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Michael Praetorius's *Pfeifflin zur Chormaß**

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IT IS EVIDENT that Michael Praetorius intended in *De Organographia* (the second volume of his *Syntagma musicum*), published in 1618 and 1619, to provide clear definitions of several pitch levels.[1] During the past 125 years, beginning with Alexander J. Ellis's pioneering study, "On the History of Musical Pitch" (1880), Praetorius's text and his woodcut illustrations bearing on the subject have been repeatedly examined and discussed, sometimes contentiously.[2] A particular difficulty

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1. Michael Praetorius, *Syntagma musicum* 2, *De Organographia* (Wolfenbüttel, 1619); the principal discussion about pitch is on pp. 14–18. (*De Organographia* was originally published in 1618; most copies, however, are dated 1619.)

2. Important studies with interpretations of Praetorius's pitch include Alexander J. Ellis, "On the History of Musical Pitch," *Journal of the Society of Arts* 28, no. 1424 (5 March 1880): 293–336 (with corrections and supplements in subsequent issues); Arthur Mendel, "Pitch in the 16th and Early 17th Centuries," parts 1–4, *Musical Quarterly* 34 (1948) [Ellis's and Mendel's papers are reprinted in *Studies in the History of Musical Pitch* (Buren: Frits Knuf, 1968)]; Karl Bormann, *Die gotische Orgel zu Halberstadt* (Berlin: Verlag Merseburger, 1966); Paul G. Bunjes, *The Praetorius Organ* (St. Louis: Concordia Publishing House, 1966), 722–866; W. R. Thomas and J. J. K. Rhodes, "Schlick, Praetorius and the History of Organ-Pitch," *The Organ Yearbook* 2 (1971): 58–76; Arthur Mendel, "Pitch in Western Music Since 1500: A Reexamination," *Acta Musicologica* 50, fasc. 1/2 (1978): 1–93; Dominic Gwynn, "Organ Pitch, Part 1 – Praetorius," *FoMRHI Quarterly* 23 (April 1981): 72–77; Stanley Sadie, ed., *The New Grove Dictionary of Musical Instruments* (London: Macmillan, 1984), s.v. "Pitch" (written mainly by Thomas and Rhodes); Herbert W. Myers, "Praetorius's Pitch," *Early Music* 12, no. 3 (August 1984): 369–371; Ephraim Segerman, "Praetorius's Pitch?" *Early Music* 13, no. 2 (May 1985): 261–263; Cary Karp, "Pitch," in *Performance Practice: Music after 1600*, Howard Mayer Brown and Stanley Sadie, eds., *The Norton/Grove Handbooks in Music* (New York: W. W. Norton, 1990), 147–168; Bruce Haynes, "Pitch Standards in

has been that his diagram labelled *Pfeifflin zur Chormaß* (fig. 1),[3] which incorporates measurements for a set of pipes at his standard pitch, has usually led to the conclusion that this *Chormaß* was about a quarter-tone below modern pitch, while Praetorius's alternative method of sounding this pitch on a trombone has usually led to the conclusion that it was about a semitone *above* modern pitch.

Further confusion has arisen from Praetorius's use of two terms, *Cammerthon* (chamber pitch) and *Chorthon* (choir pitch); for the latter he also uses the term *Chormaß* (choir measure). Additional misunderstanding has stemmed from his use of a particular term to mean different things in different contexts and from his use of more than one term to mean the same thing. Nevertheless, careful reading of Praetorius's text and knowledge of the context in which he worked allows a conclusive interpretation of his meaning. In some areas ("Prague and some other Catholic chapels") two pitch levels were in use: *Cammerthon*, identical to Praetorius's "present usual pitch," and *Chorthon*, which was a whole tone lower.[4] In Praetorius's own region, however,

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the Baroque and Classical Periods" (Ph.D. thesis, Université de Montréal, 1995); Herbert W. Myers, "Praetorius' Pitch: Some Revelations of the *Theatrum Instrumentorum*," in *Perspectives in Brass Scholarship: Proceedings of the International Historic Brass Symposium, Amherst, 1995*, Stewart Carter, ed., Bucina: The Historic Brass Society Series, no. 2 (Stuyvesant, N.Y.: Pendragon Press, 1997), 29–45; Steve Heavens and Ephraim Segerman, "Praetorius' Brass Instruments and *Cammerthon*," *FoMRHI Quarterly* 78 (January 1995): 54–59; Ephraim Segerman, "Praetorius's *Cammerthon* Pitch Standard," *Galpin Society Journal* 50 (1997): 81–108; Herbert W. Myers, "Praetorius's Pitch Standard," ibid. 51 (1998): 247–267; Stanley Sadie and John Tyrrell, eds., *The New Grove Dictionary of Music and Musicians*, 2nd ed. (New York: Grove's Dictionaries, 2001), s.v. "Pitch, §I: Western pitch standards" (written by Bruce Haynes); and Bruce Haynes, *A History of Performing Pitch: The Story of 'A'* (Lanham, Md.: Scarecrow Press, 2002).

3. *De Organographia*, 232.

4. *De Organographia*, 15. (This and all subsequent translations are my own.) He also mentions (ibid., 16) the existence, in some places, of an even lower pitch, a minor third below his "present usual pitch": "In England formerly and in the Netherlands still up until now they voiced and tuned most of their wind instruments a minor third lower than our present *Cammerthon* such that their F is our *Cammerthon* D and their G is our E. Likewise, the excellent instrument maker in Antwerp, Johannes Bossus, voices and tunes to the same pitch most of his *Clavicymbeln* [i.e., wing-shaped harpsichords] and *Symphonien* [i.e., virginals] and also the organs built into them [i.e., *claviorgana*]." The scaling of the one surviving instrument by Bossus, a virginal of 1578 (in the Monasterio de Santa Clara, Tordesillas, Spain), with its c^2 string length of 386 mm, is about the factor of a semitone longer than the scalings of seventeenth- and eighteenth-century harpsichords tuned to about a^1 = 410 Hz. This suggests that Bossus's a^1 was about 385 Hz and that of Praetorius's *Cammerthon* was about 460 Hz.

