresden	Frauenkirche[f]	Silbermann	1732–36	iii/p/43			1736		2	x
Erfurt	Augustinerkirche[g]	Hartung	Re 1753	iii/p/49		1716			2	
Gera	Salvatorkirche	Fincke	1724	?		1724			2	
Gera	St. Johanneskirche[h]	Fincke	1722–24	iii/p/43		1724			2	
Halle	Marktkirche[i]	Contius	1713–16	iii/p/65		1716			2	x
Hamburg	St. Katharinen[j]	Besser/Richborn	ca 1682	iv/p/58			1720	1700–02	2	x
Hamburg	St. Jacobi	Scherer/Fritsche/ Schnitger	1693	iv/p/60			(1720)		(2)	x
Kassel	Martinskirche[k]	Stertzing	1730–32	?		1732	1732		2	
Langewiesen	Church[l]	Albrecht	1706	?		1706			2	
Leipzig	Paulinerkirche[m]	Scheibe	1711–17	iii/p/48		1717			2	
Leipzig	Paulinerkirche	Scheibe	1711–17	iii/p/48	1723–50*	1717			(1), 2	
Leipzig	Thomaskirche, large	Scheibe	1721–22	iii/p/36	1723–50*				(1)	
Leipzig	Neukirche (Matthäikirche)	Scheibe	1721–22 (R)	ii/p/21	1723–50*				(1)	
Leipzig	St. Johanniskirche	Scheibe	1742–43	ii/p/22	1723–50*	1743			(1)	x
Leipzig	Johanniskirche[n]	Scheibe	1742–43	ii/p/22	1723–50*	1743			(1), 2	
Leipzig	Thomaskirche, small	Scheibe/ Hildebrandt	1721–22/ 1727–28 (R)	iii/p/21	1723–50*				(1)	
Leipzig	St. Johanniskirche	T.G. Trost	1694–95	i/p/10	1723–50*				(1)	x
Leipzig	St. Nikolaikirche	Thayssner	1693–94 (R)	iii/p/36	1723–50*				(1)	
Lübeck	Marienkirche (small)	several	repair 1701	iii/p/40				1705	(2)	

Location	Building	Builder	Year	Size	Organist	Examined	Recital	Visits	Category	Temperament
Lübeck	Marienkirche[o] (large)	several	repair 1704	iii/p/54				1705	(2)	
Mühlhausen	Divi Blasii[p]	Wender	(1709)	iii/p/37				1709	1	x
Mühlhausen	Beatae Mariae Virginis[q]	Wender	1735–39	iii/p/43		1735			2	x
Mühlhausen	Divi Blasii[r]	Wender	Re 1708	iii/p/37	1707–08				1	x
Naumburg	Wenzelskirche[s]	Hildebrandt	1743–46	iii/p/53		1746			2	x
Ohrdruf	Michaeliskirche[t]	Brunner	1685/1690	ii/p/21				1695–1700	(2)	
Potsdam	St. Nikolaikirche	Röder	1713	ii/p/23				(1747)	(2)	
Potsdam	Heiliggeistkirche[u]	Wagner	1730	?			1747		2	
Potsdam	Garnisonkirche	Wagner	1747	iii/p/42				(1747)	(2)	
Stöntzsch (Hohnstein)	Church[v]	Schmieder	1731–32	i/p/12		1731, 1732			2	
Störmthal	Kreuzkirche[w]	Hildebrandt	1722–23	i/p/14		1723	1723		2	
Taubach bei Mellingen	St. Ursula[x]	Trebs	1709–10	i/p/11		1710	1710		2	
Weimar	Schlosßkirche			ii/p/24 (1737)						
Weimar	Schloßkirche	Compenius	1658	ii/p/20	1703			1703	1	(x)[y]
Weimar	Schloßkirche	Trebs	1712–14	?	1708–17				1	
Weimar	Schlosßkirche	Trebs	1719–20	?	1708–17				1	
Weimar	Schloßkirche[z]	Weißhaupt	1707–08	?	1708–17		1708		1	
Weißenfels	Augustusburg[aa]	Förner	1673	ii/p/30				1713, 1716	(2)	x
Weißensee	Church[ab]	Schäfer	1737–38	?		1738			2	
Zschortau	Church[ac]	Scheibe	1744–46	i/p/13		1746	1746		2	

a. BD II/453, Friedrich 1989: 71f.
b. Kröhner, C. 1995.
c. NBR 14, 15.
d. BD II/515.
e. BD II/193, NBR 118, BD 11/294, NBR 307.
f. BD II/389, NBR 191.

g. BD I/86, NBR 62.
h. BD II/183, 183a.
i. BD I/85, NBR 58–61.
j. Wolff 2000: 211ff.
k. BD II/315–17, NBR 157–58.
l. BD II/18.
m. BD I/87, NBR 71–73.
n. BD II/519.
o. David 1951: 85.
p. Wolff 2000: 115, 208. Performance of a cantata, now lost. (Spitta 1: 395, suggests examination.)
q. BD II/365.
r. BD I/83, NBR 29–31.
s. BD I/90, NBR 236.
t. David 1951: 79.
u. BD II/554, NBR 239, NBR p. 430.
v. BD II/298.
w. BD II/163–64, 181.
x. BD II/50, 50a. Wolff 2000: 143.
y. The organ probably had subsemitones (Ortgies 2000), suggesting a mean-tone temperament.
z. Schrammek 1988: 100f; Wolff 2000: 526.
aa. Wolff 2000: 134f.
ab. Braun 1999.
ac. BD I/89, NBR 235.

Basic chronology for J. S. Bach	
1685–1695	Eisenach
1695–1700	Ohrdruf
1700–1702	Lüneburg
1703	Weimar
1703–1707	Arnstadt
1707–1708	Mühlhausen
1708–1717	Weimar
1717–1723	Köthen
1723–1750	Leipzig

A different kind of problem is how to evaluate the influence and significance of instruments not directly connected to a tenure of Bach’s – instruments in the surrounding area. When working in Arnstadt and Mühlhausen Bach was probably not ignorant about the organs in the churches he was not directly responsible for – the Barfüßerkirche in Arnstadt and the Marienkirche in Mühlhausen. Still, since we have no further information we have to assume that they played a lesser role, if any, for Bach’s organ music. On the other hand, the Marienkirche is in the list since Bach examined the rebuilt organ there in 1735, and thus it belongs to the second category.

A special case is the organ built by Christian Förner in the chapel of the castle in Weißenfels. Bach was not the chapel organist, but already in 1713 he was commissioned to compose the music for the Duke’s birthday (*Frohlockender Götter-Streit*, BWV 208), performed again in 1716. Around 1729 Bach received a titular Capellmeistership from the Duke.[184] Considering his frequent visits to Weißenfels it is very likely that he got to know the organ. Therefore it is included in the table. One should also note here that the father of Bach’s second wife Anna Magdalena was trumpeter at the court in Weißenfels. In summer 1721 she joined the Capelle in Köthen as a singer, and in December she married the Kapellmeister Bach.[185] Since the Weißenfels organ is the only instrument that clearly, according to the sources, had a pedal compass to f^1, it has been associated with the Toccata in F major (BWV 540).[186]

When moving to Köthen in 1717, Bach began a new career. From now on he was in charge of the music, first as Kapellmeister in Köthen and later as Kantor in Leipzig. The years in Köthen seem not to have been an important period when it comes to organ composition, and with regard to this and the lack of information about the organ in the St. Agnus church,[187] where Bach attended the Lutheran services, Köthen is not included in the table.

Serving as Kantor in Leipzig, Bach had a special responsibility over the music. Although not organist, he composed and published for organ during this period[188] and he also inspected organs.[189] Compared to the Köthen period we have clear evidence of Bach’s organ-related activity, and consequently the organs in Leipzig are in the table.

To the third category in Friedrich’s definition can be added other instruments by the builders represented in the table. As mentioned before, the Contius organ in Abbenrode, with extant historic pipe material, is highly interesting. In Halle

184 Wolff 2000: 134f.
185 Wolff 2000: 217.
186 Trost, J. C. 1677:31. Williams 1980a: 103f.
187 Wolff 2000: 199. See also Henkel 1985.
188 *Clavier-Übung III*, 1739 (NBR 206).
189 For example the new organ (with old material from the small organ of the Thomaskirche) from 1742–43 by Johann Scheibe in the Johanniskirche (Dähnert 1980:177), and the organ in Naumburg, built by Zacharias Hildebrandt (see below, chapter 3.1.5.).

only the façade is preserved from the large organ built by Christoph Contius in 1716, and inspected by, among others, Bach.

As mentioned above, Johann Kuhnau writes in 1717[190] that Gottfried Silbermann and Johann Friedrich Wender did not use equal temperament. If we consider the years between Johann Georg Neidhardt's publication and Johann Kuhnau's letter, 1706–1717, we find two organs by Wender in our table: the organ in Divi Blasii in Mühlhausen and the organ in Ammern. The statement is too vague to offer any helpful information. It could refer to everything from mean-tone to well-tempered tunings like Werckmeister or Neidhardt. The organ in Arnstadt, built by Johann Friedrich Wender, has recently been restored (1999),[191] but since the information considering Wender's temperament is not more specific, the instrument has not been considered for the present work.[192]

According to the criteria set forth, the following instruments of organ builders that can be put in relation to Bach and his organ music, in so far as we have sufficient information regarding the temperament, will be considered: the organ in St. Katharinen, Hamburg, enlarged and repaired by Johann Friedrich Besser and Joachim Richborn; the organ in St. Andreas in Abbenrode, built by Christoph Contius; the organ in the chapel of the Altenburg Castle, built by Heinrich Gottfried Trost; the organ in the Cathedral of Freiberg, built by Gottfried Silbermann; and, the organ in St. Wenzel in Naumburg, built by Zacharias Hildebrandt. The instruments are listed in chronological order, and the information in the specification for the chosen instruments refers to the present situation where applicable.

3.1.1. St. Katharinen, Hamburg – Johann Friedrich Besser/Joachim Richborn (ca. 1682)

In November 1720, Johann Sebastian Bach traveled to Hamburg to apply for the position as organist of the St. Jacobi church. From this visit we have the famous report of Bach performing on the great organ in St. Katharinen in the presence of Johann Adam Reincken.[193] Bach was reported improvising over "An Wasserflüssen Babylon," after which Reincken commented: "I thought that this art was dead, but I see that in you it still lives."[194] Bach did not get the position in St. Jacobi, because a competitor "was better at preluding with his talers than with his fingers," as Johann Mattheson put it.[195] The organ in St. Katharinen has a long history starting in the 16th-century. Johann Mattheson writes that Johann

190 See p. 41.
191 More information is available at <http://www.orgelbau-hoffmann.eucenter.com/wenderorgel/bericht.htm> (2002-07-24).
192 Further research on Johann Friedrich Wender would most likely provide important information about this slightly neglected builder of "Bach organs."
193 Wolff 2000: 211f.
194 Quoted after Wolff 2000: 212.
195 Quoted after Wolff 2000: 215.

Friedrich Besser restored the organ,[196] and it is after these enlargements and repairs, including those by Joachim Richborn, that we know the organ. The specification is from ca. 1682.

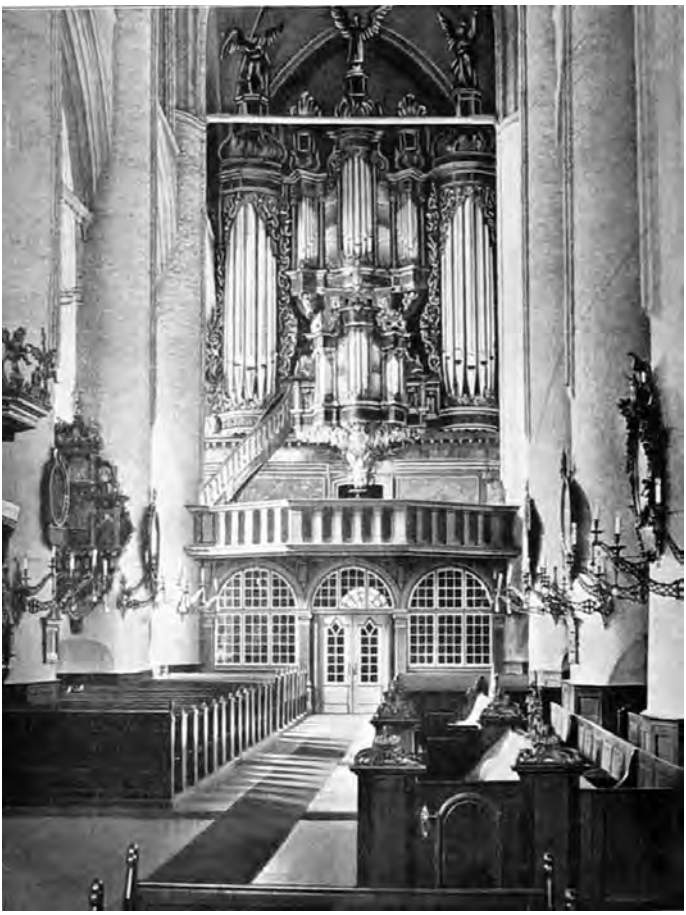


Fig. 27: The organ in St. Katharinen, Hamburg (from Cortum 1928)

196 Johann Mattheson in Niedt 1721: 176f.

Table 15: Specification – St. Katharinen[a]

Rück-Positiv		Wer[c]k		Ober-Werck		Brust		Pedal	
Principal	8	Principal	16	Principal	8	Principal	8	Principal	32
Gedact	8	Quintadena	16	Hohlflöte	8	Octava	4	Principal	16
Quintadena	8	Bordun	16	Flöte	4	Quintadena	4	Sub-Baß	16
Octava	4	Octava	8	Nasat	3	Waldpfeiffe	2	Octava	8
Blockflöte	4	Spitzflöte	8	Gemshorn	2	Scharff	VII	Gedact	8
Hohlflöte	4	Querflöte	8	Waldflöte	2	Dulcian	16	Octava	4
Quintflöte	1 1/2	Octava	4	Scharff	VII	Regal	8	Nachthorn	4
Sifflet	1	Octava	2	Trommete	8	Rauschpfeiffe	II	Groß-Posaun	32
Sesquialtera	II	Rausch-Pfeife	2	Zincke	8	Cimbel	III	Posaune	16
Scharff	VIII	Mixtura	X	Trommete	4	Mixtura	V	Dulcian	16
Regal	8	Trommete	16					Trommete	8
Baarpfeiffe	8							Krumhorn	8
Schallmey	4							Schallmey	4
								Cornet-Baß	2

a. Spelling after Fock 1997: 75.

Tremulant W, Tremulant RP
2 Zimbelsterne, Timpani, Vogelgesang
Coupler: W/P[197], and the manuals (not specified)
Ventils to W, OW, B, RP, P

When it comes to the temperament, we have an interesting passage in the church records for the St. Katharinen from 1742.

> Furthermore, our organist Uthmöller charged that he was not happy with the new temperament, …but wanted the organ in the old temperament, and so our above-named organist and the organ builder [Johann Dietrich Busch] were summoned into the Sacristy, and the latter explained how the temperament is now set … and he had his way, especially since the cantor Telemann was also summoned, who … said that this temperament was better than the last.[198]

Even if the term "the old temperament" is quite vague, we can at least say two things about what it could be. Firstly, it was not equal temperament. Equal temperament would not have been referred to as the old temperament. Secondly, returning to an "old temperament" could either mean 1/4-comma mean-tone with the terminology of Andreas Werckmeister, or "old" in the meaning previously used, which could have been an un-equal temperament like Werckmeister's. It could also have referred to a modified mean-tone temperament. Georg Philipp Telemann's approval of the temperament to re-tune might indicate that it was something close to a 1/6-comma mean-tone temperament because that would very closely match Telemann's recommended 55-division of the octave in ensem-

197 The accessories are according to *Orgeldispositionen* (Smets: 1931). It is very unlikely that there was a coupler W/P. The great pedal divisions of this tradition did not need such a coupler. A tremulant in the Werk is also very unlikely. A tremulant in the Ober-Werck is more likely.
198 Fock 1997: 107f.

Fig. 28: The organ in St. Jacobi, Hamburg. (Photo: Henrik Tobin)

ble playing.[199] As a member of Mizler’s “Societät der musikalischen Wissenschaften,” Telemann was involved in discussion on intonation. Telemann writes that “my system has no basis in a temperament for the keyboard, but shows how the tones can be played on an un-restricted instrument such as the cello and the violin, in a nearly pure way.”[200]

Since the organ in St. Katharinen is not extant, we need to turn to an instrument such as the one in St. Jacobi[201] to be able to experience the sounds of such an organ. And it was, as a matter of fact, this position Bach actually applied for. The organ in St. Jacobi was built by Arp Schnitger (1648–1719), one of the most prominent figures in the history of North-German organ building. The instrument as well as its history is well documented. The documentation was made in connection with the recent restoration (1993), and is a good example of what a thorough documentation can produce in regard to an instrument’s history.[202]

199 Klingfors 1991: 56. See discussion on Telemann in Mizler 1752, vol iii, part 4: 713ff. According to Klingfors Silbermann’s preference for this temperament probably originated from his French roots. At the beginning of the eighteenth century Joseph Sauveur discussed the similarity between the 55-division and the 1/6-comma mean-tone. Considering that Gottfried Silbermann build several organs in chamber-pitch, which was normally used by orchestras, it is noteworthy that the use of 1/6-comma mean-tone produces a very good agreement between organ and orchestra. This is a matter that needs further investigation.

200 “Mein System hat keine Claviermäßige Temperatur zum Grunde, sondern zeiget die Klänge, so, wie sie auf uneingeschränkten Instrumenten, als Violoncell, Violine etc. wo nicht völlig, döch bey nahe, rein genommen werden können, welches denn die tägliche Erfahrung lehret.” Mizler 1752, vol iii, part 4: 716.

201 Or the new North German Baroque organ in Örgryte Nya kyrka, Göteborg, Sweden.

202 Fock 1974; Ahrend 1995; Edskes 1996. The organ was re-inaugurated after its restoration in 1993.

Specification – St. Jacobi, Hamburg[a]

Rückpositiv		Werck		Oberpositiv		Brustpositiv		Pedal	
Principal	8	Principal	16	Principal	8	Principal	8	Principal	32
Gedackt	8	Quintadehn	16	Rohrflöht	8	Octav	4	Octava	16
Quintadehna	8	Octava	8	Holtzflöht	8	Hollflöht	4	Subbaß	16
Octava	4	Spitzflöht	8	Spitzflöht	4	Waldtflöht	2	Octava	8
Blockflöht	4	Viola da Gamba	8	Octava	4	Sexquialtera	II	Octava	4
Querpfeiff	2	Octava	4	Nasat	3	Scharff	IV–VI	Nachthorn	2
Octava	2	Rohrflöht	4	Octava	2	Dulcian	8	Rauschpfeiff	III
Sexquialtera	II	Flachflöht	2	Gemshorn	2	Trechter Regal	8	Mixtur	VI–VIII
Scharff	VI–VIII	Rauschpfeiff	II	Scharff	VI			Posaune	32
Siffloit	1 1/2	SuperOctav	2	Cimbel	III			Posaune	16
Dulcian	16	Mixtur	VI–VIII	Trommet	8			Dulcian	16
Bahrpfeiffe	8	Trommet	16	Vox humana	8			Trommet	8
Trommet	8			Trommet	4			Trommet	4
				Cornet	2				

a. According to Reinitzer 1995: 148.

