The Amateur Wind Instrument Maker

Revised Edition

Trevor Robinson

LOST OR DAMAGED LIBRARY MATERIALS

THE CARE OF LIBRARY MATERIALS IS THE RESPONSIBILITY OF THE BORROWING PATRON. TAX DOLLARS SHOULD NOT BE USED TO REPLACE OR REPAIR MATERIALS ABUSED BY INDIVIDUALS. A FEE SCHEDULE HAS BEEN SET TO REFLECT THE COSTS TO THE LIBRARY OF REPLACING OR SPECIAL HANDLING OF LOST AND DAMAGED MATERIALS.

MATERIALS WERE SELECTED AS AN INTEGRAL PART OF THE LIBRARY COLLECTION, AND FOR THE USE OF ALL PATRONS. IF A BOOK IS OUT OF PRINT, THE SUBJECT AREA WILL STILL NEED TO BE RESTORED DUE TO THE LOSS OF THE MATERIAL.

FEES WILL BE CHARGED AS FOLLOWS:

DAMAGE

1. VISIBLE DAMAGE (WATER, COFFEE, INK, ETC.) WHICH REDUCES LIFE OF MATERIAL BUT STILL CAN CIRCULATE........................$2.00

2. DAMAGE REQUIRING ANY SPECIAL HANDLING (SAND, PENCIL MARKS, ETC.)........................$3.00

3. DAMAGE REQUIRING THE BOOK BE REBOUND........................$6.00

LOSS

THE REPLACEMENT COST OF THE MATERIAL WILL BE CHARGED, PLUS A $2.00 MATERIALS AND HANDLING FEE.

IF THE MATERIAL ITSELF CANNOT BE REPLACED: 1.) THE PRICE WE PAID WILL BE CHARGED PLUS A $2.00 PROCESSING AND HANDLING FEE FOR A NEW BOOK. 2.) A FLAT FEE OF $10.00 WILL BE CHARGED TO REPLACE THE LOSS TO THE COLLECTION.

(THE AVERAGE PER-VOLUME COST OF A BOOK IS $18.00)

THE AMATEUR WIND INSTRUMENT MAKER

THE AMATEUR WIND INSTRUMENT MAKER

TREVOR ROBINSON

Revised edition

The University of Massachusetts Press 1980

Library of Congress Catalog Card Number 80–5381
ISBN 0–87023–312–2
Printed in the United States of America

Library of Congress Cataloging in Publication Data
Robinson, Trevor.
The amateur wind instrument maker.
Bibliography: p.
1. Wind instruments—Construction.
I. Title.
ML930.R62 1980 788 80–5381
ISBN 0–87023–312–2

TO MY FATHER,

who gave me my love of

music and of craftsmanship.

Contents

Preface xi

1 Introduction 1
2 Wooden Instruments: Materials and Methods 9
3 Flute and Fife 27
4 Recorders 37
5 Clarinet 45
6 Shawm and Oboe 49
7 Krumhorns 59
8 Racketts 69
9 Cornetti 77
10 Brass Instruments: Materials and Methods 81
11 Trumpets 91
12 Horns 97

Appendix A
Some Museum Collections of Instruments 99

Appendix B
Sources of Materials 105

Appendix C
Making Shell Augers 109

Appendix D
Miscellaneous Useful Addresses 110

Appendix E
Table of Decimal Inches and Metric Equivalents 111

Bibliography
Works Cited in the Text 113
General Books on the History of Musical Instruments 115

Illustrations

1 Tuning Fork on Resonator 6
2 Making a Tapered Reamer 16
3 Reamers 18
4 Wrapping a Tenon with Thread 25
5 Key Designs 26
6 Flutes and Fife 28
7 Fife in the Key of B-flat 30
8 Baroque Flute 31
9 Baroque Flute Modified to Modern Pitch 32
10 Walking Stick Flute 33
11 Recorders 36
12 Recorder Terminology 38
13 Renaissance-type Alto Recorder 41
14 Baroque Recorders 42
15 Baroque Tenor Recorders 43
16 Clarinet 46
17 Clarinet 47
18 Musette and Shawms 50
19 Oboes 52
20 Musette 53
21 Soprano Shawn 54
22 Baroque Oboe 55
23 Baroque Oboe Modified to Modern Pitch 56
24 Krumhorns 60
25 Soprano Krumhorn 61
26 Bending Jig and Supporting Strap for Krumhorns 63
27 Reed Making Tools and Supplies 65
28 Three Krumhorns 67
29 A Family of Racketts 70
30 Cant and Tenor-Alto Racketts 72

31 Baroque Rackett 75
32 Curved Cornett, Russian Bassoon, and Mute Cornett 76
33 Curved and Mute Cornetts 79
34 The Workshop of a *Chaudronnier* 80
35 Brass Instrument Tools and Parts 83
36 Steps in Forming and Seaming a Cone 85
37 Some Trumpets 90
38 Trumpet in the Key of D 95
39 Trumpet and Horn Mouthpieces 96
40 Horns 98
41 Making a Shell Auger 108

Tables

3.1 Fife Hole Dimensions 34
3.2 Flute Hole Dimensions 35
4.1 Recorder Finger Hole Dimensions 44
5.1 Clarinet Finger Hole Dimensions 48
6.1 Shawm Hole Dimensions 57
6.2 Oboe Hole Dimensions 58
7.1 Krumhorn Hole Dimensions 68
8.1 Rackett Hole Dimensions 73

Preface

The making of musical instruments of any kind is a rewarding hobby because of the versatile craftsmanship that it calls for, and because the finished product continues to bring joy to the player long after it is made. In a society which enjoys an increasing amount of leisure it is essential that satisfying avocations be available, and I have decided to write this book to call attention to one of the most satisfying and one of the least exploited that I know. It is surprising that while amateur makers of violins, guitars, and harpsichords are a well-recognized group catered to by publishers and dealers in wood and supplies, amateur makers of wind instruments are almost nonexistent.

I have found instrument making to be a very rewarding hobby for the friendships it has initiated and cemented. Others who take it up will discover that they will find kindred spirits all over the world who will give freely of their knowledge and support. A few of these whom I wish to give special thanks for helping me with particular problems or for their general interest and encouragement are Friedrich von Huene; Mr. and Mrs. R. K. Lee, Jr.; Charles J. Lehrer; Kenneth C. Parker; and Narcissa Williamson.

There is no end to the process of learning better ways to make things. By the time this book appears, I should expect to have improved on some of my procedures; and after it has appeared, I shall look forward to receiving suggestions and corrections from my readers.

Preface to Second Edition

In the years since the first edition appeared, interest in early instruments has grown enormously. There are both many more players and many more commercial makers, but I believe that there is still a place for the amateur craftsman. I have, indeed, received useful suggestions and corrections from my readers, and many improvements in this edition are the result of such assistance. Comments are still welcome, except for the one that says my approach is not sufficiently rigorous for the professional musicologist. To that my reply is that the next musicologist who writes a book entitled *The Amateur Biochemist* may expect to receive a similar comment from me.

I

Introduction

The craftsman who embarks on the making of musical instruments must already have acquired some basic skills in wood-working and metalworking and must have a shop which is well equipped with common hand and power tools. It is perhaps superfluous to point out that he should also have an ear for music, because the finest appearing instrument is worthless if it can't be played and is nearly worthless if it is not pitched to agree with accepted standards. In this chapter I shall deal with some of the most general aspects of instrument making, and throughout the rest of the book I shall treat more specialized techniques and particular instruments.

Much can be done by trial and error and by copying successful instruments, but anyone who concerns himself for very long with musical instruments will probably want to learn more about the physics of sound production and the science of acoustics. For a good start in this direction I should like to refer him to the brief and clear book, *Horns, Strings, and Harmony*, by A. H. Benade and the more advanced book by the same author, *Fundamentals of Musical Acoustics*. A book recommended not for its advice on practical techniques but for its outstandingly perceptive and witty outlook on instrument making is Kottick's *The Collegium: A Handbook*, particularly the chapter "The Old Instrument Rackett." I pass on one piece of practical advice from it. ". . . the inside of a shawm need not resemble the interior of a banana crate."

Equipping the Shop

There are very few hand tools required in instrument making that will not be found in the average shop. A collection of tapered reamers is handy for enlarging tone holes and making the back bore on mouthpieces for brass instruments. Calipers are essential for measuring both inside and outside diameters.

Beyond the circular saw and drill press, which are probably stock items in the average shop, the major power tool for the instrument maker is a wood-turning lathe. Thirty inches between centers will permit making practically any instrument. A heavily constructed wood-turning lathe also serves for the metal spinning required to make brass instruments. A metalworking lathe is required to make special reamers. It is useful for making brass mouthpieces, but these can be made on the woodworking lathe. A miniature lathe like the Unimat can be used for making brass mouthpieces and is also handy for turning small ivory rings. It is just possible to manage all of the turning operations for a soprano recorder on the Unimat. Basic techniques of lathework will not be discussed here. Several good introductory books are available to cover wood turning, metal turning, and spinning.

A small, high-speed hand grinder such as the Dremel Moto-Tool is very valuable for shaping small parts, smoothing the inside of finger holes, and polishing brass or ivory.

Sources of Designs

The instruments described in this book are only a beginning. They have been chosen to illustrate techniques that can then be applied to all sorts of other instruments. There are a number of beautifully illustrated books about historical musical instruments. The instrument maker will want to examine those that are available in libraries and perhaps to buy some. A list of such books is given in the Bibliography. The *Encyclopaedia Britannica* (11th ed.) has excellent articles on musical instruments, and the plates on instrument construction in Diderot's great French *L'Encyclopédie* are gorgeous (they may be found under "Lutherie" and "Chaudronnier"). A complete facsimile edition of *L'Encyclopédie* is available now in major libraries. The selection of plates from the facsimile edition of *L'Encyclopédie* published by Dover does not include most of the instrument plates.

Acquaintance with several organizations is essential for the serious instrument maker. The Galpin Society is the original and best known association for the study of musical instruments, and the annual *Galpin Society Journal* always has articles of value. The American Musical Instrument Society has been in existence a shorter time but publishes a similar annual journal. The Fellowship of Makers and Restorers of Historical Instruments exchanges much helpful information in its publication, *The FOMRHI Quarterly*. Membership in all of these organizations is strongly recommended. The journal *Early Music* is slanted more to performance than to instrument construction, but it frequently has articles that give helpful advice on playing and maintaining instruments. (cf. Appendix D for addresses)The only book to give much detail about current techniques of instrument construction is *The Making of Musical Instruments* by T. C. Young. There is an excellent series of articles entitled "Woodwind Instruments" by P. Tomlin in *Woodworker* in which directions are given for making several woodwind instruments. A book collecting these articles has been promised. E. D. Brand's book on instrument repairing, *Band Instrument Repairing Manual*, while it does not describe instrument making from scratch, is very valuable for its descriptions of many useful techniques.

Books are fine so far as they go, but there is no substitute for seeing, handling, and measuring actual instruments. While some nineteenth-century instruments can still be found at reasonable prices in antique shops, the ancient instruments that the craftsman will be most interested in copying are either sold at very high prices by specialists or are in museum collections. The wind instrument collections in the United States that are most readily available for observation and, by permission, examination and measurement are those at the Smithsonian Institution and the Library of Congress, Washington D. C.; the Metropolitan Museum of Art, New York; the Museum of Fine Arts, Boston; and the University of Michigan, Ann Arbor. In Europe there are major collections at Brussels, Berlin, and Munich and in other large cities. Bessaraboff's *Ancient European Musical Instruments* is based on the Boston collection and is in fact a much elaborated catalog. A checklist of the Dayton Miller Collection in the Library of Congress is also available, and a similar list for wind instruments at the Smithsonian is in preparation. Catalogs of the other major collections were published many years ago and are now out of print, although it may be possible to find them in some libraries. A listing of collections is given in Appendix A.

Several museums and individuals offer instrument plans for sale. These vary greatly in detail and price. Some give less information than the plans in this book, some much more. Museums that offer plans are indicated in Appendix A; other sources are frequently mentioned in *The FOMRHI Quarterly*. One of the major ones of these is the NRI Design Service (cf. Appendix D). I also have additional plans for sale.

Pitch and Tuning

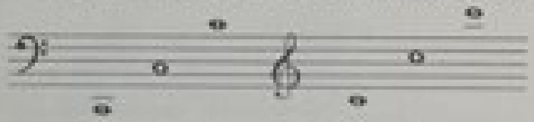
The subject of proper pitch can become extremely complicated as anyone who consults standard musical encyclopedias or musicological works will discover. My purpose here is to give just a few helpful hints to the craftsman.

The presently accepted evenly tempered musical scale exemplified by the piano keyboard is about two hundred years old, and instruments made before that time will have slightly different intervals between notes. Most old woodwind instruments used compromised tunings that were adjusted by forked fingerings, and these tunings were made to favor certain keys (e.g., F for recorders; D for flutes). Purists may wish to duplicate the old uneven tunings, and many will insist that old music sounds better when played as its composer heard it. However, most reproductions of old instruments are given modern tuning.

The basic pitch of instruments has also undergone change over the years. That is, the sound that today we call C might in earlier times have been called C-sharp or D. A result of this is that when an exact reproduction of an old instrument is made, it cannot be played along with modern instruments unless the player transposes keys. The pitch of orchestral instruments from about 1600 to 1800 was a half tone below modern pitch (their C is our B) and is called *Hoch Kammerton*. In contrast, outdoor band musicians tuned their instruments a full tone higher than modern pitch (their C is our D). As with the division of the scale, then, the pitch becomes a problem for the instrument maker, who must choose between making an exact reproduction of an old instrument or making an instrument that resembles it but is pitched like a modern instrument. If the latter course is to be followed, the dimensions of the old instrument will have to be adjusted. For example, to raise the pitch of a baroque flute by a half tone the length must be shortened by about 1½ in. and all the finger holes must be moved up. The result will be an instrument that possesses many characteristics of its prototype; but it cannot strictly be called a replica, for notes of identical pitch played on the two instruments will differ in tone quality and strength.

In this book I take no position on the issue of exact replica versus somewhat modified "antique types" of instruments. The techniques that are described are obviously generally applicable to either. Some of the designs given are for exact replicas, and reference is made to their prototypes; others I have modified somewhat. The craftsman is advised to let musicians and musicologists argue and get on with his work, realizing that there are many degrees of accuracy, and that in this business *absolute* fidelity to an original is unattainable.

The amateur will probably not wish to invest in electronic standards for tuning and will rely on aural comparisons. As primary standards, tuning forks of several pitches can be obtained. The intensity of sound from a tuning fork can be strengthened by mounting it on a simple resonator box (fig. 1). A pitch pipe, well-tuned piano, or other commercial instrument is also valuable when adjusting the notes not covered by the tuning forks. Although it depends on aural comparison, I have found an electronic tone generator very useful in tuning. Such a device, called the "Pitch Box," is sold for about $70. (see Appendix B) Two commonly accepted notations for designation of octaves are illustrated below.



C_2	C_3	C_4	C_4	C_5	C_6
C	c	c'	c'	c''	c'''

Thus the note on the middle line of the treble staff can be referred to unambiguously as b', or the range of a tenor recorder described as C_4 through C_6.

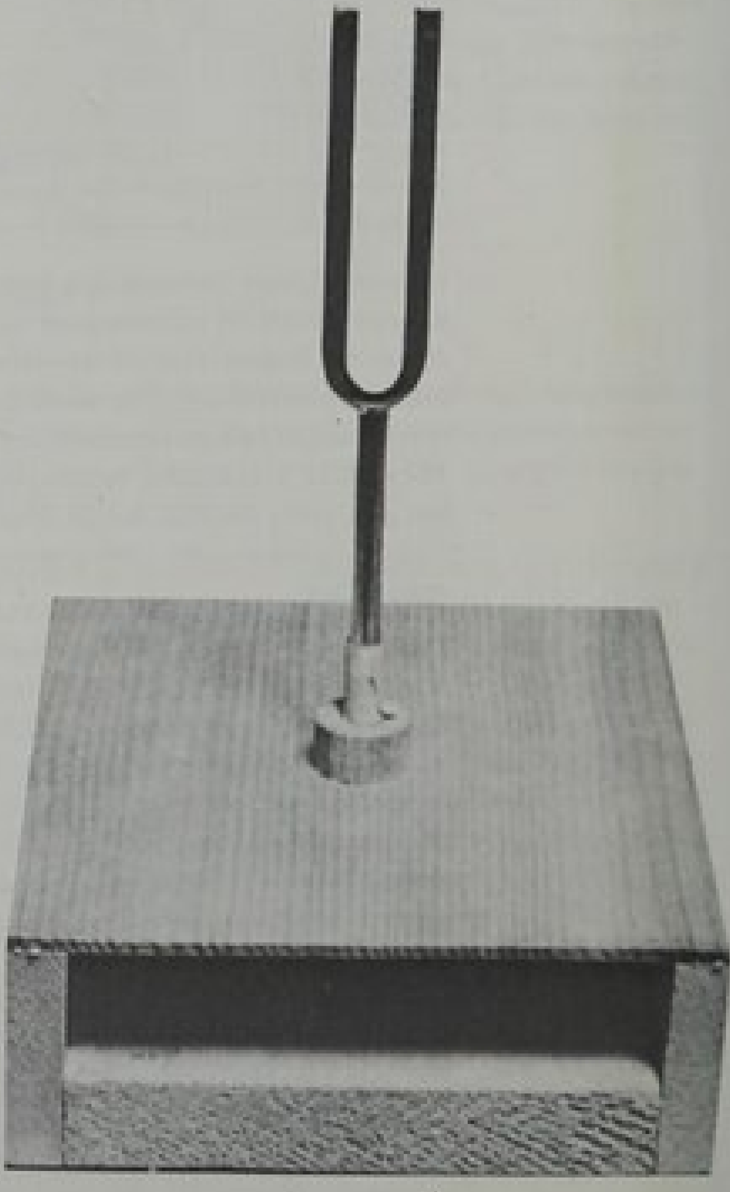


FIGURE 1. Tuning fork on resonator.

Measurements

For anyone who has taken time to become familiar with it, the metric system is far easier to use; and all measurements in such books as Bessaraboff's are given in the metric system. Still, the English system lingers on, and I have been reluctant to discard it completely. A trumpet 7 ft. long seems to be more readily visualized than one which is 2,128 mm. in length. However, for measurement of finger holes and trumpet mouthpieces the metric system seems far superior. To assist the craftsman whose calipers and drills may be gauged according to the English system, Appendix E is a conversion table. The figures throughout the book give dimensions in millimeters, with the background ruling in inches.

Anyone who consults old books that give measurements of instruments will encounter some other measurement systems. In French small dimensions may be measured in *lignes* with 12 *lignes* to the *pouce*. The *pouce* is 1.0658 in., so the *ligne* is 2.25 mm. or slightly more than 1/12 in. German writers, such as Praetorius, give measurements in Brunswick feet. The Brunswick foot equals 0.94 of a modern foot and was divided into 12 in., so that a Brunswick inch equals 0.94 of a modern inch or 23.88 mm.

For the craftsman who has the opportunity to measure actual instruments in preparation for reproducing them, I want to make only a few suggestions. The application of steel measuring devices to antique instruments tends to make museum curators nervous. Plastic vernier calipers are readily available and can be read with an accuracy of 0.1 mm.—quite sufficient for most purposes. For measurement of conical bores it is useful to make a set of plastic discs that can be attached in turn to the end of a rod and inserted into the bore from the large end. When the disc sticks, a record is made of its diameter and the length of rod inserted. A problem with the disc method is that unequal shrinkage will have left many old instruments with bores of elliptical cross-section. The difference between major and minor axes can be as much as 5%, and the disc will indicate only the minor diameter. The solution to this problem, if it is required, is to use a telescoping gauge on a long handle and at each gauge setting measure two insertion distances for the two axes. Having done this, though, it is not obvious what to do about it. An instrument made with a circular bore that averages the two axes should play like the old instrument in its current state; but in its original state the old instrument presumably had a circular bore with diameter almost equal at each distance to the present major axis of the ellipse. A very thorough article by C. Karp discusses problems and procedures in woodwind bore measurement.

2

Wooden Instruments

Materials and Methods

The subject matter of this chapter is chosen from the point of view of manufacturing methods rather than from that of acoustics because, for example, cornetti are acoustically "brass" instruments although made of wood. It is a surprise to most people that the construction material is not of major importance in controlling the characteristic sound of an instrument. The importance lies not in the material itself but in the different results of machining. For instance, the harder the material, the sharper the corners may be at the edges of joints and finger holes. V. C. Mahillon in his classic *Eléments d' Acoustique* (pp. 63-65) tells of making a cavalry bugle of standard dimensions from wood and being unable to distinguish its timbre from that of a brass instrument. This story, though, is doubted by modern scholars of musical instruments.

Choice of Wood

As mentioned above, the choice of wood for instrument construction is based more on consideration of mechanical properties and appearance than consideration of acoustic properties. Hard, fine-grained woods are preferred, because they can be machined with greater precision than soft woods and have greater dimensional stability. Woods that have a tendency to swell or warp are generally to be avoided, although modern penetrating finishes for wood are quite successful in preventing absorption of moisture. The instrument maker should not have to be much concerned with the proper seasoning of wood, since a reputable dealer will have seen to it that the wood he sells is ready for working. However, it is always a good idea to put wood aside for a while at the humidity where it will be used and to notice if any twisting or cracking appears. It is a heartbreaking disaster to see a finished instrument ruined by movement of the wood.

Occasionally you may want to season your own wood if, for example, you can acquire orchard trees at little or no cost. After cutting the wood roughly to size, paint the end grain with paraffin or tar, and stack the pieces in an unheated building or outside to allow circulation of air around them (but cover them to keep off rain and snow). About one year of seasoning for each inch of thickness is usually recommended, and after this time another year in a heated building is a good idea. Carefully managed kiln drying can speed up this process, but it is not an operation for the amateur to undertake. Another useful procedure that has recently become available for stabilization of wood is to immerse the green pieces in a 30% to 40% (by weight) aqueous solution of polyethylene glycol 1000 (available from dealers in industrial chemicals). After two or three months in this solution allow the wood to dry for a few more months, and it will not undergo any further shrinking. With this treatment instruments may be made out of branches in the round that would surely split if simply seasoned in the usual way.