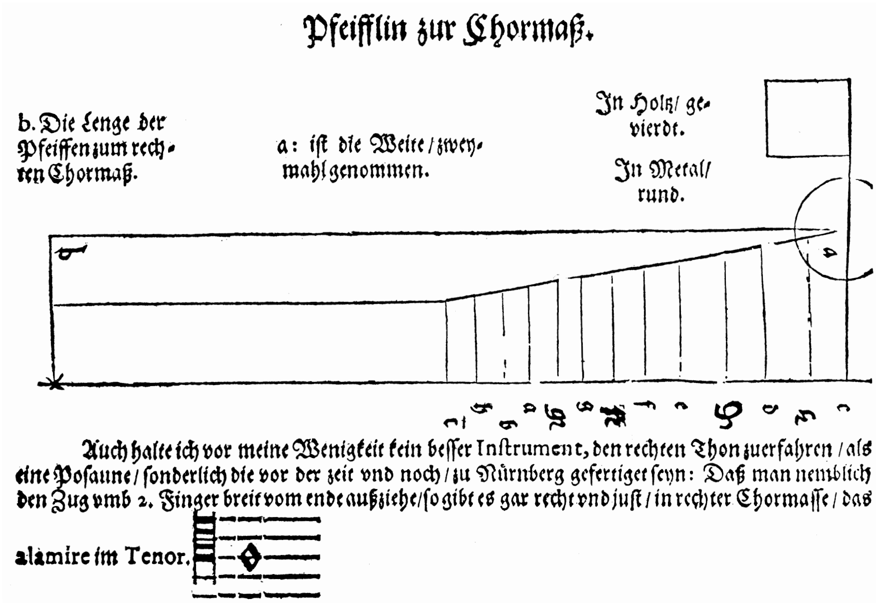

FIGURE 1. *Pfeifflin zur Chormaß*, from Michael Praetorius, *De Organographia* (*Syntagma Musicum* 2) (Wolfenbüttel, 1619), 232.

only the higher pitch, which he preferred to call *Cammerthon*, was in general use. Because this was used not only in secular chambers but also in churches it was usually called *Chorthon* or *Chormaß* in Praetorius's environs and throughout Protestant Germany; indeed, Praetorius himself sometimes slipped into calling the higher pitch *Chorthon* or *Chormaß*.[5] Therefore, even though his illustration of dimensions for a set of organ pipes in the octave c^3 ($^1/_2$') to c^4 ($^1/_4$') is labelled *Pfeifflin zur Chormaß*[6] it was intended to convey his idea of *Cammerthon*, the "present usual pitch."

5. A succinct demonstration that Praetorius's own *Cammerthon* and *Chorthon* were the same is provided by Heavens and Segerman, "Praetorius' Brass Instruments and *Cammerthon*," 56–57. See also Haynes, *Story of 'A'*, 76–82. (One should note that the high pitch continued to be called *Chorthon* into the eighteenth century in Protestant Germany, where the pitch a tone or a minor third lower, having became fashionable under French influence toward the end of the seventeenth century, was known as *Cammerthon*. This terminology, the reverse of what Praetorius reported as customary in Prague, is often encountered in studies of pitch in J. S. Bach's environs.)

6. Immediately below he refers to it not in the feminine but the alternative neuter gender, *zum rechten Chormaß*.

Nothing seems so simple as to make a pipe or set of pipes following Praetorius's dimensions and then to measure the pitch. Alexander J. Ellis was the first to do this in modern times, publishing in 1880 his result that Praetorius's *Chormaß* a^1 was 424.2 Hz.[7] Working directly from an original example of *De Organographia,*[8] Ellis measured the length of the c^3 pipe as 133.8 mm and the line marked *a*, indicating its "width taken twice" as 25.2 mm. Ellis noted, however, that in Praetorius's *Theatrum Instrumentorum* of 1620,[9] which is the supplement with the illustrations for *De Organographia* (the two are bound together in most copies), the printed scale (*Maßstab*) of one-half foot or one-quarter of a Braunschweig ell (fig. 2) was about one and a half percent shorter than it should be according to Braunschweig measurement standards known from other sources.[10] He therefore assumed that the paper had shrunk after printing.[11] He further assumed that the *Pfeifflin* diagram had also shrunk by the same amount. Thus he multiplied his *Pfeifflin* measurements by 1.0155 to obtain the dimensions from which his test pipe was made.

Several investigators subsequent to Ellis have more or less confirmed his results, to the extent that Praetorius's *Chormaß* was found to be about a quarter-tone below the modern a^1 of 440 Hz. All have used Ellis's methodology in determining and applying a paper-shrinkage factor, and their raw and converted measurements closely agree with Ellis and with each other. One further aspect of interpreting the *Pfeifflin* diagram should be noted. The explanation in the diagram that the dimension marked "*a* is the width, twice taken" (*a: ist die Weite / zweymal genommen*) is ambiguous: "width" could mean either the diameter or

7. Ellis, "On the History of Musical Pitch," 320–321. Because of his misunderstanding about Praetorius's terminology, Ellis further concluded, incorrectly, that Praetorius also had a chamber pitch that was a fourth higher, that is, a^1 = 567.3 Hz (ibid., 332).

8. Thomas and Rhodes, "Schlick, Praetorius and the History of Organ-Pitch," 64, 71 (note 51), and 76, state that they examined Ellis's *Pfeifflin* reconstructions, preserved at the Royal Institution, London, and "the same copy [of Praetorius's book] that Ellis used." For access to Ellis's materials they acknowledge the help of the librarians of the Royal Institution and the Reid School of Music at Edinburgh University, so by process of elimination the latter must be the location of the book.

9. *Theatrum Instrumentorum seu Sciagraphia* (Wolfenbüttel, 1620), sig. a1'.

10. According to most sources (for example, Horace Doursther, *Dictionnaire universel des poids et mesures anciens et modernes* [Brussels, 1840], 405), the Braunschweig foot was 285.36 mm.