Compass: Werck/Oberpositiv/Brustpositiv CDEFGA–c^3; Rückpositiv CDE–c^3; Pedal CD–d^1.
Couplers:BP/W, OP/W
Haupt-Ventiel and 5 Ventiele for the different divisions
2 tremulants, Cimbelstern, Trommel
Temperament: modified mean-tone 1/5 syntonic comma
Pitch: a^1=495,45 Hz at 18˚C

During the documentation of the pipework, some rather well preserved inside pipes were found. In addition to these pipes there is documentation done by Alexander J. Ellis in the 1860s regarding the pitch.[203] Based on this information, a reconstruction of the temperament and the original pitch was done, which showed that the original temperament was mean-tone in some form.[204]

Other options for an instrument in this style would be the reconstruction Harald Vogel suggests, based on the information in the minutes from 1641 after the inspection of the organ in the Liebfrauenkirche, Bremen, by Jacob Praetorius and Heinrich Scheidemann.

> will Er versuchen so viehl immer mügligen dieselbe Quinta zwischen a. und d. Rein zu stimmen vnd die tertien zu schärffen vnd die schwebende Quinta an andere Öhrter zu bringen.[205]

203 Edskes 1996: 20ff.
204 Edskes 1996 and Ahrend 1995 disagree on the result of the analysis. Edskes suggests modified mean-tone, and Ahrend pure mean-tone. Still, they agree on a temperament in the mean-tone style. Furthermore there was a disagreement within the restoration committee on what temperament to use for the restored organ. Part of the committee wanted a temperament where, in regard to the repertoire, "the road into the eighteenth century is not fully closed" ("…, dennoch ist der Weg ins 18. Jahrhundert nicht völlig versperrt." Rudolf Kelber in Ahrend 1995: 228.). The organist in St. Jacobi, Rudolf Kelber, proposed a compromise, which was accepted (Ahrend 1995: 227ff.). The compromise is a modified fifth syntonic comma mean-tone temperament.
205 Piersig 1935: 405.

Fig. 29: The console in St. Jacobi, Hamburg. (Photo: Henrik Tobin)

> Joh. Sieborch [Sieburg] shall try as much as possible to tune the fifth between a and d pure, and sharpen the thirds and distribute the beating fifth in other places.[206]

The table below shows the structure of the chromatic scale of the temperaments in cents.

Table 16: Edskes’ – reconstruction[a]

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	84,11	193,16	299,51	386,31	503,42	579,47	696,58	783,38	889,74	998,78	1085,58

a. Edskes 1996: 31.

Table 17: Kelber – Jacobi

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	87,88	195,31	296,09	390,61	502,35	585,92	697,65	789,83	892,96	1000,40	1088,27

Table 18: Vogel – Scheidemann/Praetorius

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	86,80	193,16	294,15	391,69	503,42	584,85	696,58	783,38	895,11	1001,47	1088,27

206 Translation quoted after Vogel 1986: 242.

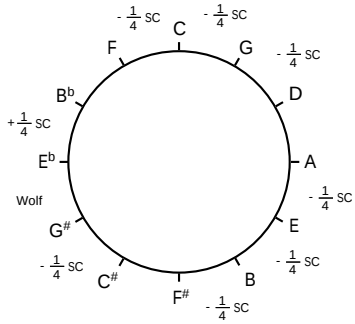


Fig. 30: Vogel's reconstruction of Scheidemann/Praetorius

3.1.2. St. Andreas, Abbenrode – Christoph Contius, 1708

In May 1716, Johann Kuhnau, Christian Friedrich Rolle, and Johann Sebastian Bach examined the new organ in the Marienkirche (Marktkirche) in Halle, built by Christoph Contius (1676–1722), who also built the organ in Abbenrode. From the report after the inspection in Halle we know that the question of temperament was discussed. Contius was asked to correct some things in the voicing, to correct the tuning, and "to [tune] according to the passable and good temperament that he once showed us."[207] It is not clear what is meant with a "passable and good temperament."[208] The term is neither used by Andreas Werckmeister nor by Johann Georg Neidhardt. Since this is the only documented instance where the temperament of an organ is discussed involving Bach, we will look further into it. This was not Bach's first visit to Halle. In 1713, November 28 to December 15, he was in Halle applying for the position as organist of the Marienkirche. Bach was elected on December 13, but later he withdrew his candidacy. We can assume Bach met Christoph Contius, since the work on the organ started already in 1712.

As mentioned earlier, Johann Kuhnau referred to Neidhardt's definition of equal temperament from 1706 as the "exact temperament" in a letter dated December, 1717, to Johann Mattheson. The organ builders Nicolaus [sic] Wender from Mühlhausen and Gottfried Silbermann did not like it.[209] Kuhnau also states that even if Neidhardt's temperament seems to be the most reasonable one, he has not seen it used in any organs.

207 "nach der von ihm uns einmahl gezeigten noch passablen guten Temperatur einzurichten" in BD I/85, NBR 59.

208 The same word (passable) is used in the reports from the inspection of the Silbermann organs in Frauenkirche in Dresden, and in the Johanniskirche in Zittau (Greß 1989: 114).

209 Se above p. 41. Should be Johann Friedrich Wender.

Fig. 31: The organ in Abbenrode. (Photo: Reinhard Menger)

> Sowohl aber als des Neidhardts *Temperatur* der Vernunfft am gemässesten zu sein scheinet, so habe ich doch noch kein Werck von einem *habil*en *Instrument*- oder Orgelmacher darnach eingerichtet angetroffen.[210]
>
> Even if Neidhardt’s temperament seems the most reasonable, I have so far not seen an instrument from a good instrument or organ builder tuned according to it.

This is written a year after the examination of the organ in Halle. Considering the options of mean-tone, a well-tempered tuning, or equal temperament, and taking into consideration Kuhnau’s clear statement, the most plausible temperament seems to be a well-tempered tuning. Neidhardt did not describe mean-tone, and Kuhnau writes that he has not yet seen an organ tuned to equal temperament. A “passable and good temperament” must then refer to a well-tempered tuning. Other authors used different designations. Werckmeister calls his well-tempered tunings in the *Musicalische Temperatur* “correct,” as opposed to the “incorrect” mean-tone.[211] In *Musicalische Paradoxal-Discourse,* posthumously pub-

210 Mattheson 1722, book 2: 234.

lished in 1707, Werckmeister calls for equal temperament to produce a "well tempered harmony."

> Wir schreiten weiter, und wißen, wenn die *Temperatur* also eingerichtet wird, daß alle *Quinten* 1/12 *Commat:* die *Tert: maj:* 2/3 die *min:* 3/4 *Comm.* Schweben und ein *accura*tes Ohr dieselbe auch zum Stande zubringen, und zustimmen weiß, so dann gewiß eine wohl *temperirte Harmonia*, durch den ganzen *Circul* und durch alle *Claves* sich finden wird[.] [212]
>
> We continue, and know, that when a temperament is so arranged, that all fifths are tempered 1/12; the major thirds 2/3; the minor thirds 3/4 of a comma, and when an accurate ear can achieve and tune this, then surely a well-tempered euphony will be found, through the whole circle of fifths and in all keys.

As mentioned earlier, Werckmeister nevertheless states some pages later in the *Paradoxal-Discourse* that he prefers to keep the diatonic keys, which one uses more often, purer than the others.[213] Finally we can note that Neidhardt calls his book on equal temperament "The best and easiest temperament."[214] As mentioned earlier, Contius used Werckmeister's temperament according to Christoph Albert Sinn.[215]

In Abbenrode, 15 km from Goslar, one can listen to the very well preserved small organ by Christoph Contius, built in 1708. Almost all of the original pipework is extant, including the Principal 4' of the façade.[216] Today the organ is tuned to equal temperament.

Table 19: Specification – Abbenrode[a]

Werk		Pedal	
Gedact	8	SubBaß	16
Quinta Toen	8	OctavBaß	8
Principal	4	Waldfloete	1/2
Floete douce	4	Posaune	16
Quinta	3	BaßTrompete	8
Octava	2	CornettBaß	2
Tertia	1 3/5		
Mixtur	IV		
Trompet	8		

a. Spelling after Schmidt 1985: 77.

Compass: Werk C, D –c^3; Pedal C, D–c^1
Tremulant, Cymbelstern
Temperament: Equal temperament
Pitch: a^1=454Hz at 2,5°C

211 "richtige" and "unrichtige". Werckmeister 1691. Engraving for a monochord.
212 Werckmeister 1707: 110.
213 See above p. 26.
214 *Beste und leichteste Temperatur* (Neidhardt 1706).
215 See p. 28. See also Williams 1984: 189, and, Wegscheider and Schütz 1988: 30.
216 Schmidt 1985.

Fig. 32: The console in Abbenrode. (Photo: Reinhard Menger)

When an appropriate organ had to be chosen for the sampling, this instrument immediately came to mind. Above all, its sound characteristics have to be considered, thanks to the large amount of historic pipe material, as a unique example of a historic soundscape. Furthermore the practical conditions were good. The organ was easily accessible, and its size was appropriate for recording and sampling.[217] The plenum registration in this instrument is, with regard to the number of stops, smaller than that on an organ based on 8'- or 16'-principal. This is of importance since it keeps the sounding material manageable.

3.1.3. Cathedral, Freiberg – Gottfried Silbermann, 1711–14

Gottfried Silbermann (1683–1753) may be the best-known organ builder ever connected to Johann Sebastian Bach. His organs have even been considered the only true Bach organs. J. S. Bach performed on several occasions on instruments built by Silbermann, and Wilhelm Friedemann Bach was appointed organist of the Sophienkirche in Dresden in 1733, which had an organ built by Silbermann.[218] Nevertheless J. S. Bach was never commissioned to examine an organ built by Gottfried Silbermann.

217 I am grateful to the congregation, and to pastor emerita Mrs. König and the cantor, Mrs. Kantorin Eilert, for giving me access to the organ, and for their kindness and help.

Table 20: Specification – Cathedral, Freiberg[a]

Brustwerk (I)		Hauptwerk (II)		Oberwerk (III)		Pedal	
Gedackt	8	Bordun	16	Quintadehn	16	Untersatz[b]	32
Principal	4	Principal	8	Principal	8	OctavBaß	16
Rohrflöte	4	Viola da Gamba	8	Gedackt	8	PrincipalBaß	16
Nasat	3	Rohrflöte	8	Quintadehn	8	SubBaß	16
Octava	2	Octava	4	Octava	4	OctavBaß	8
Tertia	1 3/5	Quinta	3	Spitzflöte	4	OctavBaß	4
Quinta	1 1/2	Super-Octava	2	Super-Octava	2	Pedalmixtur	VI
Sifflöt	1	Tertia	1 3/5	Flaschflöt	1	PosaunenBaß	16
Mixtur	III	Cornet	V	Echo	V	TrompetenBaß	8
		Mixtur	IV	Mixtur	III	ClarinBaß	4
		Cimbeln	III	Cimbeln	II		
		Trompete	8	Krummhorn	8		
		Clarin	4	Vox humana	8		

a. Spelling after Dähnert 1980: 106f and Greß 2001a: 36ff.
b. Playing together with the OctavBaß 16.

Compass: Hauptwerck/Oberwerk/Brustwerk CD–c^3; Pedal CD–c^1.
2 Tremulants; 2 Shove-coupler: Brustpositiv/Werck, Oberpositiv/Werck
Temperament: modified mean-tone (1/5 syntonic comma)
Pitch: a^1=476,3 Hz

Helmut K. H. Lange, Kristian Wegscheider, Peter Vier, and, Frank-Harald Greß among others have discussed intensively since the 1970s the question of what temperament Silbermann used; but, by 1748, Georg Andreas Sorge had already described the temperament.[219] The large organ in the cathedral of Freiberg is perhaps the best-documented Silbermann organ with regard to temperament, and thus of chief interest for the present work.

Today authors disagree on whether Sorge's judgment of Silbermann's temperament, based on two instruments[220] Sorge knew, is accurate enough. Sorge wrote: "How does the triad A^b, C, E^b sound by itself, and with other instruments? Like a duet between the devil and his grandmother."[221] On the other hand, we have comments like Jacob Lehmann's, who in a dedicatory poem about the organ in Reinhardtsgrimma wrote: "The temperament the artist [Silbermann] knows how to divide, so that you cannot hear the awful wolf howl."[222] The well-known Silbermann expert, Frank-Harald Greß, makes a thorough survey of the situation with regard to temperament in Gottfried Silbermann's organs in his excellent book *Die Klanggestalt der Orgeln Gottfried Silbermanns.* During the latest restoration

218 Wolff 2000: 369. In 1746, W. F. Bach accepted the post as organist of the Marienkirche in Halle (Wolff 2000: 154).
219 Lange 1972/1973a/b; Vier 1987; Greß 1989; Sorge 1748.
220 The organs in Greiz and Burgk (Greß 1989: 115).
221 "Wie klingt die *Trias as, c, es*, mit sich, und andern Instrumenten? Nicht anders, als wann der Teufel mit seiner Großmutter ein Duett macht", quoted after Adlung 1758: 320, note (i).
222 "... Die Temperirung weiß der Künstler so zu theilen, Daß man nicht irgendwo den schlimmen Wolff hört heulen...", after Greß 1989: 114.

Fig. 33: The large organ in the Cathedral, Freiberg.
(Photo: Sandra Petojevic)

of the organ in the cathedral in Freiberg, some tendencies of the temperament could be deduced from the sizes of the wooden pieces that were glued on to the Holzprinzipal 16'.[223] A similar case was the Principal 4', and the body-length of the Subbaß-pipes in Burgk an der Saale.[224] These measurements, together with historical comments on Silbermann’s temperament, are the sources available. Greß comes to the conclusion that the temperament must be a modified mean-tone temperament, with fifths tempered less than 1/4 syntonic comma. The two reconstructions Greß offers are based on the assumption that an historic temper-ament must basically be very practical to set and check, which means that the

223 Wegscheider and Schütz 1988.
224 Greß 1989: 119f.

Fig. 34: The console in the Cathedral, Freiberg. (Photo: Sandra Petojevic)

beats between the differently tuned intervals should stand in proportion to each other, or pure intervals should be used as checkpoints. These are two ways suggested by Frank-Harald Greß and Kristian Wegscheider to be able to control and set a temperament.[225] Greß' first reconstruction uses the proportion n/2n and the other uses n/4n. The tuned intervals in the first reconstructed temperament beat at the frequency n, and three others at 2 times the frequency. The second temperament has one interval beating 4 times the frequency of the other tuned intervals.

The organ builder Kristian Wegscheider, Dresden, who took part in the restoration of the organ, has also suggested a possible reconstruction of Silbermann's temperament. Wegscheider's reconstruction is a 1/5 syntonic comma mean-tone temperament, and utilizes proportional beats between intervals as checkpoints. Wegscheider calls it a praxis-reconstruction, emphasizing the applicability of the temperament before the theoretical design. Thus it is not in the circle of fifth that the design is visualized, but in a table with beat rates. Altogether Wegscheider has presented two praxis-reconstructions, listed in the table below as Wegscheider 1 and 2. The temperament was further modified to better fit the actual length of the historical pipework in Freiberg, to avoid further changes in the pipework.[226] The actual temperament used is presented in Table 26 as Freiberg 1985.

225 Greß 1989: 121ff.
226 Wegscheider 1986: 58f.

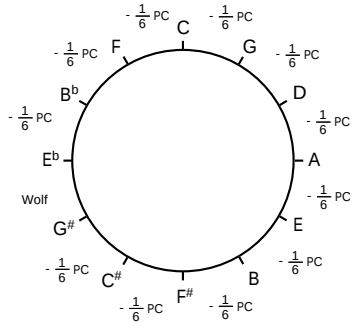


Fig. 35: Silbermann’s 1/6-comma mean-tone according to Sorge

All of these proposed reconstructions of Silbermann’s temperament, including Sorge’s, are possible reconstructions, and can therefore be used in the analysis of the music. A circle of fifths is not provided for the temperaments based on proportional beating since the circle of fifths does not show how such temperaments are conceived.

Table 21: Silbermann – Sorge

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	86,31	196,09	305,87	392,18	501,96	588,27	698,04	784,36	894,13	1003,91	1090,22

Table 22: Silbermann – Greß 1

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	83,9	194,4	306,4	389,7	502,3	586,0	696,2	780,4	891,2	1003,6	1087,1

Table 23: Silbermann – Greß 2

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0	93,6	197,4	302,5	395,6	500,9	594,4	698,1	791,8	895,9	1001,2	1094,1

Table 24: Silbermann – Wegscheider 1[a]

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	84,55	193,89	303,34	391,41	501,25	585,65	697,66	782,42	892,01	1001,70	1088,20

a. Cent values after Wegscheider and Schütz 1988: 100ff.

Table 25: Silbermann – Wegscheider 2

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	84,55	193,89	305,73	388,84	501,25	585,65	697,66	782,42	892,01	1004,10	1088,20

Table 26: Freiberg 1985

C	C♯	D	E♭	E	F	F♯	G	G♯	A	B♭	B
0,00	90,22	196,09	298,05	394,14	500,00	590,23	698,05	790,23	896,09	1000,00	1092,18

Fig. 36: The organ in the chapel of the Altenburg Castle. (Photo: Ulrich Kneise)

3.1.4. Chapel, Altenburg Castle – Heinrich Gottfried Trost, 1735–39

One of the best-known "Bach organs" is the instrument built by Heinrich Gottfried Trost (1681–1759) for the chapel at the castle in Altenburg. One reason is, of course, that Johann Sebastian Bach himself visited the organ, probably early in September 1739,[227] and well-known reports like the following from the *Dresdner*

227 Friedrich 1983: 102.

Gelehrten Anzeigen from 1798 of Bach accompanying the congregation in the Credo, adds to the picture of a true Bach organ.

> Das Nachgeben des Organisten gegen die singende Gemeinde ist besser als sich durchsetzen wollen. Nur wenige vermögen die Gemeinde so zu lenken wie der alte Bach, der auf der großen Orgel in Altenburg einmal den Glauben aus D-moll spielte, beim zweiten Vers aber die Gemeinde ins Es-moll hob, und beim dritten gar ins E-moll. Das konnte aber auch nur ein Bach und eine Orgel in Altenburg.[228]
>
> It is better for an organist to follow the singing congregation than to force his will upon them. Only few are able to lead the congregation like the old Bach, who once played the Credo on the great organ in Altenburg starting in D minor, raising the second verse into E^{b} minor, and the third even into E minor. But this could only be done by a Bach and an organ like the one in Altenburg.

Table 27: Specification – Altenburg[a]

Hauptwerk		Oberwerk		Pedal	
Groß Qvintadena	16	Geigen-Principal	8	Principalbaß	16
Flaute travers	16	Lieblich Gedackt	8	Violonbaß	16
Principal	8	Vugara	8	Subbaß	16
Bordun	8	Qvintadena	8	Qvintadenbaß (tr)	16
Rohr-Flöte	8	Hohl-Flöte[b]	8	Flaute traversenbaß (tr)	16
Viol di Gamba	8	Gemshorn	4	Octavbaß	8
Spitz-Flöte	8	Flaute douce II	4	Bordunbaß (tr)	8
Octava	4	Naßat	3	Octavbaß (tr)	4
Klein-Gedackt	4	Octava	2	Mixturbaß (tr)	VI–VII
Qvinta	3	Wald-Flöte	2	Posaunenbaß	32
Super Octava	2	Super-Octava	1	Posaunenbaß	16
Block-Flöte	2	Cornett	V	Posaunenbaß	8
Sesqvialtera	II	Mixtur	IV–V		
Mixtur	VI–IX	Vox humana	8		
Trompete	8				

a. Spelling after Dähnert 1980: 22. Friedrich 1989.
b. To be used with the Vox humana 8.