Boxwood (*Buxus sempervirens* and *B. balearica*) was for many years the favorite wood for making flutes, recorders, oboes, and clarinets, as it was the hardest, finest grained wood that was readily available in Europe. Its disadvantage was a pronounced tendency to warp, and bent boxwood instruments can be seen in any large collection of old instruments. The purist who is determined to make exact reproductions of old instruments will want to try boxwood, but it is practically unobtainable in large enough dimensions nowadays. Some possible sources are listed in Appendix B.

The undistinguished color of new boxwood is a disappointment in comparison to the rich orange yellow of old instruments. The old makers sometimes colored boxwood by treating it with chemicals such as nitric acid. Deep staining with the usual wood stains is not possible because of the hardness of the wood, but a pretty good approximation is possible. For those who wish to try acid staining, 70% nitric acid is swabbed on until the desired color is achieved. Excess acid is then washed off and the wood rubbed with linseed oil. For a darker color 40% to 50% nitric acid with a few nails dissolved in it is used. Nitric acid is extremely corrosive, and its fumes are irritating, so great care must be used in this procedure. Another way to darken wood is to burn it lightly with a torch. This must be done with a very hot torch and very short exposure so that only the immediate surface is charred. Longer exposure inevitably causes cracking because of expansion in the deeper layers.

Because of the shortage of genuine boxwood, other species have been introduced into the trade to replace it. Only one of these, the Cape or East London Boxwood (*Buxus macowani*) from Africa, is botanically a true boxwood. Also from Africa is Knysna boxwood or kamassi (*Gonioma kamassi*). West Indian boxwood or zapatero seems to come from a confusing number of species that are lumped together under this name, including species of *Phyllostylon*, *Gossypiospermum*, *Tecoma*, *Casearia*, and *Aspidosperma*. There is general agreement that none of these substitutes is as good as genuine boxwood, but that they may be the best available.

If the wooden instrument business had developed in North America rather than Europe, it seems likely that the commonly used wood might have been hard maple (*Acer saccharum*). It is not so dense as boxwood and is also adversely affected by moisture, but it has a fine grain and machines well. As with boxwood, its uninteresting color can be improved by light staining. Its low cost recommends it for experimentation, and its availability in quite large dimensions (e.g., 4 in. x 4 in. squares) makes it almost the only wood that can be used for some instruments.

Among the other native North American woods the fruit woods apple, cherry, and pear are most useful to the instrument maker. Of these only cherry is usually available commercially, but apple and pear may be obtained from orchardists who are removing old trees or by finding abandoned trees that are fairly common around old communities. Birch is rather similar to maple in its characteristics but is usually slightly softer. Some European recorders are made of birch, but I would not consider it as a first choice. American black walnut is a beautiful wood to look at and to work with. It is softer than hard maple, though, and is rather coarse grained so that filler may have to be used for a smooth surface. Despite these disadvantages walnut seems to be the ideal wood for krumhorns because of the ease with which it can be bent.

During the nineteenth century, tropical woods gradually replaced northern woods in the making of instruments. Not only were some very hard woods available from the tropics, but many of them showed beautiful colors and figures. The naming of these tropical woods has been extremely confusing. Sometimes two or more names have been applied to the same wood; sometimes different woods have been called by the same or similar name. I have tabulated some of these woods below giving first the botanical names, which alone are free from ambiguity. The reader interested in learning more about these woods will want to consult the following valuable books: *World Timbers*, by B. J. Rendle; *Timbers for Woodwork*, by J. C. S. Brough; *What Wood is That?*, by H. L. Edlin; *Know Your Woods*, by A. Constantine, Jr.; and *Properties of Imported Tropical Woods*, by B. F. Kukachka. The British Ministry of Technology publishes a useful booklet, "Timbers Used in the Musical Instrument Industry," but it devotes only five pages specifically to wind instruments. Another valuable British publication is the *Directory of Suppliers to Craftsmen Musical Instrument Makers* by Ian Firth. It lists not only sources of wood but also of many other necessities.

Brya ebenus, green ebony, cocus wood. A dark brown, hard, and heavy wood obtained mostly from the West Indies. Not readily available.

Caesalpinia granadillo, brown ebony, granadillo, partridge wood. Very similar to the above and sometimes confused with it. Also from the West Indies and not readily available. (The common name "partridge wood" is also applied to an unrelated species, *Andira inermis*.)

Diospyros ebenum, ebony. This species is the original ebony obtained from India and Ceylon. Other species of *Diospyros* are also called ebony and include *D. celebica* or Macassar ebony, *D. dendo* or Gaboon ebony, and *D. marmorata* or marble wood. To add to the confusion some entirely unrelated trees are called ebony only because they have dark-colored wood. Ebony is not generally used now for construction of complete instruments since it does not have good dimensional stability although it is valuable for mouthpieces or decorations. All dealers in rare woods stock some kind of ebony.

Dalbergia retusa, cocobolo. A hard, heavy wood of reddish orange color. It is difficult to work but gives a beautiful end result. Cocobolo is available from all dealers in rare woods.

Dalbergia nigra, Brazilian rosewood, rio jacaranda, palisander. A beautiful, heavy wood ranging in color from a rather bright red to a deep reddish brown, with black streaks. Although somewhat brittle, rosewood makes excellent instruments and is readily obtained from dealers in imported woods. Other so-called rosewoods are available, for instance *Dalbergia stevensonii* or Honduras rosewood, *Dalbergia latifolia* or East Indian rosewood, and *Guibourtia demeusii* or bubinga or African rosewood. All have the reddish color of rosewood but do not have the strongly contrasting black streaks of the Brazilian species.

Dalbergia melanoxylon, African blackwood, grenadilla. Although related to the rosewoods this wood is so dark as to resemble the ebonies. It is very scarce but is traditionally used for clarinets, oboes, and Highland bagpipes.

Peltogyne pubescens, purpleheart, amaranth. Obtained from the West Indies and South America, this wood is readily available and unique for its rich purple color.

Pterocarpus dalbergiodes, padouk, padauk, vermilion, Andaman redwood. A heavy, hard wood of a striking red color. It has a rather coarse grain that may need filling. It is available from most dealers in imported woods.

Dalbergia oliveri, D. variabilis, tulip wood, Bahia rosewood. A hard wood of density similar to *Dalbergia nigra* but with a striking figure contrasting rich purple with cream color. With age the color tends to fade.

Almost all species of *Dalbergia* have been reported to cause dermatitis in some individuals. Cocobolo is most known for this, and no one should work with or acquire an instrument made of it without being tested for sensitivity. Purpleheart and padouk are also known to cause allergic reactions.

Boring and Reaming

Boring is the first step in making any wooden instrument. When the bore has been completed, the piece is held between conical centers for turning the exterior. In this way the exterior will be concentric with the bore even if the boring has not gone perfectly straight.

The average woodworking shop is not likely to be equipped for the type of boring that is necessary in making instruments. Acquisition of suitable tools for this operation is likely to be the most expensive and time-consuming aspect of getting started in the instrument making business. Cylindrical bores up to 8 in. or 9 in. long and ⅜ in. to 1 in. in diameter can be made with ordinary spade bits and an extension shank. With luck it is even possible to drill from both ends and meet in the middle for holes of this length. With longer holes the tendency to drift to the side becomes too great, and twist drills are even worse in this respect. Acquisition of a set of Ridgway shell augers is the key to successful long hole boring. These augers are available in sizes of ¼ in. to ½ in. in increments of 1/16 in., and lengths of 12 in. to 36 in. in increments of 6 in. When used for very long holes the ¼-in. size shows some tendency to wander, especially if it is not kept very sharp; but it can be controlled by going slowly and clearing chips frequently. The bigger sizes are perfectly reliable for drilling straight holes up to their maximum length. Once a straight hole has been drilled with one of these augers, it can easily be enlarged by running a twist drill or a homemade flat-tipped drill of the desired size through it. Therefore it is not necessary to acquire the Ridgway augers in all diameters. The setup for boring with these augers requires a hollow dead center in the lathe through which the auger is inserted. This center can be made easily from a ½-in. bronze water pipe tee. One end of the tee is beveled to a sharp edge, and a length of pipe attached to the side outlet can be held in the usual tool rest holder. Shallow 11/16-in. holes are drilled in the centers of the wood to be bored. One end is turned at the live center by a chuck or dog, while the other is supported by the hollow center through which the auger is fed. A speed of about 1,000 rpm or less is satisfactory for this boring, and the auger must be withdrawn frequently to clear chips. The wood should be reversed before boring all the way through so that the tip of the auger is not damaged by running onto the live center. A craftsman handy in blacksmithing can make a reasonable facsimile of the Ridgway augers. Instructions are given in Appendix C. I have been told that long, straight holes can be made with twist drills if they are ground to have almost no rake; but I have not tried this method.

Except for krumhorns, clarinets, and racketts, the wooden instruments described in this book have a conical rather than a cylindrical bore. Special tools are available in the industry for boring conical holes in a single operation, but for the small-scale craftsman the easiest approach is to bore a cylindrical stepped bore first and then ream it to the required conical shape. Standard machinists' taper pin reamers come in a wide range of diameters all with a taper of 1:48 (¼ in. per foot). This happens to be just about right for recorders and several other instruments, so that acquisition of several of these reamers is desirable. However in the larger sizes they can be quite expensive (some sources of used and low-priced surplus reamers are listed in Appendix B). To decrease the expense and to obtain reamers in nonstandard tapers, it is necessary for the craftsman to make his own.

Steel-fluted reamers are made by first turning a rod to the required taper, then milling or grinding one or more grooves along it, and finally sharpening and relieving the cutting edges. An abrasive disc mounted in the tool post grinder can be used for cutting grooves while the reamer is mounted in the lathe (see fig. 2). Another approach is to make a vee block with its base slanted, so that when the reamer blank is placed into the vee its top surface is level. An abrasive disc mounted on a radial saw can then be passed over and successively lowered to grind out the grooves. For cutting wood it is not necessary to use tool steel or to harden the cutting edges. A reamer that cuts very smoothly is made by milling a single deep groove so that in cross-section a 90° sector is removed from the cone. Then one corner is raised above the surface with a burnisher and honed to a sharp edge.

For larger diameter reamers (i.e., ¾ in. at the small end) the body of the reamer can be turned from hard wood to the correct taper and a cutting edge inserted into a slot sawed into the wood. Old hacksaw

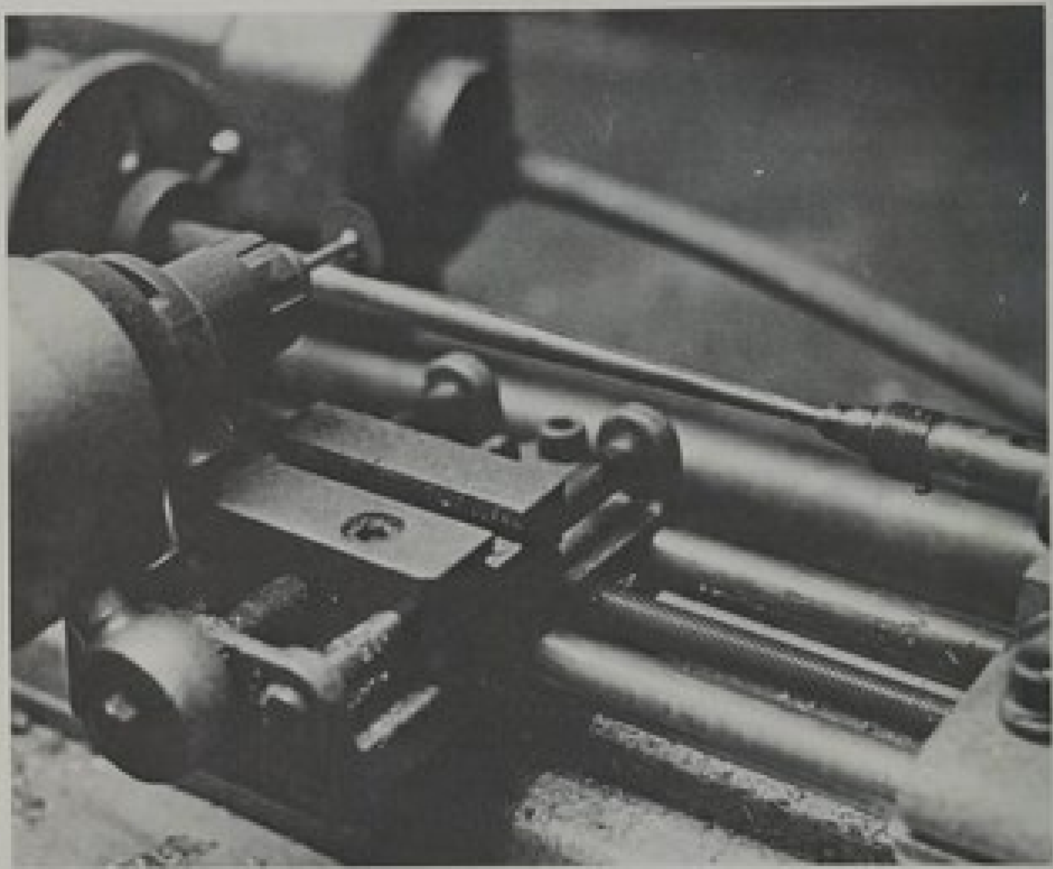


FIGURE 2. Making a tapered reamer.

blades are good for this purpose. The slot should be sawed carefully to expose less than 1/16 in. of the inserted blade. The blade is held in place by cutting grooves around the wood to match holes drilled through the blade (after heating to draw the temper). Wire pulled through the holes and around the grooves is twisted together, and any spaces along the blade are filled with epoxy cement. The protruding edge of the blade is finally ground to a sharp, beveled edge, and wood is cut away from the face of the blade to provide clearance for shavings.

The easiest reamer to make is a flat one ground from a file to have the required taper and sharpened to a slight bevel along the edges.

Such a reamer has to be guided slowly and carefully, but if it is well made it will do a surprisingly smooth job.

It is a temptation to try driving the reamer with an electric drill to hasten the process, but it is not really that much faster than turning by hand if the reamer is sharp, and slow cutting seems to give a smoother finish. The three types of homemade reamers described are illustrated in figure 3.

If very precise measurements are taken of the bores of old instruments, it will usually be found that they are not perfectly uniform cones or cylinders but have some abrupt steps in diameter. While these steps are not large in any absolute sense—less than half a millimeter over a distance of one or two centimeters—they may have important influence on tone and pitch. A. Baines, in *Woodwind Instruments* (p. 277), believes that some of these irregular profiles are to be regarded as "primitive" rather than the result of "deliberate experiment in pursuit of musical objectives." However, the musical effects are by no means negligible. A. H. Benade has told me about "transforming" instruments by adding or subtracting as little as 0.005 in. (ca. 0.1 mm.) from selected places in the bore. This observation points out again, though, the dilemma facing anyone who is a perfectionist in pursuing exact replication of old instruments: whether to copy irregularities precisely, or make an average, uniform cone.

Joints

The earliest woodwind instruments were made of single pieces of wood (e.g., Renaissance recorders and shawms), but towards the end of the seventeenth century it became customary to make instruments with several detachable tenon and socket joints. The bore can be made with greater ease and accuracy in a short length, and the resulting instrument is more convenient to carry. These advantages outweigh the increased fragility and the work of making the joints.

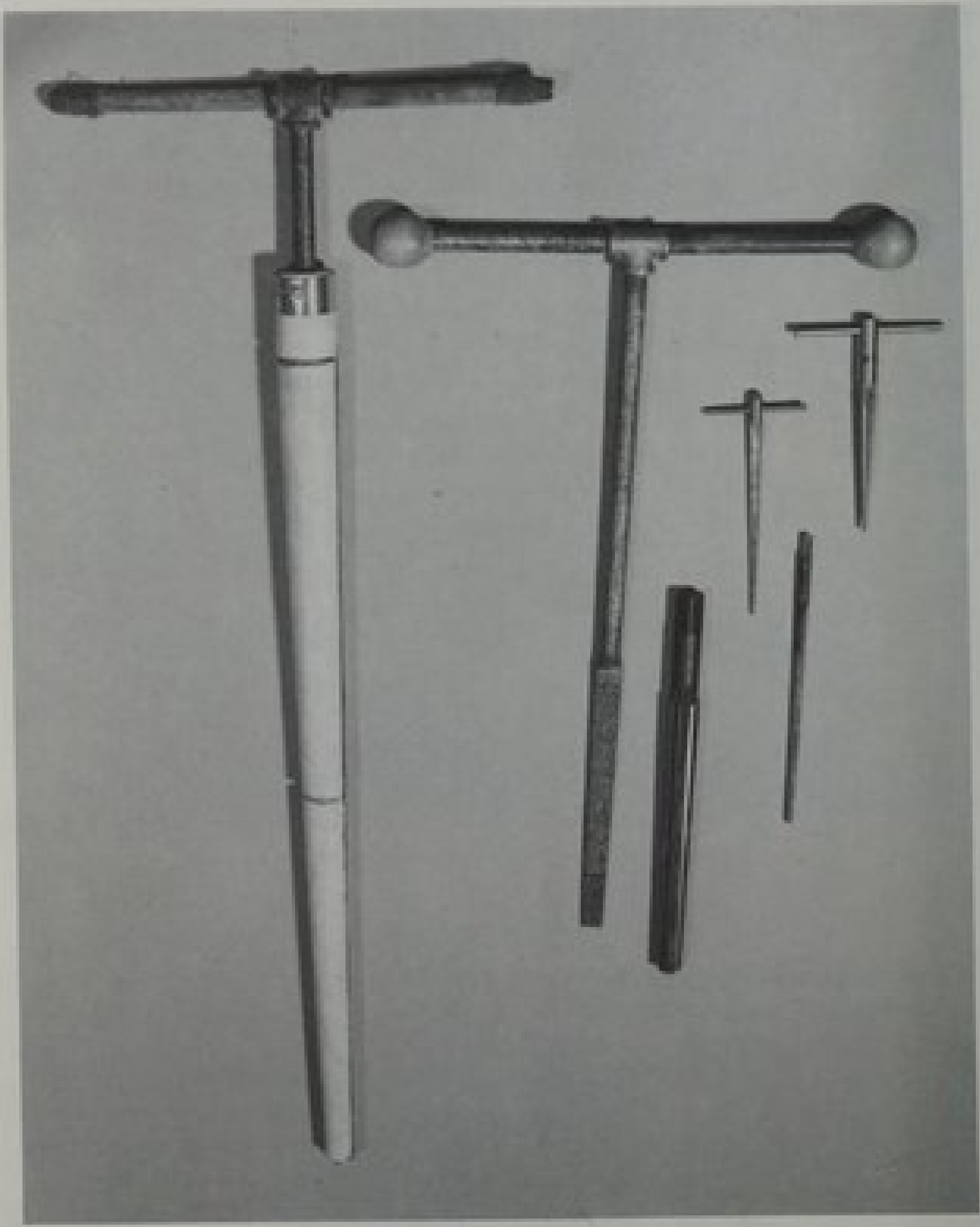


FIGURE 3. *Left*, four steel-fluted reamers; *center*, flat reamer ground from file; *right*, wooden bodied reamer.

The socket is more likely to be concentric with the bore if it is bored first in the end of the piece of wood, and then the smaller drill used for the rest of the bore; but when the long shell augers are used for the bore, it is easier to bore through the length first, then glue in a short plug of wood to provide a center, and enlarge the socket end with a larger drill. A slight lack of concentricity will not be noticed in the assembled instrument, since the outside will be turned concentric with the socket rather than with the main bore. For strength, the wall of the instrument should be thickened around the socket or a ferrule added. Another useful trick for minimizing strain on the socket is to bore about the first ⅛ in. just slightly larger than the rest of the socket. In this way when the joint is assembled, the wedging pressure of the tenon is not exerted on the fragile edge of the socket where cracks are most likely to start.

Tenons are turned after the rest of the exterior of the instrument so that their thin walls will not be cracked during the turning of the other parts. In the earliest instruments, joints were made tight by wrapping the tenons with waxed thread. If this method is to be used, the fit between tenon and socket should be quite close so that only a few layers of thread are needed. Figure 4 shows how the thread is wrapped. A rather soft, fuzzy thread rubbed with cork grease is best for this purpose. Suitable stuff is called *lapping thread* by instrument makers. Waxed dental floss can be used. The hemp used for bagpipe stocks is also satisfactory. Modern instruments use cork on the tenons. To apply this the tenon should be turned about 1/16 in. smaller in diameter than the socket, and then an additional wide, shallow groove should be made to keep the cork band from any tendency to slide off. A strip of 1/16 in. thick cork is cut the width of the groove, beveled at the ends to fit, and glued in place with contact cement or white glue. Careful sandpapering or filing will bring the cork down to a tight fit in the socket, and application of a little grease after the instrument is finished will make the fit just right. Sheets of ground cork composition and sheets of natural cork are both available from instrument repair shops. The former are much cheaper and tougher; but the latter, being softer and more resilient, make for a tighter joint.

Ferrules, Bushings, Decorations

Various parts of instruments devised originally for practical reasons can also be valued for their ornamental effects. The ivory rings around the joints of old instruments were probably intended to strengthen these joints, but in many cases it can be seen that it is the ivory that has cracked while the wood underneath remains whole. Still, ivory rings add a lot to the appearance of a fine instrument and are not overly expensive or difficult to make. The general procedure is to take a cross-sectional slice from a tusk and, using a drill or hole saw, cut the inner diameter to a snug fit on the wooden instrument and the other diameter somewhat larger than the finished outer diameter. A groove should then be cut around the inside of the ring and a matching groove cut around the outside of the instrument. The grooves can be made on the lathe or freehand with a high-speed hand grinder. Both grooves are filled with epoxy cement and the ring pressed on. In this way a ring of epoxy surrounds the instrument underneath the ivory ring, and it is the epoxy that really does the strengthening job. When the cement has hardened, the instrument is returned to the lathe for final shaping of the exterior, including the ivory ring. Ivory cuts easily with sharp wood-turning tools and should be finally buffed to a shiny finish using Tripoli compound on a cotton wheel. The wood underneath an ivory ring should be kept thin so that when it swells it will be less likely to crack the ivory.