11. I am grateful to Roland Hoover for the information that paper was normally moistened as it was printed. It then would shrink as it dried.

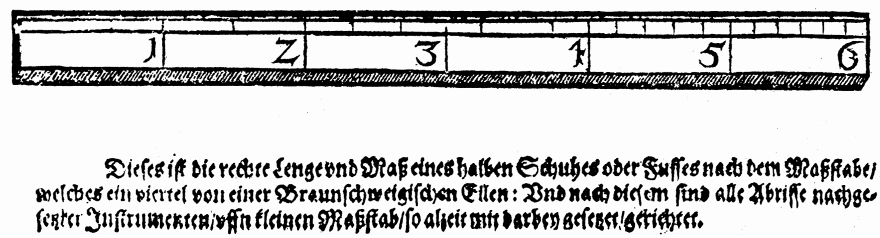

FIGURE 2. *Maßstab,* from Michael Praetorius, *Theatrum Instrumentorum* (Wolfenbüttel, 1620), sig. a1'.

the circumference of the pipe, while "twice taken" could mean either that the given dimension is twice the actual size or that the given dimension is to be taken twice (that is, doubled) for the actual size. Two of the four possible permutations can be eliminated: to double the given dimension for the diameter or to halve it for the circumference would result in pipes grotesquely fat or thin. As for the viable possibilities, W. R. Thomas and J. J. K. Rhodes, working together in the early 1970s, halved the given dimension to obtain a diameter of about 12.5 mm for the c^3 pipe. (Ellis, similarly, had taken 12.59 mm as the side of a pipe made of wood with a rectangular cross section, a material and form offered by Praetorius as an alternative.)

Paul Bunjes and Karl Bormann, however, working independently in the 1960s, and later Dominic Gwynn took Praetorius's dimension *a* for the width to be one-half the circumference, that is, the width of the metal plate from which the round pipe would be fashioned, about 52 mm. This interpretation accords well with what is known about early pipemaking practice: organ builders from the fifteenth century to the eighteenth used the plate width (that is, π times the diameter) to scale their pipes and they generated and recorded their scalings in a graphic form very similar to that of Praetorius's diagram.[12] In *De Organographia*

12. Examples are the *fimbria* in the mid-fifteenth-century manuscript of Henri Arnault of Zwolle (Paris, Bibliothèque Nationale, ms. lat. 7295, fol. 129; see G. le Cerf and E.-R. Labande, eds., *Instruments de musique du xv^e siècle: les traités d'Henri-Arnault de Zwolle et de divers anonymes* [Paris: Éditions Auguste Picard, 1932], pl. 9); the *schilt* in Heinrich Schreyber (Grammateus), *Ayn new kunstlich Buech* (printed in Nuremberg for publication in Vienna, 1518), sig. m3; the numerous scales drawn by the North German organ builder Christian Vater (1679–1756; see Uwe Pape, ed., *Das Werkstattbuch des Orgelbauers Christian Vater* [Berlin: Pape Verlag and Hannover: Selbstverlag des Stadtarchivs, 2001]); and the many *diapasons* in Dom François Bedos de Celles, *L'Art du facteur d'orgues* (Paris, 1766– 1778), pls. 19–29 and 137.

Praetorius himself followed convention in measuring the width of the largest pipe of the fourteenth-century organ in Halberstadt Cathedral in terms of its circumference.[13] Also, it was common in organ building for the plate widths in scaling diagrams to be drawn at half size.[14] A pipe with a plate width of 52 mm has a diameter of about 17 mm externally or 16 mm internally. Tolerably close to this is the diameter of the circle in the *Pfeifflin* diagram, somewhat roughly rendered and breaking off at the margin, about 17.5 mm on the outside of the line, about 16.5 inside.

Bormann and Bunjes, using actual organ pipes, found a^1 to be, respectively, 427 and 436.1 Hz.[15] More recent investigators, using theoretical formulae for calculating organ-pipe pitch from length and diameter data, have obtained similar results: Thomas and Rhodes found a^1 to average about 427 Hz; Gwynn's result was 432.8 Hz.[16] The minor variations from one measurement or calculation to another can easily be explained by different assumptions about wind pressure and the dimensions of the pipe mouth, about which Praetorius says nothing. Some variation is also attributable to the different ambient temperatures: perhaps, for example, the air around Ellis was colder than the 15 or 20° Celsius used for the calculations by some other investigators.

In an article published in 1990, Cary Karp questioned the validity of all these results. He meticulously compared the *Pfeifflin* and *Maßstab*

13. *De Organographia*, 101.

14. See, for example, Christian Vater's *Werkstattbuch.* Points and arcs marked by compasses to transfer dimensions from scaling diagrams to the metal plate have been observed on the interior surfaces of metal pipes by various sixteenth- and seventeenth-century Dutch organ builders: see Jan van Biezen, *Het Nederlandse Orgel in de Renaissance en de Barok, in het Bijzonder de School van Jan van Covelens* (Utrecht: Koninklijke Vereniging voor Nederlandse Muziekgeschiedenis, 1995) 1:137, 159, 160, 199, 226, and 318; also John Koster, "The Compass as Musical Tool and Symbol," *Musique-Images-Instruments* 5 [2003]: 16–17). The radii of the arcs indicate that the compasses were set to the half widths. Not only did drawing just half widths make the diagrams more compact, but the procedure also facilitated marking the centerline to place the mouth exactly in the middle of the plate, directly opposite the seam of the completed pipe.

15. Bormann, *Die gotische Orgel zu Halberstadt*, 70; Bunjes, *The Praetorius Organ*, 773 (Table 115, part 3, col. 5: I have calculated the a^1 equivalent from the 1038.3 Hz "adjusted frequency" of the *Pfeifflin* for c^3). One should mention that Bunjes also measured the pitch of organ pipes modelled after those shown in Praetorius, *Theatrum Instrumentorum*, pls. 37–38, and reached a general conclusion that Praetorius's *Chormaß* was about a^1 = 445 Hz (*The Praetorius Organ*, 787).

