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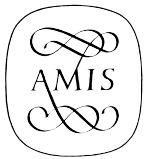

Theophilus on Making Organ Pipes

Wilson Barry

In his treatise *De diversis artibus*,[1] "Theophilus" (probably the pseudonym of Roger of Helmarshausen, a Benedictine monk and metalworker[2] who flourished around 1100) gives us not quite the first, but certainly the most detailed and practical description we have of the tools and procedures used in the organ-pipe making of his day.

This treatise, written in about 1125, has been described as "an essay upon various arts, in three books, by Theophilus, called also Rugerus, priest and monk, forming an encyclopedia of Christian art."[3] The first book contains thirty-eight chapters about the art of the painter, the second book thirty-one chapters about the art of the worker in glass, and the third book ninety-six chapters about the art of the metal worker.

Four chapters of this third book deal with the organ:

Chapter 81	De Organis	About Organs
Chapter 82	De Domo Organaria	About the Wind Chest
Chapter 83	De Conflatorio	About the Wind Collector
Chapter 84	De Domo Cvprea et Conflatorio eivs	About the Copper Wind Chest and its Wind Collector

1. John G. Hawthorne and Cyril Stanley Smith, eds. and trans., *On Divers Arts: The Treatise of Theophilus* (Chicago: The University of Chicago Press, 1963; corrected reprint, New York: Dover Publications, 1979); C. R. Dodwell, ed. and trans., *Theophilus, De diuersis artibus. Theophilus, The Various Arts* (London and Edinburgh: Thomas Nelson and Sons, 1961).

"There are many manuscripts of different dates and varying accuracy scattered throughout European libraries . . ." (Hawthorne and Smith, xvii–xviii).These manuscripts exhibit varying lines of descent and varying degrees of completeness; the most complete is London, British Museum, Harley 3915, from the thirteenth century. Other copies containing book 3, chapters 81–84 are Vienna, National Bibliothek 2527, and Wolfenbüttel, Herzogliche Bibliothek 4373, both from the twelfth century. The complete treatise has been translated into German (1781, 1874 and 1933), French (1843 and 1851), and Polish (1880).

2. Examples of his skill at metalworking are still preserved in Nuremberg (a bejewelled book cover) and Paderborn (two portable altars).

3. Robert Hendrie, trans., *Theophili, qui et Rugerus, presbyteri et monachi libri III. De diversis artibus: seu diversarum artium schedula. An Essay upon Various Arts, in Three Books, by Theophilus, Called also Rugerus, Priest and Monk, Forming an Encyclopedia of Christian Art of the Eleventh Century* (London: John Murray, 1847). More recent scholarship has placed the treatise in the first half of the twelfth century; see Hawthorne and Smith, xvi. Hendrie's translation of Theophilus' book 3, chapters 81–84, is reprinted in George Ashdown Audsley, *The Art*

Although there have been five English translations of chapter 81 on organ-pipe making in the past century and a half,[4] there seems to be a need for yet another, for reasons that reveal something about the process of translation itself (the five previous translations of the opening passage of this chapter are given for comparison in the Appendix). The Latin text as edited by C. R. Dodwell, together with a new translation of the entire chapter, is offered below, with notes and commentary that may clear up certain doubtful points and ambiguities.[5] Finally, new translations will be offered of brief passages from two eleventh-century documents—Aribo Scholasticus, *De musica,* "Qualiter ipsae congruentur fiant fistulae," and Anonymous of Berne, *De fistulis organicis quomodo fiant*—that present descriptions that differ from that of Theophilus and may represent a different, perhaps earlier, tradition.

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of Organ-Building (New York: Dodd, Mead, and Company, 1905; corrected reprint, New York: Dover Publications, 1965), vol. 1, pp. 23–27.

4. In addition to the three English translations of the complete *De diversis artibus* by Robert Hendrie, C. R. Dodwell, and John G. Hawthorne and Cyril Stanley Smith, there are two translations of chapters 81–84 of the third book, one by William Leslie Sumner and one by Jean Perrot.

"Hendrie has extensive notes . . ., and he frequently quotes other sources for comparison. It was a great contribution and the edition is still useful . . ." (Hawthorne and Smith, xx). Dodwell discusses the various manuscripts and gives extensive bibliography. "Dodwell's . . . text is definitive, apart from an occasional reading" (Hawthorne and Smith, xxii). Dodwell's edition, like Hendrie's, includes a Latin text on the facing page. Book 3, chapter 81, appears at pp. 142–44. Hawthorne and Smith discuss the various manuscripts and give extensive bibliography; the corrected reprint gives additional bibliography to 1978. "We—a classicist and a metallurgist in collaboration—envisioned our edition as one that would pay especial attention to the detailed technology that Theophilus describes" (p. xxii).