Bushings of ivory on the inside of tone holes are also pretty; and in cases where a hole has accidentally been made too big, the mistake can not only be saved by inserting a bushing, but the instrument may even look better for it. The embouchure hole of old flutes was often bushed with ivory in order to present a hard, stable surface. To make bushings, thin discs of ivory are cut out with a plug cutter. The hole in the instrument is made to fit the disc, and ivory is fastened into place with epoxy or contact cement. When the cement has hardened, a new hole of the right size can be drilled through the ivory.

Other materials can be substituted for ivory. Indeed many people, because of illegal elephant killing and a U. S. law prohibiting ivory imports, would say that other materials *must*, on moral grounds, be substituted for ivory. Ordinary beef bones, if polished, are hard to distinguish from ivory at a distance, although they lack the characteristic grain pattern of ivory; and pieces suitable for making large rings, such as around the bell of an oboe, are not available. Fresh beef bones should be cleaned and aged for several months by burying them in the ground. A faster procedure used by old makers of bone implements was to steep the cut bones in a 1% brine solution for three or four days, and then simmer them in water for about six hours. Plastics can of course be substituted for the natural materials; but their uniform color and texture makes them less attractive than ivory or bone. Sources of plastic, imitation ivory are listed in Appendix B. Rather than being machined from solid plastic, some decorations can be cast in acrylic of the type used by dentists for filling teeth. This method requires making molds of plaster. Tinting powders are available from dental supply dealers so that any desired shade of ivory can be produced.

For real strength brass ferrules are preferred. They are cut with a tubing cutter from brass tubing. Various sizes of brass tubing are available from plumbing shops. Some tubing is chrome plated but can be used after sanding off the chrome. If tubing of the right size is not available, ferrules can be made from sheet brass with a brazed butt joint.

Keys

Most of the instruments that the amateur will make will not require keys, and even those that do have only one or two. Most common are closed keys that open a hole when the lever is pressed. Open keys, in contrast, close a hole when operated and are used at the lower end of the oboe and larger recorders to obtain the lowest notes of these instruments. The general forms of the two mechanisms are illustrated in figure 5. The key is shaped from 1/16-in.

brass sheet by sawing, filing, and hammering it against a lead anvil. Brass that is too soft can be stiffened by preliminary cold working with the hammer. If too much working makes it brittle, brass must be annealed by heating it red hot and quenching in water. The pivot bearing can be made by leaving projections at the sides of the key, bending them down at right angles and drilling holes through them; or a shallow, rounded groove can be filed across the underside of the key and a length of fine brass tubing silver-soldered into it. Springs are made of thin spring brass or steel that should be riveted and not just soldered to the key. Small brass escutcheon pins make excellent rivets for this purpose. I prefer steel springs to brass ones because the steel can be shaped just right while annealed and then tempered to get the proper stiffness. Some makers have used helical springs fitted into sockets on the underside of the key and on the top of the instrument. This is not the traditional method, but it gives satisfactory results. In the oldest instruments the key fastening was made by leaving a ring turned around the instrument, cutting a channel through it for the key, and running the axle through holes drilled across the channel. In later instruments much of the ring was cut away to leave just two wooden posts supporting the axle. Finally, inserted metal posts came into common use to support the axle. Pads on early instruments were made of soft leather; if suitable leather can be obtained it is quite satisfactory. The pad can be attached to the key by roughening the metal surface and using contact cement. A flat, smooth surface must be made around the hole that is to be closed. A slightly raised rim around the hole may make for a better air seal, but it was not usually present on old instruments.

For polishing keys a high-speed hand grinder is very useful. In the initial stages rubber-bonded abrasive wheels are used, then a buffing wheel loaded with Tripoli compound, and finally rouge. The bottom of the spring also needs to be polished so that it slides easily on the wood.

Reeds

Making reeds is a complex and difficult art requiring much practice and specialized tools. I have a letter from Josef Marx in which he mentions spending one or two nights for five hours each night to make one successful baroque oboe reed. The high price of commercial reeds thus becomes understandable, and my best advice is to buy them if possible. I sometimes break that advice in the interest of economy or experimentation. Others who would like to try their hand at reed making should see an excellent short article by Meyer and Kottick on Renaissance double reeds and two articles by Haynes on baroque oboe reeds (see Bibliography).

Placement of Finger Holes

It comes as a surprise to many that there is a certain amount of latitude possible in the placement of finger holes. In general there are three main goals to be satisfied, and the final hole positions and sizes reflect a compromise among them. (1) An inconvenient reach for the fingers should be avoided. To accommodate a player with small hands it may be possible to move the holes closer together or to move the holes for the third and fourth fingers out of line with the other holes. (2) The volume of sound coming from a hole is controlled by the size of the hole so that for all notes to be of equal loudness, holes should be of nearly the same size. (3) Control of pitch is, of course, the primary consideration; the rule of thumb is that a small hole nearer the mouthpiece will give the same pitch as a larger hole farther down. Thus if a hole is to be moved up to satisfy the first goal, it must also be made smaller. If it is enlarged to satisfy the second goal, it must be moved down. The place where the hole meets the air column on the inside is the major determinant of the pitch, so that in a thick-walled instrument the finger holes may be drilled at an angle to make them closer together on the outside than they are on the inside. Where double holes are used to make it easier to play chromatics, it is useful to slant the lower note hole toward the bottom of the instrument and the higher one toward the top. The wall thickness of the instrument will also affect the pitch, because the length of the air column is increased by the length of the open finger hole. Since closed holes also contribute to the volume of the bore, big finger holes have more of an effect on the pitch issuing from lower holes (flattening it) than small holes do.

With the foregoing considerations in mind the procedure for making the finger holes follows logically. Approximate hole positions are decided on, and small holes are drilled. Then, starting with the lowest note, each note is tuned to a standard by sounding the instrument and enlarging the hole until it sounds the right pitch. After boring all the holes by this procedure the bottom notes will be flat, because the effect of closed upper holes is not the same as an unbroken bore. The lower holes must therefore be enlarged, and the correct tuning approached by successive approximations always working from the bottom up. Even when copying other instruments or following the designs in this book, it is wise to start by making the finger holes smaller than the given measurements and then gradually enlarge them until the right pitch is achieved.

Finish

The finish to be applied to the wood is largely a matter of personal taste unless one desires to make an exact replica of some historical instrument. A penetrating finish should be applied to the bore of wooden instruments as a seal against moisture. One end can be plugged with a cork, finger holes closed with masking tape, and the tube filled with finish and allowed to drain after a time. The outside can be stained if desired, then finished with either a varnish or a penetrating oil finish such as Watco oil, and finally waxed. Polyurethane varnish thinned 1:1 makes a good first coat for both bore and exterior since it will penetrate well. Later coats can be thinned less. Before applying the interior finish and after each application is hard, the bore should be given a smooth, hard surface. The tool for this internal smoothing is simply a dowel with a saw kerf in the end to hold a strip of abrasive cloth that is wrapped around it. The

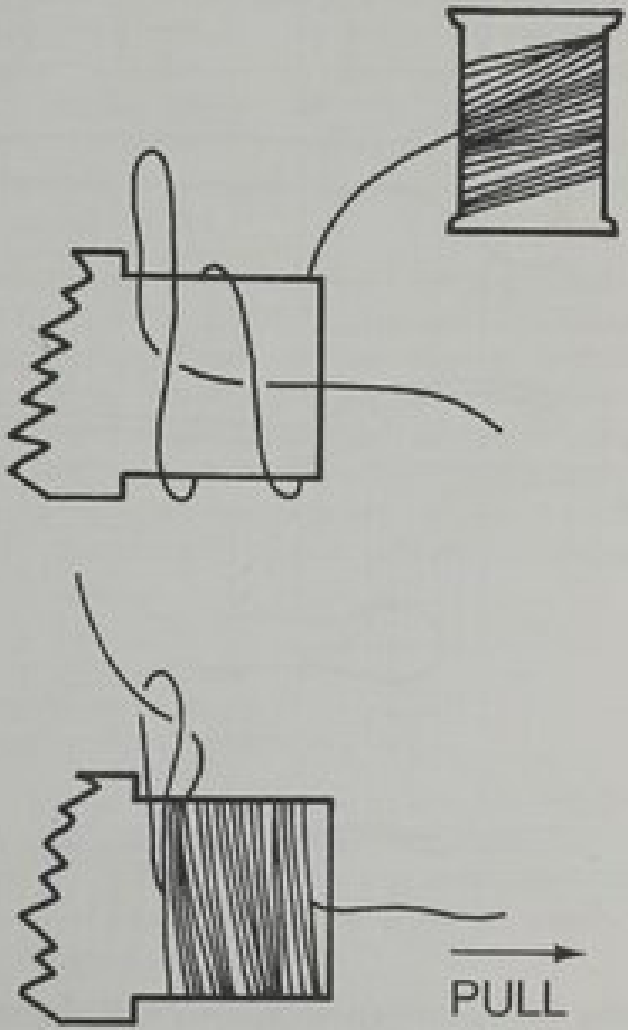


FIGURE 4. Wrapping a tenon with thread.

dowel is then turned in a drill press at 1,000 to 2,000 rpm while the instrument is worked back and forth over the abrasive. Finally a slight chamfer should be made on the inside edge of each finger hole. Such chamfering improves the loudness and dynamic range by effectively smoothing the bore.

Metal or ivory parts are smoothed with a rubber-bonded fine abrasive wheel and finally buffed with Tripoli compound on a cloth wheel.

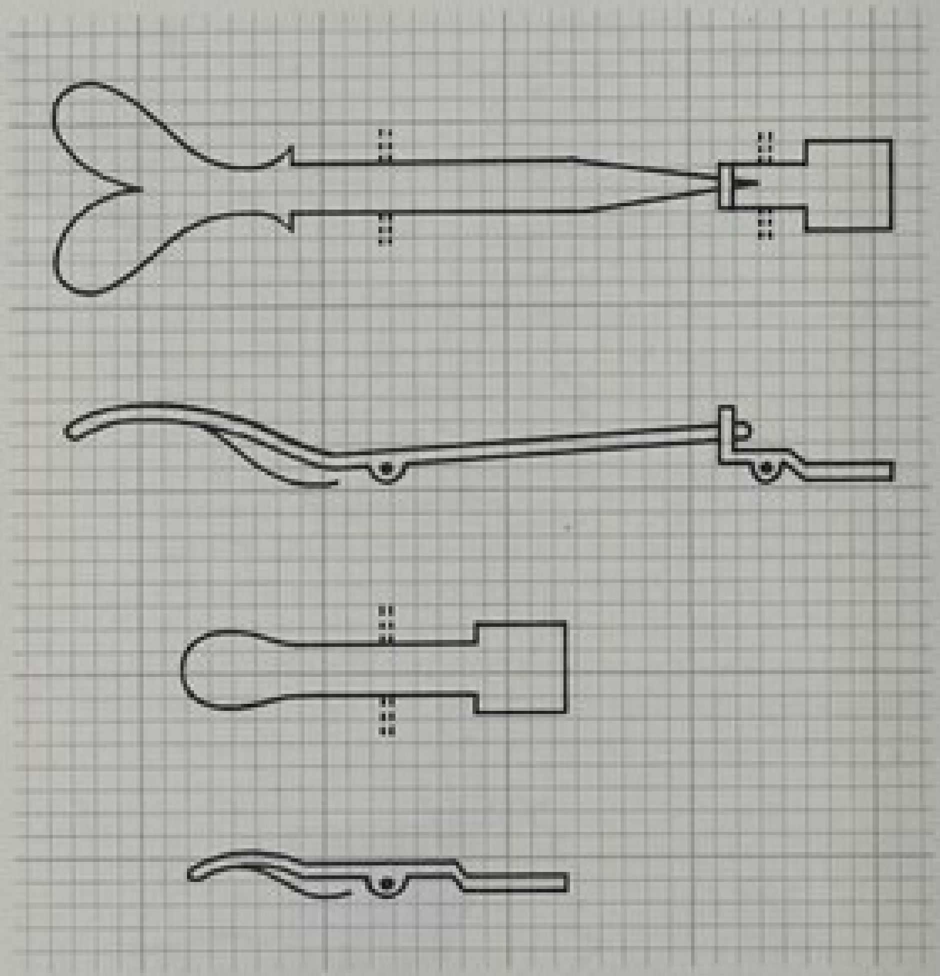


FIGURE 5. Key designs, top and side views: *above*, open key; *below*, closed key.

3
Flute and Fife

The fife is probably the simplest to make of all the instruments described in this book, since it is one piece with a completely cylindrical bore. Dimensions are given here for a fife in B-flat (fig. 7, table 3.1). The lowest note is C5, but the lowest two or three notes are weak, and it is a much more effective instrument in its upper range. For positioning the cork plug, see the discussion below regarding the flute.

Flutes of the Renaissance period were simply low-pitched fifes. That is, they were made in one piece and had a cylindrical bore. Several sizes existed, and the one chosen for presentation here is the tenor—the same size as the modern orchestral flute. A decorated version shown in figure 6 is based on a drawing in Mersenne's *Harmonie Universelle* of 1636. Most of them had plain exteriors. No drawing is given here because the design is so simple that the tabulated dimensions (table 3.2) should suffice with the additional data as follows:
overall length 605 mm.
inside diameter 17.7 mm.
outside diameter 27.0 mm.
top end to embouchure center 82.0 mm.

The one-keyed flute of a design like the one presented here (fig. 8, table 3.2) came into use at the end of the seventeenth century. During the eighteenth century additional keys were added until, at the beginning of the nineteenth century, flutes with six, seven, or eight keys were in use.

The chief problem in making a conically bored flute is getting suitable reamers. These must be made, since the necessary taper is much more gradual than can be found in commercially available reamers of such diameter. It is tempting to try to compromise, such as by making the cylindrical section longer and then tapering more abruptly with a ¼ in. to the foot reamer, but experience shows that this creates a flute in which it is almost impossible to get the low and high registers in tune with each other. The diameters must also be adhered to quite strictly (at least not increased), or the result will be,

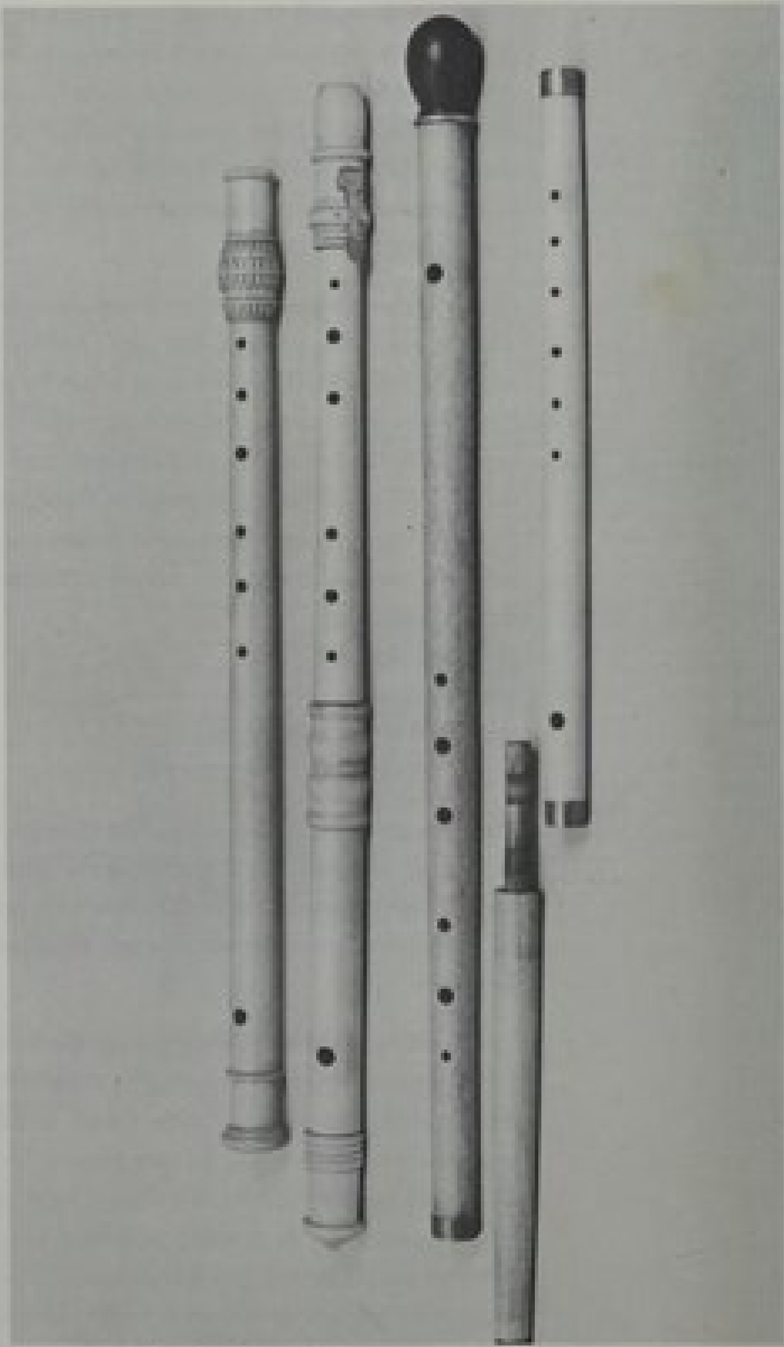


FIGURE 6. *From left to right,* Renaissance type of flute, baroque flute, walking stick flute, and fife.

again, a flute in which either the high or the low register can be brought into tune but not both together. The embouchure hole on many old flutes was undercut, that is, the diameter increased as it approached the bore. Undercutting facilitates production of high notes but reduces the power of the lowest octave. A very *slight* chamfering of the outer edge is considered desirable.

Placement of the cork is an operation peculiar to tuning the flute (and fife). The rule of thumb is to locate the cork as a first approximation at a distance back from the center of the embouchure equal to the diameter of the bore at this point. The lowest note (d' on the flute) is hardly sensitive to cork position and can be tuned by cutting off the lower end of the instrument if required.

When this is satisfactory, the cork is moved until the octave (d'') can be overblown accurately. Moving the cork toward the embouchure sharpens the overblown note, and moving it away flattens it. When the cork has been located so that the octave is in tune, the note holes can be drilled and adjusted to give the intervening tones. For final tuning it is best to adjust so that the octave overblows most accurately at G. This gives the best compromise for other notes. Notes in the upper octave are apparently more sensitive to hole diameter than notes in the lower; so if the lower note is in tune, but its octave is flat, the note hole can be enlarged enough to sharpen the octave without noticeably sharpening the fundamental.

The walking stick flute (see fig. 10) was a nineteenth-century novelty. The simple design of the flute part makes it resemble flutes of a much earlier period. Some walking stick flutes did have keys, but they would have been awkward if the instrument was, in fact, used as a walking stick. The only constructional difficulty worthy of mention is the result of the flute section being unjointed. This necessitates adding extensions to the reamers for the boring operation. The bottom end of the flute needs to have a cylindrical bore for proper fitting of the foot section, and the upper end must allow for enough space above the cork for insertion of the handle.

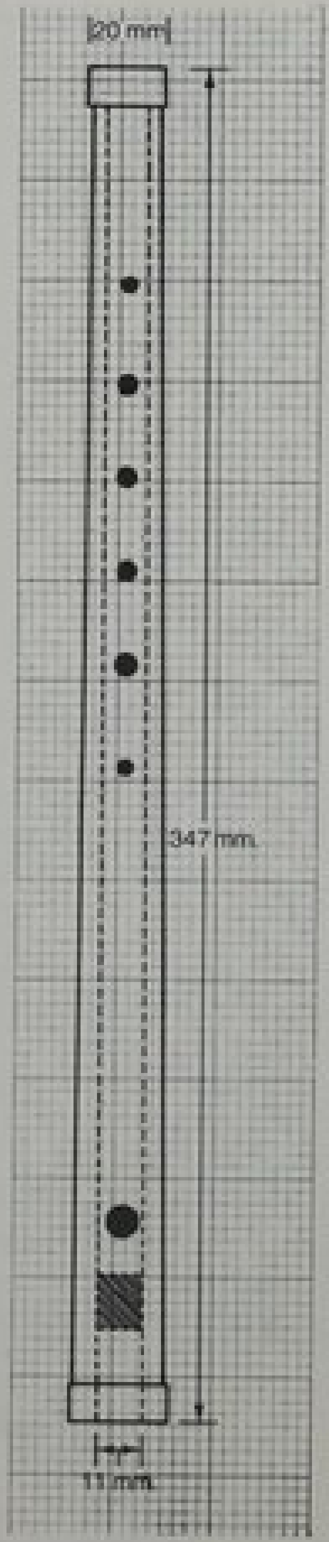


FIGURE 7. Fife in the key of B-flat.