16. Thomas and Rhodes, "Schlick, Praetorius and the History of Organ-Pitch," 75; Gwynn, "Organ Pitch," 75.

dimensions in two examples of *De Organographia* and *Theatrum Instrumentorum* kept under carefully controlled conditions. He found that, as the humidity varied, different pages reacted differently and that even the same page could react differently in different directions simultaneously. At increased humidity some dimensions "remained unaltered, while both slight shrinkage and significant expansion were noted with others."[17] Karp also pointed out that the wood blocks from which Praetorius's illustrations were printed would themselves have been subject to expansion and contraction not only during the time between their cutting and the initial printing but also later, when, he presumed, these books were reissued in new impressions from time to time after their original publication. Because the date of the title page would not have been altered for each subsequent printing,[18] we would have no idea of exactly when any particular copy was printed or how the dimensions of the *Pfeifflin* diagram have changed before or since. Thus, Karp deconstructed the sense of the diagram. He concluded that "it is hard to see how it would be possible to interpret the Praetorius drawing in any genuinely useful manner."[19]

Nevertheless, Karp proceeded to calculate Praetorius's *Chormaß* from measurements of the *Pfeifflin* diagram in a single copy of Praetorius's book. Like Ellis, he applied a shrinkage correction factor determined from the *Maßstab* in a copy of *Theatrum Instrumentorum* bound together with *De Organographia*. Karp found that a^1 could be calculated to vary from 426 up to 449 Hz according to different assumptions about ambient temperature and other factors. Ultimately, however, he rejected this result and, with considerable hedging, seemed to settle on the likelihood of Praetorius's pitch being "in the neighbourhood of A-460."[20] In any case, he offered a sensible suggestion: "It would be wise in most cases to regard pitch in terms of the nearest even 5 or 10 Hz figure, rather than with specious 1 Hz or 0.1 Hz precision."[21]

Ignoring, for the moment, the *Pfeifflin* evidence, there is much to be said for the neighborhood of $a^1 = 460$ Hz, about a semitone above modern $a^1 = 440$, as Praetorius's *Chormaß*. On the same page with his

17. Karp, "Pitch," 156.

18. If (as Karp assumed) there were any subsequent printings after 1619, the date remained unchanged.

19. Karp, "Pitch," 158.

20. Ibid., 159.

21. Ibid., 165.

Pfeifflin diagram (fig. 1), Praetorius offers an alternative method of communicating his pitch standard:

> Further, I humbly maintain that there is no better instrument from which to obtain the correct pitch than a trombone, especially those formerly and still made in Nuremberg. Namely, when one pulls out the slide the breadth of two fingers it gives an absolutely correct and proper *Chormaß* tenor A.

A good number of Nuremberg trombones has survived. Generally, with the slide all the way in, the Nuremberg tenor trombones (played without crooks or shanks to adjust the pitch downward) are now described as being in B-flat at modern pitch.[22] More specific measurements of their pitch usually show this B-flat to be "slightly above" modern B-flat,[23] that is, above 466 Hz, in the vicinity of 475 Hz or so.[24] When the slide is pulled out by the breadth of two reasonably large fingers (about 38 mm for the index and middle fingers of my own left hand) the acoustical length of the instrument, about 2600 mm, is lengthened by twice that amount (because the U-shaped slide has two branches), that is, 76 mm or about 3%. (Even if substantially larger or smaller finger breadths are used, the percentage varies only insignificantly, from 2.5% to 3.3% over a range of lengthening from 66 to 86 mm.) Thus, the pitch is lowered by about a quarter tone to about 460 Hz.[25] Important corroboration is provided by Bruce Haynes's finding that the predominant pitch of German cornetti of the period is also in the neighborhood of a^1 = 460 to 465 Hz.[26] In fact, *Cornett-Thon* was a fre-

22. See Anthony Baines, *Brass Instruments: Their History and Development* (London: Faber & Faber, 1976), 115. Several tenor trombones with fundamental pitches described as modern B-flat, made in Nuremberg by Erasmus Schnitzer in 1551 (the pitch "rather high"), Anton Drewelwecz in 1595, and Sebastian Hainlein II in 1642, are described by John Henry van der Meer in *Verzeichnis der Europäischen Musikinstrumente im Germanischen Nationalmuseum, Nürnberg, Band I, Hörner und Trompeten, Membranophone, Idiophone* (Wilhelmshaven: Heinrichshofen's Verlag, 1979), 91–93.

23. See Myers, "Praetorius's Pitch" (1984), 370.

24. Henry George Fischer, *The Renaissance Sackbut and Its Use Today* (New York: The Metropolitan Museum of Art, 1984), 8, reports the a^1 of a tenor trombone by Jörg Neuschel, 1557 (now in the Edinburgh University Collection of Historical Musical Instruments) to be 452.4 Hz, which is equivalent, in equal temperament, to a b-flat^1 of 479.3 Hz.

25. See Myers, "Praetorius's Pitch" (1984), 371.

26. Bruce Haynes, "Cornetts and Historical Pitch Standards," *Historic Brass Society Journal* 6 (1994): 84–109, especially the graph on p. 87 which shows, for sixteenth- and seventeenth-century German instruments, a predominant number at a pitch of about a^1 = 465 Hz. See also Haynes, *Story of 'A'*, 426–427.

quent synonym for *Chorthon*,[27] and Praetorius himself slipped into this usage in a reference to "our proper *Cornetten* or *Cammerthon*,"[28] by which he meant his high *Cammerthon*, equivalent to the *Chormaß* of the *Pfeifflin* diagram. Further, this same pitch is commonly found in recorders and other woodwind instruments.[29]

Most significantly, this pitch is also found in an organ built in 1610 by Esias Compenius with the collaboration of his colleague Praetorius.[30] This is the famous instrument now in Frederiksborg Castle in Hillerød, Denmark. It was presented to the King of Denmark in 1616 and since then has been preserved essentially unaltered. Since the pipework is entirely of wood, which is far less subject to damage and alteration than metal, the pitch remains unchanged. Because the instrument was originally made for the *Schloß* in Hessen, not far from Wolfenbüttel, where Praetorius resided, it was presumably tuned to what Praetorius called the "present usual pitch," that is, *Chormaß*.