William Leslie Sumner, *The Organ: Its Evolution, Principles of Construction and Use* (first ed., 1952) 3rd ed., revised and enlarged (London: Macdonald and Co., Ltd., 1962), 39–44. In its first two sentences Sumner's translation is identical to Hendrie's version except for two words.

Jean Perrot, *L'Orgue de ses origines hellénistiques à la fin du XIIIe siècle* (Paris: A. et J. Picard et Cie, 1965); trans. by Norma Deane under the title *The Organ from its Invention in the Hellenistic Period to the End of the Thirteenth Century* (London: Oxford University Press, 1971), with a Latin text at pp. 297–302. An original translation, with commentary and comparable passages from the treatises of the Anonymous of Berne and of Aribo, is given at pp. 232–52.

5. References to Theophilus may be found in the following recent works in the field of the history of the organ: Karl Bormann, *Die gotische Orgel zu Halberstadt: Eine Studie über mittelalterlichen Orgelbau* (Berlin: Verlag Merseburger, 1966), 87–88; Sibyl Marcuse, *A Survey of Musical Instruments* (New York: Harper and Rowe, 1975), 610–12; Klaus-Jürgen Sachs, "Remarks on the Relationship between Pipe-measurements and Organ-building in the Middle Ages," *The Organ Yearbook* 4 (1973): 87–100; Peter Williams, *A New History of the Organ From the Greeks to the Present Day* (Bloomington and London: Indiana University Press, 1980), 41–45.

Theophilus, De diversis artibus, *Book 3, Chapter 81,* De organis

[Part 1. The Treatise of Measurements, the Mandrel(s) and the Burnisher]

Facturus organa[6] primum habeat lectionem mensurae, qualiter metiri debeant fistulae graues et acutae et superacutae.[7] Deinde faciat sibi ferrum longum et grossum ad mensuram qua uult esse fistulas, quod sit in circuitu rotundum, summa diligentia limatum et politum, in una summitate grossius et modice attenuatum, ita ut possit imponi in alterum ferrum curuum per quod circumducatur, iuxta modum ligni in quo uoluitur runcina, et in altera summitate gracile secundum mensuram inferioris capitis fistulae, quod domo organaria debet imponi.

He who would make organs[8] should first have a treatise of measurements, showing how the grave and acute and superacute pipes[9] should be laid out [on the flat sheets—*laminae*—of metal]. Next he should make for himself a mandrel of a length and diameter according to the size which he wishes the pipes to be. This mandrel must be round,[10] and filed and polished with the utmost care. It is thicker at one end and somewhat tapered (so that it will fit inside a curved burnisher shaped like a bit brace), and at the other end slender, in accordance with the diameter of the lower end of the pipe, which should be placed upon the windchest.

Since the absolute dimensions are to be determined by the wishes of the maker, the treatise of measurements probably dealt only with proportions. The *alterum ferrum curuum* seems to be a burnisher shaped like

6. *Facturus* is a future participle, as in *morituri te salutamus* (we who are about to die salute you); some translations do not convey this. *Organa* is the plural form of the noun; this is not clear in some translations.

7. Since it is not clear just what Theophilus understood by *graues, acutae,* and *superacutae,* it seems better to preserve the uncertainty by reading "grave, acute, and superacute."

8. Perrot reads "organ pipes," but the dimensions of the pipes also determine the dimensions of the wind chest.

9. Hendrie and Sumner read "grave and sharp and treble;" Dodwell "bass, treble and alto;" Hawthorne and Smith "bass, alto, and treble." The notion of bass, however, seems to have been a Renaissance idea, first appearing ca. 1450; Perrot reads "low, high, and very high," and remarks that Theophilus presumably plans to have three octaves. However, one suspects that Theophilus' compass did not exceed two octaves and a sixth, or from *G* to *e″*, which is not very high. (See Willi Apel, "Hexachord," *Harvard Dictionary of Music,* 2nd ed. rev. (Cambridge: Belknap Press, 1986), 377. Henri Arnaut de Zwolle (Burgundian, ca. 1440) does show about three octaves, and calls them *Barduni, Naturales,* and *Supernaturales,* which I have translated elsewhere as tenor, middle, and treble. See *Henri Arnaut de Zwolle on Small Keyboard Instruments,* The Historical Harpsichord, ed. Howard Schott (Stuyvesant, NY: Pendragon Press: forthcoming). Similarly, fifteenth-century English sources use tenor, meane, treble (third voice), and quatreble (fourth voice). See Apel, "Sight", *Harvard Dictionary of Music,* 748.