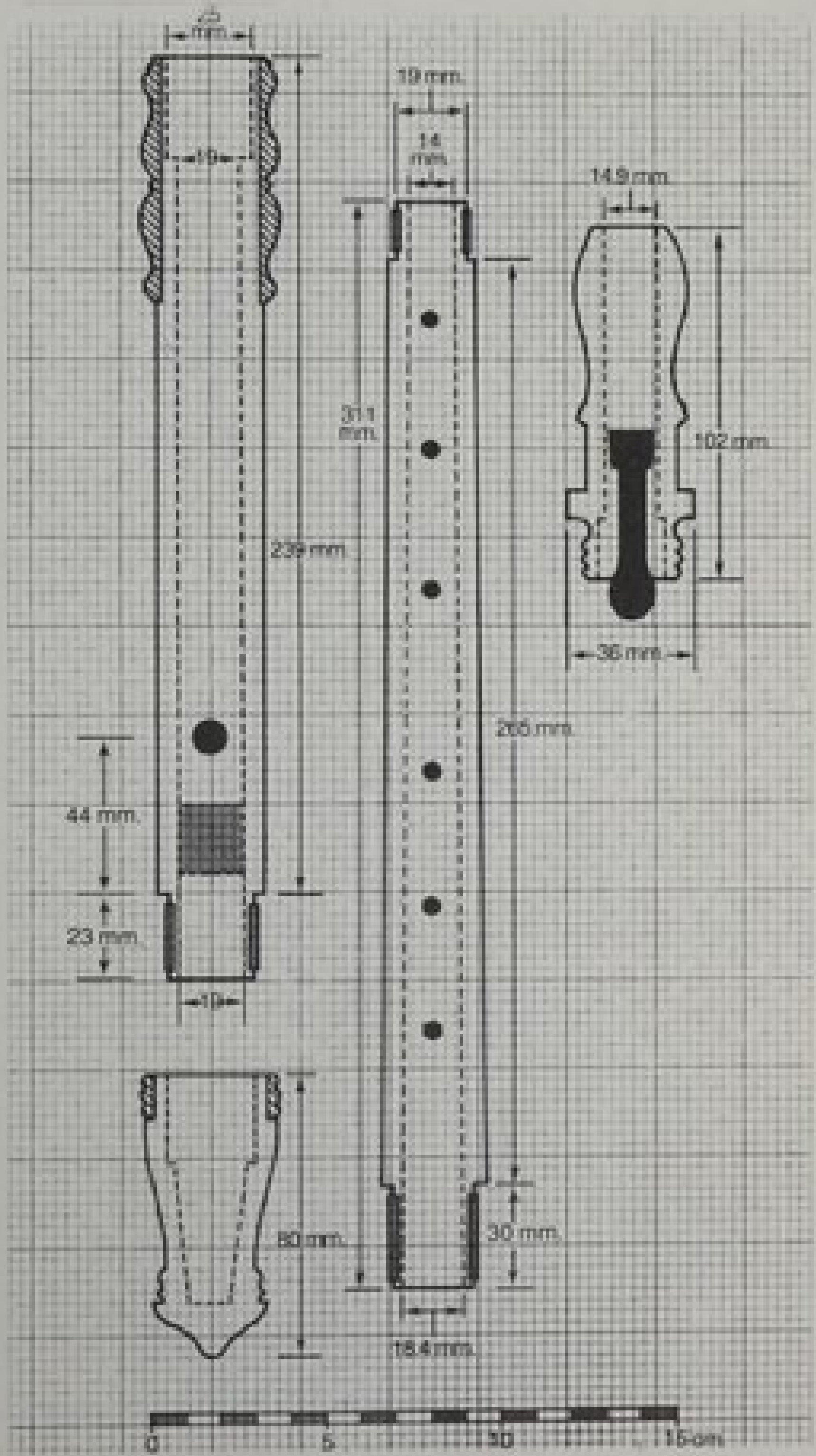


FIGURE 8. A copy of a baroque flute in the Boston Museum of Fine Arts collection (no. 38). The original is made of boxwood with ivory rings.

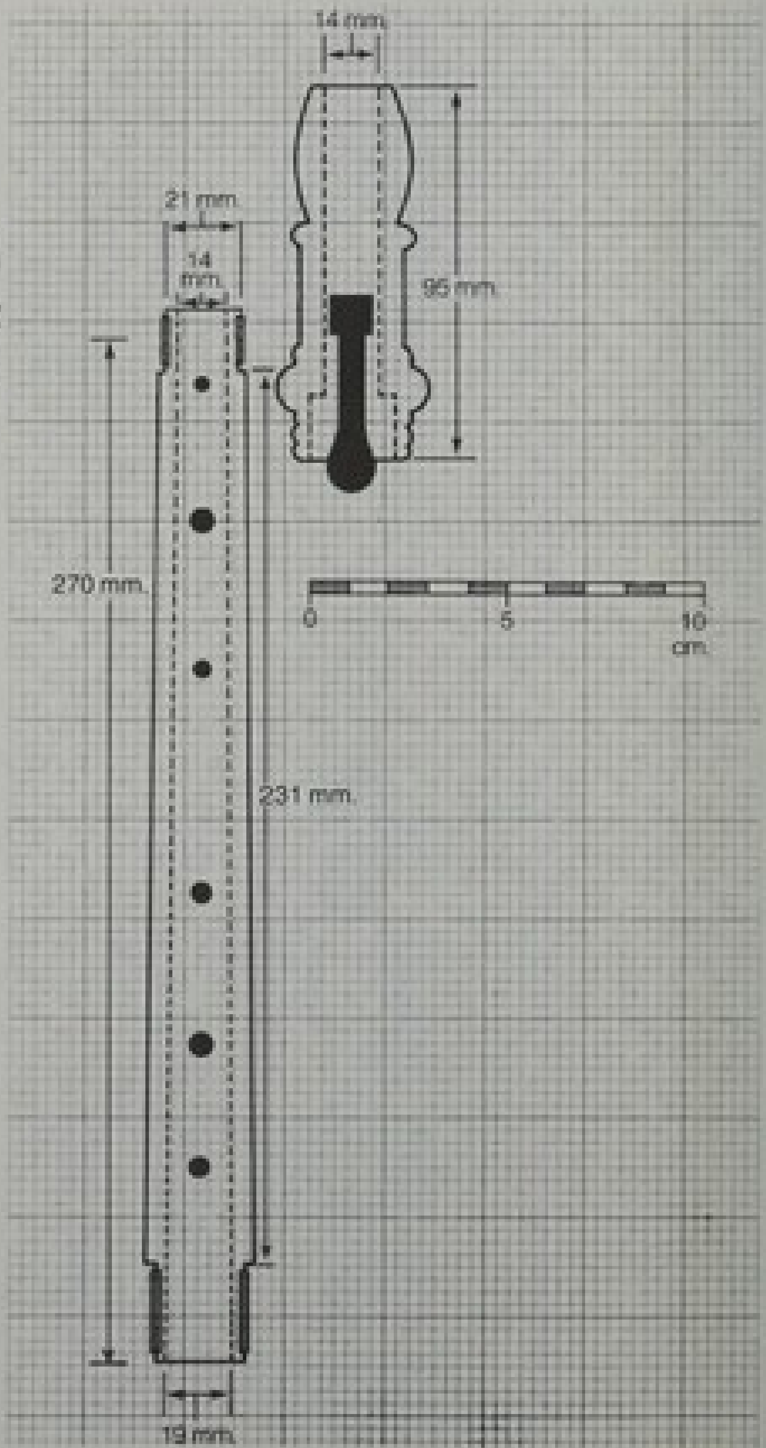


FIGURE 9. Modified joints which will bring the instrument up a semitone to modern pitch.

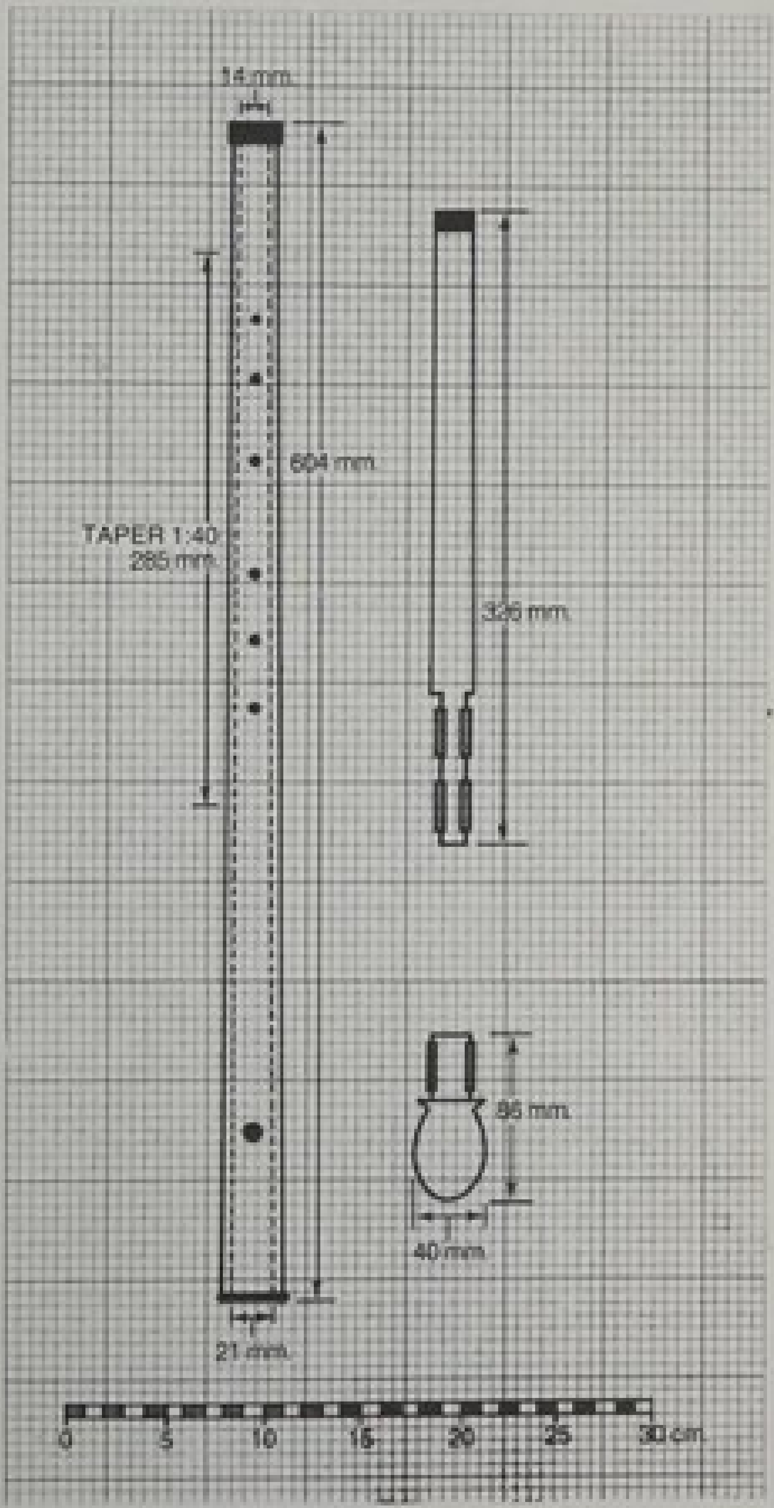


FIGURE 10. Walking stick flute.

TABLE 3.1 *Fife Hole Dimensions*

Finger hole distances measured from center of embouchure hole to centers of finger holes.

	B-flat fife	
Hole number	Distance (mm.)	Diameter (mm.)
Embouchure	0	7.5
1	121	4.5
2	147	6.0
3	171	7.0
4	197	7.0
5	220	8.5
6	246	7.0
Bottom End	292	11.0

TABLE 3.2 *Flute Hole Dimensions*

Finger hole distances measured from center of embouchure hole to centers of finger holes.

	Renaissance		Baroque			
			Original		Modern Pitch	
Hole number	Distance (mm.)	Diameter (mm.)	Distance (mm.)	Diameter (mm.)	Distance (mm.)	Diameter (mm.)
Embouchure	0	9.5	0	9.8 × 9.3	0	9.0
1	223	7.0	239	7.0	216	6.5
2	263	8.3	274	7.0	248	7.5
3	297	7.5	313	6.0	284	8.0
4	345	8.4	365	6.0	343	6.5
5	380	7.5	405	5.8	380	7.5
6	412	7.0	442	5.0	410	5.0
7	——	——	497	6.0	462	6.0

FIGURE 11. Recorders: *Left*, Renaissance-style alto; *center*, baroque-style soprano; *right*, baroque-style tenor.

4 Recorders

The recorder achieved nearly its modern form as early as the fourteenth century and continues even today to be a popular instrument with amateur players because of the relative ease with which it can be played. However, in the hands of a virtuoso, it can be an impressive instrument. Six sizes of recorder are well recognized ranging from sopranino to great bass. The lower pitched instruments often suffer from weak sound, and there is little music written for the shrill sopranino. The alto recorder is probably most popular because of its relative loudness and the range it covers. In writing this chapter I am especially indebted to Arthur Benade who has given me the results of many experiements relating constructional modifications to acoustic results. A very useful article by R. Marvin, "Recorders and English Flutes in European Collections," gives precise measurements for fifteen important museum specimens of recorders.

Recorders of the Renaissance period were generally made of a single piece of wood and had a bore with large diameter and little taper. They also might have a slight flare of the same taper at the bell end starting at the seventh hole. Because of this type of bore the Renaissance recorders were loud in the lower octave but would not overblow for the full second octave. The Renaissance-type alto recorder shown here (fig. 13, table 4.1) is not based on any original instrument because I wanted it to be at modern pitch. After the bore has been reamed to the right dimensions and the outside turned, the edge and windway are shaped as described below for the baroque-type recorders. One last peculiarity of the Renaissance recorder (and other woodwinds of the same period) is the double seventh hole. One or the other of these two holes was plugged with wax according to whether the player put the right or left hand below. Nowadays, as everyone plays with the right hand below, only one hole need be drilled through, but the other can be drilled part way for appearance.

The designs presented here for baroque recorders (figs. 14, 15; table 4.1) follow traditional dimensions and styling, although they are in modern pitch. The boring and turning operations for the middle and foot joints present no special problems. I have fixed on a taper of 1:48 (¼ in. per foot) for recorders. This is in

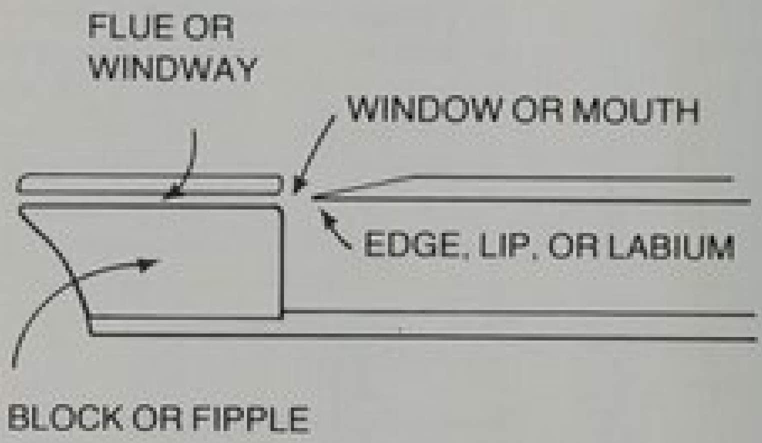


FIGURE 12. Longitudinal section of the top end of a recorder, with terminology of the parts.

the range for baroque instruments and is convenient because of the availability of machinists' taper pin reamers that have this taper. For the soprano recorder, sizes no. 6 through no. 8 reamers are needed, for the alto sizes no. 9 through no. 11, and for the tenor sizes no. 10 through no. 12. Since the larger sizes are expensive, the amateur may wish to make wooden-bodied reamers as described in chapter 2.

The top joint is the crucial part of the recorder. Great precision is required in its construction, therefore the recorder is one of the most difficult instruments to make well. Step-by-step instructions are given as an aid in meeting some of the difficulties. A ¼-in. hole is first drilled straight through the piece. This serves to guide the larger bits for boring in order the socket joint, fipple bore, and main bore. The outside is then turned, being especially careful that the bottom edge of the ring just above the mouth coincides exactly with the bottom of the fipple bore. If a spade bit has been used for the fipple bore, the bottom will be flat; but if a twist drill has been used, the bottom will be chamfered toward the main bore, the fipple will have to be beveled to fit this chamfer, and the ring must be turned to coincide with the flat end of the fipple. When the outside turning is finished, the mouth is cut through by drilling and filing to a rectangular cross-section. The windway or flue is chiseled and filed along the top of the fipple bore, removing just enough wood so that it is flat where it meets the mouth. The fipple should be turned of red cedar because of the moisture-resistant properties of this wood.

When the diameter and length are right to fit closely in the fipple bore, a flat is filed along the top to match the chiseled windway, and a thin slip of cedar is glued to the flat to make a good seal with the bottom edge of the chiseled groove. When the fipple has been fitted so that its end coincides with the external ring and the windway opening at the mouth is the right size, the lip can be shaped by chiseling alternately from the outside and the inside so that the sharp edge comes slightly below the middle of the windway. This is achieved by sighting through the flue at the lip as the chiseling proceeds. During the chiseling it is a good idea to insert a slip of wood in the mouth so that the chisel does not strike the fipple or rear edge of the mouth. The relationship between lip and flue is crucial to a good recorder, and a slip in the chiseling is difficult to correct. Narrowing the flue from front to back makes the upper octave easier to play; but if it is too narrow, the lower octave becomes hard to play, and condensed moisture may obstruct the passage. Arched windways are made in some recorders and have an advantage in that condensed moisture runs to the edges, but the lip must also be curved so that its edge follows the center of the curved windway. Some of the best old instruments (e.g., those made by the Denners and the Stanesbys) have the top of the flue arched at the blowing end and gradually flattened out to give a rectangular section at the window end. Experiments by Benade have confirmed the value of shaping the flue in this way to smooth out the response, particularly for the lower notes. *Slight* chamfering at the window end of the flue is also helpful in brightening the tone and stabilizing the attack. No finish should be applied to the top of the fipple, because moisture tends to collect in large droplets on a finished surface rather than to spread out in a thin film. Benade has found that cutting away the underside of the fipple to create a cavity above the mouth helps to increase the dynamic range. Some Stanesby instruments were made this way. Since this modification also lowers the pitch, it cannot be simply applied to an instrument without also shortening the middle joint.

It appears that internal smoothness is more vital to the construction of the recorder than to that of any other instrument. In the main bore high polish, closely fitting joints with slightly chamfered and rounded ends, and slightly rounded edges on the finger holes make considerable improvement in the clarity of speech and smoothness over the whole range as well as increase the loudness of the low notes. A smooth flue is important throughout the range and can make an all-or-none difference in the highest notes.

The recorder designs given here are intended to be played with baroque fingering. For German fingering the fifth hole is made somewhat smaller so that the sixth hole does not have to be closed when playing F on the soprano and tenor or B-flat on the alto.

Several articles by Loretto are listed in the Bibliography. They give detailed procedures for fine adjustments to recorders. A more recent article by Stern deals with many of the same matters.

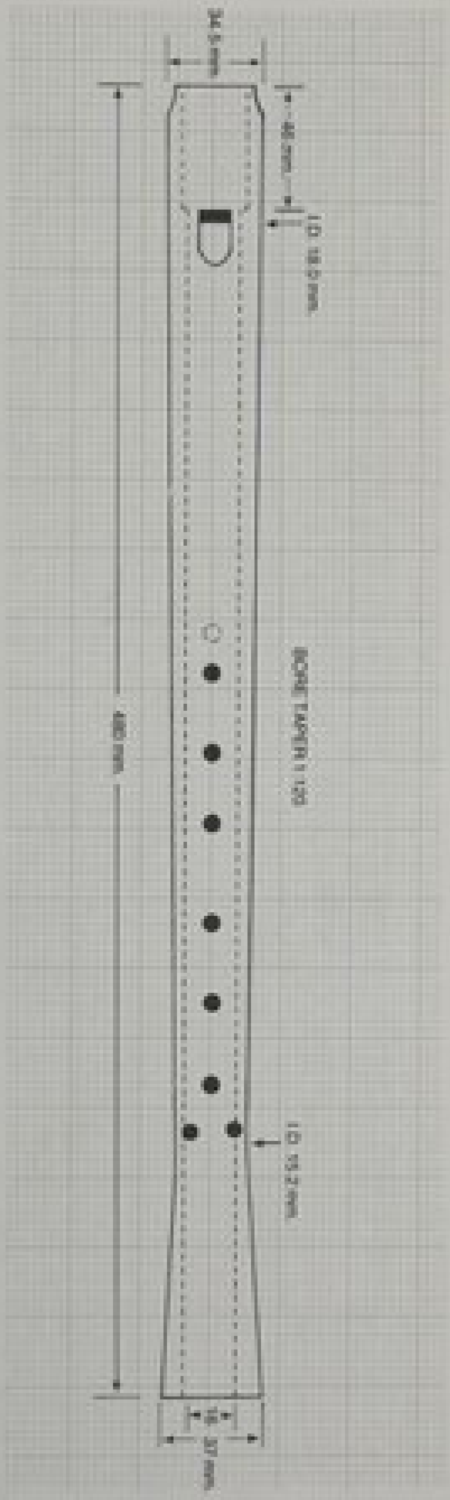


FIGURE 13. Renaissance-type alto recorder.