Compass: Hauptwerk/Oberwerk C–c^{1}, Pedal C–c^{1}
Shove-coupler OW/HW, Windkoppel HW/P
Tremulant HW, Slow tremulant, Fast tremulant, Cymbelstern, Glockenspiel
Pitch: a^{1}=468 at 18,2°C
Temperament: Neidhardt for a village, 1724

The organ is unique in another way, which is of great interest for the present work. An extensive discussion started in 1738 about what temperament should be used to tune the organ being built. This discussion continued until the final inspection of the organ in 1739, when the court organist commented on the temperament. Luckily the material has been preserved in the castle archives. In-

228 Quoted after Friedrich 1989: 72.

Fig. 37: The console in the chapel of the Altenburg Castle.
(Photo: Ulrich Kneise)

volved in the discussion were three parties: the organist, the organ builder, and, indirectly, the theorist.[229]

In short, the court organist, Lorenz, asked H. G. Trost to tune equal temperament because it is the best temperament for transpositions needed when playing together with the orchestra. In the minutes from the inspection, by the Kapellmeister Gottfried Heinrich Stölzel and the court organist Johann Gottfried Golde from Gotha, the temperament received some critique. It was judged possible to play in all keys, but $B^{\flat}$ and $D^{\#}$ were not perfect. As mentioned, the discussion about the temperament had started already in 1738, when the first notes can be found in the archive. In the archival material is also a list of five temperaments, with tables giving the beats. The first cannot at the present be identified, and the other four of the five listed temperaments are Johann Georg Neidhardt's, presented in the same manner as in Neidhardt's writings (1732).[230] In this sense the the-

229 The case has been discussed in Friedrich 1983 and 1989, Dähnert 1988; and, Vier 1990.

230 Peter Vier (Vier 1990: 106f.) has already noted that four of the temperaments are Neidhardt's, not only three as Felix Friedrich writes (Friedrich 1989: 51). As mentioned earlier the definitions of the temperaments differs slightly between the 1724 and 1732 publication. The list in Altenburg follows the 1732 version.

orist Neidhardt is involved in the discussion about temperament in the Trost organ at Altenburg.

It is difficult to say what the criticized B♭ and D♯ imply. The most plausible interpretation is the one suggested by Vier,[231] that the criticism be due to Trost’s lack of experience in tuning equal temperament.[232] This is supported by the fact that in 1768 the D♯-pipes had to be lengthened to “correct the offensive temperament.”[233] The pipes were obviously cut too short with respect to equal temperament. In the documentation of Trost’s work in, among other places, Eisenberg and Waltershausen, the pipework has shown that Trost’s way of tuning came out of the mean-tone tradition.[234] This is not surprising and supports Vier’s interpretation. Andreas Werckmeister, for example, regarded organ builders as old-fashioned with respect to temperament.[235]

It is important to notice that Neidhardt’s writings obviously were known and used. In this case it was the organ builder who introduced the writings of Neidhardt. This is clear from the comment regarding the first temperament in the list of temperaments in Altenburg, which is addressing the court organist, Lorenz.[236]

From the occurrences in Altenburg we see that the musicians were the ones wanting equal temperament, defined by the theorists. The application in practice, however, was difficult and not fully successful, probably due to the organ builder’s inexperience with the new temperament. It can also be noted that the court organist was the one who wanted equal temperament, which may have been symptomatic of his desire and ability to play in all keys, and obviously noted by Neidhardt who recommended equal temperament for the court.[237]

As a historical case this is invaluable to the present investigation, since it gives a partial answer to one of the questions raised in the present work: whether the theoretical writings of, for example, Johann Georg Neidhardt were used in practice.

3.1.5. St. Wenzel’s church, Naumburg – Zacharias Hildebrandt, 1743–46

The organ builder considered to have been closest to Johann Sebastian Bach built the organ in the St. Wenzel church in Naumburg in 1746. It has recently been restored, and was re-inaugurated in December, 2000. Zacharias Hildebrandt (1688–

231 Vier 1990: 107. See also Wegscheider and ffSchütz 1988: 114ff.
232 The pipes might have been cut too short to be able to tune to equal temperament, since the scaling of the pipes probably was not planned to fit equal temperament.
233 Friedrich 1989: 51.
234 Heinke 1998: 92ff.
235 See above, p. 23.
236 “Temperatur einer Orgel, wie die Quinten und Tertien gegen einander schweben, so in Zahlen angedeutet. Nun kann H. Lorenz seine Meinung hierüber entdecken.” Friedrich 1989: 49.
237 Neidhardt 1724: 20.

Fig. 38: The organ in Naumburg. (Photo: Hermann Eule Orgelbau, Bautzen)

1757) learned the trade as a journeyman of Gottfried Silbermann's. In 1722 Hildebrandt, as an independent organ builder, built his first organ in Langhennersdorf just west of Freiberg (Saxony). In 1723 Bach inaugurated the organ in Störmthal, built by Hildebrandt, and after this they maintained contact with each other. The most famous instrument Hildebrandt built was the organ in Naumburg, which was inspected and approved by Gottfried Silbermann and Bach in September 1746. The organ was, according to Jakob Adlung, one of the best he had ever heard.[238]

238 "Es ist eins der besten Werke, so ich gehört." Adlung 1758: 522.

Table 28: Specification – Naumburg[a]

Hauptwerk		Oberwerk		Rückpositiv		Pedal	
Principal	16	Burdun	16	Principal	8	Principal Bass	16
Quintadehn	16	Principal	8	Quintadehn	8	Violon Bass	16
Octava	8	Hohl-Floete	8	Rohr-Floete	8	Subbass	16
Spitz-Floete	8	Praestanta	4	Viol di Gamba	8	Octaven Bass	8
Gedakt	8	Gemshorn	4	Prestanta	4	Violon Bass	8
Octava	4	Quinta	3	Vagara	4	Octaven Bass	4
Spitz-Floete	4	Octava	2	Rohr-Floete	4	Octava	2
Quinta	3	Wald-Floete	2	Nassat	3	Mixtur Bass	VII
Sesquialter		Tertia	1 3/5	Octava	2	Posaune	32
Octava	2	Quinta	1 1/2	Rausch-Pfeife		Posaune	16
Weit-Pfeife	2	Sif-Floete	1	Mixtur	V	Trompet. Bass	8
Cornet	IV	Scharff	V	Fagott	16	Clarin Bass	4
Mixtur	VIII	Vox humana	8				
Bombart	16	Principal und. mar.	8				
Trompete	8						

a. Spelling according to *Die Hildebrandt-Orgel zu Naumburg, St. Wenzel. Festschrift anlässlich der wiederinweihung nach vollendeter Restaurierung am 3. Dezember 2000* (Naumburg, 2000), 54f.

Compass: Hauptwerk/Oberwerk/Rückpositiv C, D–c^3, Pedal C, D–d^1
Shove-coupler: RP/HW, OW/HW, Wind Coppel (HW/P)
Tremulant, Schwebung zum Oberwerk, Zimbelstern
Temperament: Neidhardt for a village, 1724
Pitch: a^1=464 Hz at 15°C

Johann Christoph Altnickol, a former student and son-in-law of Bach’s, was appointed organist of the church in 1748. He writes in 1753, describing the organ, that Hildebrandt tuned according to Neidhardt.[239] Which of Neidhardt’s temperaments is not clear, since Altnickol is not more specific. This is the only source we have for the temperament, since the organ has been rebuilt several times during its history.[240]

3.1.6. A special case – The organ in the chapel of the Weißenfels Castle, 1673

One of the rare contemporary organ descriptions is the *Ausführliche Beschreibung deß neuen Orgelwercks auf der Augustus=Burg zu Weissenfels* by Johann Caspar Trost.[241] The organ was built by Christian Förner. It is the description of the temperament, in particular, that makes this book interesting, apart from the fact that Johann Sebastian Bach must have played the organ on several occasions[242] and

239 See p. 41.
240 Werner 2000. For an organ history of the St. Wenzel church see Greulich 2000: 21f.
241 Trost 1677.
242 Wolff 2000: 208. In 1729, at the latest, Bach was appointed “Capellmeister” to the court.

Fig. 39: The console in Naumburg. (Photo: Hermann Eule Orgelbau, Bautzen)

that the pedal compass goes up to f^1.[243] Of particular interest is the genesis of the Toccata in F (BWV 540), since it is very rare with such a pedal compass in the organ building traditions of Thuringia and Saxony in the first half of the eighteenth century.[244]

243 See also Adlung 1758: 360f, note "i".

244 Older organs, from the seventeenth century, had more often a compass to e^1 or f^1. See for example the Compenius family in Schneider 1937.

Table 29: Specification – St. Trinitatis, Castle, Weißenfels[a]

Oberwerck		Brust		Pedal	
Quintadehn	16	Gedackt	8	Sub=Baß	16
Principal	8	Quintadehn	8	Principal	8
Grob=Gedackt	8	Principal	4	Octav	4
Spiz=Flöt	8	Gedackt	4	Quinta	3
Octav	4	Quinta	3	Octav	2
Quinta	3	Octav	2	Mixtur	IV
Octav	2	Sesquialtera		Posaunen=Baß	16
Sexquialtera		Mixtum	III	Trompet	8
Mixtum	IV	Krumhorn	8	Cornet	2
Fagott	16	Schalmey	4		
Trompet	8				

a. Trost 1677: 19ff.

Tremulant

Trost gives us the length of the pipes in string lengths, to be used with a monochord.[245] These lengths give us a chromatic scale which would result in 2 “wolf-thirds” on $C^{\#}$ and $F^{\#}$ (both 427 cent), and 2 thirds on B^{b} and B that are closer to equal temperament (408 and 406 cent respectively). The rest of the thirds are pure or very close to pure (386/387 cent). Such a temperament hardly allows one to play in all keys.[246]

In addition, we also have a table with information about the beats of the fifths and the major thirds.[247] The information in this second table does not correspond with the first table, if it is to describe the temperament as Trost writes. The explanation lies most likely in Trost’s wording. In the first case he uses the word “tune” (*stimmen*), and in the second case “temper” (*temperiren*).[248] The first table is then very likely the scaling which is a modified Pythagorean scaling, and the second table is the temperament.[249]

245 Trost 1677: 38.

246 “Dieses Werck nun ist dermassen in der Stimmung temperiret, daß es in allen, so wol Alters hero, als jetziger neuen gesetzten Stücken, nach rechtem Vergnügen kan gebrauchet werden.” Trost 1677: 37.

247 Trost 1677: 39.

248 “Dem *Monochordo* nach ist das Werck auf diese folgende Masse gestimmet: …”, in Trost 1677: 37. “Nach den *corporibus* der Pfeiffen ist es folgender massen, wie das Tabelgen weiset, gar behutsam temperiret: …”, in Trost 1677: 39.

249 I am indebted to Munetaka Yokota, organ builder and researcher at the Organ Research Workshop of Göteborg University, for this information.

Table 30: Description of temperament (Weißenfels)

g		c	∧	B		d	∧	2
gs		cs	∧	H		ds	∧	3
a		d	∧	c		e	∧	2
b		ds	∨	cs		f	∨	3
h¹	beats against	e	∧	d	beats against	fs	∧	1
c¹		f	∧	ds		g	∧	2
cs¹		fs	∧	e		gs	∨	2
d¹		g	∨	f		a	∧	1
ds¹		gs	∨	fs		b	∨	3
e¹		a	∧	g		h	∧	1
f		B	∧	gs		c	∨	3
fs		H	∨	a		cs	∧	1

The signs ∧ and ∨ indicate how to tune the interval, and refer to the tools of an organ builder. ∧ indicates pressing together the top of the pipe, i.e., lowering the pitch. ∨ indicates the opposite.

Still, this temperament seems very odd, even if it is not uncommon for German conditions to have fifths wider than pure.[250] They are also to be found in the French so-called *Tempérament Ordinaire*.[251] But, according to the part of the table that describes the major thirds, the temperament also includes major thirds narrower than pure. Thus, Frank-Harald Greß assumes there are some misprints. Greß departs from the 8 fifths narrower than pure and the 4 fifths wider than pure, and synchronizes the beats of the fifths (except for the fifth $G^{\#}$–$D^{\#}$ which will be the result of the others and not tuned). Greß' reconstruction for the chromatic scale is presented in the table below.[252]

Table 31: Weißenfels – Greß

C	$C^{\#}$	D	E^{b}	E	F	$F^{\#}$	G	$G^{\#}$	A	B^{b}	B
0	97,1	201,9	296,9	397	502,5	599,3	696	793,4	898,6	1003,9	1094,2

Unfortunately this instrument cannot be considered in the present work. When the organ was ready in 1673, the chapel was still under construction. In 1680 the organ builder Christoph Dressler, from Leipzig cleaned and tuned the organ,[253] and when the chapel was inaugurated in 1682, the organ had to be retuned to be

250 According to Lindley it occurs in Andreas Werckmeister's instruction from 1698 (Lindley 2001: 256). It can already be found in the second temperament in Werckmeister's "Orgelprobe" (1681), and in Werckmeister IV and V (1691), which uses fifths wider than pure. See also above, chapter 2.1.3.

251 Padgham 1986: 79ff.

252 Letter to the author, dated February 20, 2001. Franz Josef Ratte also assumes that there are some misprints in the tables, and suggests two slightly different reconstructions (Ratte 1989, and 1994a).

253 Werner 1911: 127. Friedrich 2001: 32.

possible to play with the orchestra. Three stops were retuned again by Dressler: the Gedakt 8' and the Principal 4' in the Brust, and the Subbass 16' in the pedal.[254] It is not clear why the organ had to be retuned instead of letting the organist transpose the parts. Maybe the temperament did not permit transpositions? In 1691 Andreas Werckmeister, who obviously had been criticized by Förner, judged the temperament in Weißenfels incorrect, and wrote that it should have been changed long ago.[255] The tuning history of the organ makes it very difficult to say anything about the temperament when Bach was working for the court.

3.2. Discussion

According to the investigated written sources and instruments, we have found that relevant temperaments for Johann Sebastian Bach's organ works are extending from mean-tone and variants thereof, to different well-tempered tunings. There is no historical evidence that Bach played on an organ tuned to equal temperament. But still, the option should be considered in the analysis since several authors, contemporary with Bach, advocate equal temperament, and furthermore, it is the most common temperament of today against which all other temperaments usually are compared.

This survey has given us the prerequisites, when it comes to choosing temperaments for an analysis. There is also an agreement between the written sources and the instrument sources. Both Werckmeister's and Neidhardt's temperaments were applied in practice. Information about the use of Bendeler's temperaments is lacking. The great amount of different temperaments relevant for the context of Bach's organ works can partially be explained by the fact that Bach did not stay in just one place during his lifetime. Consequently he met the different styles of several regions such as the north, Thuringia, and Saxony. The following table (Table 32) is an overview of the temperaments discussed.

Many of these temperaments are similar and have much in common. The differences are sometimes negligible. When we do not have any information of their practical use (Bendeler), the temperaments are not considered in the analysis; when there is a great similarity between temperaments (Neidhardt 1724 and 1732), it suffices to compare one of them. When it comes to the temperaments of Werckmeister, the choice was made according to Werckmeister's own grading, where Werckmeister III is the first correct temperament, best suited for chromatic music.

254 Koschel 2000: 37.

255 "Hiervon mögen nun andere urtheilen, ob man die *Temperatur* nicht besser einrichten möge, wie ich denn vernommen, daß dieselbe *Temperatur* im Weißenfeldischen Orgel=wercke wegen ihrer Unrichtigkeit, schon längst von einem andern soll geändert seyn." Werckmeister 1691: 83.

Table 32: Discussed temperaments

No.	Temperament	C	C$^{\#}$	D	E^{b}	E	F	F$^{\#}$	G	G$^{\#}$	A	B^{b}	B	C
1	1/4-comma mean-tone	0	76,05	193,16	310,26	386,31	503,42	579,47	696,58	772,63	889,74	1006,84	1082,89	1200
2	Werckmeister III	0	90,22	192,18	294,13	390,22	498,04	588,27	696,09	792,18	888,27	996,09	1092,18	1200
3	Werckmeister IV	0	82,40	196,09	294,13	392,18	498,04	588,27	694,13	784,36	890,22	1003,91	1086,31	1200
4	Werckmeister V	0	96,09	203,91	300,00	396,09	503,91	600,00	701,96	792,18	900,00	1001,96	1098,04	1200
5	Werckmeister Via	0	96,88	199,50	294,57	395,17	501,98	599,08	701,95	792,62	888,29	1000,02	1031,79	1200
6	Werckmeister Vib	0	90,66	186,33	298,07	395,17	498,04	594,92	697,54	792,62	893,21	1000,02	1097,12	1200
7	Bendeler I	0	90,22	188,27	294,13	392,18	498,04	588,27	694,13	792,18	890,22	996,09	1094,13	1200
8	Bendeler II	0	90,22	188,27	294,13	392,18	498,04	596,09	694,13	792,18	890,22	996,09	1094,13	1200
9	Bendeler III	0	96,09	192,18	294,13	396,09	498,04	594,13	696,09	798,04	894,13	996,09	1092,18	1200
10	Dorf 1724	0	94,14	196,10	296,10	392,19	498,04	592,19	698,06	796,10	894,15	996,09	1092,20	1200
11	Kleine Stadt 1724	0	96,10	196,10	298,06	394,14	500,01	596,10	698,06	796,10	894,15	1000,02	1096,10	1200
12	Grosse Stadt 1724	0	96,10	196,10	298,06	394,14	498,04	596,10	698,06	796,10	894,15	998,06	1096,10	1200
13	Dorf 1732	0	94,14	198,06	296,10	390,24	498,04	592,35	700,01	794,14	894,15	998,06	1092,20	1200
14	Kleine Stadt 1732	0	94,14	196,10	296,10	392,19	498,04	592,19	698,06	796,10	894,15	996,09	1092,20	1200
15	Grosse Stadt 1732	0	96,10	196,10	298,06	394,14	500,01	596,10	698,06	796,10	894,15	1000,02	1096,10	1200
16	Hof 1732	0	100,01	200,01	300,01	400,01	500,01	600,02	700,01	800,02	900,01	1000,02	1100,02	1200
17	Edskes/Jacobi	0	84,11	193,16	299,51	386,31	503,42	579,47	696,58	783,38	889,74	998,78	1085,58	1200
18	Kelber/Jacobi	0	87,88	195,31	296,09	390,61	502,35	585,92	697,65	789,83	892,96	1000,40	1088,27	1200
19	Vogel/Scheidemann/Praetorius	0	86,80	193,16	294,15	391,69	503,42	584,85	696,58	783,38	895,11	1001,47	1088,27	1200
20	Silbermann/Sorge Lange	0	86,31	196,09	305,87	392,18	501,96	588,27	698,04	784,36	894,13	1003,91	1090,22	1200
21	Silbermann/Greß1	0	83,9	194,4	306,4	389,7	502,3	586,0	696,2	780,4	891,2	1003,6	1087,1	1200
22	Silbermann/Greß2	0	93,6	197,4	302,5	395,6	500,9	594,4	698,1	791,8	895,9	1001,2	1094,1	1200
23	Silbermann/Wegscheider1	0	84,55	193,89	303,34	391,41	501,25	585,65	697,66	782,42	892,01	1001,70	1088,20	1200
24	Silbermann/Wegscheider2	0	84,55	193,89	305,73	388,84	501,25	585,65	697,66	782,42	892,01	1004,10	1088,20	1200
25	Silbermann/Freiberg	0	90,22	196,09	298,05	394,14	500,00	590,23	698,05	790,23	896,09	1000,00	1092,18	1200
26	Weißenfels/Greß	0	97,1	201,9	296,9	397	502,5	599,3	696	793,4	898,6	1003,9	1094,2	1200

Some modern reconstructions are not historically relevant, and have therefore not been included in the analysis (e. g., temperaments by H. A. Kellner and J. Barnes).