The evidence from extant trombones, cornetti, other woodwind instruments, and organs would be conclusive were it not for the significantly lower pitches obtained from reconstructions of Praetorius's *Pfeifflin*. Since Karp has questioned the fundamental validity of the *Pfeifflin*, we might simply reject it. Nevertheless, because Praetorius obviously intended the *Pfeifflin* diagram to mean something, it deserves another look to see whether its data can somehow be reconciled with the results from trombones. Rather than relying on measurements from a single copy of Praetorius's work, we should gather measurements from a larger number of copies. In fact, the range of variation among eight copies under actual conditions in libraries at various places on two continents is remarkably small (see table 1).

27. Ibid., 200–201.

28. *De Organographia*, 141: *unser rechter Cornetten oder Cammerthon.*

29. The woodwind evidence is discussed by Myers, "Praetorius's Pitch Standard."

30. Poul-Gerhard Andersen, *Organ Building and Design*, translated by Joanne Curnutt (New York: Oxford University Press, 1969), 22, reports the pitch as $a^1 = 460$ Hz; Haynes, *Story of 'A'*, 463, reports 470 Hz. The slight discrepancy is easily explainable by differences in ambient temperature or by the measurement of different notes in an instrument tuned in quarter-comma meantone temperament. The organ sounds essentially a semitone above $a^1 = 440$ in recordings, for example Harald Vogel's LP, *Portrait einer fürstlichen Orgel* (Organa ORA 3002, recorded in 1972) and Per Kynne Frandsen's CD, *The Historic Organ: The Compenius Organ at Frediksborg Castle, Music from the 17th Century* (Da Capo/Marco Polo 8.224057, recorded in 1996). In notes accompanying the latter recording, Mads Kjersgaard states that the pitch is $a^1 = 467$ Hz at 20° C.

TABLE 1. Measurements of the *Pfeifflin zur Chormaß* and *Maßstab* in original copies of *De Organographia* and *Theatrum Instrumentorum* (in mm).

Location	*Pfeifflin zur Chormaß**		*Maßstab*	Measurer
	length	½ width		
Eastman School of Music Sibley Library call no. ML 100 P89 cop 1	134.5	25.5	140	Koster
Eastman School of Music Sibley Library call no. ML 100 P89 cop 2	134.5	25.5	140	Koster
Harvard University Houghton Library call no. *H620-39	134.5	25.5	141	Koster
Harvard University Houghton Library call no. *54-1796	134	25	140.5	Koster
Haags Gemeentemuseum	135	25.5	141	Michael Latcham
Oxford University Bodleian Library	134.5	25.5	141	Charles Mould
Newberry Library, Chicago	134.5	25	140	H. J. Hedlund
Edinburgh University	133.8	25.2	140.5	A. J. Ellis (1880)

*These measurements are for the c^3 (½') pipe.

The problem, then, is to see whether the *Pfeifflin* data could possibly yield a result in the neighborhood of $a^1 = 460$ Hz. To err on the side of caution, let us use the largest measurements, those which will result in the largest pipe and the lowest pitch. Thus, we take the smallest measurement of the *Maßstab* (140 mm), to obtain the largest correction factor for paper shrinkage: $285.36 \div (2 \times 140) = 1.019$. Applying this to the largest available length and width measurements of the *Pfeifflin* diagram (135 and 25.5 mm), we obtain for the c^3 pipe a speaking length of 137.6 mm and a plate width of 52.0 mm, resulting in an internal diameter of about 16 mm.

Precise measurements are available of one of the earliest and best preserved historical organs, made by Jörg Ebert in 1558 for the Hofkirche in Innsbruck.[31] This information was compiled during the restoration carried out in 1965–77 by the German firm of Ahrend and Brunzema, noted for their meticulous restorations of historical organs. The data are unusually detailed (there are twelve measurements of each *C* and *F* pipe in each rank) and include the speaking lengths, which are rarely included in measurements of historical organ pipes. It happens that the open pipes sounding c^3 are very close to our dimensions for Praetorius's c^3 pipe (see table 2). As part of the final stages of the musical portion of the restoration, the pitches of the fifteen original pipes sounding *A* in various octaves of the 8', 4', and 2' Principal ranks were measured before the final tuning of the pipework. At a temperature of 11° Celsius, the pitch of these pipes varied from a^1 = 440 to 449 Hz, with a median of 445 and an average of 444.6 Hz.[32] Choosing to intervene as little as possible, the restorers adopted the pitch a^1 = 445 Hz. For comparison with other instruments this should be raised slightly to compensate for the low temperature at which the pitch was measured. At a temperature of 17°, the pitch would be a^1 = 449.7 Hz.[33] Based on further calculations to take into consideration the unequal temperament of the organ, in which the relative pitch of the A pipes is lower than that of the C pipes from which the tuning would have commenced, the overall pitch level of the organ could be considered to be about a^1 = 452.3 Hz,[34] for all practical purposes the same as the pitch a^1 = 453 Hz

31. Egon Kraus, *Die Ebert-Orgel in der Hofkirche zu Innsbruck (1558): Ihre Geschichte und Wiederherstellung* (Innsbruck: Edition Helbling, 1989), 21–23.