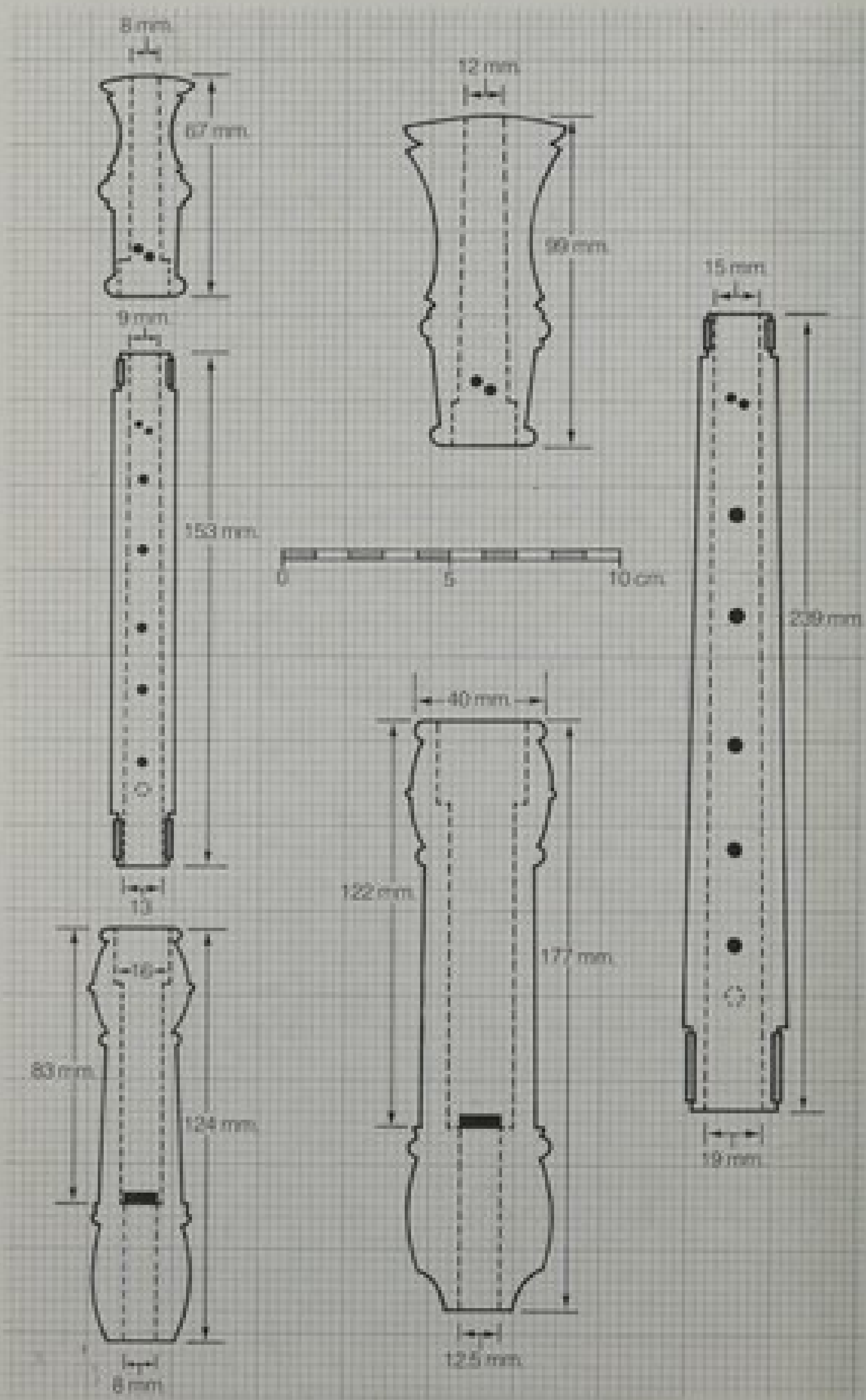


FIGURE 14. Baroque recorders: *Left*, soprano; *right*, alto.

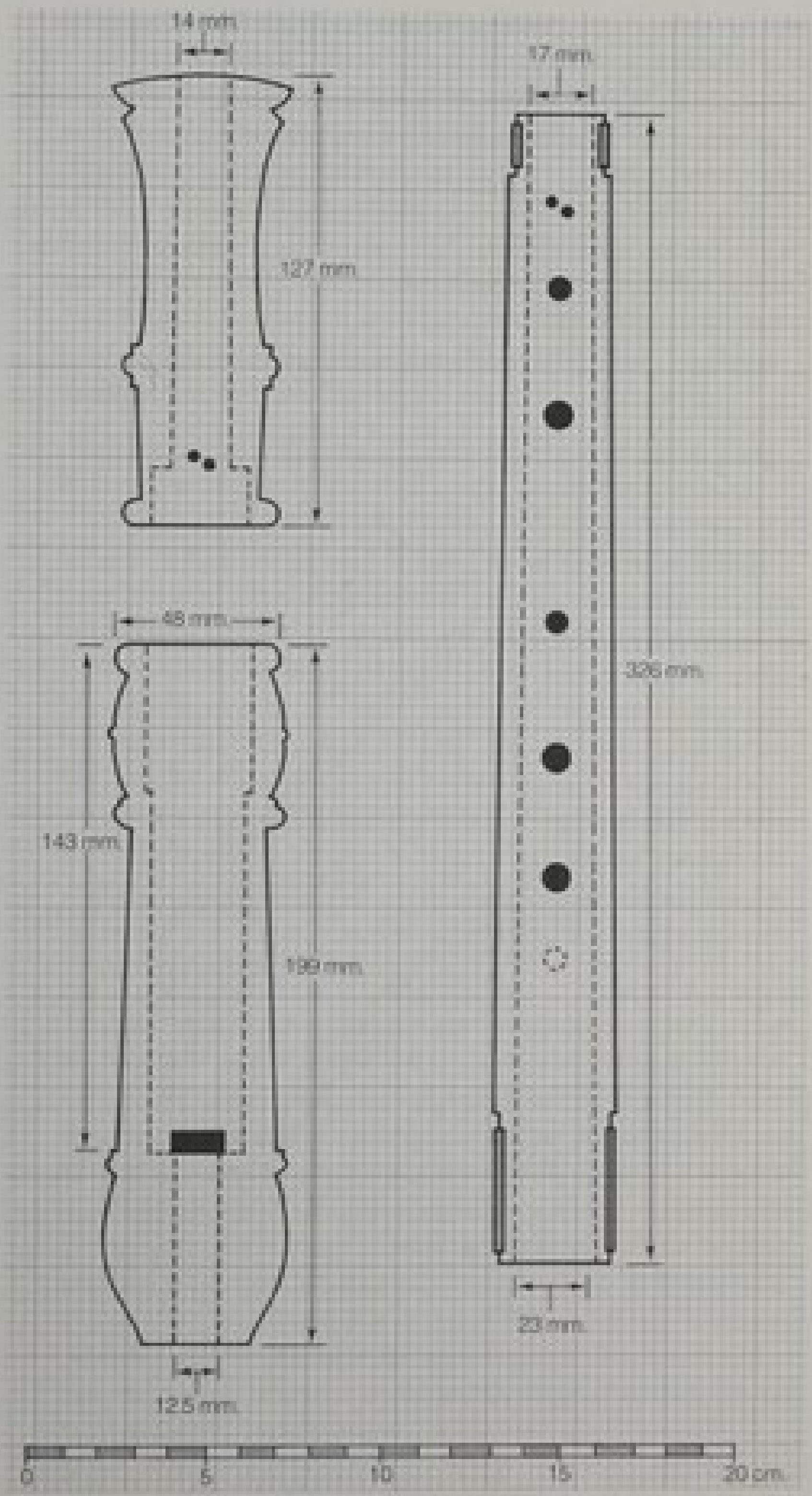


FIGURE 15. Baroque Tenor recorder.

TABLE 4.1 *Recorder Finger Hole Dimensions*

Finger hole distances measured (in millimeters) from edge of lip to centers of finger holes.

Hole number	Renaissance alto dis.	Renaissance alto dia.	Baroque soprano dis.	Baroque soprano dia.	Baroque alto dis.	Baroque alto dia.	Baroque tenor dis.	Baroque tenor dia.
Thumb	151	7.4	94	4.5	126	6.5	182	8.0
1	165	7.5	102	3.5	141	6.0	204	8.0
2	194	7.3	121	3.5	171	6.5	237	7.0
3	220	7.3	141	4.5	203	6.5	274	6.5
4	256	7.6	165	4.0	241	6.5	334	8.5
5	285	6.8	185	4.5	273	6.0	367	7.5
6A	315	6.8	200	2.5	304	2.5	392	4.0
6B	—	—	202	2.0	307	2.0	394	3.0
7A	332	5.8	227	2.5	335	2.5	421	3.5
7B	—	—	230	1.5	338	2.0	424	2.5

Window dimensions

Width	Height	Width	Height	Width	Height	Width	Height
12.0	4.0	9.0	3.0	12.0	4.5	15.0	6.0

5 Clarinet

The invention of the forerunner of the modern clarinet has been credited to Cristoph Denner of Nuremberg at about the end of the seventeenth century; although, as with most instruments, more primitive ancestors can be traced back to an indefinite beginning. The instrument presented here (figs. 16 and 17, table 5.1) preserves the general appearance of Denner's earliest design, but it has been modified in two respects: the length has been shortened to bring it up to modern pitch, and the outer diameter of the mouthpiece has been increased so that a modern ligature will fit. Well into the nineteenth century, clarinet reeds were tied on with thread—a clumsy arrangement, but one that the purist may want to preserve.

Since the bore is cylindrical except for a slight constriction at the bottom, the clarinet is one of the easiest instruments to make, and the only peculiarity that might call for some special directions is the channel at the tip of the mouthpiece. The boring of the mouthpiece joint is carried out to the distance where the outside beak starts its sharp taper. Turning of the outside is completed, the flat is filed on the top, and the square wind channel then chiseled in to meet the bore. The beak is finally shaped with a spokeshave or a file to suit the player's preference. The flat does not extend right to the tip, for if it did there would be no space under the reed for passage of air. Therefore a curve is filed starting about 15 mm. from the tip at a radius such that there is a gap of about 1 mm. between the end of the reed and the end of the mouthpiece. There is a slight constriction in the bore of the lowest joint. This is produced by boring to 7/16 in. and then using a tapered reamer.

Tuning is straightforward except for the peculiarity of the clarinet that makes it overblow a twelfth rather than an octave so that the lowest note in the low register is f, but in the high register it is c″. The gap between the two registers is filled (but incompletely) by use of the two keys. Opening either one of the keys gives a′, and opening both keys gives b′. If a player prefers, one of the two keyed holes (probably the top one) can be made slightly smaller so that opening both will give b-flat′, but there is no reliable way of providing both b′ and b-flat′ on this instrument. One of the two keys is also used to provide a vent for playing in the upper register. This key should have the smaller of the two holes, and the edges of the hole should be considerably rounded over.

FIGURE 16. Clarinet.

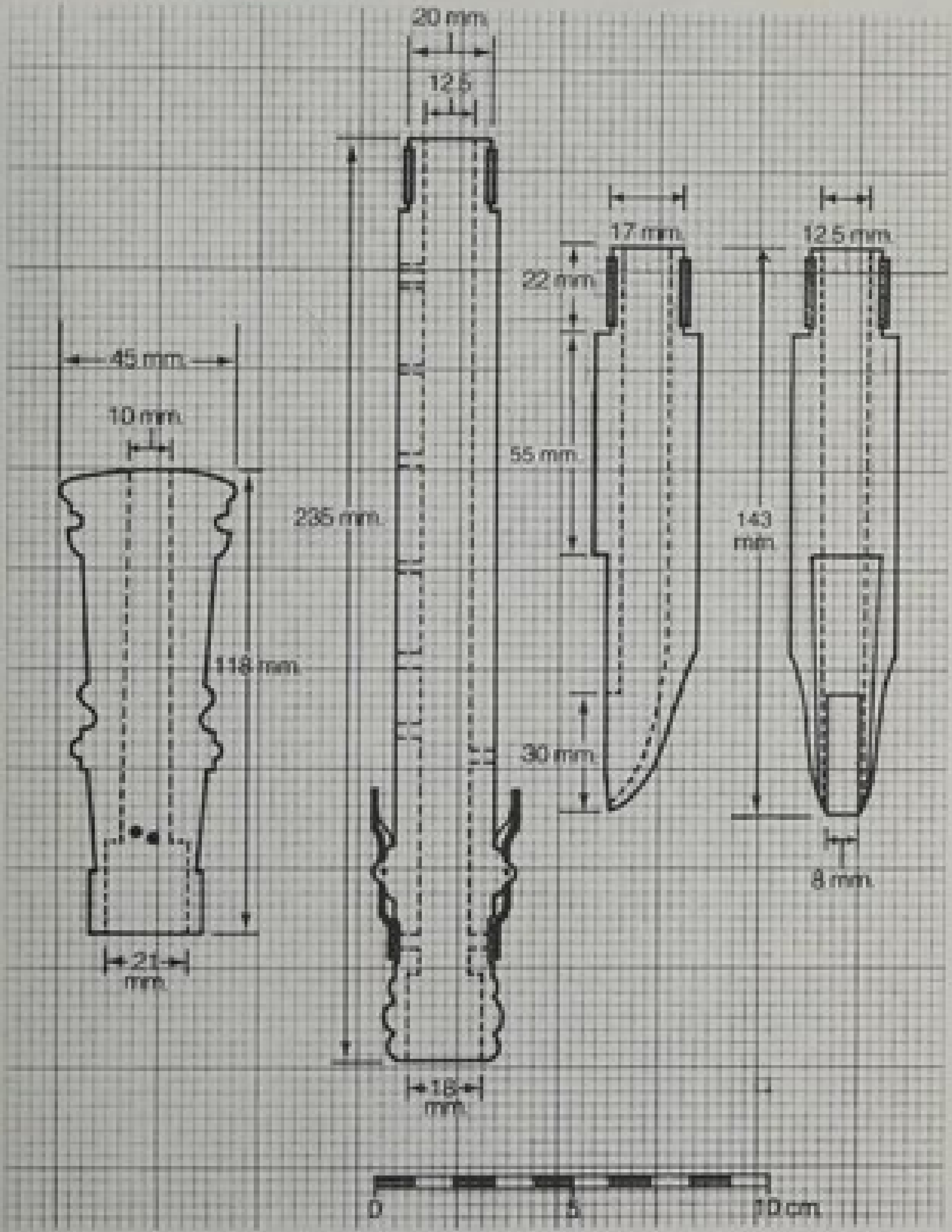


FIGURE 17. Clarinet.

TABLE 5.1 *Clarinet Finger Hole Dimensions*
Distances to center of holes from top end.

Hole number	Distance (mm.)	Diameter (mm.)
Key 1	151	3.5
Key 2	151	2.5
Thumb	196	5.0
1	203	4.5
2	221	4.8
3	243	4.0
4	272	2.8
5	296	3.2
6	317	2.9
7A	357	2.0
7B	360	2.7

6 Shawm and Oboe

The origin of double-reed instruments, like most others, is vague and lost to us; but it is generally accepted that the lineage of the modern oboe reaches back to medieval times when shawms were introduced into Europe from the Near East. The shawm had a rather wide conical bore and used a large reed that gave a loud, coarse sound. Most shawms were also fitted with a device called a *pirouette* that enclosed the bottom end of the reed. The player's lips were pressed against this, and the tip of the reed was in his mouth. Therefore the vibration of the reed could not be controlled by the pressure of the lips, and overblowing was difficult. The shawms were essential members of wind bands in the fifteenth and sixteenth centuries. During the seventeenth century they were gradually refined with narrowing of the bore, elimination of the pirouette, and reduction of the size of the reed. Instruments of this transition period are distinguished from the earlier shawms by the name *Deutsche Schalmei*. They are more commonly seen in museum collections than are the earlier shawms, and some modern reproductions purporting to be shawms are, in fact, examples of the Deutsche Schalmei. The soprano Deutsche Schalmei can be readily recognized by its peculiarity of having a fontanelle that covers only a tuning hole, not a key mechanism (an example is no. 129 in the Boston Museum of Fine Arts collection). In the first half of the eighteenth century the shawm was already regarded as an obsolete instrument, and a recognizable oboe had emerged that then remained essentially unchanged until the early nineteenth century when further narrowing of the bore and the addition of keys began to lead towards the instrument of today.

In addition to a standard soprano shawm, I am giving dimensions (table 6.1) for a shawm pitched differently from any in the recognized shawm family, one that is considered to be a type of folk instrument rather than one used by professional musicians. The two highest pitched shawms described by Praetorius went down to b' and e', and the low note of the one described here is f'. This gives it the more common F fingering so that it can be played more readily. Folk instruments of this type are sometimes called pastoral pipes or musettes, although the name musette more often refers to a type of bagpipe that was popular among the aristocrats of seventeenth-

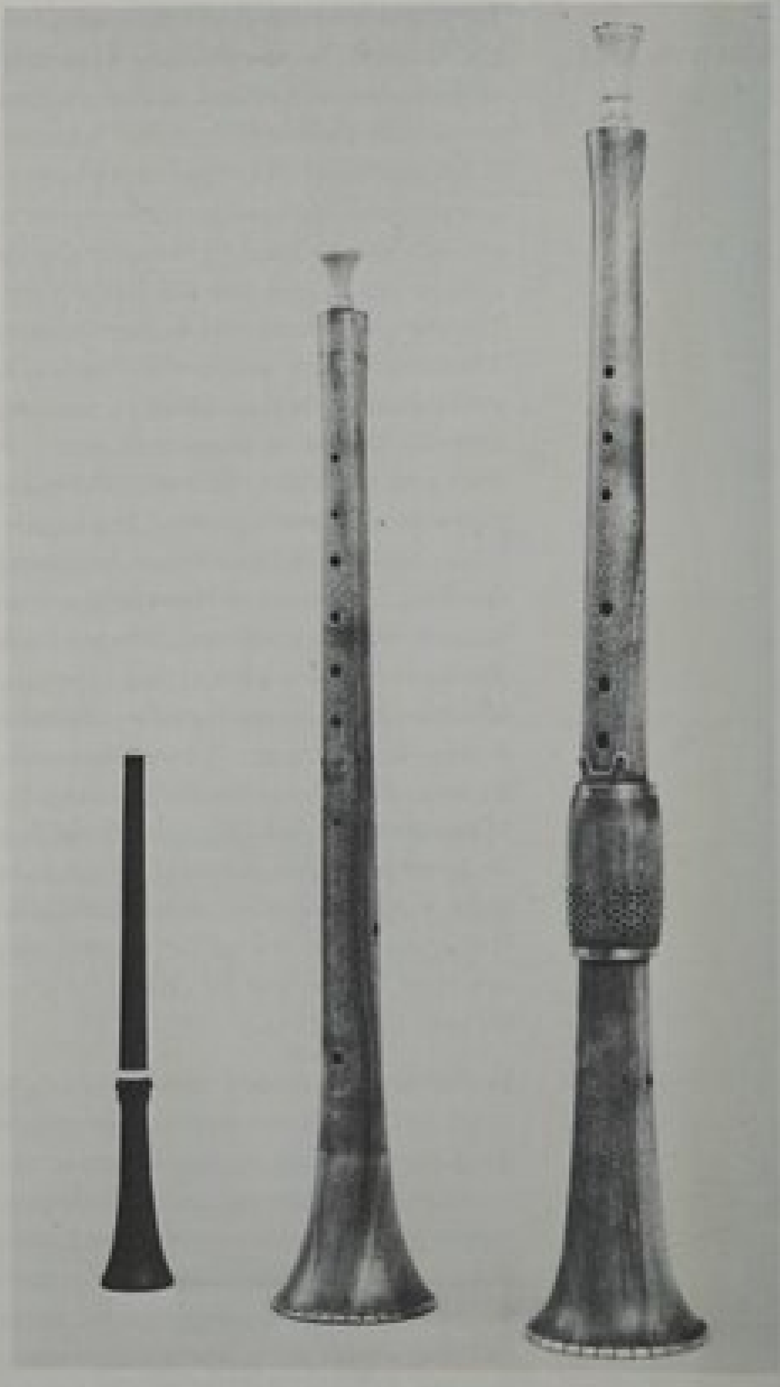


FIGURE 18. *Left*, musette; *center*, soprano shawm; *right*, alto shawm.

century France. Indeed the chanter pipe of the bagpipe is not much different from this simple musette, and this similarity presumably accounts for the correspondence in name.

The bore of all of these instruments is narrower at the upper end than the smallest (¼ in.) Ridgway shell auger. Therefore the boring cannot be carried straight through. It is necessary to stop short of the end and to finish with a twist drill.

A word also needs to be said about the bell, since shawms and oboes are the only wooden instruments described in this book that do have a flared bell. To turn the inside of this bell it is necessary to support the turning with a steady rest near the open end while driving the work with a chuck. Therefore the outside must be turned round after boring the bell joint but before reaming the inside to its final dimensions. A spear-pointed chisel suffices for shaping the shawm bells, but an L-shaped chisel is required for shaping the undercut lip on the oboe. One can be ground from an old file or made from an offset screwdriver by making the hoe-shaped end into a tang and sharpening the other end. It will be noticed (figs. 22, 23) that on the oboe there is a slight step in the bore where the middle joint meets the bell joint. This abrupt expansion of the bore is an essential characteristic of old oboes, and in some specimens the diameter increase is as much as 5 mm.

Reeds are a problem in the reproduction of old instruments, since so few original reeds have survived to our time. The musette does very well with a modern oboe reed. There is considerable difference of opinion about the proper reed dimensions for a baroque oboe (although "considerable" in this case refers to a millimeter more or less). The oboes here are in pitch if played with a modern oboe reed placed on a staple longer than usual or with a reed of about the dimensions of an English horn reed. If one is not appalled at such a liberty, a bagpipe practice chanter reed shortened to about 22 mm. will also work, but the tone will be harsher than it should properly be. In the soprano shawm a brass staple such as a modern oboe staple fits into the end of the instrument, the pirouette is pushed onto it, and a reed is then fitted to the staple. A bagpipe reed can be used if the player does not wish to experiment with making his own.