10. Not "cylindrical," as Dodwell reads, but with a truncated conical shape.

a half hoop with two handles. Such a tool is sometimes used to this day to burnish—or rather, reburnish—tin front pipes in the round on a cylindrical mandrel. Theophilus seems to have it backwards: the mandrel is not made to fit the burnisher, but the burnisher is made a little larger than the thick end of the mandrel. (The wooden tool in which an auger bit is revolved is called a bit brace today; see fig. 1.[11])

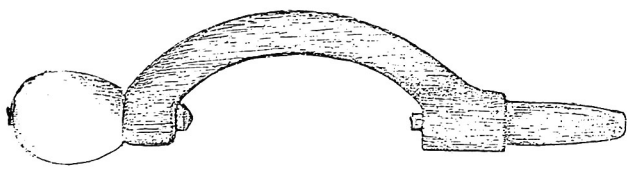

FIGURE 1. Drawing of a bit brace of a type similar to the one known to Theophilus.

[Part 2. Preparing the Lamina*]*

Deinde attenuetur cuprum purum et sanissimum, ita ut unguis impressus ex altera parte appareat. Quod cum fuerit secundum mensuram ferri lineatum et incisum ad longiores fistulas, quae dicuntur graues, fiat secundum praeceptum lectionis foramen, in quo plectrum imponi debet, et circumradatur modice ad mensuram festucae, atque superliniatur stagnum cum ferro solidatorio, radaturque in una

Next pure and very sound copper is thinned [by beating] so that the impression of a fingernail may show on the other side. When this has been marked out and cut according to the diameter of the mandrel for the longer pipes (which are called grave), an opening is made, according to the instructions in the treatise [of measurements], in which the languid should be placed, and it [the opening] is somewhat filed

11. Not a grindstone (Hawthorne and Smith) or a drill (Dodwell) or a piece of wood being bored (Perrot). Hendrie has it best: "after the fashion of the wood in which the auger is revolved." Dom Bédos shows us a bit brace and remarks that it must be of iron, or preferably of steel (implying that bit braces of wood were not good enough). See François Bédos de Celles, *L'Art du facteur d'orgues,* 4 vols. (Paris, 1766–78); trans. by Charles Ferguson under the title *The Organ Builder,* 2 vols. (Raleigh: The Sunbury Press, 1977), vol. 1, p. 14; vol. 2, plate 8, fig. 61. However, despite Dom Bédos' advice, bit braces of wood were still in use as recently as the last century in some quarters. Latin lacks many specific nouns: something made of iron (mandrel; burnisher) is called an iron (*ferrum*), and something made of wood (bit brace) is called a wood (*lignum*), a style of nomenclature not entirely extinct today, e.g., in the game of golf.

FIGURE 2. Drawing of an organ with tapered pipes, from the 1109 Bible of Etienne Harding, third Abbot of Citeaux. Dijon, Bibliothèque Municipale 14, f. 13v.

ora longitudinis interius et in altera ora exterius eadem mensura, et superstagnetur tenue. Quae stagnatura priusquam rasi tractus nouiter facti modice calefacto cupro liniantur cum resina abietis, ut stagnum leuius et citius adhaereat.

around to the width of a straw, and it is tinned with a soldering iron, and it [the *lamina*] is filed on one edge of the length inside, and on the other edge outside to the same degree, and it is tinned lightly. Before this tinning is done, and while the filed area is still fresh [i.e., unoxidized], the copper being somewhat warmed, it is anointed with fir resin, so that the tin may adhere to it more easily and quickly.

The taper of the mandrel was the one proportion the treatise of measurements could not provide. The existence of one or more additional mandrels (with different tapers?) for the shorter pipes (called acute and superacute) seems to be clearly implied. The joint will be subject to considerable hoopwise stress during the subsequent burnishing and the lapped joint is much stronger (since the solder is in shear) than the beaded butt joint used in soldering backseams today (in which the solder would be in tension). Moreover, the edge lapping over the seam protects it during the burnishing. If the lathe was right-handed, as it would be today, one can be certain that it was the left side of the pipe that lapped over the right side, rather than the other way around. Rosin is used to this day as a flux for soldering copper.