A quick and easy way to compare temperaments is to use a graphical method. Ibo Ortgies, Bremen/Göteborg, has been occupied with tuning and temperament since the 1980s and has developed a graphical method that makes it possible to see when two, or more, temperaments are related. In that case it suffices to analyze one of them. For the present work it is primarily the many versions of temperaments related to Gottfried Silbermann that need a comparison.

The values for the major and minor thirds are used, indicating the quality of the thirds. Good major thirds are located high up to the left in the graph (close to the pure major third of 386 cent), and good minor thirds are located up to the right (close to the pure minor third of 316 cents). The bad thirds are down to the right. When the temperaments 20–25 (see Table 32 above) are compared (see Fig. 40 below), they all show the same basic structure: good major and minor thirds, and, wolf-thirds. The difference lies in the quality of the good thirds and in the size of the wolf. The description of Silbermann's tuning by Sorge was chosen since it is not one of the "extremes" compared to the other six definitions and since it is a historical description by a contemporary.

Examples from Bach's organ works will be used in the next chapter to compare the selected temperaments listed below. The list of eight, adequately covers the different types of temperaments, from mean-tone over well-tempered tunings to equal temperament, and are historically relevant for Bach's organ music. The temperaments will be referred to by the abbreviation in the right-hand column.

Table 33: Selected temperaments

	Temperaments	Abbreviation
1	1/4 syntonic comma mean-tone	QUARTER
2	Vogel/Scheidemann/Praetorius	VOSCH
3	Silbermann/Sorge/Lange (1748) – 1/6 Pythagorean comma mean-tone	SILB
4	Werckmeister III (1681/1691)	WERCK
5	Neidhardt "Für ein Dorf" (1732)	DORF
6	Neidhardt "Für eine kleine Stadt" (1732)	KLSTADT
7	Neidhardt "Für eine grosse Stadt" (1732)	GRSTADT
8	Neidhardt "Für den Hof" (1724/1732, Equal temperament)	EQ

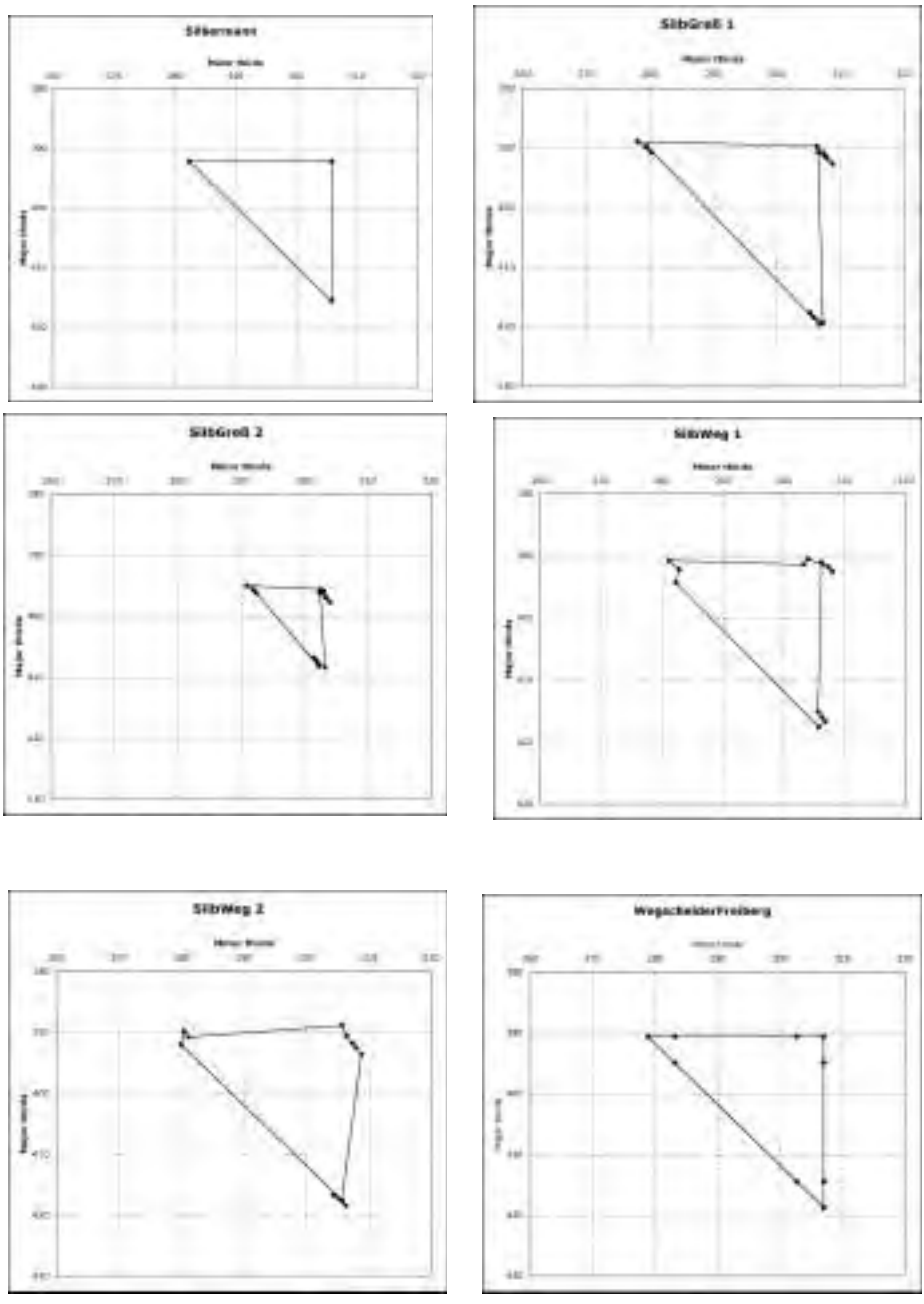


Fig. 40: Comparison of “Silbermann temperaments”

4. A New Methodology

The instruments in the previous chapter are from very different traditions and their sound is quite different. The voicing and the harmonic content of the pipes are important factors for the overall sound, as well as for the consonances and dissonances or the effect of the temperament. Other important factors are the choice of registration and the composition of the mixtures. In the Thuringian tradition, the mixtures often had a major third (Altenburg), or one finds cases where there is a separate third, which can be used with the mixture (Abbenrode). Within the frame of the present work these factors cannot be addressed. They demand a thorough study of their own. The role of voicing for example could be investigated by comparing one temperament and a single composition in different organ building traditions.

4.1. Description of the methodology

One of the problems of analyzing a musical context has been the lack of an adequate methodology. Usually tables of cents and beats have been used, which are quite far from a musical context. The context can greatly affect the experience of consonance and dissonance. It is also not possible to take the pitch in the musical setting into account if only discussing the size of the intervals in cents. In this category also belong the questions about musical texture, figurations and structural notes, and embellishments. They affect the experience of dissonance and consonance since they affect the sound through the musical texture they create. Further, the problem of re-tuning a historical instrument has been a practical obstacle.

There are basically two approaches that can be used with digital technology: sampling orsynthesis.[256] Sampling can easily be done with the great variety of samplers available on the market. Especially in the field of software samplers, the

256 For a description and discussion on sampling and synthesis see Risset and Wessel 1999.

development has been rapid in the last few years. The new methodology developed for the present work is based on sampling and MIDI. Digital technology has been useful, especially with regard to the problem of retuning. With only the available resources, synthesis was not an option.

The initial question, "How might one compare different temperaments in the same piece of music with a historical organ sound?" initiated the development of the methodology. The use of a historical instrument is crucial since the harmonic content of the tones are acoustically important for our experience of dissonance and consonance.[257] The following figure illustrates the methodology:

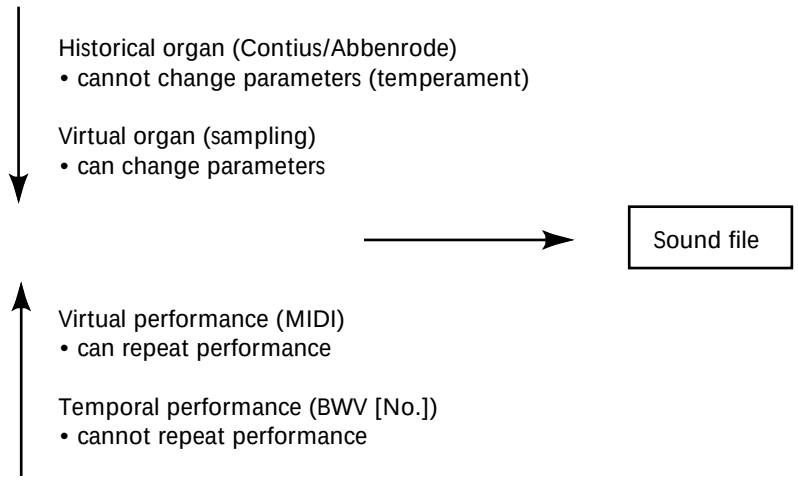


Fig. 41: Graphical representation of the methodology

There are basically two main parts: the historical instrument, and, the performance. No parameters can be changed in an existing historical instrument. Since the historical instrument must be handled with care, it creates the need to have an instrument that can be re-tuned. This is possible with a sampled instrument, a virtual organ, where all parameters can be controlled and changed when necessary. The other part is the performance. A performance is temporal, and interacting with the instrument. It cannot be repeated, which is a problem when trying to compare a parameter such as the temperament. Since the performance is not under investigation in the present work, it should be strictly controlled in the methodology. Creating a digital performance, a MIDI file, which also can be described as an in-time frozen performance, provides a means to control the interpretation. The digital performance can naturally be repeated, which was desirable

257 Sundberg 1989: 85.

for the present work. A performance prepared with sequencer software will, unfortunately, not be as dynamic when it comes to rhythm as a live performance. To make the music examples more authentic in a musical sense, a software called *Director Musices*, developed at the Department of Speech, Music and Hearing at the Royal Institute of Technology, Stockholm, was used. The software is the result of the extensive research on musical performance conducted at the department.[258] The software allows one to govern several factors making the MIDI-file more musical. Thus, it can be said that the music examples are the result of an interpretation made with the help of *Director Musices*. For the present work, the temperament aspect was integrated into the software by using pitch bend command in MIDI, which enables one to change temperament by simply creating a table of the deviation in cents from equal temperament of the chromatic scale. "Re-tuning" is thus made easy. Outlined in a linear way the initial process can be illustrated as follows:

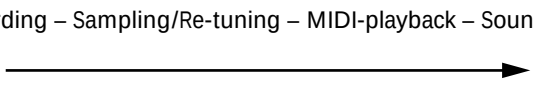


Fig. 42: Linear representation of the methodology

The methodology was developed and tested at the Lindblad studio at the School of Music and Musicology, Göteborg University.[259] It was first tested with the "Bjurum organ", built by Nicolaus Manderscheidt in Nürnberg 1643–51, and restored by organ builder Mads Kjersgaard from 1972 to 1976. The instrument is currently on loan to the School of Music and Musicology, Göteborg University. The organ is tuned to 1/4-comma mean-tone, with subsemitones to give $D^{\#}$ and $E^{\flat}$. The organ is not what we would consider a Bach organ. It was chosen for the test stage in the development of the methodology because it is an historical instrument to which we had free and easy access. The methodology was discussed and evaluated in discussions with sound engineers, acousticians, organ builders, and organists. The same procedure was used in Abbenrode.

The first step involved recording short examples of every tone in every stop. This was done with a DAT recorder. The microphones, two AGK C414 with a microphone amplifier (*SMF-5* by Marenius), were placed (x-y-stereo) rather close

258 Winner of the Fourth International Music Software Competition (see *Computer Music Journal* vol. 24, no. 3, 2000). <http://www.speech.kth.se/music/music_research_topics.html> I am indebted to Anders Friberg and Roberto Bresin at the department of Speech, Music, and Hearing at the Royal Institute of Technology, Stockholm, for their kind help and assistance.

259 The work was carried out in the Lindblad studio at the School of Music and Musicology, Göteborg University. I am indebted to Per-Anders Nilsson, director of the ARC/Lindblad studio, for his invaluable help in developing the methodology. I am also indebted to Björn Asplind for his advice and help in preparing the recording of the organ in Abbenrode.

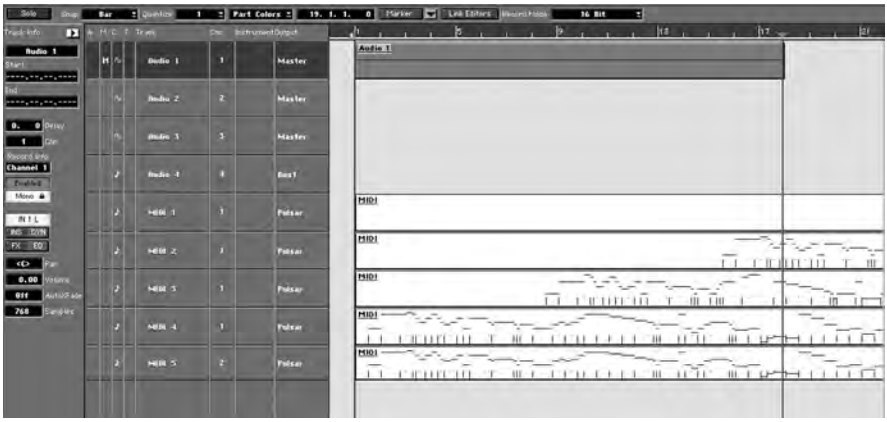


Fig. 43: The five MIDI-tracks down to the right contain the Canzona (BWV 588). Every track represents a voice. The track is assigned a MIDI-channel, which corresponds to sampled stops in the sampler. The manual stops are on channel 1 and the pedal on channel 2. A coupler is simulated by duplicating the pedal voice and playing it on channel 1 (the manual stops). Hence the "extra" voice in the Canzona. The upper track is the recording of the MIDI tracks played trough the sampler

(0.5–1 m) to the organ to eliminate the acoustics of the room. It is impossible to include the acoustics of the room in the sampling since it will interfere with the looping of the tone. If one likes, one can digitally add the impression of a room with reverb to a playback performance. One could even adjust the reverb to match the actual room in which the sampled instrument is housed, but that would demand a measuring of the characteristics of the room.

The recorded sounds were transferred to a computer and imported into a software sampler (or a hardware sampler or a sample-card). A loop was added to the sample to be able to play sustained notes. Keygroups of a keyboard were defined and assigned a sample (a sound file). This, in effect, created a digital version of the recorded instrument, which is playable from a synthesizer, or any instrument with a MIDI interface. If one uses 2–3 samples per octave, which is sufficient from an acoustical point of view, one must have the voices in the MIDI file in separate tracks to be able to send the intonation information via the pitch-bend command. Addressing the tracks in the playback to the same MIDI channel, then, achieves the effect of playing the voices together as a chord. If two notes are in the same track they will both be adjusted according to the pitch-bend data.

All stops necessary to create a principal plenum in the organ in Abbenrode were recorded (Manual: 8, 8, 4, 3, 2, 1 $^{3}/_{5}$, Mixture; Pedal: 16, 16, 8). A coupler between the manual and the pedal was simulated through playing the pedal line both with the manual registration and the pedal registration. The manual stops were played on MIDI channel 1 and the pedal stops on channel 2. Since several pipes in the organ in Abbenrode did not speak properly, a sample per key could

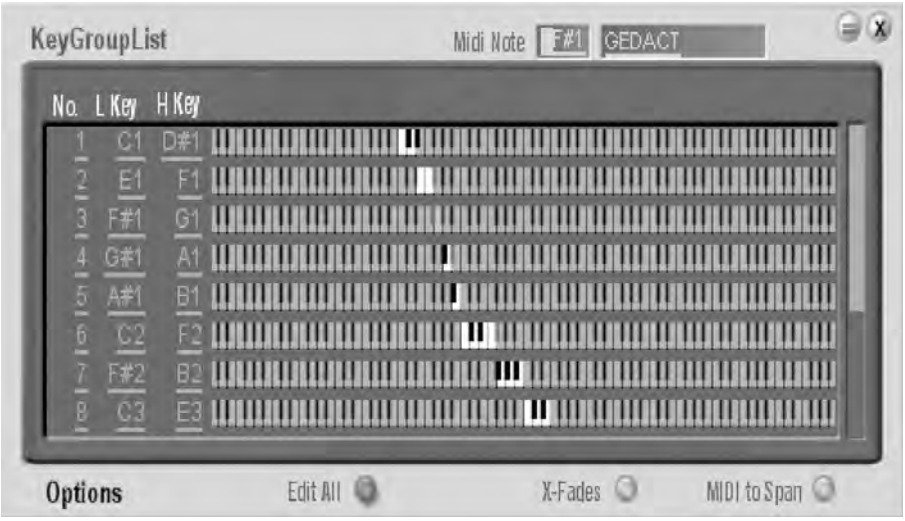


Fig. 44: Samples assigned to keys form keygroups

not be used in the present work. The mixture caused further problems. Since it consists of several pipes (4) for every note, the stop could not be sampled. The stop was recorded, but deviations between the pipes, although small, made it impossible to loop the samples. Consequently the decision was made to only use a basic registration for the sound files, consisting of the Gedact 8' and the Principal 4' in the manual and the Subbaß 16' and the Octavbaß 8' in the pedal. The Principal is important in adding overtones to the sound, since a stopped pipe has very weak even harmonics. Using one single registration for all examples also helps to focus on the temperament.

The pitch of the samples is then measured and the samples are tuned. The accuracy of the tuning is 1 cent. The precision decreases towards the bass due to the longer wavelength. The precision is close to what is usually said to be the capacity of the human ear, which is around 5 cents for melodic intervals and even less for intervals played together.[260] The harmonic content of the tones is an important factor, since it is the interaction of the harmonics that cause the beats. The ability to hear small deviations is naturally also dependent on an individual's training and experience. An organ builder is most likely more capable of detecting small deviations than an average organist. Consequently it is difficult to argue for an analysis of differences between temperaments if they amount to only 1–3 cents, since the precision of the results would be too low.