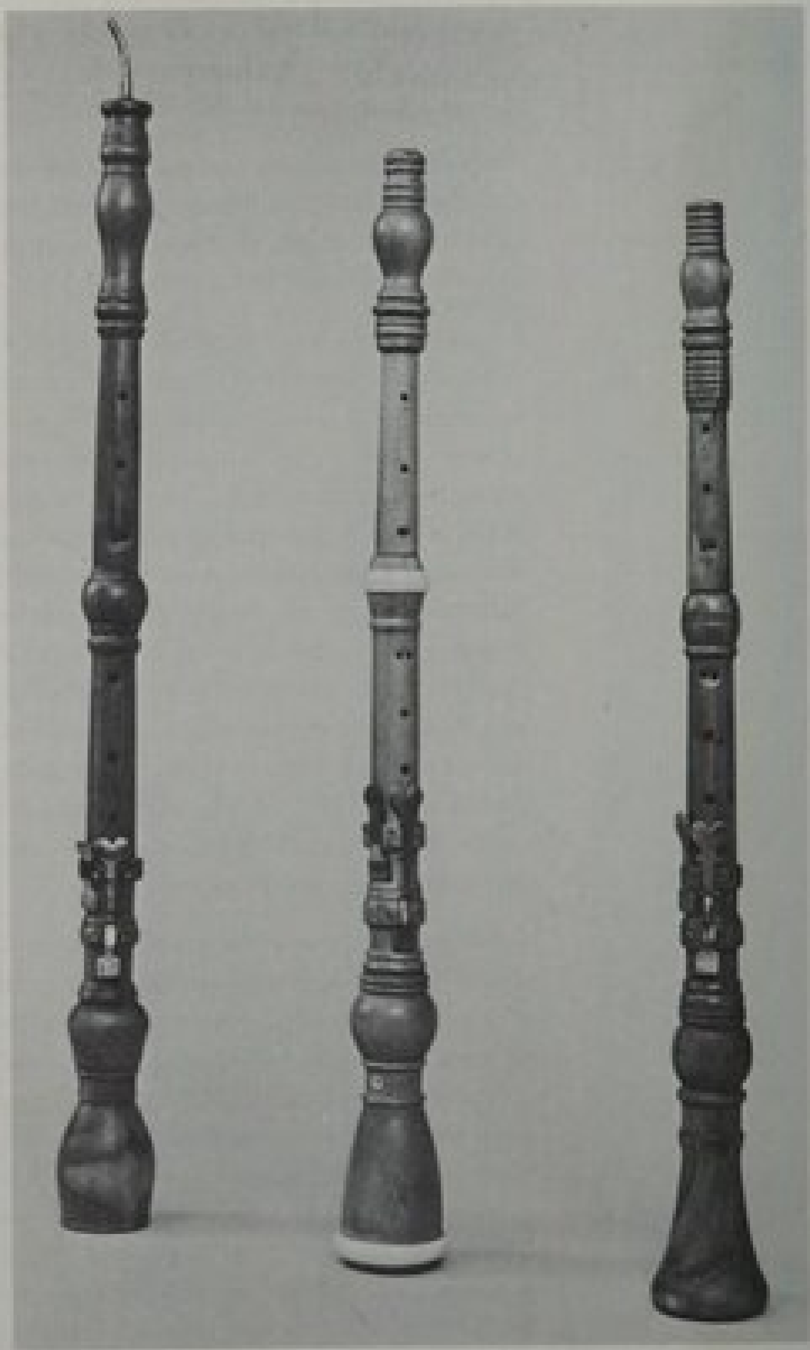


FIGURE 19. *Left*, oboe d'amore; *center*, oboe in baroque pitch; *right*, oboe in modern pitch.

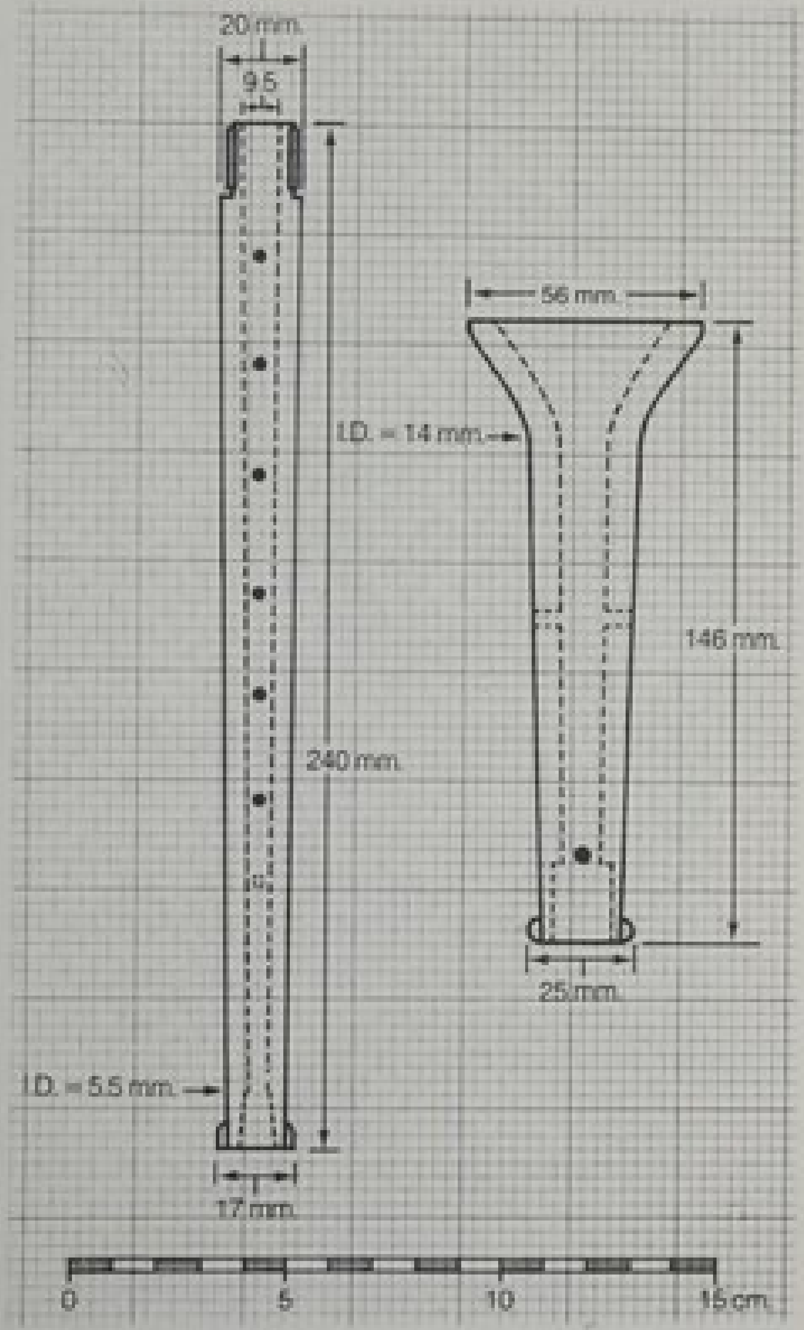


FIGURE 20. A copy of a musette in the Boston Museum of Fine Arts collection (no. 127). The original is made of rosewood with ivory rings.

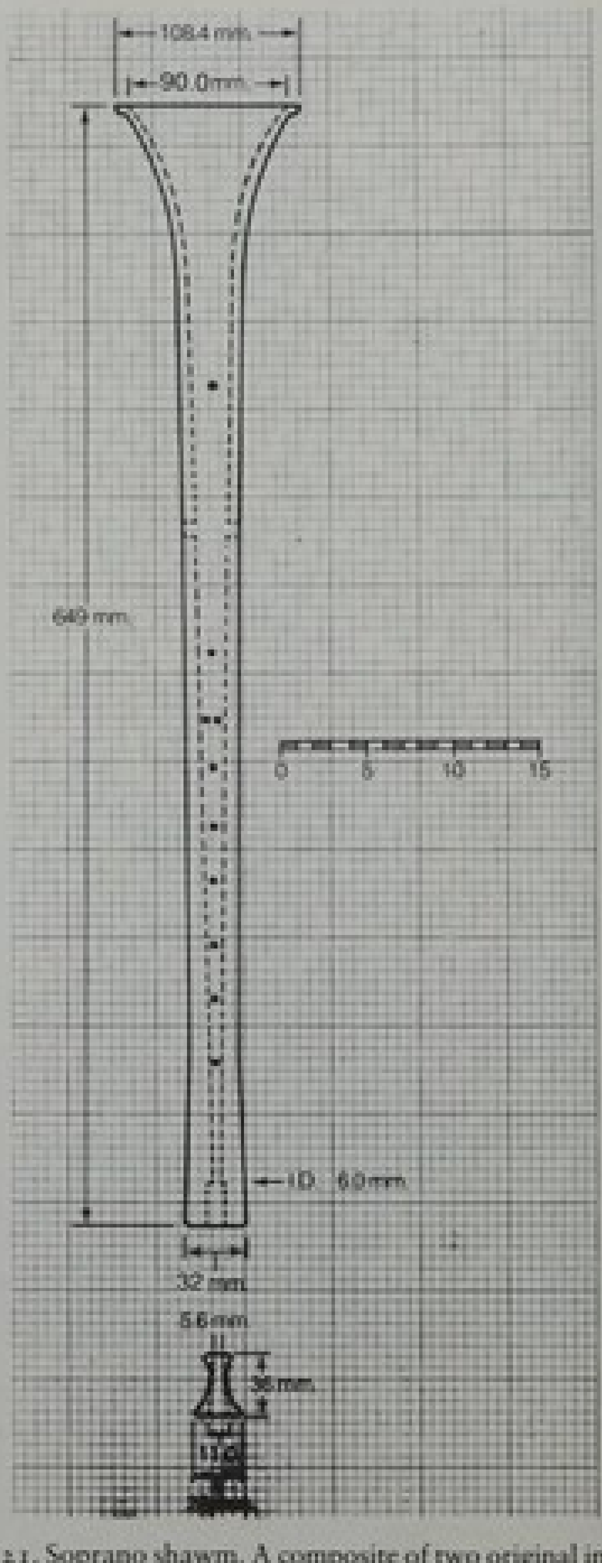


FIGURE 21. Soprano shawm. A composite of two original instruments in the Brussels collection (nos. 2,323 and 2,324).

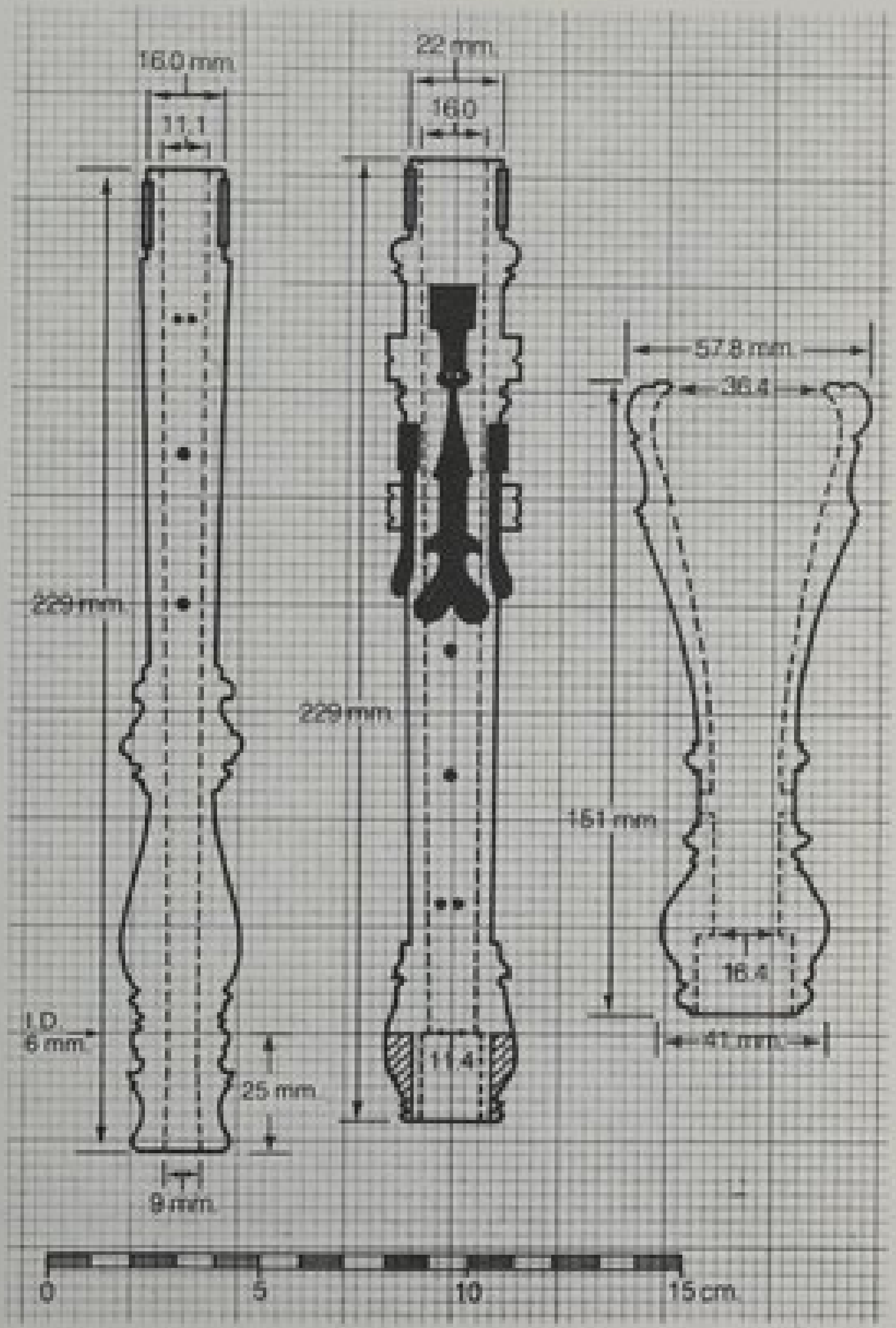


FIGURE 22. A copy of a baroque oboe in the Boston Museum of Fine Arts collection (no. 133). The original is made of pearwood.

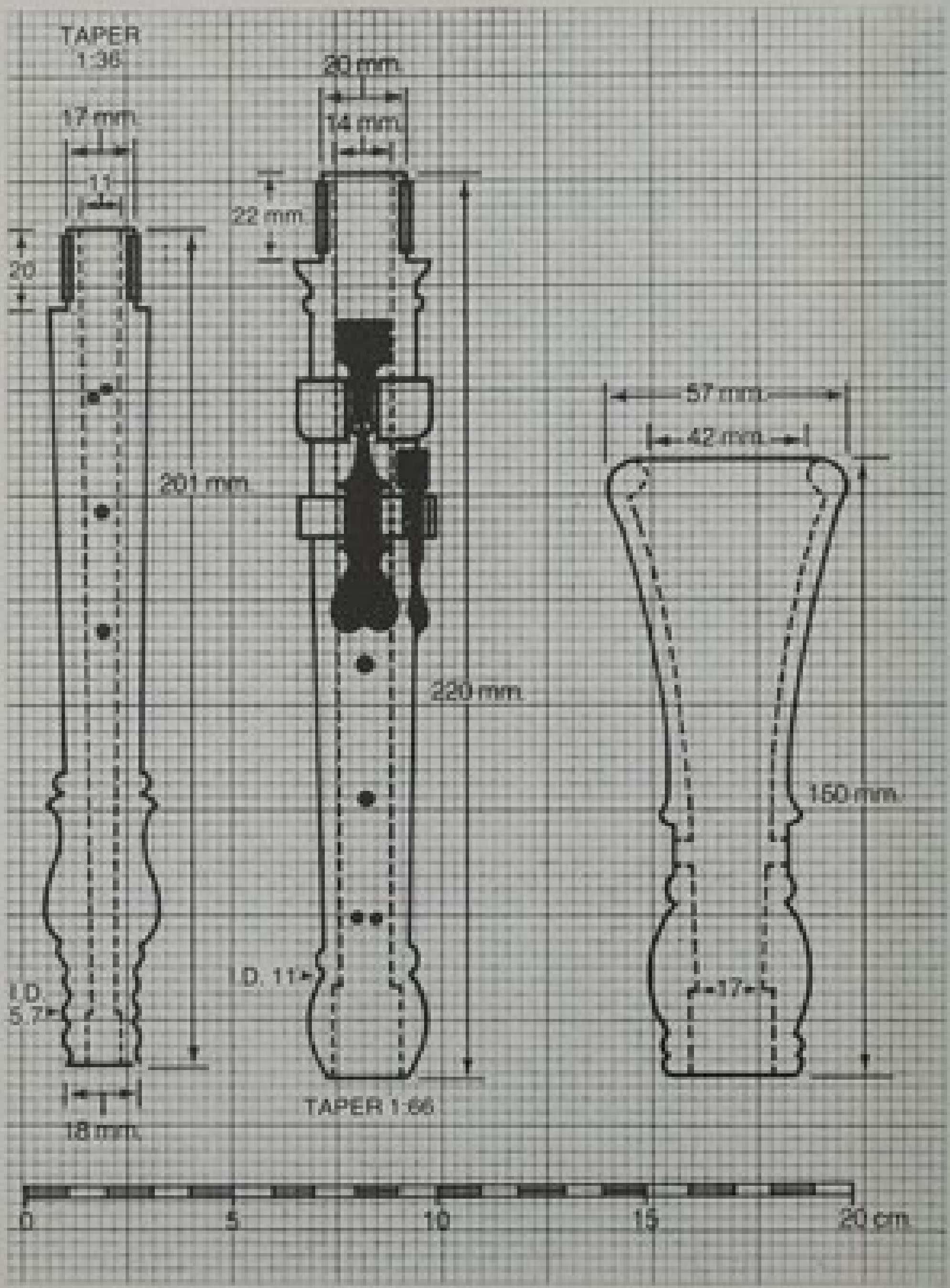


FIGURE 23. Baroque oboe modified to modern pitch.

TABLE 6.1 *Shawm Hole Dimensions*

Distances measured from top end to centers of holes.

	Soprano shawm		Musette	
Hole number	Distance (mm.)	Diameter (mm.)	Distance (mm.)	Diameter (mm.)
Thumb	—	—	60	3.5
1	95	5.0	80	3.0
2	132	5.0	105	4.0
3	162	6.9	128	4.0
4	199	6.7	157	3.5
5	233	7.0	183	3.5
6	267	7.0	208	3.5
7	293*	4.0	241	4.0
8	332	5.0	—	—
Tuning holes	403	8.0	299	3.5
	485†	8.0	—	—

*The left-hand hole is plugged.
†Holes in top and bottom.

TABLE 6.2 *Oboe Hole Dimensions*

Distances are measured from top end to centers of holes.

Hole number	Original Distance (mm.)	Original Diameter (mm.)	Modern Pitch Distance (mm.)	Modern Pitch Diameter (mm.)
1	130	3.0	108	3.0
2	166	3.0	137	3.0
3A	197	2.0	162	2.0
3B	197	2.0	167	2.0
4A	259	3.6	224	2.5
4B	259	3.6	227	2.5
5	290	4.7	254	4.0
6	319	4.6	285	4.5
7	365	6.0	335	4.5
8	403	8.3	363	6.0
Tuning holes	471	5.4	438	7.0

7
Krumhorns

Krumhorns (Cromornes) came into use in Europe at the end of the fifteenth century and were perhaps derived from folk instruments of the period. The krumhorn consort was a favorite ensemble during the sixteenth century and lasted until the end of the seventeenth century. As a soft, reed instrument the krumhorn has much to recommend it. It blends well with recorders, providing a low-pitched instrument with a stronger sound than the low-pitched recorders. It is rather easy to play, and its fingering is the same as recorder fingering. Its chief disadvantage is the limited range. Since the reed is enclosed (fig. 25) and cannot be squeezed with the lips, the overblowing capacity is severely limited. A range of only a ninth can be expected, although it may be possible to overblow the soprano krumhorn as high as f_5; and modern reproductions of krumhorns sometimes have added keys to increase the range upward by two or three notes. Although such keys were not used on the classical krumhorns, similar keys were sometimes present on other instruments of the time.

Seven sizes of krumhorns have been described ranging from the extended great bass, whose lowest note is f_1, to the descant (soprano), whose lowest note is c_4. The most commonly recognized four sizes, soprano, alto, tenor, and bass, cover the range from f_2 to d_5, that is, each one is pitched an octave below the correspondingly named instrument of the recorder family.

The obvious peculiarity in construction of the krumhorn is the bending of the tube. The first steps are, as in other wooden instruments, boring with the ¼-in. diameter shell auger and turning the outside diameter. Then the wood is steamed and bent. Certain kinds of wood are most amenable to steam bending although several species have been used. Renaissance krumhorns were often made of maple and may have been made by drilling out the pith from young, green trunks of the plant, bending them, and allowing them to season in the bent form. This is not a very practical procedure for the present-day worker. I have been successful in making krumhorns of maple, cherry, and magnolia, but by far the best wood for this purpose seems to be black walnut. Some modern reproductions are made of Brazilian rosewood. Before the actual steaming it is

FIGURE 24. *Left*, tenor krumhorn; *center*, alto krumhorn; *right*, soprano krumhorn.