[Part 3. Rounding the Pipe and Soldering the Backseam]

Quo facto complicetur ipsum cuprum circa ferrum et circumligetur filo ferreo mediocriter grosso fortiter, ita ut stagnati tractus conueniant sibi. Quod filum primo induci debet paruulo foramini, quod est in gracili summitate ferri, et in eo bis contorqueri, sicque deduci inuoluendo usque ad alteram summitatem, ibique similiter obfirmari. Deinde iuncturis sibi inuicem conuenientibus et diligenter coniunctis, ponatur ipsa ligatura pariter cum ferro ante fornacem super prunas ardentes, et sedente puero ac mediocriter flante, teneatur dextera

This done, the copper is folded around the mandrel and is firmly tied around with iron wire of medium thickness, so that the tinned edges come together exactly. This wire should be threaded into a small hole which is in the slender end of the mandrel, wound around it twice, and thus led in a spiral to the other end of the mandrel, where it is fastened in the same way. Then with the edges to be joined coming together on both sides and accurately brought together, the assembly is placed before a furnace above the glowing live coals,[12] and

12. Hendrie, Sumner, Dodwell, and Hawthorne and Smith read collectively: "on [upon] glowing [blazing; red hot] coals [embers]." Perrot reads "near a furnace of glowing coals."

manu lignum gracile, in cuius summitate fissa adhaereat panniculus cum resina, et sinistra teneatur stagnum longum gracile percussum, ut mox cum fistula incaluerit, liniat iuncturam cum panniculo resina infecto, appositumque stagnum liquefiat, ipsamque iuncturam diligenter consolidet.

with the boy sitting and gently blowing, in the right hand is held a slender wooden stick from the split end of which hangs a small cloth with resin, and in the left hand is held a length of solder beaten thin, so that as soon as the pipe becomes hot,[13] he may anoint the joint with the resin-soaked cloth, the applied solder melts, and he carefully solders the joint together.

The copper, work-hardened by being beaten to thickness, is springy and cannot be beaten round like sheets of tin, lead, or an alloy of these metals. The copper would rapidly become too hot for soldering if it were placed in the fire, and the tinning, both for the backseam and for the languid, would perish. The assembly must actually have been placed on the hearth, where it was heated by radiation from the glowing coals in the forge. In his chapter 89, "How Tin should be Soldered," Theophilus describes a solder consisting of two parts tin to one part lead, which is practically the eutectic composition, which melts at a temperature of about 185° C (365° F).[14] Even pure tin solder melts at only about 230° C (450° F).

This is a very practical way of soldering the lapped-over backseam; copper is such a good conductor of heat that it would be difficult to keep the seam hot enough, but not too hot, long enough to draw a good seam. The iron mandrel acted as a reservoir of heat, greatly stabilizing both the heating and the cooling of the pipe. When the copper was just hot enough to melt the solder, the assembly must have been removed from the hearth, so that it would not heat up any further, but would begin to cool down. Since the pipe maker obviously has his hands full, it seems that a soldering iron is not used for this operation. One can picture the pipe maker running the seam from left to right (first the flux, then the solder).

The melting solder draws heat from the seam, so that a little blowing by the apprentice would induce the solder to "freeze" again.[15] This

13. Hawthorne and Smith read "heats up" (which is good); Dodwell reads "red-hot." Like Hendrie, Sumner, and Perrot, I read "hot," meaning only a little above the melting point of the solder.

14. See Hawthorne and Smith, 182, xxxiv.

15. Herman Greunke, "The structural Stability of Lead-Tin Alloys Used in Organ-Pipes," *The Organ Yearbook* 15 (1984), 108–14, especially 110–11, for a recent description (in effect) of the behavior of solder.

passage suggests that the slender end of the pipe was to the pipe maker's left, for this end would cool faster than the thick end. If the left side of the pipe lapped over the right side, this would bring the face of the joint conveniently toward the pipe maker.

[Part 4. Burnishing the Pipe]

Quo facto refrigerata fistula, ponatur ferrum in instrumento tornatoris more parato, impositoque curuo ferro et filo soluto circumuoluat unus ferrum curuum, alter uero utrisque manibus cirothecis iam indutis fortiter fistulam teneat, ita ut ferrum circumducatur et fistula quieta maneat, donec omnino oculis gratiosa appareat, quasi tornata sit.

This done, the pipe having cooled, the assembly is placed in a lathe, and, the wire having been unfastened, the curved burnisher is applied; one rolls the burnisher around, the other now indeed having put gloves on both his hands, holds the pipe firmly, so that the mandrel revolves and the pipe remains still, until it appears altogether pleasing to the eye, as if it had been turned.

Here Theophilus seems to be confusing two distinct operations. The heat of the soldering temperature has not been sufficient to anneal the copper, which is still full of stresses—like a wound-up clock spring—trying to spring the pipe out of round and fracture the backseam. The relief, or rather, equalization, of these stresses is the objective of the operation which requires the gloves. By applying the burnisher all over the outside of the pipe, while the pipe is still and the mandrel is revolving, the pipe maker is burnishing the *inside* surface of the pipe. The burnisher is not only semicircular in plan, but also convex in section, so that the pipe maker rolls it back and forth all over the surface of the pipe, pressing the copper down against the revolving mandrel. No wonder the apprentice needed gloves to hold the pipe still!