260 Sundberg 1989: 106. See also Hall 1980: 439f.

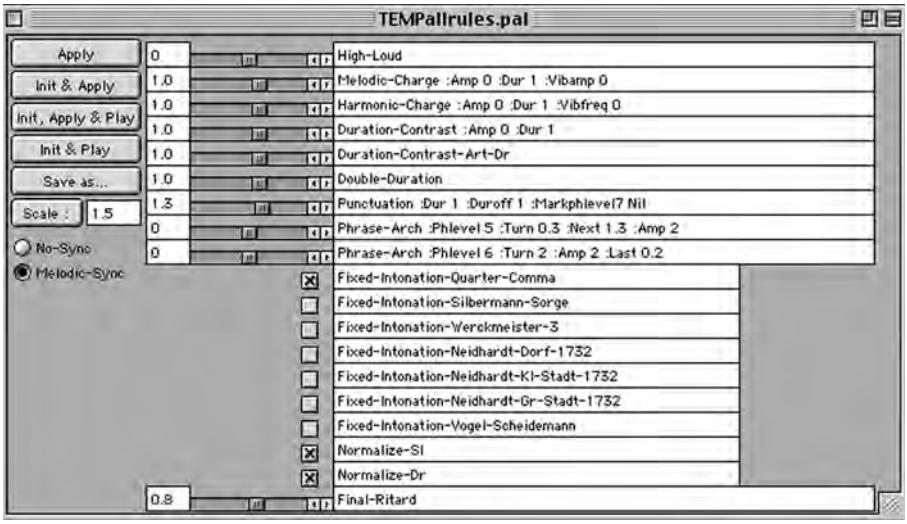


Fig. 45: *Director Musices*. Under the upper sliders are the settings for choosing an intonation, shown here, with 1/4 comma selected

Using a MIDI-file for playback has the advantage of having repeatable performances, or parts of performances, which are identical. Today several types of commercial notation software have incorporated the possibility to generate rhythmically and dynamically flexible performances – musical performances. As mentioned above, *Director Musices*, developed at the Department of Speech, Music and Hearing at the Royal Institute of Technology in Stockholm was chosen. With these new aids one can achieve musically acceptable MIDI performances. For the present work the possibility to include a temperament (fixed intonation) in a MIDI file was added to the software. A new MIDI file is generated for every temperament one wishes to analyze.

The final stage is to play back the MIDI file containing the performance parameters and intonation and record this in a sound file. The sound files form, together with tables of cent values, an important part of the present work.

The software and hardware used to edit and sample the organ was the following: *PEAK 2.58* (BIAS), *Spektral 21.11* (Magnus Eldénius/Lindblad studio) *Pulsar 3.01* and the sampler *STS 4000* (Creamware), and *Cubase VST/32* 5.01 (Steinberg) was used to play back the MIDI-files prepared with *Director Musices 2.1* and to record the sound files. The work was carried out on a Macintosh PPC G4 with *Mac OS 9.1* (Apple), with the *Pulsar II* soundcard (Creamware). A *Yamaha 01v* digital mixer and *Genelec 1031a* speakers were used for monitoring. No filters were used during the process.

4.2. Critical discussion

During the work the methodology was continuously evaluated, and some possible improvements will be discussed here. Naturally the frame of the present work also imposed some limitations, both economical and practical. On the “instrument side” (see Fig. 41) improvements could be done as follows. The recording situation can be optimized with regard to the condition of the instrument being recorded, and consequently raising the quality of the recording itself. An instrument well-tuned, and with a well-regulated wind system would give better conditions. The organ in Abbenrode has a very sensitive wind system, and this caused problems later when trying to find good loops in the samples. Some of the pipes were also not speaking properly and could therefore not be sampled. The occasion of the recording (November 2000), for example, was chosen in order to avoid problems caused by humidity during the summer. Naturally a longer visit at the organ would provide better conditions for the recording, since it would offer the opportunity to record and verify the quality, and if necessary make a new recording. A normal problem by any recording is disturbing noise from the surroundings, such as traffic, etc.

With regard to the performance, some parameters could be improved. The quality of the MIDI-performance can naturally always be discussed, since some aspects of a performance will be a question of taste. The goal for the present work was to control as many parameters as possible, and focus on only one – the temperament. When discussing the implications of temperament for the interpretation, a need for changing the interpretation may arise. Changing a MIDI-file is not difficult, but doing it directly, intuitively in a musical way, is not possible. Having a software as an interface between the musician and the performance cannot be regarded as optimal. The interaction between the instrument (temperament) and the interpreter is lost. This can be solved by playing the sampled instrument from a keyboard with a MIDI interface. My personal experience is, however, that the physical reaction from a digital keyboard is disturbing, since there is not a mechanical action interacting with the player in a manner resembling a true organ. The possibility of affecting the sound of the instrument with one’s touch and articulation is also lost.

5. The Music

5.1. Consonance and dissonance

The words “consonance” and “dissonance” are often used when discussing harmonic structures in a musical setting. William A. Sethares describes, quoting James Tenney, five different concepts in the history of consonance and dissonance: melodic, polyphonic, contrapuntal, functional, and, sensory.[261] Different explanations have been offered to the question of what causes a sensation of consonance or dissonance: numerological, psychological, cultural, and, physical. The model using beats and roughness as the explanation is the model that can be readily measured, and thus used to calculate the factors that result in the experience of consonance and dissonance.[262] Dissonance occurs when the difference in frequency of two tones is less than the critical bandwidth. The critical bandwidth varies with the frequencies and is approximately 100 Hz up to 500 Hz, after which it increases. Above 500 Hz the critical bandwidth is approximately a minor third.[263] Beats, and through them our experience of roughness, occur when the harmonics of two tones interact.[264] One can say that temperament is an acoustical phenomenon that can be explained with acoustics and mathematics, or, it is a mathematical problem that can be heard. The phenomenon of beats is used when tuning the organ. When the beats slow down and finally stop, the pipes are in tune. Consequently, a temperament is especially evident in the harmonic structure of music, when two or more notes are played together. A temperament can also be observed in melody, especially when it comes to mean-tone temperaments with their greater difference between the semitones. We will, in the present work, focus mainly on the harmonic structure.

261 Sethares 1998: 73ff.
262 Sethares 1998: 79ff.
263 Sundberg 1989: 81. See also Rasch and Plomp 1999: 107.
264 Roughness is perceived when the frequency of the beats is higher than about 20Hz. Rasch and Plomp 1999: 103.

Historically the question of consonance and dissonance has been important. Johann Gottfried Walther writes in his *Praecepta der musicalischen Composition* from 1708, quoting Wolffgang Caspar Printz:[265]

> …ihr Gebrauch und Nutz ist nicht gering in der *Composition*, und zwar kann man vermittelst derselben 1) von einem *Intervallo* zum andern desto bequehmer, und ohne Sprünge kommen. 2) kann man eine *Harmonie*, wenn es neml. der *Text* erfordert, durch sie *exasperiren*, und 3) kann man eine *Composition* durch sie verändern und ausschmükken. … Die *Dissonantien* seyn die Nacht, die *Consonantien* der Tag; das Licht würde uns nimmermehr so angenehm seyn, wenn es immer Tag und niemahls Nacht wäre.[266]

> …their use and usefulness [of dissonances and consonances] is considerable in music. Namely, with them you can 1) go easier from one interval to another, avoiding leaps. 2) When a text asks for it, a harmony can be flavored with them, and 3) one can change and elaborate a composition with them. … The dissonances are the night, the consonances the day. The light would not be so pleasing to us if it were day all the time and never night.

Here Walther refers to the vast literature on counterpoint, which, in its essence, deals with the treatment of dissonance and consonance. The definition of the two differs, of course, in the history of music theory.

Thomas Christensen has noted that in his teaching, Johann Sebastian Bach emphasized the harmonic structure in music. Bach started with the harmonization of a figured bass and chorales.[267] Also, Lorenz Christoph Mizler writes that it is the combination of chords or keys that are of importance for the expression of affect. Consequently, focusing on and analyzing the temperaments' effect is of historic relevance for Bach's organ music.[268]

Having a date of composition for a certain piece would be helpful for the present work since we can assume that mean-tone and variants thereof are likely to be more common in Bach's youth, whereas different well-tempered tunings became more common during the first half of the eighteenth century. But a general problem when working with the organ music of Bach is that the chronology is very unreliable, especially for his early works. In some cases one can place a composition in a certain period (*Clavier-Übung III*), but in many cases this is not possible. In other cases Bach worked or re-worked music (*Orgelbüchlein*).[269] Composing in a period of transition with regard to temperament further means that the different models of temperament existed side by side. Consequently, an open approach is needed when addressing the question of temperament, not excluding a temperament too early in the comparison.

The evaluation of temperament should always be done in relation to music, as already mentioned. It is not relevant to discuss temperament as an indepen-

265 Walther 1708: 140.
266 Walther 1708, s. 140.
267 Christensen 1998: 32.
268 See p. 53. Mizler 1738, i/6, footnote 2: 2f. C.f. ibid. p. 21, 26 and Mizler 1746 iii/2: 314.
269 Wolff 2000: 127ff.

dent musical object since it is in the musical context it finds its function. On the other hand it is possible to approach the question of temperament as a mathematical problem, and discuss it purely from that point of view.

Finally, it is important to be aware of the different meanings of the words "consonance" and "dissonance." For example, using the terminology from music theory one can talk about a dissonance that resolves into a consonance. This "consonance" can actually be dissonant due to the temperament. If we consider a 4–3 suspension resolving into a third, major or minor, in an unequal temperament, the "consonance" can be rather dissonant due to the poor intonation imposed by a well-tempered temperament (e.g. $f^{\#1}$ and b^{1}, with b^{1} resolving into $a^{\#1}$). It is mainly this aspect the present work deals with.

5.2. Music Examples

As mentioned before, the Baroque was a period of transition. When it comes to temperament a gradual shift from mean-tone to equal temperament occurred – not equally fast in all instrument groups. Instruments and voices with free intonation can strive for just intonation, while keyboard instruments are forced to make a compromise – a temperament. The organ was perhaps the most conservative, as we know from the history of temperament in organs in, for example, Britain. Equal temperament was not generally used until the second half of the nineteenth century.[270] This transition can serve as a point of departure for the comparison in the present work providing the order of the sound files. We will start with 1/4-comma mean-tone and modifications thereof, and continue with well-tempered tunings, finishing with equal temperament.

5.2.1. O Lamm Gottes, unschuldig (BWV 656)

This chorale (see Fig. 46) belongs to the group of chorales usually referred to as "The Eighteen" (BWV 651–668).[271] They were revised in Leipzig (1723–50), but all chorales have an earlier version, probably from the Weimar period (1708–17). The existence of an $E^{\#}$ as a major third to $C^{\#}$ (m. 37), and the frequent $D^{\#}$ (already in m. 2), excludes 1/4-comma mean-tone as temperament for the chorale. Normally 1/4-comma mean-tone has $E^{\flat}$, which is not usable as $D^{\#}$, and $E^{\#}$ is not enharmonically the same as F. The only way to overcome this is by introducing subsemitones. The question then becomes, would some of the modified variants of mean-tone be acceptable? The key is the same in both versions of the chorale,

270 MacKenzie 1979: 59 gives the year 1854. See also Padgham 1986: 7, 58. It was probably some kind of 1/5-comma mean-tone that was widely used in England at the time.
271 Williams 1980b: 124ff.

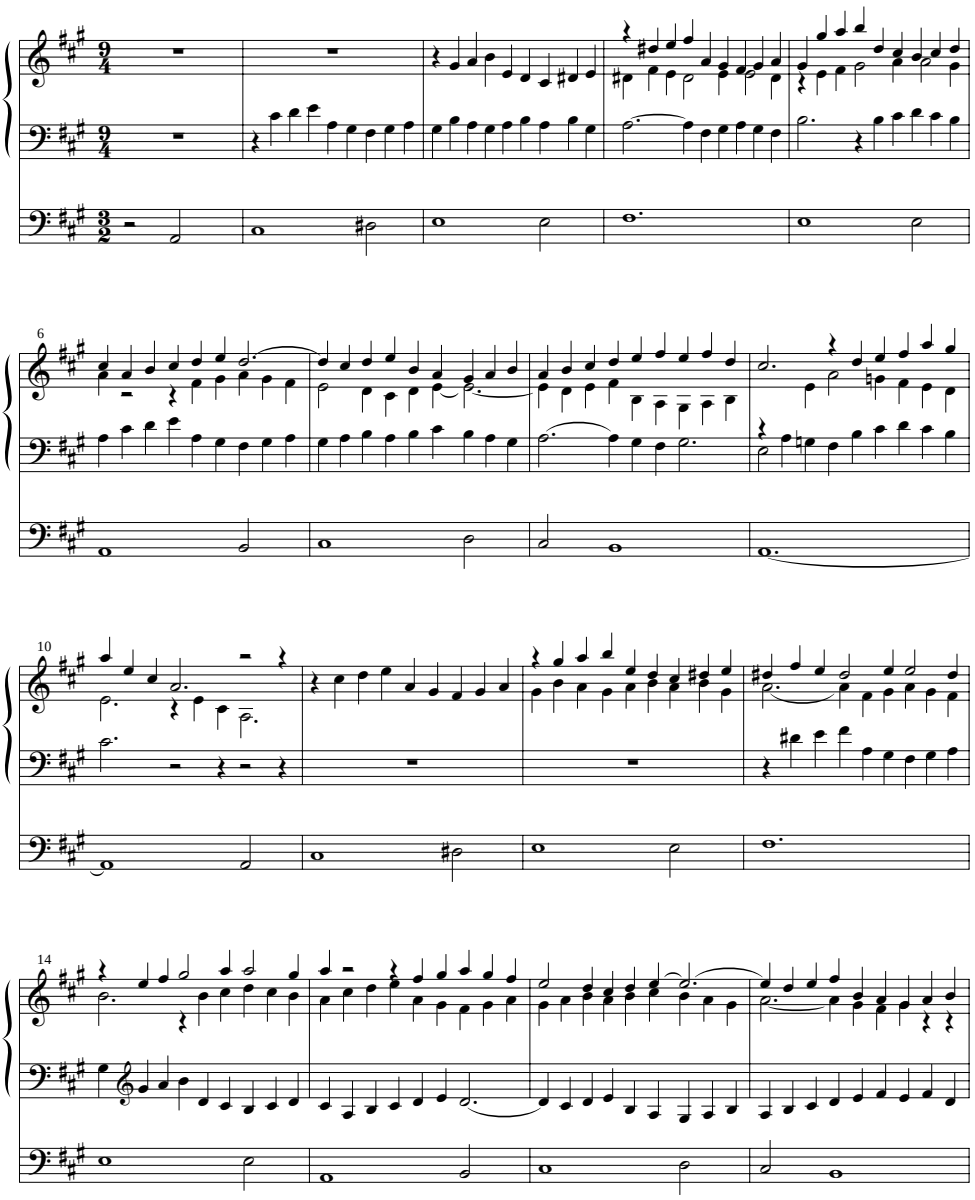
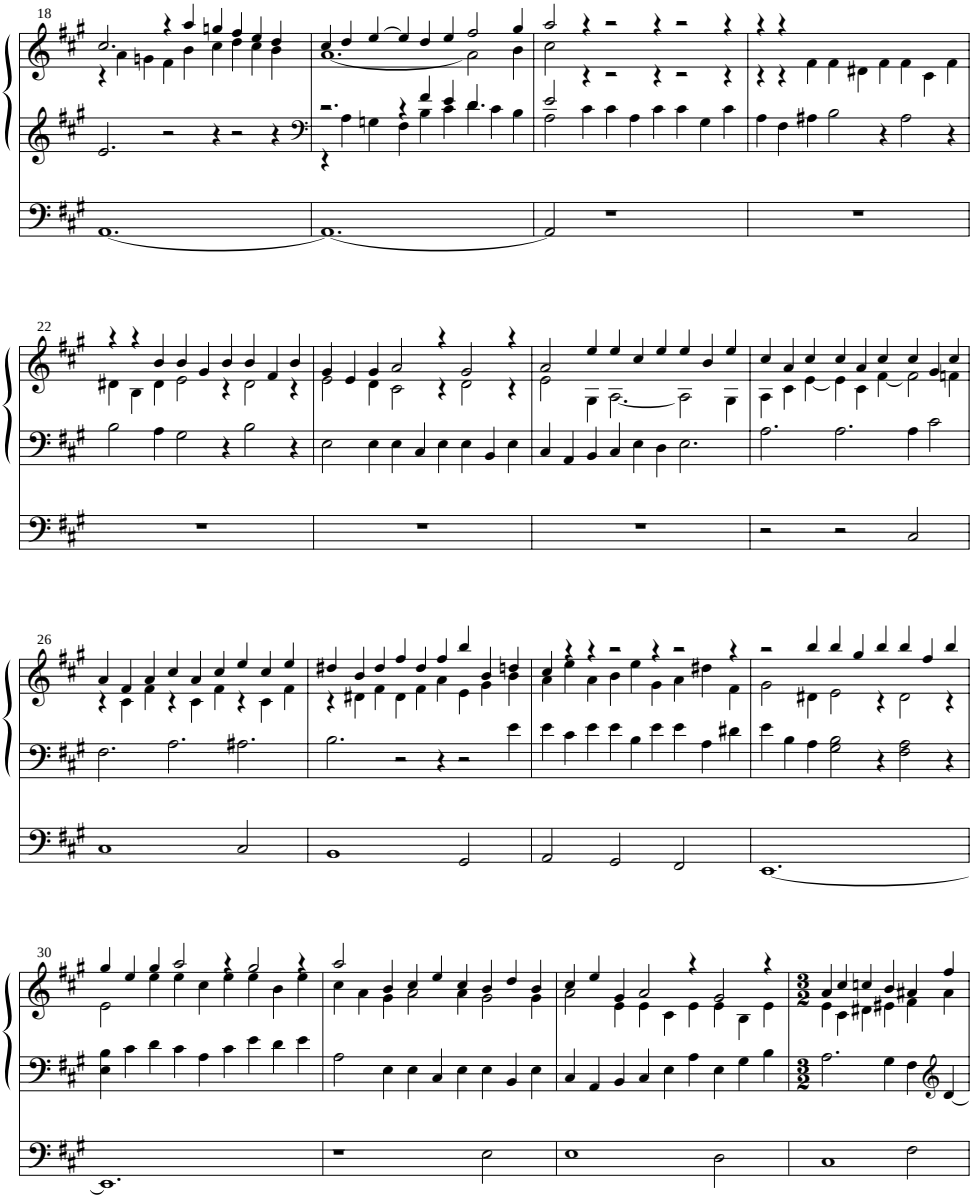


Fig. 46: *O Lamm Gottes, unschuldig*, 3 versus (BWV 656)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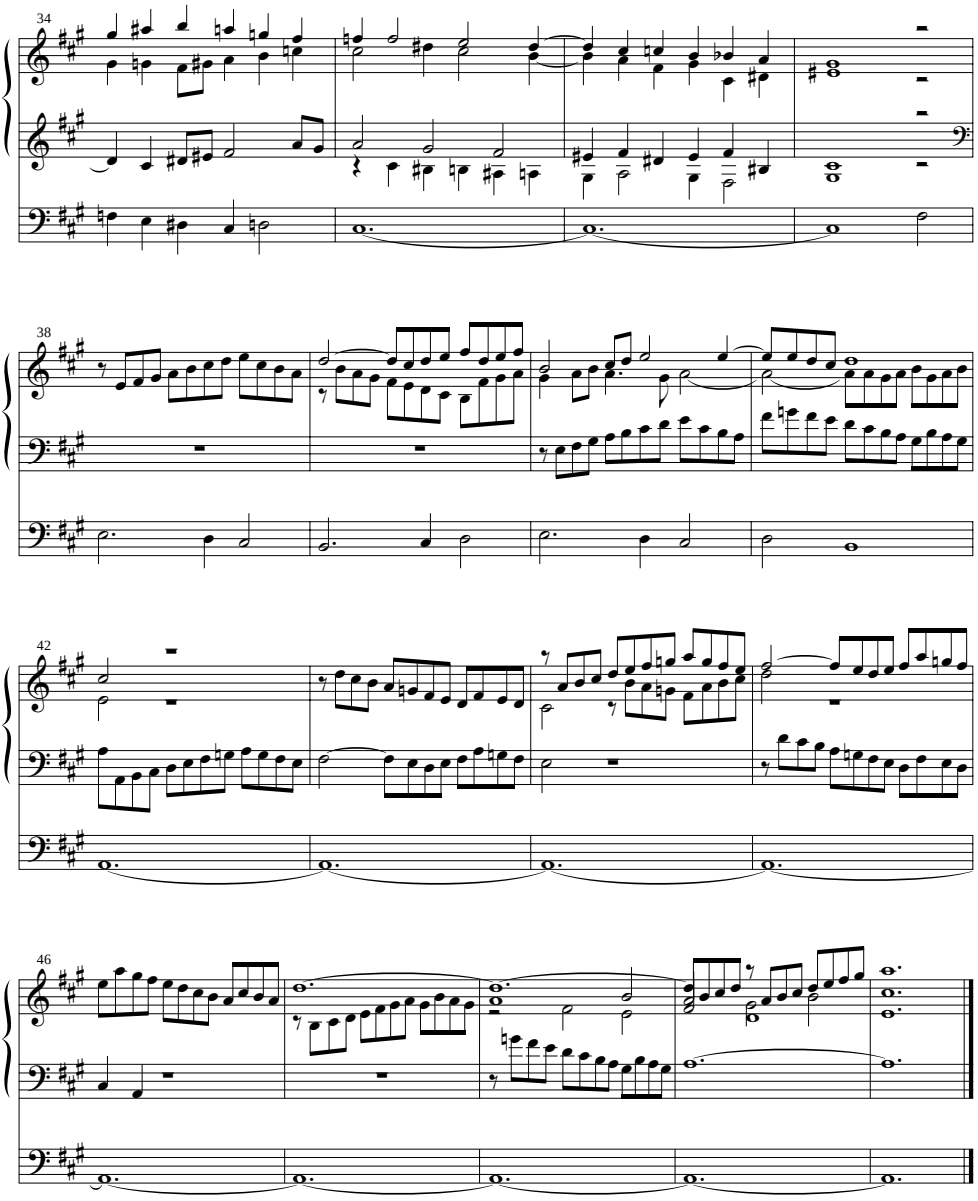
34
38
42
46

which indicates that the temperament in question in Weimar and Leipzig could have been quite similar, allowing E♯ as a major third to C♯.