32. Ibid., 36.

33. The pitch of a pipe is directly related to the velocity of sound in its air column, and the velocity is greater at higher temperatures according to the following formula, after Harry F. Olson, *Music, Physics and Engineering*, 2nd rev. ed. (New York: Dover Publications, 1967), 10:

$$c = 33100\sqrt{(1 + 0.00366t)}$$

in which c is the velocity in cm per second and t is the temperature in degress Celsius. If a pipe sounds pitch p_1 (expressed in Hz) at temperature t_1, its pitch p_2 at temperature t_2 can be found by the following formula, which has been used for the calculated values in tables 4 and 5:

$$p_2 = p_1\sqrt{([1 + 0.00366t_2] \div [1 + 0.00366t_1])}$$

34. The median pitch of the A pipes in this organ, a^1 = 445 Hz, gives a slightly misleading indication of the instrument's overall pitch level. The organ retains its tuning in quarter-comma meantone temperament (or something very close to this). Generally, historical tuners began with C, and in unequal temperaments the notes on one side of C in the circle of fifths (F, B-flat . . .) are higher in pitch than they would otherwise be, while the notes on the other side of the circle (G, D, A . . .) are lower. (This can be seen clearly when quarter-comma meantone is expressed in terms of

TABLE 2. Dimensions of Principal pipes sounding c^3 (½') in the organ by Jörg Ebert, 1558, in the Hofkirche, Innsbruck (in mm). Data from Egon Krauss, *Die Ebert-Orgel in der Hofkirche zu Innsbruck*, 21–23.

Rank	Note	Speaking Length	External Circumference (Cf)	External Diameter	Mouth Width (Mw)	Cutup (Cu)	Mw/C	Cu/Mw
octav 4'	c^2	138	52	16.6	13	5.5	0.250	0.42
quint 3'	f^1	142	51	16.2	12.5	5.7	0.245	0.46
quintez 2'	c^1	142	51	16.2	12	6	0.235	0.50
offen fletl 4'	c^2	142	53	16.9	13	6	0.245	0.46

measured from a recording of the instrument played on what must have been a moderately warm day.[35] The Ebert pipes sounding c^3 are generally about 2% longer than our measurement of Praetorius's *Pfeifflin* adjusted for paper shrinkage, so, in order to estimate Praetorius's *Chormaß* from them, an upward adjustment would be justified, from $a^1 = 452.3$ Hz to about $a^1 = 460$ Hz.

This result is significantly higher than previous estimates of Praetorius's *Pfeifflin* pitch, whether based on actual reconstructions or on calculations from theoretical formulae. Let us assume, for the moment, that the effective speaking lengths of the Ebert pipes have not been substantially shortened by alteration or damage, that is, that the pitch has not been raised, for example, by cutting away portions of the

cents, as in J. Murray Barbour, *Tuning and Temperament, a Historical Survey* [East Lansing: Michigan State College Press, 1953], 26.) Thus, if we regard the pitch of C as central, measurements made of the other notes should be adjusted appropriately. In the case of the Ebert organ, the measured $a^1 = 445$ Hz of the A pipes would be converted through multiplication by the relationship of C to A in meantone temperament, $4 \div 5^{3/4} = 1.196279 \ldots$, to yield the c^2 pitch of 532.344 Hz. For purposes of comparison, we would then convert this c^2 to what might be called the "virtual a^1" through multiplication by the ratio of a minor third in the neutral standard of equal temperament, that is, by 0.840896 . . . , and obtain the result $a^1_{virtual} = 447.646$ Hz at 11° Celsius, which becomes 452.346 Hz at 17°. In general, when the pitch of a C pipe is measured and one wishes to convert it to its equivalent at a^1, the usual note used for comparison, the conversion should be done according to equal temperament, as has been done for tables 4 and 5 of this article. In practice, this conversion is done automatically in the display of most electronic tuning devices. In any case, the typical differences of a few Hz caused by unequal temperaments are negligible in considering variations in pitch overall: see also the statement about this in Haynes, *Story of 'A'*, xxxiv.

35. CD recording by Herbert Tachezi, *Renaissance and Baroque Organ Music*, Teldec 9031-77606-2 (issued in 1995; the Innsbruck organ tracks evidently previously issued in 1980 or 1981). Haynes, *Story of 'A'*, 457, reports the pitch as approximately $a^1 = 460$ Hz.

upper rim or by outward flaring from cone tuning. Then, the most reasonable explanation for their higher pitch is that the mouths are larger than those in modern reconstructions of the *Pfeifflin* and that the wind pressure of the Ebert organ is higher. In organ building in general, higher cutups (mouth heights) correlate with higher wind pressures. The mouth widths of the Ebert pipes listed in table 2 are about one-quarter (0.25) the circumference, while the cutups (mouth heights) are upwards of two-fifths (0.40) the mouth width. These ratios may be compared with the significantly smaller ones employed by Bormann and Bunjes. The latter, for example, made the mouth width of his *Pfeifflin* only one-fifth the circumference; Bormann's cutup was only one-quarter. One might question whether pipes made by a South German master of the mid-sixteenth century (Jörg Ebert resided in Ravensburg) are typical of what Praetorius would have expected to be made. The available data (table 3) suggest that mouth widths of two-ninths (0.222) or one-quarter the circumference were common in North Germany in the first half of the seventeenth century. While the cutups are, on the average, slightly lower than Ebert's, cutups of two-fifths or higher seem not to be altogether rare.

The now-discredited myth of mid-twentieth-century neo-baroque organ building, that historical wind pressures were extremely low, is reflected in Bormann's pressure of 65 mm (water column) and especially in Bunjes's 55 mm. With ample historical evidence and justification, the restorers of the Ebert organ set its pressure at 90 mm.[36] This, of course, is a church organ, while Praetorius recommended placing the *Pfeifflin* in a regal as a more stable alternative to blowing by mouth. Regals could be considered to be chamber organs, and it is conceivable that they might have been made with lower wind pressures than church instruments. The average wind pressure of the Compenius organ in Hillerød is 57 to 58 mm.[37] Praetorius, however, describes this particular instrument as entirely unlike other organs. Since his and Compenius's intention was to make an instrument with a "strange, soft, subtle tone,"[38] its wind pressure might well have been made lower than

36. Krauss, *Die Ebert-Orgel*, 28. A seminal study showing that relatively high wind pressures were common is Helmut Winter, "Das Winddruckproblem bei den norddeutschen Orgeln im 17. und 18. Jahrhundert," *Acta Organologica* 3 (1969): 176–182.