This operation does nothing to improve the outside appearance of the pipe; however, once the inside of the pipe is thoroughly burnished, the lathe is stopped and the pipe is slid up firmly on the mandrel, so that the mandrel and the pipe will revolve together. Starting the lathe again, the pipe maker burnishes the outside of the pipe, giving it a turned appearance.

[Part 5. Flatting the Mouth and Installing the Languid]

Deinde educto ferro percutiatur ipsa fistula cum malleo mediocri iuxta foramen superius et inferius, ita ut pene usque ad medium descendat ipsa ro-

Next, the mandrel being withdrawn from the pipe, the pipe itself is beaten with a medium-sized hammer in the region of the mouth opening, above

tunditas spatio duorum digitorum; fiatque plectrum ex cupro aliquantulum spissiori quasi dimidia rotula, et superstagnetur circa rotunditatem sicut fistula superius, sicque imponatur in inferiori parte foraminis, ut sub ipsius ora aequaliter stet, nec procedat inferius aut superius. Habeat quoque ferrum solidatorium eiusdem latitudinis et rotunditatis, qua plectrum est; quo calefacto ponat modicas particulas stagni super plectrum parumque resinae, et diligenter circumducat ferrum calidum ne plectrum moueatur, sed liquifacto stagno sic adhaereat, ut in circuitu eius nihil spiraminis exeat, nisi tantum in superiori foramine.

and below, so that the roundness descends almost as far as the middle for the space of two *digiti*; and the languid is made from considerably thicker copper, like a half wheel, and is tinned around the circumference like the pipe [described] above, and thus is placed in the lower part of the opening, so that it may stand equally under the edge, going too far neither above nor below. He also has a [second] soldering iron of the same width and roundness as the languid. Which [soldering iron] being heated, he places rather small particles of solder upon the languid, with a little resin, and carefully passes the hot iron around (the languid must not be moved during this process), but the melted solder may so adhere that over the circumference no wind may pass except only into the mouth opening.

Theophilus is describing the flatting of the upper and lower lips. Whether the distance of two *digiti* is to be understood as exact (i.e., 37 mm)[16] or as approximate, the diameter of the pipe would seem to be about five *digiti* (93 mm). But if the flatting really descended "almost as far as the middle," or axis, of the pipe, the mouth would seem impossibly wide; with such a mouth, the upper and lower lips would not stay "put." This may be a misperception on Theophilus' part: perhaps the diameter of the largest pipe was about five *digiti*, but the flatting descended only about one *digitus*, giving the mouth a more normal width of one quarter the circumference.

The lower part of the opening is the slot prepared to receive the languid, and the upper part of the opening is the mouth opening. The front of the languid is parallel with the inner edge of the lower lip, and must be neither too high nor too low. The tinned surface of the soldering iron described is narrow and concave lengthwise; a concavity large enough to fit this largest pipe would serve for the smaller pipes as well. Consider the condition of the mouth of the pipe: there is a slot around the front half of the circumference, whose width is equal to the thickness

16. Werner Walcker-Mayer, *Die römische Orgel von Aquincum* (Stuttgart: Musikwissenschaftliche Verlagsgesellschaft, 1970); trans. by Joscelyn Godwin under the title *The Roman Organ of Aquincum* (Ludwigsburg: Musikwissenschaftliche Verlagsgesellschaft, 1972), 37.

of the languid, so that the languid, properly shaped, and with its circumference pre-tinned, can be slid exactly into place (the pipe was also pre-tinned previously in the flat to receive the languid—inside for the back half, and outside, on either side of the slot, for the front corners).

When the languid is in just the right position, the pipe maker "tacks" the front corners. Then, holding the pipe up at an angle so that the particles of solder slide to the rear of the languid, he completes the soldering of the back half of the languid by applying the iron to the outside of the pipe (although the resulting seam is on the inside of the pipe). He then finishes off the soldering of the front corners.

[Part 6. Voicing the Pipe]

Quo facto apponat fistulam ori et sufflet, primum modice, deinde amplius, sicque fortiter; et secundum quod auditu discernit, disponat uocem, ut si eam uult esse grossam, foramen fiat latius; si uero graciliorem, fiat strictius. Hoc ordine omnes fistulae fiant. Mensuram uero singularum a plecto superius secundum magisterium lectionis faciat, a plectro autem inferius omnes unius mensurae et eiusdem grossitudinis erunt.