The first 20 bars illustrate the different intonation of the D♯. One can hear the context as a diminished triad on D♯ (D♯–F♯–A) with a dominant function leading to E. The D♯ is then functioning as a leading note to E. For the context the step from C♯ to D♯ is also important. QUARTER and SILB have the largest deviation, while VOSCH is rather close to the other well-tempered temperaments. It is expected that the 1/4-comma mean-tone temperament has the poorest intonation with regard to the notated D♯ since it actually is an E♭. It is also interesting to note that the modification of a mean-tone temperament immediately has consequences for the intonation as can be seen in VOSCH. The following table illustrates the size of the steps between C♯–D♯ and D♯–E:

Table 34: Size of C♯–D♯ and D♯–E

Temperament	C♯–D♯–E
QUARTER	234–76
VOSCH	208–97
SILB	220–86
WERCK	204–96
DORF	202–94
KLSTADT	202–96
GRSTADT	202–96
EQ	200–100

[SOUND EXAMPLES for VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 1–20]

It is easier to hear the difference between QUARTER, VOSCH, SILB, and the DORF. With the other temperaments it becomes more difficult to hear a difference in this single case.

In mm. 20–32 we can also compare the temperaments with regard to A♯.

[SOUND EXAMPLES for VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 20–32]

In this context the A♯ is the major third on the F♯ (and the D♯ is the major third on B). Again mean-tone stands out as the temperament with the poorest intonation with regard to remote keys – keys with notes exceeding the mean-tone tonal content. Again this is expected, since the A♯ is actually a B♭. It also comes clear that the well-tempered temperaments are more flexible in this aspect, but they also have a different priority between the major thirds on F♯ and B respectively. WERCK, for example, yields a better major third on B than on F♯, following a natural grading according to the circle of fifths where F♯ is further away from C than B.

Table 35: Size of F♯–A♯ and B–D♯

Temperament	F♯–A♯	B–D♯
QUARTER	427	427
VOSCH	417	406
SILB	416	416
WERCK	408	402
DORF	406	404
KLSTADT	404	402
GRSTADT	402	402
EQ	400	400

In a musical setting like this it is quite easy to focus on a single note or interval. The texture does not hide the notes and intervals. When it comes to the next example (mm. 33–37), the situation is quite different. In this context it is literally impossible to hear the individual quality of the chords. The final chord, though, stands out, more or less depending on the temperament.

[SOUND EXAMPLES for VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 33–37]

The major third C♯–E♯, together with F♯–A♯ and G♯–B♯, are usually the major thirds with the poorest intonation in a temperament, as are all temperaments in this analysis, except EQ. The C♯ major chord discussed already in the introduction is very prominent in this passage due to the long note value. Bach clearly did not try to hide the chord, or to make it short to avoid a too dissonant appearance. It is only EQ that makes the chord relatively neutral, and that is highly related to the quality of the thirds in the preceding musical context. C♯ major is not more dissonant than C major in EQ. If the temperament's effect on the dissonance were believed to be of musical value, a well-tempered temperament would give the passage, and the text, a strong coloration.

Table 36: Size of C♯–E♯

Temperament	C♯–E♯
QUARTER	427
VOSCH	417
SILB	416
WERCK	408
DORF	404
KLSTADT	404
GRSTADT	402
EQ	400

The mean-tone family's tonal content is a strong factor when discussing a temperament's suitability for a repertoire. This criterion has usually been used to dis-

cuss the question about suitability. However, without a sounding example it is difficult to judge the temperaments that lie between 1/4-comma mean-tone and the well-tempered temperaments like WERCK and DORF. The border between acceptable and unacceptable dissonances is not always clear, and sometimes only a matter of taste. In the example above, the C♯ major clearly crosses the border for many of the temperaments, while the following example is not quite as definite.

5.2.2. Canzona (BWV 588)

A fragment of the Canzona (see Fig. 47) appears in a source that can be dated prior to 1714.[272] This could be the early Weimar period, or even earlier (Arnstadt, Mühlhausen). As mentioned, it is more likely that mean-tone temperaments are better suited for Johann Sebastian Bach's earlier works. The chromatic passage in mm. 10–13 (17–20, 24–27) is something that is very obvious in a mean-tone temperament due to the temperament's different sizes of semitones.

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 1–28]

Here we see that the three regular temperaments (QUARTER, SILB, EQ) have a regular definition of the semitones. Especially in QUARTER and SILB it is easier to hear differences between the semitones. The other temperaments involve more than two tempered fifths, and consequently the semitones are of more than two sizes.

Table 37: Size of semitones in A–G♯–G–F♯–F–E

Temperament	A–G♯	G♯–G	G–F♯	F♯–F	F–E
QUARTER	117	76	117	76	117
VOSCH	112	87	112	81	112
SILB	110	86	110	86	110
WERCK	96	96	108	90	108
DORF	100	94	108	94	108
KLSTADT	98	98	102	96	108
GRSTADT	98	98	102	98	104
EQ	100	100	100	100	100

A similar pattern can be seen in the transposed passage D–C♯–C–B–B♭–A. The steps are of different sizes, and, for example, in QUARTER the same sizes recur. In the well-tempered tunings other sizes appear.

272 Williams 1980a: 272.

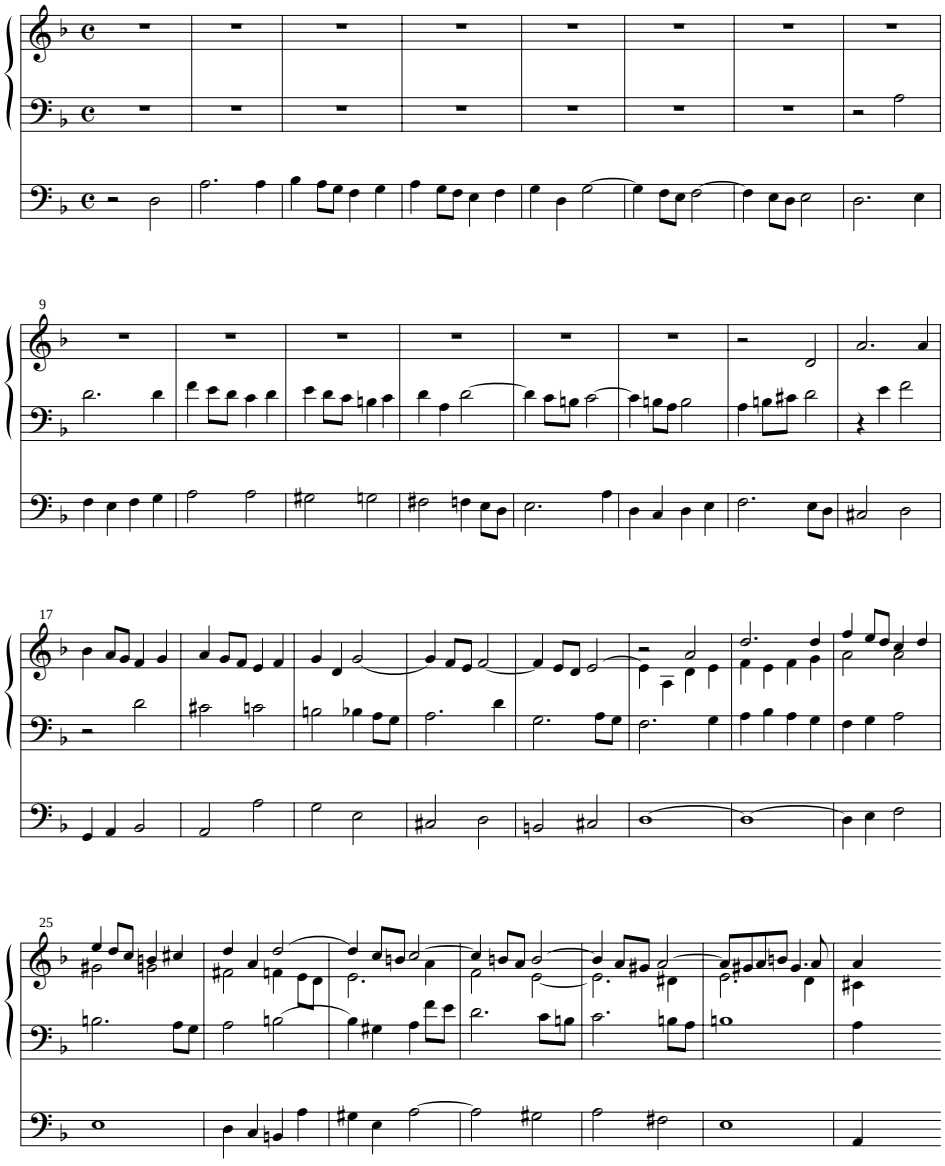

Fig. 47: Canzona, mm. 1–31 (BWV 588)

Table 38: Size of semitones in D–C♯–C–B–B♭–A

Temperament	D–C♯	C♯–C	C–B	B–B♭	B♭–A
QUARTER	117	76	117	76	117
VOSCH	106	87	112	87	106
SILB	110	86	110	86	110
WERCK	102	90	108	96	108
DORF	104	94	108	94	104
KLSTADT	100	96	104	96	106
GRSTADT	100	96	104	98	104
EQ	100	100	100	100	100

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 1–2]

Except for the semitones, it is also possible to compare the different sizes of the initial fifth (m. 1–2). The 1/4 Pythagorean comma tempered fifth in WERCK and DORF is the most tempered one, and can here be compared to the pure fifth in VOSCH.

Table 39: Size of D–A

Temperament	D–A
QUARTER	697
VOSCH	702
SILB	698
WERCK	696
DORF	696
KLSTADT	698
GRSTADT	698
EQ	700

Finally the Canzona illustrates what can perhaps be used as a marker for the border between mean-tone and well-tempered temperaments. In mm. 29–30 a diminished chord and a dominant seventh chord, D♯dim and E7 respectively, appear.

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 29–30]

In the D♯dim chord the tonal content of mean-tone is exceeded with D♯ which naturally makes it very dissonant, while in the E7 the tonal content is not exceeded. Still the E7 is quite dissonant. The reason for the very dissonant appearance of the mean-tone temperaments is the augmented fourth (or diminished fifth depending on the inversion) occurring between the third and the seventh. It is up to 20–21 cents wide (or narrow) when the tonal content is exceeded.

Table 40: Size of D–G♯

Temperament	D–G♯
QUARTER	579
VOSCH	590
SILB	588
WERCK	600
DORF	596
KLSTADT	600
GRSTADT	600
EQ	600

Looking at this from a standpoint of music history, a gradual shift from from modality to major-minor tonality is taking place around 1700. An acceptable dominant seventh chord is needed in the major-minor tonality, and provided in temperaments such as those of Werckmeister. We are not saying, of course, that Andreas Werckmeister established the major-minor tonality.

These two examples have primarily served as examples of how the music can be used to analyze a temperament's suitability for a certain repertoire. The following examples will be used to discuss the more constructive issue, whether a temperament plays a role for the interpretation and performance of the music.

5.2.3. Prelude in B Minor (BWV 544)

According to the watermark on the paper, the manuscript can be dated to 1727.[273] It is also one of the few compositions for the organ that exists as manuscript in the hand of Johann Sebastian Bach.[274] In this example (see Fig. 48) I suggest the opposite listening order, starting from EQ going to QUARTER. This will make it easier to follow the line of reasoning.

[SOUND EXAMPLES for EQ, GRSTADT, KLSTADT, DORF, WERCK, SILB, VOSCH, QUARTER – mm. 1–7]

In the cadence in m. 7 the temperament plays an important role. The 6/4 suspension with a B minor chord with F♯ in the bass resolving to F♯ major is an example of tension-release. This is the case especially when assuming EQ. Comparing the cadence in the other temperaments will reveal that the temperament can work the opposite way, i. e. the more dissonant triad is on the last chord. In all the temperaments under investigation, except EQ, the F♯ major is one of the most dissonant triads of the temperament. In QUARTER we have the wolf-thirds on F♯.

273 Williams 1980a p. 133.
274 Stauffer 1978: 5.

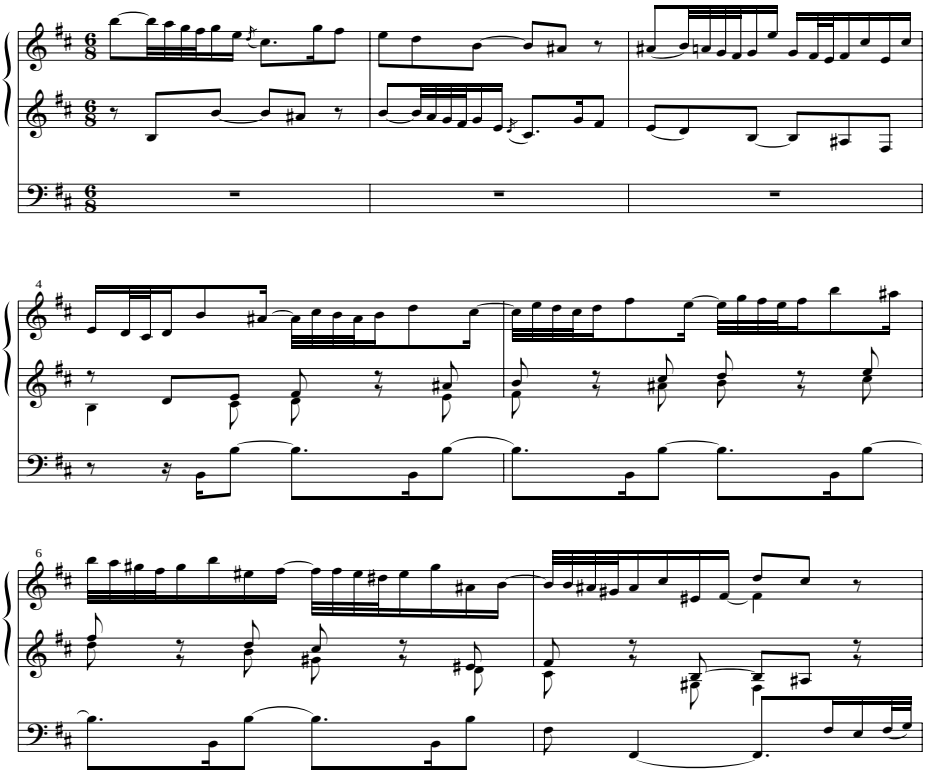

Fig. 48: Prelude in B Minor, mm. 1–7 (BWV 544)

Table 41: Intervals in B minor

Temperament	B	D	F♯
QUARTER	0	310	697
VOSCH	0	306	697
SILB	0	306	698
WERCK	0	300	696
DORF	0	306	700
KLSTADT	0	300	700
GRSTADT	0	300	700
EQ	0	300	700

Table 42: Intervals in F♯ major

Temperament	F♯	A♯	C♯
QUARTER	0	427	697
VOSCH	0	417	702
SILB	0	416	698
WERCK	0	408	702
DORF	0	406	702
KLSTADT	0	404	700
GRSTADT	0	402	700
EQ	0	400	700

[SOUND EXAMPLES for EQ, GRSTADT, KLSTADT, DORF, WERCK, SILB, VOSCH, QUARTER – m. 7]

A parallel case is the appogiatura to A♯ in mm. 1 and 2. Here the dissonance is not as obvious since it is only a 2-voice texture. The A♯ in m. 3 is also more dissonant in the mean-tone temperaments.

[SOUND EXAMPLES for EQ, GRSTADT, KLSTADT, DORF, WERCK, SILB, VOSCH, QUARTER – mm. 1–3]

If the prelude is transposed to C minor, the situation is the opposite with regard to m. 7. The tension-release, C minor resolving to G major, would be supported by the temperament. This is important to note, since both B minor and C minor are similar to the extent that they both have a chromatic tonal content (more black keys than A minor for example). This is usually a sign for poorer overall intonation, indicating that a possible general expression (*affect*) for the keys would be rather similar. Their behavior in m. 7 is, in any case, the opposite of each other with regard to temperament.

Table 43: Intervals in C minor

Temperament	C	E♭	G
QUARTER	0	310	697
VOSCH	0	294	697
SILB	0	306	698
WERCK	0	294	696
DORF	0	296	700
KLSTADT	0	298	698
GRSTADT	0	298	698
EQ	0	300	700

Table 44: Intervals in G major

Temperament	G	B	D
QUARTER	0	386	697
VOSCH	0	392	697
SILB	0	392	698
WERCK	0	396	696
DORF	0	392	698
KLSTADT	0	398	700
GRSTADT	0	398	700
EQ	0	400	700

Similar values would be valid for a transposition to A minor. A minor is, in general, a key with better intonation in a well-tempered temperament due to the few chromatic keys used. This is, of course, dependent on the musical setting, which can modulate quite far into more distant keys as is the case with the prelude in C major (BWV 545). Here we have an introduction with many suspensions (mm. 1–3), and cadences in E minor (m. 17), A minor (m. 19), diminished chords (m. 23, and 26), and finally a cadence echoing the introduction (mm. 28–31). This example points out why Mattheson's list of key characteristics from 1713 received so much criticism, since a composition's affect and expression depends much more on the modulations, or the combination of keys, as Mizler expressed it.