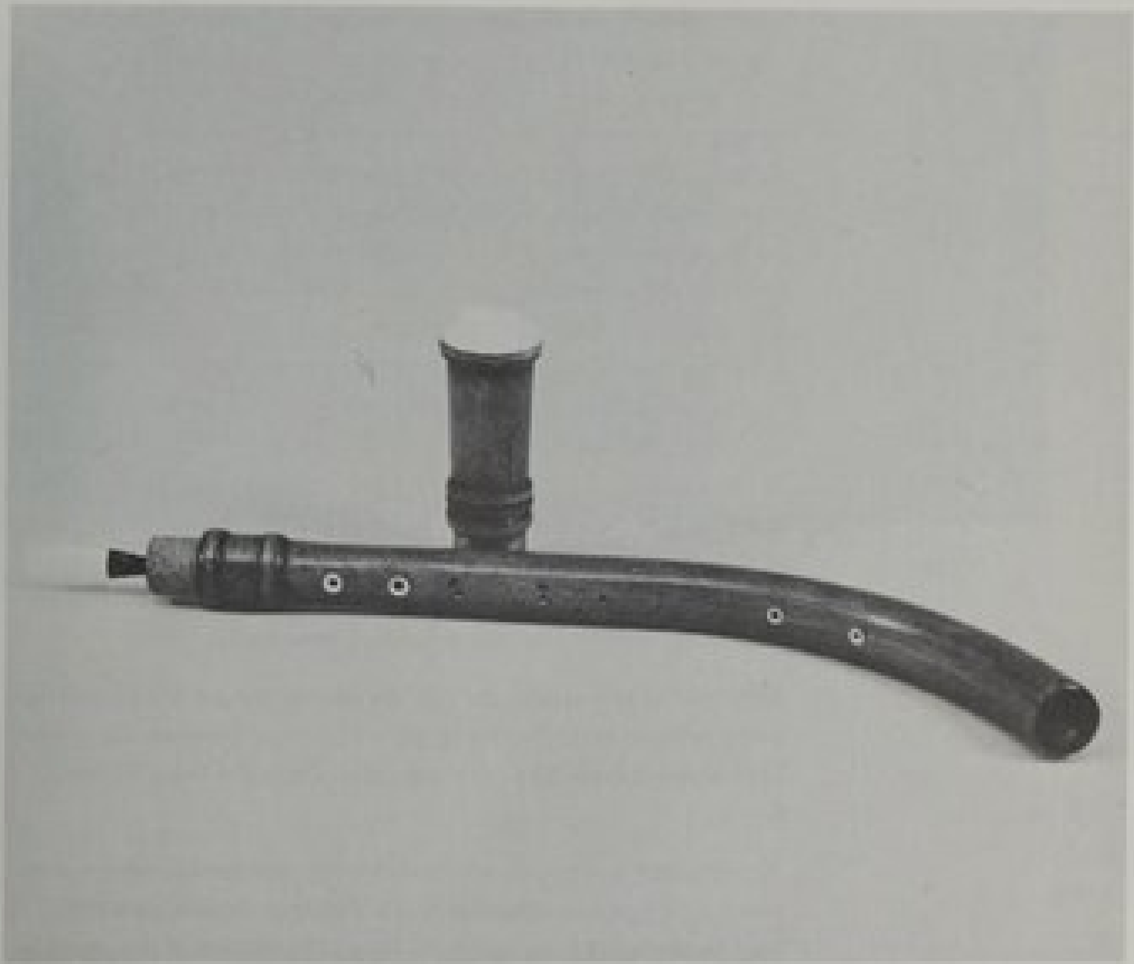


FIGURE 25. Soprano krumhorn with cap removed.

helpful to soak the piece of wood in water overnight. A simple steaming chamber can be put together from a teakettle, a length of hose, and a piece of 3-in. or 4-in. diameter sheet metal pipe arranged so that condensed water runs back into the kettle. A metal strap to support the outside of the curve must be prepared, and for this purpose a length of pipe-hanging strap can be used with wooden blocks fastened to it at a distance apart exactly equal to the length of the piece to be bent. It is a good idea to allow about ½ in. to 1 in. extra at each end of the wood, since the ends may be damaged during the bending. After steaming for one or two hours, the piece is placed into the metal strap, bent over a form of suitable radius, and clamped in place to dry for forty-eight hours. Separation of the wood fibers during bending can be minimized if the bend is made so that the growth rings in the wood are parallel to the plane of the curve. A 4-in. radius gives a satisfactory shape for all sizes of krumhorns and is not too sharp to be readily made. Figure 26 illustrates the metal strap and one form of bending jig.

After boring and turning the cap, the air channel is made by drilling a row of holes and filing away the waste wood between them. The beak shape is then cut with a coping saw, and the brass ferrule is fitted.

The simplest way to provide reeds for the soprano krumhorn is to buy bagpipe practice chanter reeds. The only modification that may be necessary is to scrape the tip a little thinner. If the sound is too rattly this can be improved by wrapping a ligature of thin brass wire around the reed and sliding it up and down to find the best position. For the tenor and alto krumhorns a larger reed is required. Bassoon reeds shaved very thin can be used, or plastic reeds can be made as follows. A mandrel is turned with a taper from 6.5 mm. to 2 mm. over a length of 50 mm. Thin copper or brass is cut following a paper template then bent and hammered around the mandrel to make a staple for the reed. The seam can be soldered, but this is probably not necessary. The small end is flattened into an elliptical cross-section. The two leaves of the reed are cut from a plastic sheet about 0.01 in. to 0.0125 in. thick in the shape shown in figure 28. Soft vinyl such as is used for many throwaway articles is quite suit-

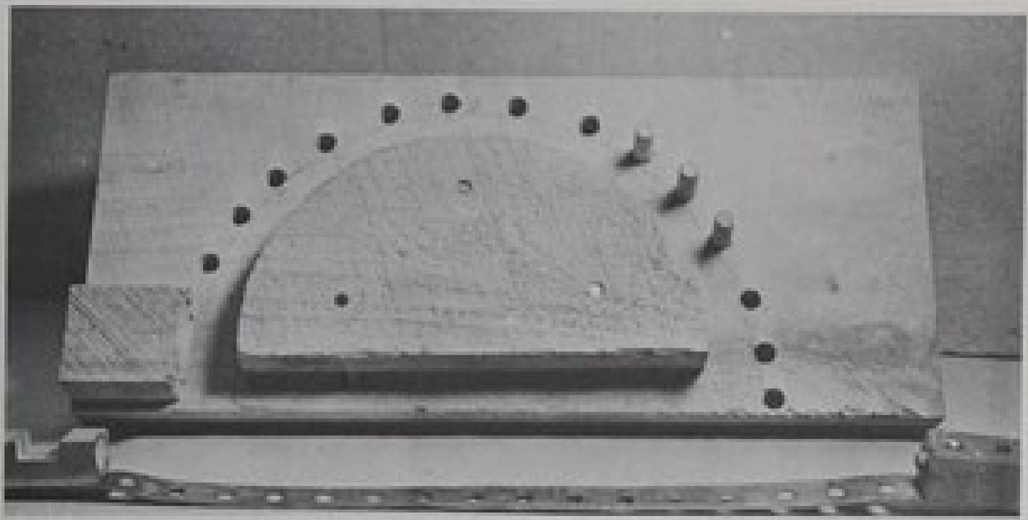


FIGURE 26. Bending jig and supporting strap for krumhorns.

able for low-pitched instruments, but if reeds are to be made for soprano and alto krumhorns, a stiffer, crisper type of plastic must be used. The two leaves are clamped together in a spring clamp so that the tapered end and about 1 cm. of the straight-sided portion stick out. With strong thread tie a clove hitch around the notches in the reed, leaving about a 2-in. end on the thread. Coat the staple with some fast-drying cement and insert it between the leaves of the reed so that its tip does not quite reach to the straight-sided part of the reed. Then wrap the thread tightly around the reed so that the edges are pulled together over the mandrel. The wrapping should extend from just above the notch down to the tip of the plastic. It is finished off by tying a square knot to the loose end that was left at the beginning. The reed should now be removed from the clamp and bent into a flattened ellipse open at the tip. The parallel sides must touch all along their length. If there is a gap just above the wrapping, it means that the wrapping is not tight enough or that the staple extends too far into the reed. The lower part of the staple is next wrapped with lapping thread started and finished in the same way as the other but with enough layers to make a tight fit in the socket of the instrument. Fast-drying cement or shellac spread over the upper wrapping and the ends of the lapping thread fixes it in place and seals any small air leaks. When the coating has dried, the reed is finished by scraping it with a sharp knife or a razor blade. The tip needs to be very thin, and the rest of the reed is scraped and tested in the instrument until a clear note can be played. Before any tone holes are made in the tenor krumhorn, this note will be in the vicinity of G. Too thick a reed will overblow to a much higher note if it sounds at all.

The tuning of the krumhorn is peculiar in that usually two (but sometimes one or three) tuning holes are made below the lowest finger hole, and the lowest tone is controlled by these holes rather than by the total length of the instrument. Another peculiarity is that the pitch of any note can be varied through at least a full tone by varying the blowing pressure. Therefore in tuning, the diameter of each finger hole should be made to give the right note with an intermediate blowing pressure; then if occasion demands, the pitch can be either raised or lowered by changing the pressure. Removing

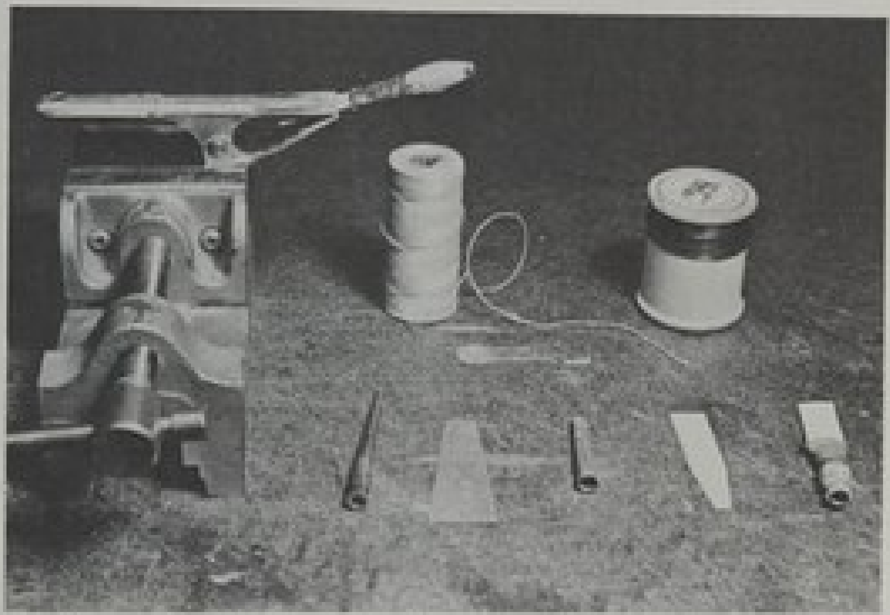


FIGURE 27. Reed making tools and supplies: *left*, reed in clamp; *upper right*, thread; *center*, key pattern; *lower right, from left to right*, mandrel; staple blank; finished staple; leaf of reed; finished reed.

the fuzz from the inside of the tone holes is especially difficult with the krumhorn because of the bend and because the holes are so small. It must be removed, however, to get a clear tone. One procedure that works fairly well is to take a piece of stranded wire cable such as is used for bicycle caliper brakes, unlay several strands in the middle of the length, and insert a tuft of coarse steel wool. By pulling the cable back and forth through the bore, small splinters of wood can be pulled off from the underside of the tone holes.

An instrument made like the krumhorn without a bend was apparently called a cornamuse. Since no original instruments of this type survive, any reconstructions are conjectural. For anyone who wants to avoid steam bending, however, the cornamuse offers a substitute that plays and sounds like a krumhorn. Further information on the cornamuse can be found in an article by Macmillan.

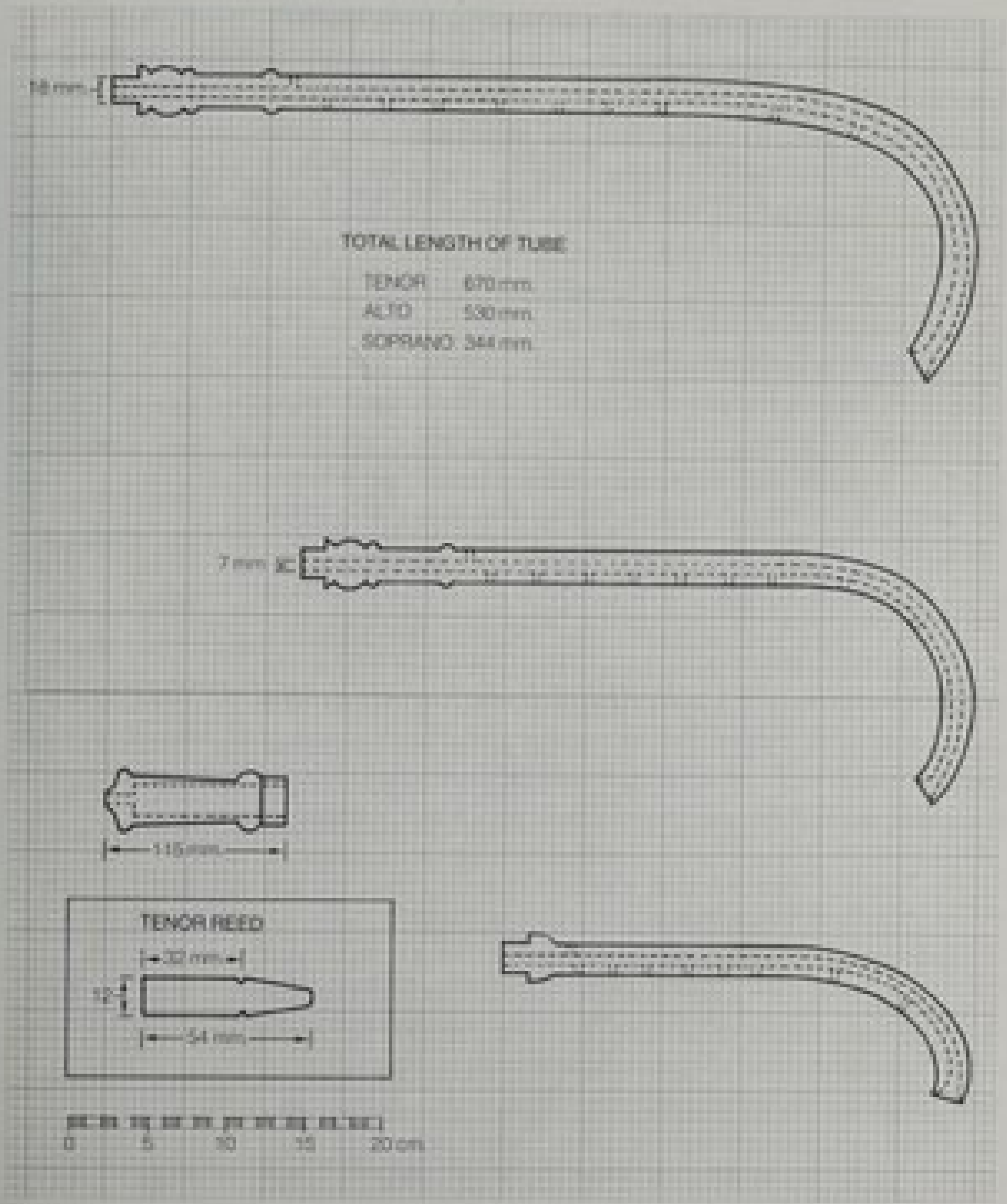


FIGURE 28. Three krumhorns. The same size wind cap is used for all three.

TABLES 7.1 *Krumhorn Hole Dimensions*

Distances are measured from top end of main tube to centers of holes.

Hole number	Soprano Distance (mm.)	Soprano Diameter (mm.)	Alto Distance (mm.)	Alto Diameter (mm.)	Tenor Distance (mm.)	Tenor Diameter (mm.)
Thumb	42	4.0	56	2.7	127	3.0
1	48	3.5	58	1.9	130	2.5
2	70	3.0	84	1.9	167	3.5
3	94	3.0	114	2.9	203	4.0
4	120	3.0	147	3.4	240	4.0
5	144	2.0	179	2.9	278	2.5
6A	162	2.0	205	2.6	310	2.5
6B	165	2.0	207	2.6	312	2.5
7A	176	2.0	238	2.6	330	2.0
7B	182	2.0	241	2.6	335	2.0
Tuning A	214	4.0	283	3.8	425	3.5
Tuning B	263	4.0	344	3.8	484	3.5

8 Racketts

The racketts or sausage bassoons were a family of instruments introduced late in the sixteenth century and already superseded by bassoons at the end of the seventeenth century. The concept of achieving a long-bored, bass instrument by interconnecting several short tubes within a single block of wood is theoretically sound, and being able to carry in one's pocket an instrument that will descend as low in pitch as a modern bassoon is still a very attractive idea. What doomed the rackett was probably not so much its quiet sound that blends well with recorders and krumhorns but rather its intractable fingering pattern. Some racketts had as many as sixteen holes to be controlled so that some holes were covered by the palms of the hands and the middle joints of the fingers. The sequence of uncovering holes to produce a scale appears from the outside of the instrument to follow a random pattern and, worse, is not the same from member to member of the rackett family. The family as described by Praetorius consisted of four sizes: cant, tenor-alto, bass, and great bass. The two instruments for which dimensions are given here (table 8.1) correspond roughly to the cant and tenor-alto, although in the interests of simplicity the number of finger holes has been reduced so that their ranges are not so wide as those in the racketts described by Praetorius. The cant covers the range from F to g and the tenor-alto from C to e, while Praetorius' instruments had a range of a twelfth.

Since the bores are all cylindrical and relatively short, they can be made with the drill press by laying out the work carefully and drilling from both ends. When the bores have been made, the outside is turned down to be concentric with the center bore, and the interconnecting passages are chiseled away between the bores. The end caps are turned so that the bottom one fits tightly and the top one is easily removable. Before gluing on the bottom end cap, I like to glue a piece of stiff paper or cambric to the bottom with contact cement to make sure that no leaks between neighboring bores exist where they should not. The arrangement I have devised for fastening the top cap is, of course, not traditional, but it is important to have the top cap easily removable to permit evaporation of moisture after playing, and it is also essential to avoid the slightest trace of air leakage between bores. Other arrangements that I have seen or

FIGURE 29. A family of racketts.

tried fail to satisfy both of these requirements. The ⅛-in. brass pipe nipple is fastened to the center bore by cutting a thread in the wood with an ordinary pipe tap. The nut that screws down on the cap must be made by drilling, knurling, and tapping a short length of brass rod. The pad of soft leather that fits into the cap should be well greased and will then make a tight seal when the nut is tightened.

The diamond-shaped arrangement for the four holes at the end of the bore was common but not universal in these instruments. In the diagrams (fig. 30) the finger holes are indicated where they enter the bore, but it is advisable to drill some of them at an angle to make them more easily reached.
The brass pipe nipple should be drilled out so that its bore is nearly that of the main bore and the top end should be reamed with a tapered reamer to give a better seat for the reed staple. The reed is made of plastic in the same way as described for krumhorns (chap. 7). For the smaller rackett a reed of the same size as that for the tenor krumhorn may be used. For the tenor-alto it could be slightly larger. A bassoon reed shaved very thin works but may need a rubber band or wire ligature around it.

Around the end of the seventeenth century, before the rackett completely died out, an improved version, the baroque rackett, had a brief existence. Although it is a much more tractable instrument than the earlier rackett, it could not compete with the bassoon, and very few examples exist. The one presented here, while based on the examination of museum specimens, is partly conjectural since I was unable to make internal measurements. Nevertheless, it works well and provides a deep bass voice in a convenient package. The overall bore taper amounts to an increase of only 0.5 mm. over each bore. It is possible to put this in with abrasive cloth wrapped around a dowel rather than go to the trouble of making reamers. Although original instruments had cork plugs at the ends of the bores, as the drawing shows, I have preferred to make caps of thin plywood lined with cork and screwed on. I have no evidence for the presence of internal cork plugs and shortened bores in original instruments; but these features, shown in the drawing, have been found necessary to arrive at accurate intonation. The cross-connections from bore D to E and G to H were burned through using a L-shaped rod heated red hot. Making the crook calls for some techniques not used for other instruments. It is made from thin brass tubing spun down over a tapered steel mandrel. About 2 in. of the mandrel should be left cylindrical and the brass tubing fitted snugly over it. This end is chucked in the lathe and then turned while the tubing is gradually forced down around the mandrel using pliers that have

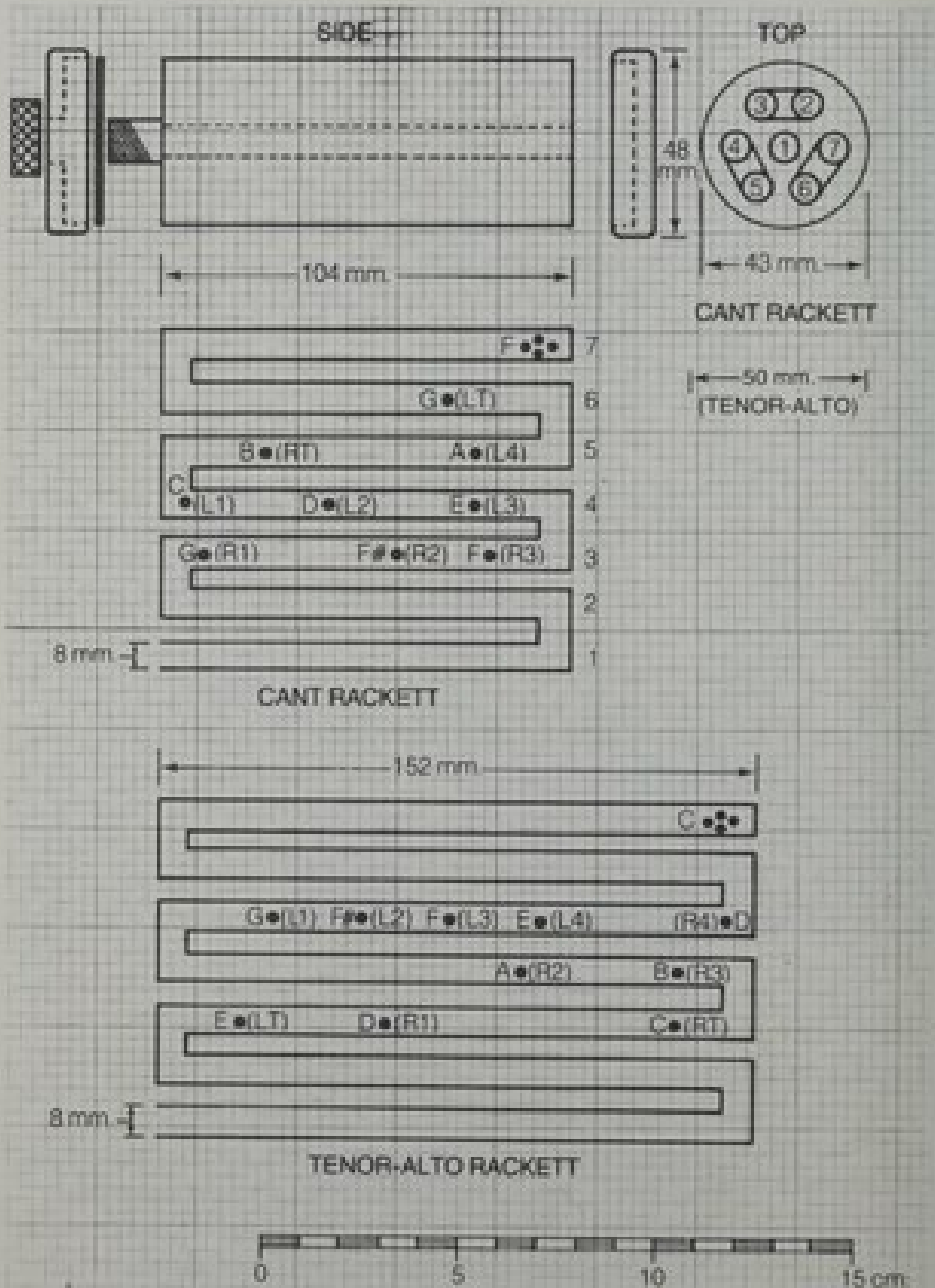


FIGURE 30. Cant and tenor-alto racketts showing the finger positions.