This done, he may bring the pipe to his mouth and blow first moderately, then more strongly and finally very strongly indeed, and according to what he perceives by hearing he voices the pipe, so that if he wishes it great he makes the opening wider; if indeed slighter, he makes it more narrow. In this manner all the pipes are made. He may indeed make the dimensions individual from the languid upward, according to the directions of the treatise [of measurements]; below the languid, however, all will be of one length and of the same diameter.

The term *foramen,* which referred, first to the opening prepared for the languid, and then to the mouth opening, now for the first time refers to the flue. Open-toe voicing is accomplished in the same manner today; it could not be otherwise. The procedure of blowing at three different pressures makes it clear that the voicer, though Theophilus does not say so, is adjusting the speech of the pipe—by correcting the position of the upper lip and of the front edge of the languid—as well as regulating the loudness by opening or closing the flue.

The comment, "In this manner all the pipes are made," might be rendered: "All the pipes [taken together] undergo this sequence [*ordo*] of operations [step by step]."

The dimensions (*mensurae*), in Theophilus' usage, include both length and diameter, as he clearly shows us at the very beginning of the chapter (*deinde faciat sibi ferrum longum et grossum ad mensuram . . .*). Both the feet and the bodies of the pipes, considered separately, have the form of truncated cones. It seems that Theophilus viewed the smallest diameter,

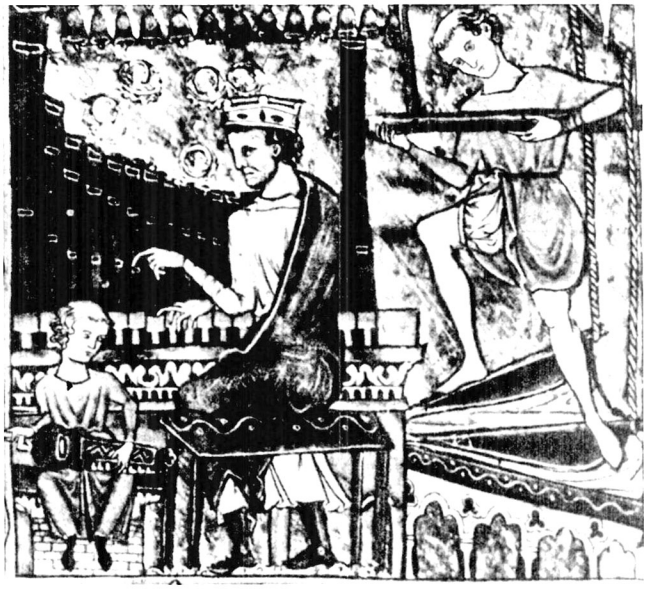

FIGURE 3. Miniature showing an organ with tapered pipes, from the Belvoir Castle Psalter of ca. 1270, f. 97v. Private collection.

both of the foot and of the body, as the definitive dimension. (Obviously the largest diameter of the foot was equal to the smallest diameter of the body, a dimension that varied from pipe to pipe.) So, as far as Theophilus could tell, the toes of all the pipes had the same diameter (and as a practical matter this dimension would not in fact vary a great deal).

We have seen that there appear to be a number of faults in Theophilus' description: he confuses the relationship between the sizes of the mandrel and the burnisher (part 1); he seems to imply a temperature too hot for soldering (part 3); he confuses the two burnishing operations (part 4); he may mistake the degree of flatting (part 5); and, finally, he may misunderstand the voicing process (part 6). One might conclude that Theophilus had certainly watched pipes being made and voiced, but had probably never done it himself. Nevertheless, he observed, understood, and reported more accurately than would most visitors to a pipe shop (even today).

Some previous commentary has taken for granted that, since Theophilus mentioned only one mandrel, his pipes all had the same diameter; but, as we have seen, the text clearly implies the existence of more than one mandrel. The obvious fact that (theoretically) an entire rank of pipes of varying diameter could be made on a single tapered mandrel, if that mandrel were long enough, has also been overlooked. (The largest and smallest pipes would stray farther from the desired taper ratio than one might wish.) But Theophilus' pipe maker doubtless had two or more shorter mandrels of convenient lengths and drafts. The tapering was not done to achieve any tonal effect (such as that of the *Tolkaan* of later years), but was required by the use of the mandrel both in the soldering of the backseam (as a heat sink) and in the burnishing of the pipes: if the pipe and the mandrel had been cylindrical, they could not have been separated.