The short chords in the inner voices in mm. 4–7 are not easy to analyze, hidden as they are in the musical setting. Together with the pedal point in the bass they add to the dissonant appearance of the measures. The last chord in m. 6 is due to the E♯ in the middle voice, which is an augmented fourth to the B in the pedal, is quite dissonant especially in the mean-tone temperaments.

[SOUND EXAMPLES for EQ, GRSTADT, KLSTADT, DORF, WERCK, SILB, VOSCH, QUARTER – mm. 4–7]

5.2.4 Toccata in F Major (BWV 540)

The genesis of the Toccata has usually been connected to the organ in Weißenfels with its pedal compass extending to f^1. On stylistic grounds the Toccata has been dated to the period 1712–17.[275]

The following example (see Fig. 49) is a characteristic passage in the Toccata. The passage in itself exhibits a growth in dissonance with regard to harmony over the first measures (mm. 169–74) ending with a short and strong cadence into C major (mm. 175–76). As with the short chords in the middle voices of the Prelude in B minor (BWV 544), it is difficult to distinguish between the well-tem-

275 Stauffer 1978: 113f.

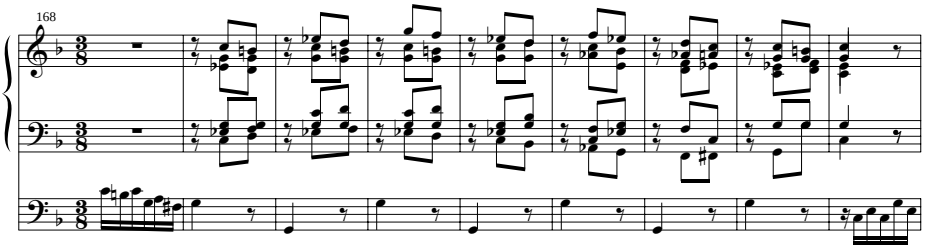

Fig. 49: Toccata in F major, mm. 168–76 (BWV 540)

pered temperaments, due to the relatively short note values and the small differences between the temperaments.

[SOUND EXAMPLES for WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 168–76]

The mean-tone temperaments on the other hand are much more dissonant in mm. 173–74. The wolf in VOSCH is exhibited on the last eight-note of m. 173, while QUARTER and SILB manage better because the wolf lies between $E^{\flat}$ and $G^{\#}$ and is, therefore, not exposed here.

[SOUND EXAMPLES for QUARTER, VOSCH, SILB – mm. 168–76]

Table 45: Size of $E^{\flat}$–$B^{\flat}$

Temperament	$E^{\flat}$–$B^{\flat}$
QUARTER	696,6
VOSCH	708
SILB	698
WERCK	702
DORF	702
KLSTADT	700
GRSTADT	702
EQ	700

Table 46: Size of $E^{\flat}$–$G^{\#}$

Temperament	$E^{\flat}$–$G^{\#}$
QUARTER	462,5
VOSCH	489
SILB	478,5
WERCK	498
DORF	498
KLSTADT	500
GRSTADT	498
EQ	500

All mean-tone temperaments are quite dissonant on the second eight-note of m. 173 due to the fact that the sounding tone is closer to G♯ than the actual notated A♭. And m. 174 is, for all the temperaments, quite dissonant due to the diminished triad in the upper voices and the major and minor seconds formed with the pedal *G*.

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 173–74]

The well-tempered temperaments underline the harmonic structure with its growing tension, including the cadence comprising the purest tonic of a well-tempered temperament, C major. However, the short note values make it difficult to perceive the tension, underlining the role of musical texture and articulation.

5.2.5 Prelude in E♭ Major (BWV 552)

The Prelude in E♭ major from *Clavier-Übung III*, is one of Johann Sebastian Bach's best known organ compositions. Since the key is E♭ major, it pushes the limits of the historic temperaments, disallowing any wolf-fifths (usually placed between E♭ and G♯).

In the manualiter passage starting at m. 40 (see Fig. 50) both D♭ and G♭ occur. For organ music this is rare, and adds special interest to the question of temperament. The first entrance of a D♭ is in m. 44, and for a G♭ in m. 45.

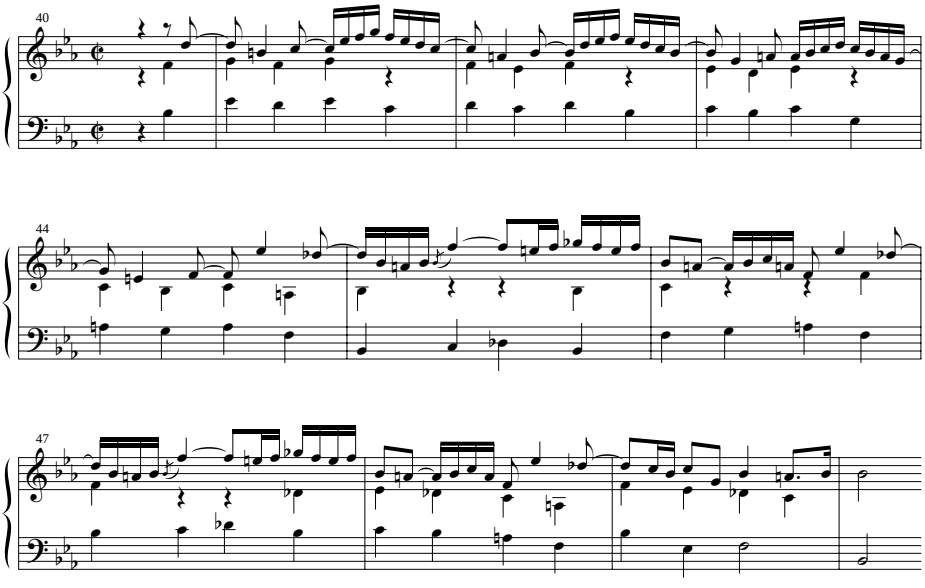

Fig. 50: Prelude in E♭ major, mm. 40–50 (BWV 552)

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 40–50]

As expected, these two notes set the limits for the temperament in this example. In this case it is not possible for the performer to ignore them since the $D^{\flat}$, for example, occur in a syncopation and in the outer voices. It seems as Bach did not want to "hide" them either.

The use of $D^{\flat}$ as minor third on $B^{\flat}$ in mm. 45, 47, and 48 is perhaps the most obvious example. The tonal content of QUARTER is clearly exceeded, while VOSCH and SILB are close to the border.

Table 47: Size of $B^{\flat}$–$D^{\flat}$

Temperament	$B^{\flat}$–$D^{\flat}$
QUARTER	269
VOSCH	285,5
SILB	282,5
WERCK	294
DORF	296
KLSTADT	298
GRSTADT	296
EQ	300

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 45–48]

As a comparison, $G^{\flat}$ as minor third on $E^{\flat}$ is presented in the table below. Here we can see that the irregular tempering of the fifths in VOSCH results in a better compromise between $F^{\#}$ and $G^{\flat}$. The intonation of VOSCH is closer to that of the well-tempered temperaments here than in the case of $B^{\flat}$–$D^{\flat}$. The modification of a mean-tone temperament can considerably change the characteristics of a temperament. A thorough analysis of the effects of such a modification is therefore important, and shows that a modified mean-tone temperament can in certain cases show characteristics similar to those of a well-tempered temperament.

Table 48: Size of $E^{\flat}$–$G^{\flat}$

Temperament	$E^{\flat}$–$G^{\flat}$
QUARTER	269
VOSCH	290,5
SILB	282,5
WERCK	294
DORF	296
KLSTADT	296
GRSTADT	298
EQ	300

[SOUND EXAMPLES for WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 45–48]

The well-tempered temperaments have little problem in the same passages. Since the texture is not dense, and the notes are in the outer voices, it is still possible to hear a small difference between the temperaments.

5.2.6 Fantasia in G Minor (BWV 542)

The Fantasia (see Fig. 51) is of special interest since it has been claimed that it was composed in Köthen and prepared for Johann Sebastian Bach's travel to Hamburg in 1720, when he applied for the position as organist in the St. Jacobi church.[276]

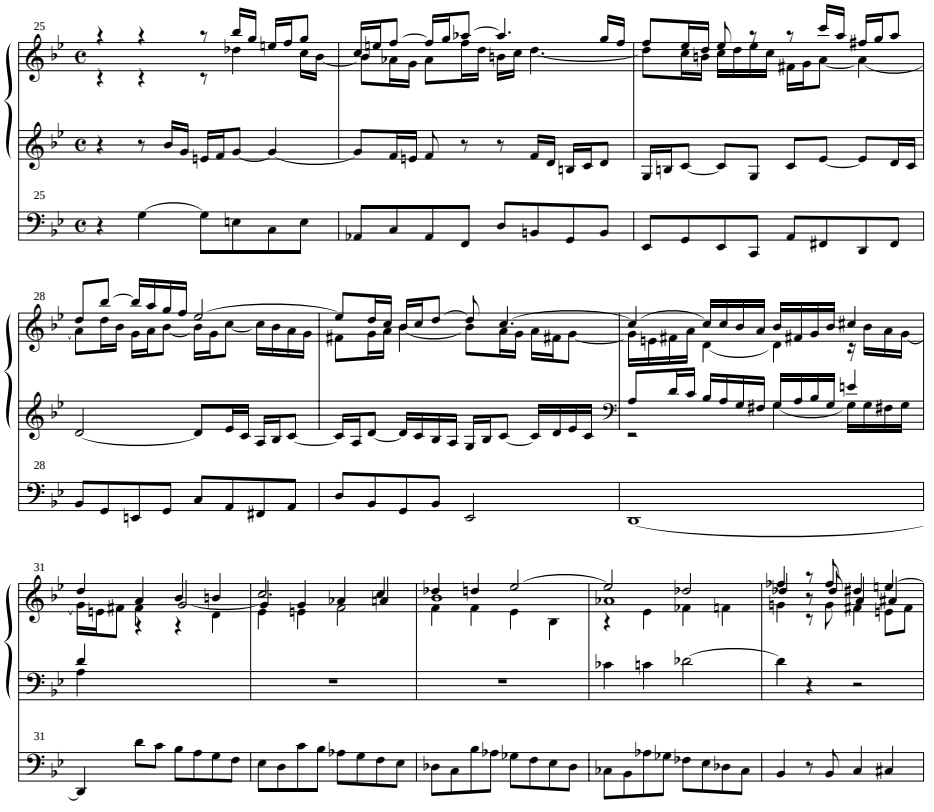

Fig. 51: Fantasia in G minor, mm. 25–35 (BWV 542)

276 See discussion in Williams 1980a: 119f., and Williams 1996: 152f.

The use of both D♭ and C♯ (mm. 25 and 30) as enharmonically exchangeable and the modulating passage in mm. 31ff. focuses again on the question of temperament. Since some kind of mean-tone temperament has been suggested for St. Jacobi, Hamburg, the following sound examples makes it possible to compare some historically appropriate temperaments.

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 25–35]

In the first part (mm. 25–31) it is clear that a well-tempered temperament is needed to facilitate the enharmonic use of, for example, D♭ and C♯. Mean-tone temperaments are not forgiving when exceeding their tonal content.

The modulating passage, starting in m. 31, illustrates to what extent a temperament allows for modulation.

[SOUND EXAMPLES for QUARTER, VOSCH, SILB, WERCK, DORF, KLSTADT, GRSTADT, EQ – mm. 31–35]

Judging from these sound examples it is difficult to imagine a mean-tone temperament as appropriate for the performance of the Fantasia, if not our experience of the temperaments today differ substantially from earlier ones. Considering this circumstantial evidence and the discussion of 1742 about the retuning of the organ in St. Katharinen, it seems very likely that “the old temperament” then could refer to a well-tempered temperament.[277]

5.3. Discussion

For the examples discussed above it is very likely that these compositions were not conceived for QUARTER. They clearly extend the tonal content of QUARTER. When it comes to VOSCH and SILB, personal taste becomes a factor in some cases. It is not possible to make a general statement about when or whether something is too dissonant. When it comes to WERCK and Neidhardt’s temperaments, except for EQ, it is very difficult to hear a difference, especially in a musical context. With EQ it is a different case. All chords are equal, the tonal content is the same for all keys, and the temperament can therefore not have a function for the musical expression other than staying within the more general limits of consonance and dissonance. The temperament can give the music a somewhat flat or dull appearance.

This tripartite division of temperaments (mean-tone, well-tempered temperaments, equal temperament) can also be traced in the history of temperament. There has often been a debate about the borders of these groups. Andreas Werck-

277 See above p. 70.

meister argued heavily against mean-tone promoting his well-tempered temperament. After Johann Georg Neidhardt had clearly introduced EQ in the discussion on temperament for keyboard instruments, the debate about the general acceptance of EQ grew stronger and stronger. Meanwhile, mean-tone was modified. It was trying, perhaps, to meet the new demands, but also was keeping something of the qualities in the pure thirds of 1/4-comma mean-tone. In addition, many new circulating temperaments were defined and presented in parallel with the gradual introduction of equal temperament.

The question is not only about suitability. In the example from the B minor prelude (BWV 544) the question about the musical function of a temperament is raised. The cadence in m. 7 can be approached basically in two ways: disregarding the temperament's behavior or integrating it into the interpretation and the performance. Disregarding it could be done by keeping with the interpretation that the cadence must represent a tension-release relationship, and therefore trying to minimize the impact of an possible well-tempered temperament by adjusting the articulation. This could mean playing the "release" on F♯ major short, trying to hide the dissonance or at least to make it less prominent. The other option would be to see the dissonance as a musical quality, preventing one from interpreting the cadence as a "normal" cadence closing a musical line. Instead the dissonance on the F♯ major could help to keep the musical flow going, extending

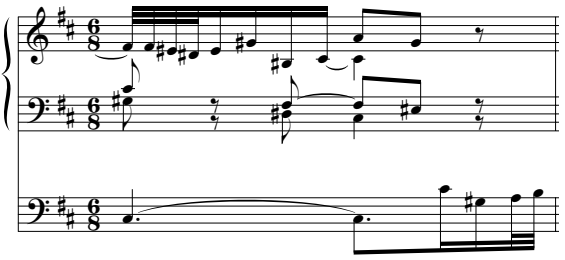

Fig. 52: Prelude in B Minor, m. 33 (BWV 544)

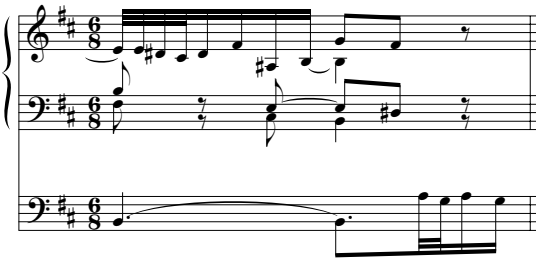

Fig. 53: Prelude in B Minor, m. 64 (BWV 544)

the line over m. 7 to the next cadence. Such a prolongation of the phrase would be indicated with a phrasing-slur in a composition of today. This interpretation is valid also in the parallel places in mm. 33 (see Fig. 52) and 64 (see Fig. 53), which indicates that it is not a coincidence in m. 7.

Perhaps the final chord (see Fig. 54) of the prelude is an example of a notation where Bach tries to minimize the effect of the rather dissonant major third B–D♯. The unconventional notation of the final measure could be a result of the temperament.

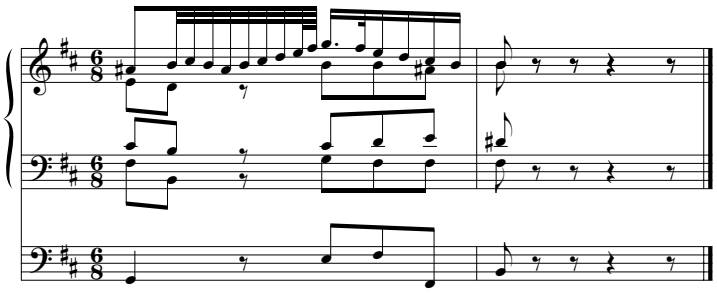

Fig. 54: Prelude in B Minor, end (BWV 544)

The Toccata in F major (BWV 540) allows to a certain degree the performer to effect the result of the temperament by making it possible to shorten the articulation of the eight-note chords, on the second and third eight-note. The problem with the passage in the examples above is the very dense texture. It would have been desirable to have different plenum registrations to experiment with, especially in this example. The role of the registration remains unclear and also raises the question of whether or not it should be based on 16' or 8'.

In the Prelude in E♭ major (BWV 552) it is not possible to “hide” the dissonances imposed by the temperament. Placing a crucial note on a syncopation makes this difficult, if not impossible. The option then would be that it is desirable to hear that particular note. If this is the case, then the intonation of a temperament has a clear role in creating the soundscape and the *affekt*, and also shaping the performance. But, the effect of the temperament is, to a certain degree, mitigated in this example by the thinner texture (manualiter). Even a temperament like DORF is therefore not very dissonant on the notes at the borders of the tonal content of the temperament (D♭ and G♭).

The question of modulation is in focus in the Fantasia (BWV 540). It is a good example of how a well-tempered temperament allows the composer to use distant keys. It also shows that the enharmonic use of C♯ and D♭ is made possible through the introduction of well-tempered temperaments in the style of Andreas Werckmeister.

Many more examples could have been discussed and analyzed, but the frame of the present work does not permit investigating all the organ music of J. S. Bach. Rather, the aim of the present work is to enable a comparison with regard to temperament. A new methodology had to be developed and tested with these examples. A general conclusion regarding the effect of temperament is that there are two main aspects that must be considered: 1) the general suitability of a temperament, and 2) its interpretative implications. If a composition well exceeds the tonal content of a temperament, it was most likely not conceived in that tonal context. If the tonal content is only exceeded in a single, or in only a few instances, it could be considered a musical expression, which has to be evaluated from case to case. This leads to the second point regarding interpretative implications. The introduction of well-tempered temperaments and the contemporary discussion about key characteristics show the importance of the question. A general consensus was, and is still, not reached. The reason for this is the character of the compositional process: it is open to choices. In this it resembles the interpretative process. A composer can make choices with regard to many aspects. Mattheson's list of key characteristics (1713) received some heavy criticism, precisely because it was too definite or closed. Therefore every composition must be approached individually, taking into account the freedom of the composer. A composition in C major might, or might not, modulate quite far from the tonic key, which has consequences for the soundscape in a well-tempered temperament.

The examples discussed above have shown that the temperament clearly has a role for J. S. Bach's organ music. They should, therefore, be considered to contribute to the discussion about appropriate temperaments, for instance, when planning restorations or new organ projects. The temperament also contributes to the musical expression of Bach's organ music.

6. Conclusions

The aim of the present work was to enable an organist to compare several temperaments in a musical setting. A new methodology had to be developed, and based on an investigation of the historical background and context of J. S. Bach's organ music with regard to temperament, a comparison of a selection of music examples was discussed.

The investigation of the sources relevant for J. S. Bach's organ music showed that there is a wide range of different temperaments relevant for the musical context. This can partially be explained by the fact that Bach did not stay in just one place during his lifetime. Consequently, Bach met the different styles of several regions such as the north, Thuringia, and Saxony. The time was also a time of transition, when a gradual shift from mean-tone over unequal temperaments to equal temperament occurred. However, there is no indication in the available sources that J. S. Bach played on an organ tuned to equal temperament. Further, there is an agreement between the written sources and the instrument sources with regard to temperaments presented and used. This indicates that the writings of theorists were read, and that they, not too long after their publication, were applied in practice. An exception here seems to be EQ. An example of this is the case in the chapel in Altenburg. EQ was strongly recommended by J. G. Neidhardt in 1706, but the introduction of EQ was not as successful, at least not in the context of Bach's organ music. This is also clear from the later writings of Neidhardt where he presented several well-tempered temperaments. This would not have been necessary if EQ had been adopted by organ builders and musicians. If Andreas Werckmeister can be regarded as the leading figure in the field of temperament around 1700, Johann Georg Neidhardt can be seen as his successor as the most important German writer in the field of tuning and temperament in the first half of the eighteenth century.