37. According to Mads Kjersgaard (see note 30, above), who also states that the wind pressure varies from about 54 to 60 mm.

38. *De Organographia*, 141.

TABLE 3. Dimensions of Principal pipes sounding c^3 (½') in seventeenth-century North-German organs (in mm).

Location Maker Date	Stop	Circumference (Cf)	Mouth Width (Mw)	Cutup (Cu)	Mw/Cf	Cu/Mw
Osteel Edo Evers 1619	Principal 8'	48.7	10.8	4.0	0.222	0.37
"	Octav 4'	54.7	12.0	4.5	0.219	0.38
"	Octav 2'	52.5	10.8	4.5	0.206	0.42
Cappel pre-Schnitger before 1680	Octav 4' (Hauptwerk)	46.8	10.6	4.4	0.226	0.42
Hamburg, St. Jacobi Hans Scherer I 1605	Octav 4' (Hauptwerk)	54.3	12.3	3.9	0.227	0.32
Hamburg, St. Jacobi Gottfried Fritsche 1635–1636	Octav 2' (Oberwerk)	51.5	11.7	3.4	0.227	0.29
"	Scharff (Oberwerk)	49.0	11.8	3.5	0.241	0.30
Altenbruch pre-Fritsche before 1647	Principal 8' (Rückpositiv)	50.0	11.1	4.6	0.222	0.41

"	Octav 4' (Rückpositiv)	48.7	12.3	4.0	0.252	0.33
Altenbruch Hans Chr. Fritsche 1647–1649	Principal 8' (Hauptwerk)	64.4	16.1	5.0	0.250	0.31
"	Octav 4' (Hauptwerk)	48.1	14.6	4.5	0.304	0.31
"	Mixtur (Hauptwerk)	49.3	13.1	3.8	0.266	0.29
"	Cimbel (Hauptwerk)	47.8	12.0	4.5	0.251	0.38
Stade Berendt Huß 1668–1673	Octav 8' (Oberwerk)	51.8	13.6	5.0	0.263	0.37
"	Octav 4' (Oberwerk)	52.8	12.5	3.8	0.237	0.30
"	Octav 2' (Oberwerk)	52.2	12.8	4.2	0.245	0.33
"	Octav 2' (Brustwerk)	46.5	11.4	4.5	0.245	0.39
"	Octav 4' (Rückpositiv)	46.8	11.7	3.5	0.250	0.30
"	Mixtur (Pedal)	50.0	12.0	4.8	0.240	0.40

Sources: **Osteel** - Walter Kaufmann, *Die Orgeln Ostfrieslands* (Aurich: Verlag Ostfriesische Landschaft, 1968), 311–312; **Cappel** - Helmut Winter, *Die Schnitger-Orgel in Cappel,* Orgel-Studien 2 (Hamburg: Karl Dieter Wagner, 1977), 24; **Hamburg** - Jürgen Ahrend, "Die Restaurierung der Arp Schnitger-Orgel von St. Jacobi in Hamburg," in *Die Arp Schnitger-Orgel der Hauptkirche St. Jacobi in Hamburg,* Heimo Reinitzer, ed. (Hamburg: Christians Verlag, 1995), 255–258; **Altenbruch** - Bernard Contax, ed., *Orgues Historiques* 19, 20–23; **Stade** - Helmut Winter, *Die Huß-Orgel in Stade,* Orgel-Studien 1 (Hamburg: Karl Dieter Wagner, 1979), 40–47.

that of typical chamber organs. There is little reliable information about the wind pressures of historical regals.[39] Bernhardt Edskes reports a pressure of 60 mm in a regal made by Christophorus Pfleger in 1644, which has its original bellows weights.[40] Each of the top boards of the two bellows is 831 mm long by 337 wide; the two weights are 20 mm thick and are set into compartments that are 75 mm wide but slightly different in length, 272 and 276 mm; the two weights are slightly different, 3.6 and 3.7 kg. The weights on the regal bellows depicted in Praetorius's *Theatrum Instrumentorum* (pl. IV), however, are larger than Pfleger's. To judge from the *Maßstab* included in the illustration, the dimensions of the weights are about 325 by 60 by 33 mm, resulting in a volume of about 640 cubic cm. This volume of lead, with a specific gravity of 11.34, would weigh about 7 kg. Thus, the wind pressure of Praetorius's regal (especially since the top boards of its bellows, about 760 mm long by 330 wide, are somewhat smaller than Pfleger's) would have been significantly higher than Pfleger's 60 mm.

The foregoing discussion demonstrates that the pipes of the Ebert organ, with their large mouth dimensions and voicing on relatively high wind pressure, are not necessarily irrelevant to the problem of Praetorius's *Pfeifflin*. There still remains the possibility that the effective speaking lengths of the Ebert pipes are shorter than the actual measured lengths. The question is best answered directly, by making and measuring the pitch of a new reconstruction of the *Pfeifflin*, with length and circumference derived from *De Organographia* together with the mouth dimensions of the Ebert pipes. The results (table 4) certainly approach the neighborhood of a^1 = 460 Hz and would be quite firmly established there if one were to use shorter available measurements of the *Pfeifflin* in conjunction with smaller paper-shrinkage correction factors. According to the *Pfeifflin* length measured in any one of the eight copies of *De Organographia* corrected according to the *Maßstab* in the copy of *Theatrum Instrumentorum* bound together with it, the speaking

39. Reinhardt Menger, *Das Regal* (Tutzing: Hans Schneider, 1973), 17, reports a range of wind pressures, measured during restorations, from 35 to 75 mm. The weights of regals, however, were usually not fastened to the bellows and have often been lost or replaced.

40. Bernhardt Edskes, "Das Regal des Orgelmachers Christophorus Pfleger von 1644: zur Frühgeschichte des Regals," in *Basler Studien zur Interpretation der alten Musik*, Veronika Gutmann, ed., *Forum Musicologicum* 2 (Winterthur: Amadeus Verlag, 1980), 73–106; see especially p. 90.