Theophilus' *De organis* is the only documentary evidence we have that some medieval organs in the period ca. 1100–1300 were furnished with tapered copper pipes, though some iconographic evidence may be found in a few manuscripts such as the 1109 Bible of Etienne Harding, third Abbot of Citeaux (fig. 2),[17] and in the Belvoir Castle Psalter of ca. 1270 (fig. 3).[18]

The Testimony of Aribo

In his treatise *De musica*[19] Aribo Scholasticus, writing somewhat earlier than Theophilus, seems to describe a different practice:

Sicut fistulae eiusdem sunt grossitudinis, ita laminae, de quibus fiant, eiusdem sint latitudinis . . . Hae laminae in lateralibus extremitatibus attenuentur praecipue. Quae extremitates cum

Just as the pipes are the same diameter, so the *laminae* from which they are made will have been the same width . . . These *laminae* are especially thinned on their very edges.[20] These

17. Dijon, Bibliothèque Municipale MS 14, f. 13v°. Detail in Perrot, plate 25, no. 1, with description on pp. 280–81.

18. Detail in Perrot, plate 27, no. 2, with description at pp. 282–83. See also Wilson Barry, "A 12th-century English Organ," *The Diapason* 887 (October, 1983): 10–11.

19. Aribo Scholasticus, *De musica*, "Qualiter ipsae congruentur fiant fistulae" (eleventh century). Admont MS 496, now in the Sibley Musical Library, Eastman School of Music, Rochester, N.Y. Printed in *Aribonis de Musica*, ed. Jos. Smits van Waesberghe, Corpus Scriptorum de Musica 2 (Rome: American Institute of Musicology, 1951): 45–46. A Latin text is given in Perrot, p. 305, with a translation and commentary at pp. 236–38.

20. Perrot reads: "These sheets should be beaten very thin along their lateral edges," but the text does not say that they are beaten, only that they are tapered or thinned (*attenuentur*).

fabrili manu eas incuruante conueniant, non superponantur sibimet, sed osculo tantum collidantur coniunctissimo. Ad cuius osculi commissuram tegendam praeparentur laminellae festucae tenuitatem et latitudinem habentes, quae sibi tenacissimo conglutinentur stagno . . .

edges, bent around by the pipe maker's hand, come together, not overlapping, the lips meeting. For the covering of this joint, little metal strips are prepared, having the width and thickness of a straw, which are soldered to it with the most tenacious tin . . .

Aribo does not specify the metal from which the pipes are made; it is obviously not springy, like Theophilus' copper, but can be bent (or beaten?) round by hand. The edges of the *laminae* are probably chamfered with a cutting tool, and the backseam seems to be a beaded butt joint, like those made to this day. The "little metal strips" seem to be equivalent to Theophilus' "length of solder beaten thin." Thus, although Aribo does not mention any flux[21] or any sizing[22], he seems to be describing (imperfectly) the making of pipes of tin, lead, or an alloy of these metals.

Representations of organs with the cylindrical pipes of constant diameter described by Aribo may be found in the eleventh-century Pommersfelden Psalter[23] and in the twelfth-century Cambridge Manuscript.[24]

The Testimony of the Anonymous of Berne

The description of the Anonymous of Berne,[25] also from the eleventh century, seems to contain a few details which cannot be reconciled with the accounts of either Theophilus or Aribo:

21. Consisting for this purpose of wax or tallow.

22. In pipe making, "size" is a paint consisting of whiting suspended in water with a little glue; it is used to protect pipes of tin or lead from the heat of the soldering iron.

23. Pommersfelden, Gräflich Schönbornsche Bibliothek cod. 2777, f. 1 (a Rhineland psalter, ca. 1070).Detail in Perrot, plate 25, no. 2; description at p. 280. See also Barry, 10.

24. St. John's College, Cambridge MS B 18, fol. 1 (Rheims?). Detail in Perrot, plate 25, no. 3; description at pp. 281–82; also in Hawthorne and Smith, plate 15.

25. Anonymous of Berne, *De fistulis organicis quomodo fiant,* eleventh century (Codex Bernensis Martiani Capellae 56b). The origin of this document is not Switzerland, but probably the Benedictine Abbey of Fleury. (See Perrot, 233; Williams, 42.) Printed in P. Anselm Schubiger, *Musikalische Spicilegien über das liturgische Drama, Orgelbau und Orgelspiel, das ausserliturgische Lied und die Instrumental-Musik des Mittelalters* (Berlin: L. Liepmannssohn, 1876); reprinted in *Publikation Äelterer Praktischer und Theoretischer Musikwerke* 5 (New York: Broude Brothers, 1966): 82–85. A Latin text is given in Perrot, p. 302, with a translation and commentary at pp. 235–38.

Cuprum purissimum tundendo ad summam tenuitatem extenditur et complicatur ferro, ad hanc rem propter equalem latitudinem omnium fistularum aptato, pene quattuor pedibus longo, in modum chilindri bene rotundo, tantum ex una parte plus minus uno palmo paulatim restringitur acuendo ut, concauitas omnium fistularum in superiori foramine ouum columbae, in inferiori ouum lodici [vel] alaudae posset recepire. In eo uero loco, ubi incipit equalis grossitudo ex transuerso admorsa et patefacta fistula ex cupro in modum semicirculi una interius solidatur, ad quam hinc inde fistulam debet comprimi, ut uox possit formari.