Some factors can be used as markers for the general suitability of a temperament in organ music. One is the tonal content of the music in relation to the tonal content of the temperament. Here, 1/4-comma mean-tone is the strictest in this sense, and does not tolerate overstepping the limits of its tonal content. Adding

subsemitones to the instrument extends the tonal content, since E♭ and D♯, for example, are not enharmonically interchangeable in 1/4-comma mean-tone. The use of the dominant seventh is the second important marker, indicating the gradual entrance of the major-minor tonality. This is well exemplified in the first musical examples, *O Lamm Gottes, unschuldig* (BWV 656) and the Canzona (BWV 588).

The appearance and experience of dissonance and consonance is related to the musical context. It is more difficult to hear the difference between dissonances in a generally more dissonant context. Consider the third musical example, the Prelude in B minor (BWV 544). Why are mean-tone temperaments so intolerant to dissonances? It is the pure, or nearly pure, thirds that make the dissonances stand out in an stark way. The uniformity of equal temperament results in the opposite. The relatively dissonant thirds of EQ are not experienced as such, since all the thirds are equally impure. An example of the latter is the first musical example *O Lamm Gottes, unschuldig* (BWV 656).

A temperament can also have interpretative consequences, affecting the articulation and phrasing in the music. Examples of that are the Prelude in B minor (BWV 544), the Prelude in E♭ major (BWV 552), and the Toccata in F major (BWV 540).

The role of different musical textures can be seen in the Toccata in F major (BWV 540) and the Prelude in E♭ major (BWV 552). A dense texture does not necessarily mean a thick and full sound and stronger dissonances, if only the notation permits a lighter articulation (BWV 540). A thin texture, on the other hand, can through the notation (syncopation) emphasize the effect of a temperament (BWV 552).

Andreas Werckmeister stated in the title of *Musicalische Temperatur* (1691) that in his temperament "all *modi ficti*, can be used to make a pleasant and tolerable harmony".[278] An example of this is the Fantasia in G minor (BWV 542), where the modulations demand a well-tempered temperament that allows modulations into distant keys.

The characteristics of a temperament can influence a performance, both with regard to choice of repertoire with a certain instrument and temperament in mind, but also with regard to choices of interpretative character, which can be compared to using historical sources on registration practice when preparing a registration. A style sheet for integrating the aspect of temperament in interpretation can be outlined and further subdivided as follows:

1) understanding the construction of temperament
   - how are the fifths tempered?
   - is there a wolf?
   - which intervals/keys have the best/poorest intonation?

278 Werckmeister 1691, title page. See above, p. 25.

2) observing the historical context of the music with regard to both written sources and instruments,
   - what historical temperaments are described in the sources?
   - what historical temperaments are used in organs?
3) analysing the composition from the perspective of temperament
   - does the music exceed the tonal content of the temperament?
   - is any harmonic/melodic material affected by the temperament?
4) interpretative decisions with regard to articulation, phrasing, choice of tempo, registration, etc.
   - mitigate or emphasize the effect of the temperament trough articulation, phrasing, choice of tempo and registration.

Finally, one could also argue that interpretative decisions based on such an approach could influence a performance without a historical soundscape. Performing the Prelude in B minor (BWV 544) on a modern (or historical) instrument tuned to equal temperament could well integrate a phrasing of m. 7 (and mm. 33, 64) based on the interpretation that the temperament suggests a less prominent cadence and instead a continuation of the musical flow. In the same way, an organist can respect a historical registration indication asking for a certain reed, by using any available reed even if it is far from the original.

Two general conclusions can be made. First, every single piece has to be approached individually with regard to temperament, since the choices and modulations made by the composer can result in very different tonal soundscapes. Therefore, a general list of key characteristics like Johann Mattheson's of 1713 cannot be presented. Secondly, the best recommendation with regard to temperament for the organ works of J. S. Bach is a historical one. The four temperaments defined by Johann Georg Neidhardt are a perfect solution, obviously born out of practical experience, providing a solution for the various needs in different contexts. If the organ frequently is to be used together with an orchestra, a flexible temperament with regard to transpositions is desirable. Here the temperaments for the court and for a large city are appropriate, providing smaller differences between the keys. On the other hand, the temperaments for a village and a small city provide purer intonation in keys more often used, and are also acoustically rewarding for the organ sound. The key signatures used in J. S. Bach's organ works, never exceeding four accidentals, fit well within the boundaries of such temperaments.

My personal opinion is that temperament primarily affects the choice of tempo because it tends to put a focus on details in the intonation. This is more prevalent in music written with more accidentals, such as the Prelude in E♭ major (BWV 552). The expressiveness of the D♭ and G♭ is easily lost if a tempo and character is chosen that does not allow them to be heard. Choosing a more majestic

rather than festive tempo would better incorporate the aspect of intonation in the performance.

Cadenza

At first, it might seem that the present work is quite far from music, occupied as it is with computers and numbers. But, if we return to medieval times, we would study at a university according to the seven liberal arts. These are grouped into *quadrivium* and *trivium* (4+3). The *quadrivium* consists of arithmetic, music, geometry, and, astronomy. The *trivium* consists of grammar, rhetoric, and, logic.[279] Music was seen as a numerical art side by side with arithmetic, geometry, and, astronomy. The present work fits more comfortably into this medieval perspective. Perhaps we are returning to a situation where we have to reevaluate our view of music as a part of the humanities, or perhaps we need to loosen up our categorizations. Today interdisciplinary research is again in fashion, and the present work can be seen as an attempt within musicology to answer a musical question with the help of acoustics and digital technology.

We have also touched upon the thorny question of interpretation. When trying to reach an historically informed performance, one encounters some dangers. An analysis must be interpreted and result in something; in this case, a performance based on choices governed by the knowledge achieved through the analysis. Otherwise the analysis is made for its own sake, an effort with little value. It would be like the child who took its toy apart (deconstruction) and could not put it back together (reconstruction), resulting in nothing but a pile of parts rather than a toy to play with. The result of the reconstruction will naturally always be subject to discussion.

> But, even though the interpreters cannot decide which interpretation is the privileged one, they can agree on the fact that certain interpretations are not contextually legitimated.[280]

279 Butt 1994: xiii.
280 Eco 1990: 41.

Appendix A – Introduction to Temperament

The question of temperament is crucial for keyboard instruments with fixed intonation (keys) in general, and particularly in the organ due to its sound production. Several excellent books and articles have been written on the subject.[281] For the present work this can serve as a short introduction.

There are two factors that serve as points of departure: the laws of acoustics, and the musical scale in our western tradition. A pure interval, an interval without beats, can be described in simple ratios: 2:1 for the octave, 3:2 for the fifth, and 5:4 for the major third. These ratios correspond to the harmonic overtones of for example a flue pipe. A small deviation from this in one of the frequencies/tones will result in beats, as a result of interference between the overtones of the two tones. This phenomenon is used to tune musical instruments such as the organ. Today the most common way to represent intervals is the logarithmic system introduced by Alexander J. Ellis around 1880,[282] where an octave equals 1200 cent (1 cent = $1200\sqrt{2}$). The cent-value (C) for an interval (i) can be calculated with the following formula: C= 1200 log i/log 2. Without decimals the pure fifth (3:2) is 702 cents.

In our western tradition, the octave is divided into twelve tones.[283] If we use the ratio 3:2 for the fifth and 2:1 for the octave, 12 fifths ((3:2)^12) does not equal seven octaves ((2:1)^7). The difference between 12 pure fifths and seven octaves is ca. 24 cents (the Pythagorean comma), while the difference between 4 pure fifths and, an octave and a pure major third is ca. 22 cents (the syntonic comma). A temperament is basically a division of this excess: the comma (Pythagorean or syntonic comma), between the fifths. The equal temperament distributes the difference equally over all twelve fifths.

The chromatic scale can be defined through a chain of fifths (transposed down an octave when necessary). Consequently, the distance between two tones

281 For example Padgham 1986 and Kent 1998. A good pedagogical tool is also Pierre Lewis' *JavaTuner* at <http://pages.globetrotter.net/roule/accord.htm> (2002-07-24).
282 <www.grovemusic.com>, s.v. *interval*.
283 Here we distinguish between the tone (sounding) and a note (written in a score).

can be different in different temperaments, depending on how the fifths are tempered. It is only the octave which always is a pure (not tempered) interval. The 1/4 syntonic comma mean-tone temperament consists of eleven tempered fifths,[284] which results in a twelfth fifth which is so large that it is unusable as a fifth (ca. 738 cents) – the wolf. Temperaments with fifths tempered equally are also called regular.

The chain of four fifths (C–G–D–A–E) defines the major third (C–E) above the tone of departure. In the 1/4 syntonic comma mean-tone, the major third is pure (386 cents). This gives eight pure thirds. To increase the number of usable major thirds one has to incorporate subsemitones since a G♯ (major third on E) is not usable as A♭ for the major third A♭–C. This means splitting a key into two parts, allowing both a G♯ and an A♭.

Towards the end of the seventeenth century Andreas Werckmeister defined his well-known "No. III," which is a so-called well-tempered tuning (temperament). In a well-tempered tuning, the fifths are usually of two, or more, types. They can be tempered in different ways, or pure. In Werckmeister III the fifths C–G, G–D, D–A, and B–F♯ are tempered by a 1/4 Pythagorean comma. The rest of the fifths are pure. This gives no pure intervals in the scale, except for the octave, but all intervals are usable (the wolf is domesticated). The different sizes of the major thirds give every key a different definition when it comes to the size of the intervals in the scale. This was one of the causes for theorists assigning different characteristics to different keys.[285] Because there is no wolf-fifth in these temperaments, they are also called circulating (or closed) temperaments, or well-tempered temperaments since they allow the transposition through the circle of fifths.

284 This is in a sense an equal temperament. All fifths, except for the wolf which is a result of the other tempered fifths, is equally tempered.
285 See Steblin 1981 for a history of key characteristics.

Appendix B – Digital Sound

A tone is pressure waves propagating through the air. The wave has amplitude (loudness) and frequency (pitch). When we record a sound, we convert this movement-energy recorded with the microphone into electrical energy (ADC – Analog Digital Converter). This can be stored magnetically on tapes, or one can convert it into digital data. Through the speakers, the information is converted back into pressure waves (DAC – Digital Analog Converter). The words *analog* and *digital* are key words, and understanding them is important for understanding digital sound.

Comparing a normal thermometer with a digital helps to explain the difference. The mercury in a normal thermometer follows the changes in temperature. If the change is 0,01°C the mercury moves accordingly. For a digital thermometer the problem is that the scale is divided into steps. If the thermometer has a precision of 0,5°C it can only show differences of this size, and consequently it will not change its display until the threshold is reached. Another example is analog and digital watches. If an analog watch has a second hand moving in steps of a second this is sufficient for everyday use, but not if we want to time a 100-meter run. Then we need to be able to measure down to a hundredth of a second. We need better precision, or resolution. Time is quantized into respectively chosen increments – minutes or seconds. This means that an exact position in time, with adequate precision for the purpose, can be described with a number – a momentary value.

In the computer we use the binary notation to represent numbers. A computer can only interpret two positions – on or off (like a light switch). Numbers or letters are represented by using a system based on eight "switches" that can be either on or off. This is called a byte, with eight bits (binary digit). 00000000 means zero, and 00000001 means one. 00000010 means two since this system is binary and moving to the next position doubles the value. In the decimal system moving a position increases the value ten times – 10 and 100. The on-position for the eight positions gives this row: 128, 64, 32, 16, 8, 4, 2, and 1.

Digitalizing sound means that we have to quantize two dimensions – sound

pressure (loudness) and frequency (pitch) – and represent them in numbers. With the Compact Disc some standards were set for the equipment used. The sample frequency should cover the audible range of ca 20–20000 Hz and is set to 44100Hz (or 48000).[286] The dynamic range (96dB, in increments of 6dB) is described in 16 bits (24 and 32 bit-technology is already in use, increasing the precision).

One of the benefits of digital sound is that it can be copied several times without loss of quality. It also gives new possibilities to manipulate sound, as the present work shows. With the computer revolution during the 90's, and the hardware prices going down, the digital technique is made available to everyone. Now a private person can afford a fast computer with a good soundcard and software for editing the music.

286 The sample frequency has to be 2 times the sounding frequency according to Nyqvist's law.

Appendix C – Neidhardt's Temperaments (1732)

Neidhardt 1732 – Erste Art

1 (Equal temperament)		2		3		4	
Fifths	Beats	Fifths	Beats	Fifths	Beats	Fifths	Beats
c:g	1	c:g	2	c:g	0	c:g	3
g:d	1	g:d	-2	g:d	2	g:d	0
d:a	1	d:a	2	d:a	0	d:a	0
a:e	1	a:e	2	a:e	2	a:e	3
e:h	1	e:h	2	e:h	0	e:h	0
h:fs	1	h:fs	-2	h:fs	2	h:fs	0
fs:cs	1	fs:cs	2	fs:cs	0	fs:cs	3
cs:gs	1	cs:gs	2	cs:gs	2	cs:gs	0
gs:ds	1	gs:ds	2	gs:ds	0	gs:ds	0
ds:b	1	ds:b	-2	ds:b	2	ds:b	3
b:f	1	b:f	2	b:f	0	b:f	0
f:c	1	f:c	2	f:c	2	f:c	0
	12		12		12		12

5		6		7		8 (Large city)	
Fifths	Beats	Fifths	Beats	Fifths	Beats	Fifths	Beats
c:g	1	c:g	1	c:g	3	c:g	2
g:d	1	g:d	3	g:d	2	g:d	2
d:a	2	d:a	-1	d:a	2	d:a	2
a:e	-1	a:e	1	a:e	-3	a:e	1
e:h	1	e:h	3	e:h	2	e:h	0
h:fs	2	h:fs	-1	h:fs	2	h:fs	1
fs:cs	1	fs:cs	1	fs:cs	2	fs:cs	1
cs:gs	1	cs:gs	3	cs:gs	-2	cs:gs	1
gs:ds	2	gs:ds	-1	gs:ds	2	gs:ds	0
ds:b	-1	ds:b	1	ds:b	2	ds:b	0
b:f	1	b:f	3	b:f	2	b:f	1
f:c	2	f:c	-1	f:c	-2	f:c	1
	12		12		12		12

9		10		11		12	
Fifths	Beats	Fifths	Beats	Fifths	Beats	Fifths	Beats
c:g	1	c:g	3	c:g	1	c:g	1
g:d	3	g:d	0	g:d	2	g:d	2
d:a	0	d:a	3	d:a	3	d:a	0
a:e	0	a:e	2	a:e	1	a:e	3
e:h	1	e:h	0	e:h	-1	e:h	0
h:fs	3	h:fs	0	h:fs	1	h:fs	0
fs:cs	0	fs:cs	2	fs:cs	2	fs:cs	1
cs:gs	0	cs:gs	0	cs:gs	-1	cs:gs	2
gs:ds	1	gs:ds	0	gs:ds	3	gs:ds	0
ds:b	3	ds:b	2	ds:b	1	ds:b	3
b:f	0	b:f	0	b:f	-1	b:f	0
f:c	0	f:c	0	f:c	1	f:c	0
	12		12		12		12

Neidhardt 1732 – Andre Art

1 (A village)		2 (Small city)		3		4		5	
Fifths	Beats	Fifths	Beats	Fifths	Beats	Fifths	Beats	Fifths	Beats
c:g	1	c:g	2	c:g	2	c:g	2	c:g	1
g:d	2	g:d	2	g:d	2	g:d	2	g:d	1
d:a	3	d:a	2	d:a	1	d:a	2	d:a	1
a:e	3	a:e	2	a:e	2	a:e	0	a:e	2
e:h	0	e:h	1	e:h	2	e:h	2	e:h	1
h:fs	1	h:fs	1	h:fs	-2	h:fs	0	h:fs	1
fs:cs	0	fs:cs	0	fs:cs	2	fs:cs	1	fs:cs	0
cs:gs	1	cs:gs	0	cs:gs	1	cs:gs	1	cs:gs	1
gs:ds	0	gs:ds	1	gs:ds	1	gs:ds	1	gs:ds	1
ds:b	0	ds:b	1	ds:b	-2	ds:b	-1	ds:b	1
b:f	1	b:f	0	b:f	2	b:f	2	b:f	0
f:c	0	f:c	0	f:c	1	f:c	0	f:c	2
	12		12		12		12		12

Appendix D – Index of CD

Sound examples

BWV 540
540DORF.aif
540EQ.aif
540GRSTADT.aif
540KLSTADT.aif
540QUARTER.aif
540VOSCH.aif
540WERCK.aif

BWV 542
542DORF.aif
542EQ.aif
542GRSTADT.aif
542KLSTADT.aif
542QUARTER.aif
542SILB.aif
542WERCK.aif
542VOSCH.aif

BWV 544
544DORF.aif
544EQ.aif
544GRSTADT.aif
544KLSTADT.aif
544QUARTER.aif
544SILB.aif
544WERCK.aif
544VOSCH.aif

BWV 552
552DORF.aif
552EQ.aif
552GRSTADT.aif
552KLSTADT.aif
552QUARTER.aif
552SILB.aif
552WERCK.aif
552VOSCH.aif

BWV 588
588DORF.aif
588EQ.aif
588GRSTADT.aif
588KLSTADT.aif
588QUARTER.aif
588SILB.aif
588WERCK.aif
588VOSCH.aif

BWV 656
656DORF.aif
656EQ.aif
656GRSTADT.aif
656KLSTADT.aif
656QUARTER.aif
656SILB.aif
656WERCK.aif
656VOSCH.aif

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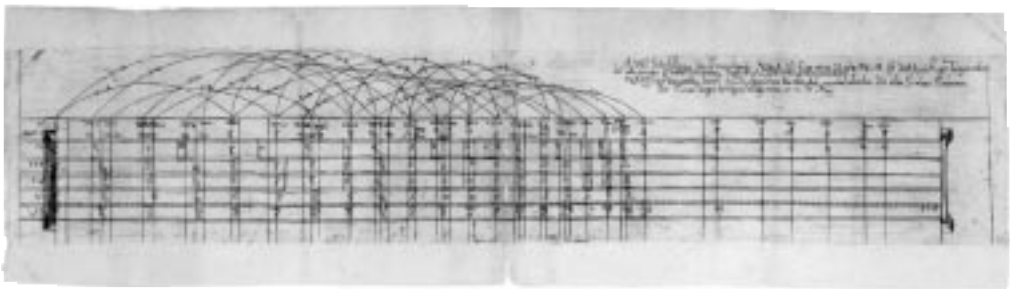

SKRIFTER FRÅN MUSIKVETENSKAPLIGA INSTITUTIONEN
GÖTEBORGS UNIVERSITET, NR 70, 2002

STUDIES FROM THE DEPARTMENT OF MUSICOLOGY
GÖTEBORG UNIVERSITY, NO. 70, 2002

ISBN 91 85974 66-8 ISSN 1650-9285