TABLE 4. Pitch measurements of a metal *Pfeifflin zur Chormaß* for c^3 (½').

Reconstruction by the author, 1999
Speaking length, 138 mm; Plate width, 52
External diameter, 17; Internal diameter, 16
Mouth width, 13; Cutup, 5.7

Wind pressure (mm H_2O)	Pitch, a^1 equivalent, in Hz		
	at 22° C.	at 17° C. (calculated)	at 17° C., with 136 mm speaking length (calculated)
60	454	450	457
70	456	452	459
80	458	454	461
90 (extrapolated)	460	456	463

length would be from 136 to 137 mm long, not the 138 mm of the tested pipe.

Praetorius also directs that a *Pfeifflin* may be made of wood. In that case, the dimension used for the plate width of the metal pipe was presumably intended to be divided into four parts (*gevierdt*) for the internal dimensions of the wooden pipe; that is, twice the width plus twice the depth of the wooden pipe equals the width of the plate for the metal pipe. Wooden pipes were generally made with their widths slightly narrower than their depths, and the upper right-hand corner of the *Pfeifflin* diagram shows a slightly oblong, not square, cross section for a wooden pipe, evidently c^3. Measured inside the lines, the dimensions of this rectangle (12.2 by 13.6 mm) add up to a perimeter, 51.6 mm, almost exactly equal to the plate width of the metal pipe. While the mouth width is equal to the internal width of the pipe (12.2 mm), there are major questions about other details of the construction of the mouth and windway.[41] The upper surface of the block, which serves as the floor of the air column, may be level with the upper edge of the cap, which forms the lower lip of the mouth; or it may be set above the cap or possibly even below. One cannot be sure which arrangement Praetorius would have preferred or whether he would

41. Again, the Compenius organ in Hillerød would not necessarily be a reliable guide to what was considered normal in Praetorius's day.

have measured the speaking length from the upper edge of the block or that of the cap. The appropriate cutup is also unknown. A speculative reconstruction of a wooden *Pfeifflin*, with the block set level with the cap and a cutup ratio similar to that in a wooden *Principal* stop presumably made by Gottfried Fritsche in 1635–1636,[42] yields pitches about a third of a semitone lower than those of the reconstructed metal *Pfeifflin* (see table 5). Various explanations are possible, for example, that Praetorius expected a different windway construction or chamfering of the inner edges of the wood at the top of the pipe, or that he was not so very concerned about differences of less than half a semitone. Alternatively, since Praetorius cast his diagram in the traditional format used for metal pipes (scaling diagrams for wooden pipes indicated the depths and widths of the rectangular pipes,[43] not just the length of the perimeter), he must have regarded the wooden *Pfeifflin* as a secondary possibility and might not have actually realized that it would yield a slightly lower pitch. Still, the results for the wooden *Pfeifflin* are somewhat higher than a^1 = 440 Hz and significantly higher than those from previous reconstructions.

The preceding has been only an outline of an interpretation of Praetorius's evidence about pitch. Most of the major points have been made by previous investigators: that Praetorius's *Pfeifflin* diagram conveys useful information; that Nuremberg trombones with the slide positioned as he describes sound about a semitone above modern pitch; that Praetorius's local *Chorthon* and *Chormaß* were the same as his *Cammerthon*; and that this was in the neighborhood of a^1 = 460 Hz. The major new point is that, with certain reasonable assumptions about the parameters of organ pipes, the *Pfeifflin* diagram is, after all, consistent with this high pitch level. Certainly this point could be developed further, especially by measurement of the diagram and *Maßstab* in more copies of *De Organographia* and *Theatrum Instrumentorum*, by experimentation with further reconstructions of metal and wooden *Pfeifflin* (including those for the rest of the c^3 to c^4 octave indicated in Praetorius's

42. Principal 8' in the Brustwerk of the organ at St. Jacobi, Hamburg: see Jürgen Ahrend, "Die Restaurierung der Arp Schnitger-Orgel von St. Jacobi in Hamburg," in *Die Arp Schnitger-Orgel der Hauptkirche St. Jacobi in Hamburg*, Heimo Reinitzer, ed. (Hamburg: Christians Verlag, 1995), 215–216 and 259. Basically, the cutup in the treble is one-half the mouth width, plus a little more, presumably trimmed off during the voicing process.

43. Several examples are in Christian Vater's *Werkstattbuch*, 17 and 22–23.

TABLE 5. Pitch measurements of a wooden *Pfeifflin zur Chormaß* for c³ (½').

Reconstruction by the author, 2000
Speaking length, 138 mm
Internal width (= Mouth width), 12.5; Internal depth, 13.5
Cutup, 6.3

Wind pressure (mm H_2O)	Pitch, a¹ equivalent, in Hz		
	at 20.7° C.	at 17° C. (calculated)	at 17° C., with 136 mm speaking length (calculated)
60	445	442	448
70	447	444	451
80	449	446	453
90 (extrapolated)	451	448	455

diagram), and by more thorough study of the relationship between dimensions and pitch in well-preserved organ pipes of Praetorius's era.

A vigorous proponent of the view that Praetorius's pitch standard was $a^1 = 430 \pm 5$ Hz has asserted that the proposed *Chormaß* of about $a^1 = 460$ "can be a serious contender for Praetorius's pitch only if [one] can similarly give a reasonable interpretation of the pitch-pipe information that makes it fit."[44] This has now been done.

44. Ephraim Segerman, "Praetorius's Pitch?" 263. It is only fair to note that Dr. Segerman, who was provided with a copy of my Bremen paper, has refused to accept my fulfillment of his challenge: see his response in "A Survey of Pitch Standards Before the Nineteenth Century," *Galpin Society Journal* 54 (2001): 200–218; Herbert W. Myers's and my own comments in the same issue, 420–424; Bruce Haynes's letter ibid. 55 (2002): 405–407; Segerman's two letters ibid. 56 (2003): 241–245; and my letter ibid. 57 (2004): 252.