The purest copper is extended by beating to the utmost thinness, and wrapped around a mandrel suitable for this because of the equal width of all the pipes. This mandrel is nearly four feet long,[26] well rounded in the form of a cylinder. About a hand's breadth (*palmus*)[27] from one end it gradually narrows to a point, so that the interior of all the pipes can accept the egg of a pigeon at the upper end, [but only] the egg of a *lodix* or lark[28] at the lower end. At the same place where the equal diameter begins, the pipe of copper is cut and laid open crosswise around half its circumference. A languid is made fast inside. The pipe ought to press hard against this all the way around, in order to have a voice.

The description of the Anonymous of Berne seems to conflate the technology later described by Theophilus with that described by Aribo, although it includes some further details of its own. I suspect that the cylindrical pipes of equal width seen by the writer were really of a lead-tin alloy (perhaps gilded?), and that he never saw the mandrel, but assumed (wrongly) that it was provided with a tapered "foot," as was the finished pipe.

The future development of the organ lay with cylindrical pipes of tin or lead, or an alloy of these metals, which were burnished in the flat and beaten round on cylindrical mandrels. This technology coexisted with that described by Theophilus, and once it was perfected by incorporating the concept of varying pipe diameters, it ultimately prevailed.

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26. This would be about 1100 mm (a Roman foot is nearly 296 mm).

27. A *palmus,* or "span," is one-fourth of a Roman foot, or 74 mm.

28. According to Perrot (p. 236, note 29), the crosswise diameter of a pigeon's egg is about 30 mm, and that of a lark's egg, about 10 mm. The use of the word *lodix,* meaning a species of small bird that we today cannot identify, seems to be unique to this manuscript.

Appendix

The Five Previous Translations of the Opening Passage of Theophilus, *De diversis artibus,* Book 3, Chapter 81, *De organis,* In Chronological Order

Robert Hendrie (1847); William Leslie Sumner (1952):

The manufacturer [Sumner: maker] of organs should first possess the knowledge of the measure, how the grave and sharp and treble pipes should be meted out; he may then make for himself a long and thick iron to the size which he wishes the pipes to possess; this must be round, filed and polished with great care, thicker at one extremity and slightly diminished, so that it can be placed in another curved iron, by which it is encompassed, after the fashion [Sumner: portion] of the wood in which the auger is revolved, and at the other extremity let it be slender, according to the size of the lower end of the pipe which should be placed on the bellows.

C. R. Dodwell (1961):

The maker of organs should first have a specification of the sizes of the bass, treble and alto pipes. Then he should make for himself a long thick piece of iron, to the size which he wishes the pipes to be. This is cylindrical in shape and filed and polished with the greatest care. At one end it is thick and slightly drawn out, so that it can be inserted into a cranked iron handle, rather like the wooden handle of a drill, by which it is turned round. At the other end it is thin, and the same size as the lower end of the pipe, which is to be inserted in the wind chest.

John G. Hawthorne and Cyril Stanley Smith (1963):

A man who is going to make an organ should first have a table of dimensions giving the measurements for the bass pipes, the alto, and the treble. Then he should make a long, thick iron (mandrel) of the dimensions that he wants the pipes to be. It should be round in circumference, filed and polished with the greatest care, thicker at one end and slightly flattened so that it can be inserted into a bent iron (crank) like the wooden handle of a grindstone, by means of which it can be turned. At the other end it should be slender, corresponding in size to the pipe at the lower end which is to be put into the wind chest.

Jean Perrot (1965), translated by Norma Deane (1971):

He who would make organ pipes[29] should first provide himself with a Treatise on Measurements, wherein he will find the specifications for the low, high,

29. Perrot's footnote (p. 233, note 12): "Here 'organa' refers to the organ pipes. Vitruvius uses the same term when describing the pipes on his instrument."

and very high pipes.[30] Thereafter he is advised to make himself an iron (mandrel) of the same length and diameter as the pipes he intends to fashion. This mandrel must be rounded, and should be filed and polished with the utmost care, and made thicker at one end, then tapering slightly, so that it may be inserted into another piece of curved iron, which will encase it as an auger (runcina) is enclosed by the piece of wood in which it turns. At its other end the mandrel should be slender, corresponding to the diameter of the lower end of the pipe, which will rest on the wind chest.

30. Perrot's footnote (p. 234, note 14): "Presumably Theophilus plans to have three octaves."