TABLE 8.1 *Rackett Hole Dimensions*

See figure 30 for hole locations.

Cant		Tenor-Alto	
Hole designation	Diameter (mm.)	Hole designation	Diameter (mm.)
G	2.0	E	2.5
F-sharp	2.0	D	2.5
F	2.0	C	2.5
E	3.0	B	2.5
D	2.5	A	2.0
C	2.0	G	2.0
B	2.0	F-sharp	2.0
A	2.0	F	2.0
G	2.0	E	1.5
F (4 holes)	2.0	D	2.0
		C (4 holes)	2.0

been ground to have smooth, concave faces on their jaws. Many times during this process the brass will have to be annealed by heating it red hot and quenching in water before proceeding. It is surprising that the tubing hardly increases in length during this process—the piece of cylindrical tubing used must be nearly the length of the finished crook. When the spinning is completed, the brass is annealed once more and poured full of molten lead so that it can be coiled without flattening. After bending the crook around a wooden cylinder, the lead is removed by melting it out. The best reed for this instrument is a contra bassoon reed, but an ordinary bassoon reed works pretty well.

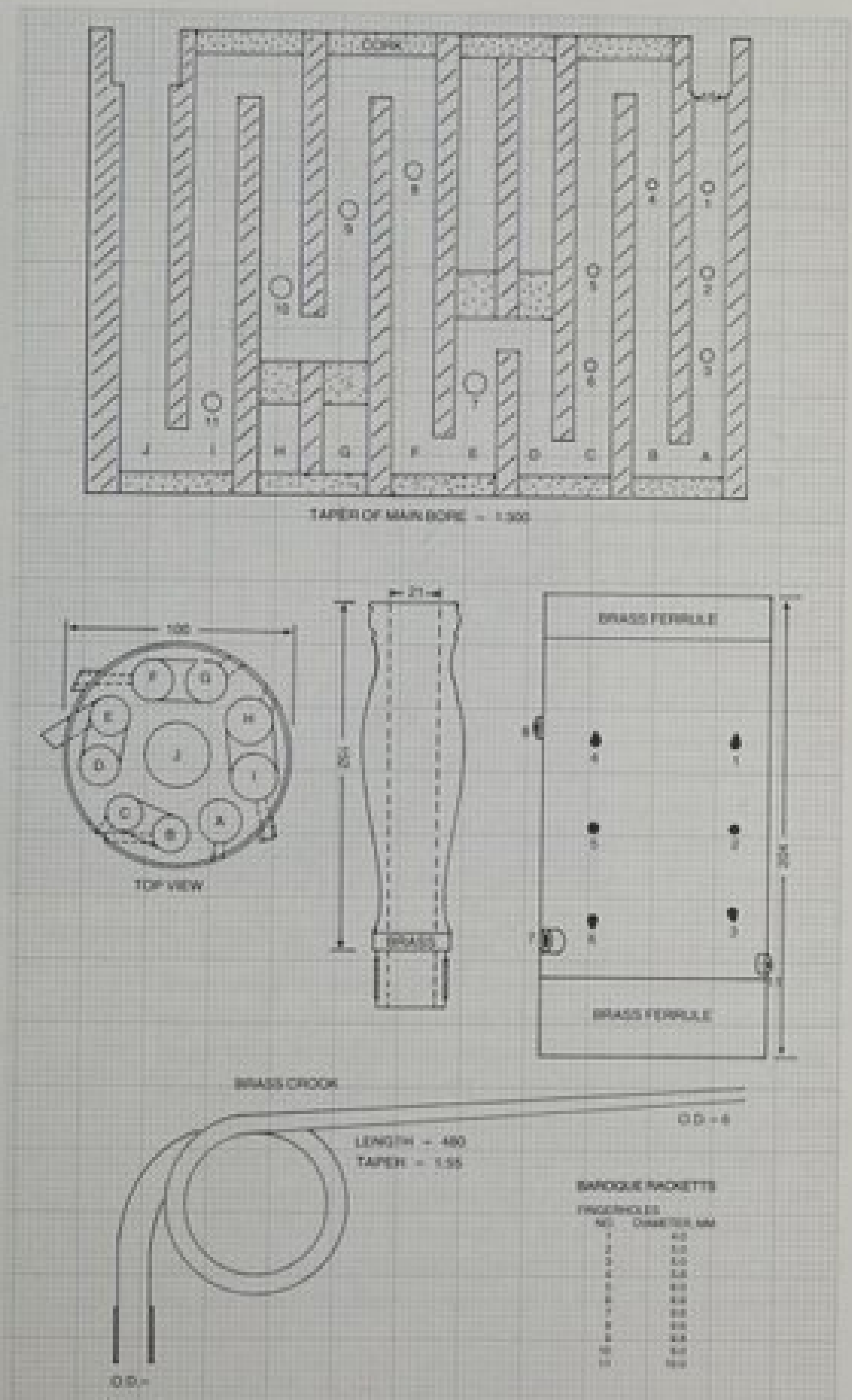


FIGURE 31. Baroque rackett

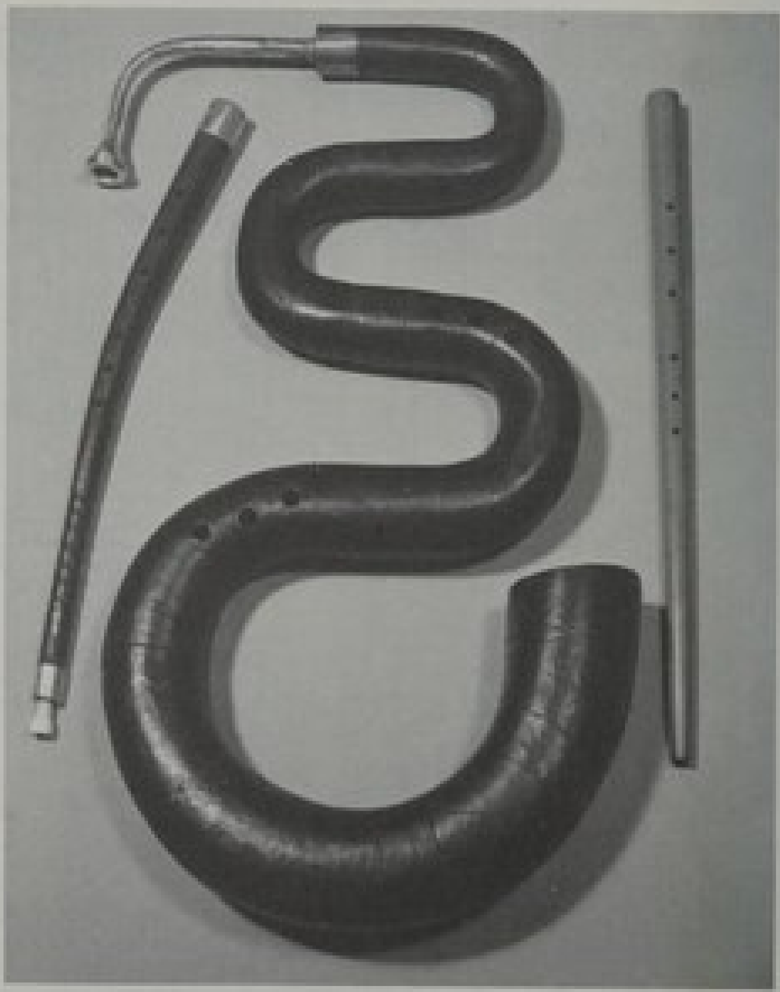


FIGURE 32. *Left*, curved cornett; *center*, serpent; *right*, mute cornett.

9 Cornetti

The cornetto was an important instrument during the Middle Ages, Renaissance and the beginning of the baroque period. Actually there were three somewhat different instruments known by this name, and the terminology across three or four different languages becomes rather confusing. The curved instrument was the best known and the one that lasted the longest. It is and was known as a *cornett* (English), *krummer Zink* (German), *cornet recourbé* (French), or *cornetto curvo* (Italian). Since it was wrapped with black leather, it was also sometimes called a *black cornett*. It had a separate, cup-shaped mouthpiece made of ivory, horn, or wood. A straight version is known as *gerader Zink* (German), *cornet droit* (French), or *cornetto diritto* (Italian). It also had a separate mouthpiece, but it was not wrapped with leather. The third version was also straight, but its mouthpiece was turned as an integral part of the body and was more funnel shaped. It is known as a *mute cornett* (English), *stiller Zink* (German), or *cornetto muto* (Italian). All these names suggest its quieter sound. It was also known as a *white cornett* since it was not wrapped with black leather.

The dimensions given here for the curved cornetto result in an instrument in whose lowest note is as. This is the traditional pitch of the most familiar size known as soprano. Both smaller and larger sizes existed. Because of the curved bore, this instrument must be made in two halves that are gouged out and then glued together with waterproof adhesive such as epoxy, resorcinol-formaldehyde, or urea-formaldehyde glues. Thin garment leather or lamb skiver is suitable for the leather covering, and it works best if it is soaked in water and then squeezed until just damp. Ordinary white glue painted on the wood works well. The seam runs along one side. The finger holes should be made before wrapping, and the wrapping then carefully cut through at the holes. Since this instrument has an octagonal cross-section, the ferrules are made up of soldered strips rather than seamless tubing. The upper ferrule is especially important, since insertion of the mouthpiece tends to wedge apart the glue joint. Two sizes of mouthpiece are given. The smaller is more usual and facilitates playing in the upper range. The larger is less tiring and makes the lower range easier to play. A hard, smooth surface is important for the cornett mouthpiece; so although some were made of wood, ivory or plastic is a better choice.

A traditional decoration on cornetts is a series of facets cut into the wood at the upper end. These are not hard to make but are hard to show in a picture. It is suggested that makers try to examine an actual instrument to see this design feature.

The boring and reaming of the mute cornett is straightforward except that the taper of ⅜ in. per foot (1:35) requires making special reamers; or like the curved cornett this one too can be glued up from two gouged-out halves, and the outside then turned. If it is bored from a solid piece, the boring must not be carried right through to the upper end, or the hole at the bottom of the mouthpiece cup will be too large. There is some latitude possible in the placement and the diameters of the finger holes of the mute cornett since lip adjustment allows a range of tones for any given finger position. The instrument whose dimensions are presented here has a useful range beginning at a3 and extending upwards for about two octaves. By relaxing lip tension it is possible to play as much as an octave lower than the normal range, but the pitch of the notes so obtained is difficult to control, and the tone is unsatisfactory.

For any instruments that are made in two halves and glued together it is essential to have a series of half-circle gauges to follow the hollowing process. There should be enough gauges to permit checking about every 5 cm. along the bore.

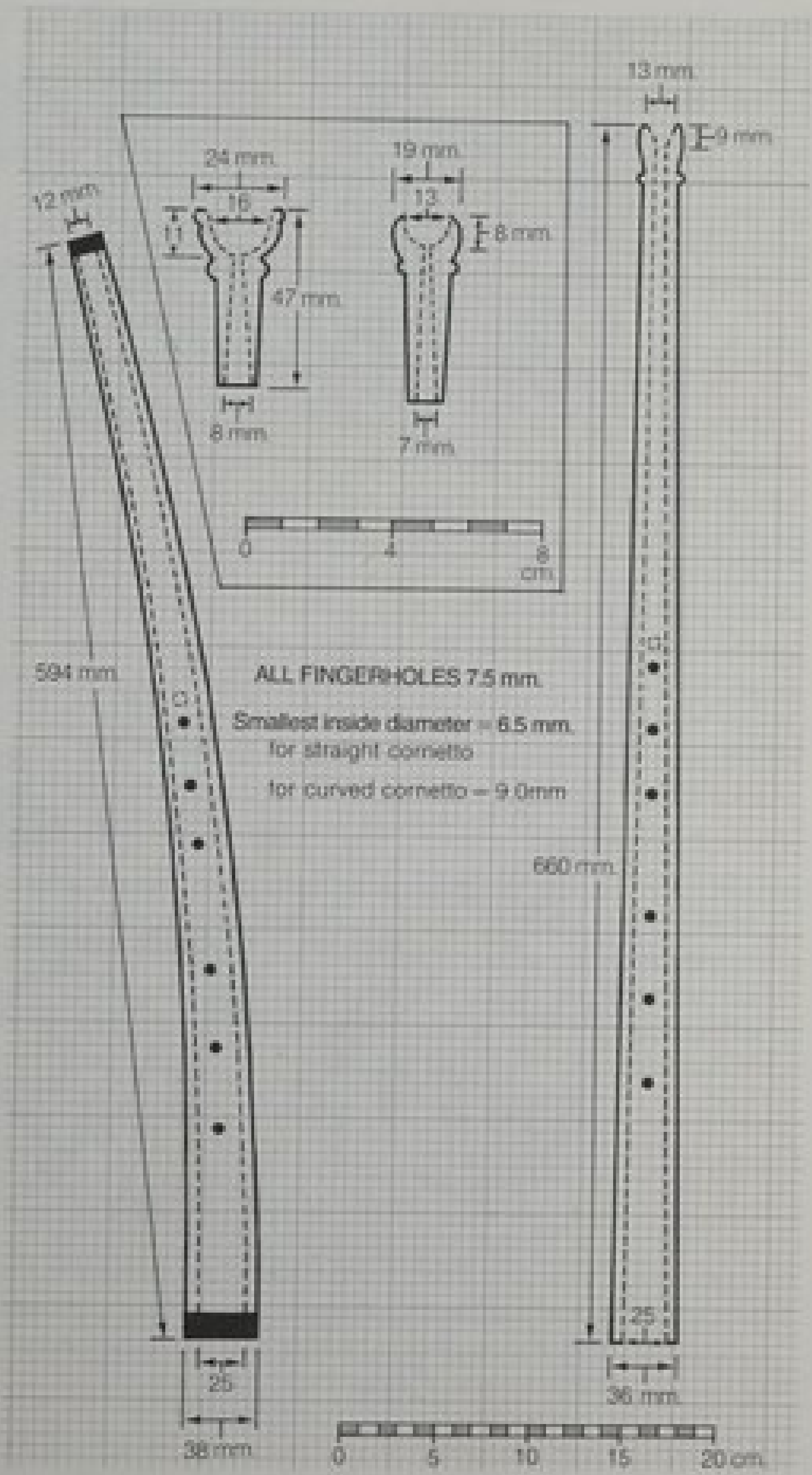


FIGURE 33. *Left*, curved cornett; *right*, mute cornett.

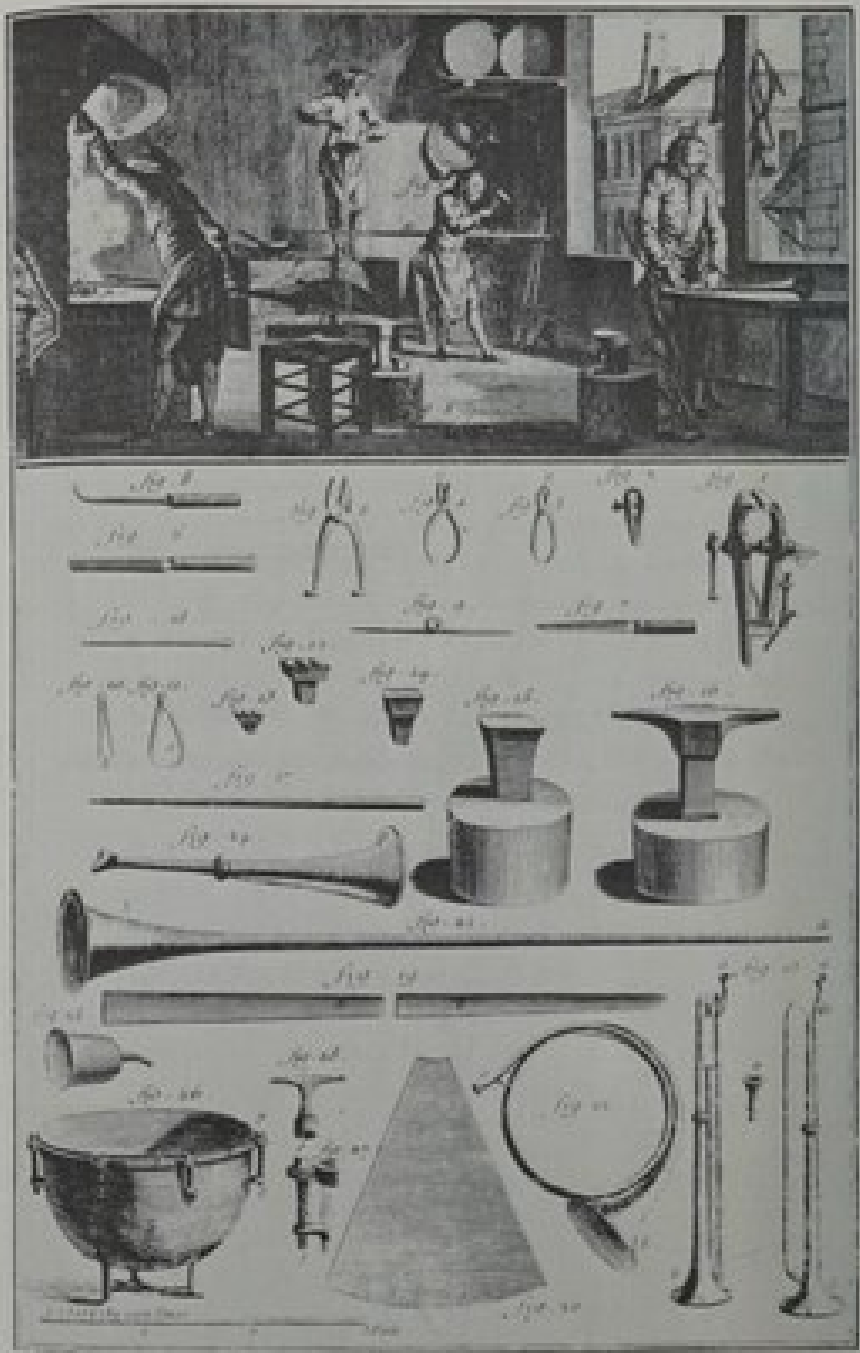


FIGURE 34. The workshop of a *chaudronnier* (eighteenth century). Reprinted from Diderot's *Encyclopédie*, volume 3, plate 4 of the volumes of plates (Paris, 1762–72).

10

Brass Instruments

Materials and Methods

In many respects reproductions of ancient brass instruments are easier to make than those of wooden instruments. For one thing, tuning is much simpler. Once the tube has been cut to the right length to give the proper fundamental note, all the other notes of the harmonic scale follow automatically. Since valves were not used on the old instruments, they were played at the high range of the harmonic series where available notes come closer together. For an instrument in the key of C the harmonic series is as follows:

C, c, g, c', e', g', b-flat', c'', d'', e'', f-sharp'', g'', a'', b-flat'', b'', c'''

The f-sharp'' and a'' of this series are noticeably flat, the f-sharp'' so much that by adjustment of the embouchure it can be used for f'', giving a complete major scale between c'' and c'''. Since b-flat'' is also available, the key of F can be played fairly well on old brass instruments in C. Instruments in D can be played fairly well in G, and instruments in F fairly well in B-flat. It is these limitations of the harmonic series that governed the choice of keys used by baroque and Renaissance composers for brass instrument compositions. Some tightly coiled clarino trumpets are now being made with two small finger holes to help in obtaining certain notes and correcting the pitch of the f-sharp''. Historical precedent for this construction is dubious.

The series of sixteen harmonics given above might not be all available on a single instrument, and on some instruments a skilled player might be able to reach still further to the twentieth or twenty-second harmonic. A narrow bore favors the higher harmonics but gives a weaker sound, while the converse is true of a wide bore. A shallow, cupped mouthpiece also makes it easier to attain the higher tones but again at a sacrifice of loudness.

Materials

With regard to materials, the typical brass instrument can be dissected into three portions: the cone and bell are shaped from thin sheet metal, the main cylindrical tube is purchased as a tube and only cut to size and bent by the instrument maker, and the mouthpiece is machined from a solid block of brass.

Although referred to generally as "brass" instruments, some old trumpets and horns were made of copper; and for the amateur instrument maker copper has much to recommend it. It is more readily available, less expensive, and easier to work. Copper sheet used for roofing is referred to in the trade as *16-oz. sheet*, meaning that a square foot weighs sixteen ounces. It measures 0.02 in. in thickness. Copper sheet in 24- and 32-oz. sizes is available from some sheet metal dealers. If it can be obtained, the 24-oz. sheet seems to be best for both the bell and the cone. The 16-oz. size is all right for the cone and is recommended for a cone that is to be curved, but it makes a bell that is lighter than it should be. The 32-oz. sheet is difficult to work, and the results obtained in most cases do not justify its expense. Brass is, of course, stiffer than copper and can therefore be used in thinner sheets. Brass shim stock of 0.020 in. is available in widths of 6 in. and 12 in. from dealers in industrial supplies, and it can be used for both bell and cone, although I generally prefer to use 0.032-in. brass for trumpet bells. Although less readily available, 0.025-in. brass makes a fine compromise for bell and cone.

For the tubing, copper again has advantages for the amateur in that copper water pipe is readily available from plumbing suppliers, and in the flexible L grade it is easily bent. Brass tubing can be found in a wider range of diameters than copper pipe, but dealers in it are much less common (see Appendix B).

Brass is the common material for turning mouthpieces, although some old mouthpieces were made of ivory, horn, or wood; and some modern mouthpieces are made of plastic (usually acrylic). Aluminum mouthpieces are unsatisfactory because they blacken the player's lips. It is a waste of brass to turn the whole mouthpiece from a rod the diameter of the widest part, since the shank of the mouthpiece is so much smaller. The best solution is to make rough castings larger than the finished mouthpiece but of a similar shape and then to finish them on the lathe. A small, gas-fired furnace (see Appendix B) will melt brass nicely, and either a sand mold or a

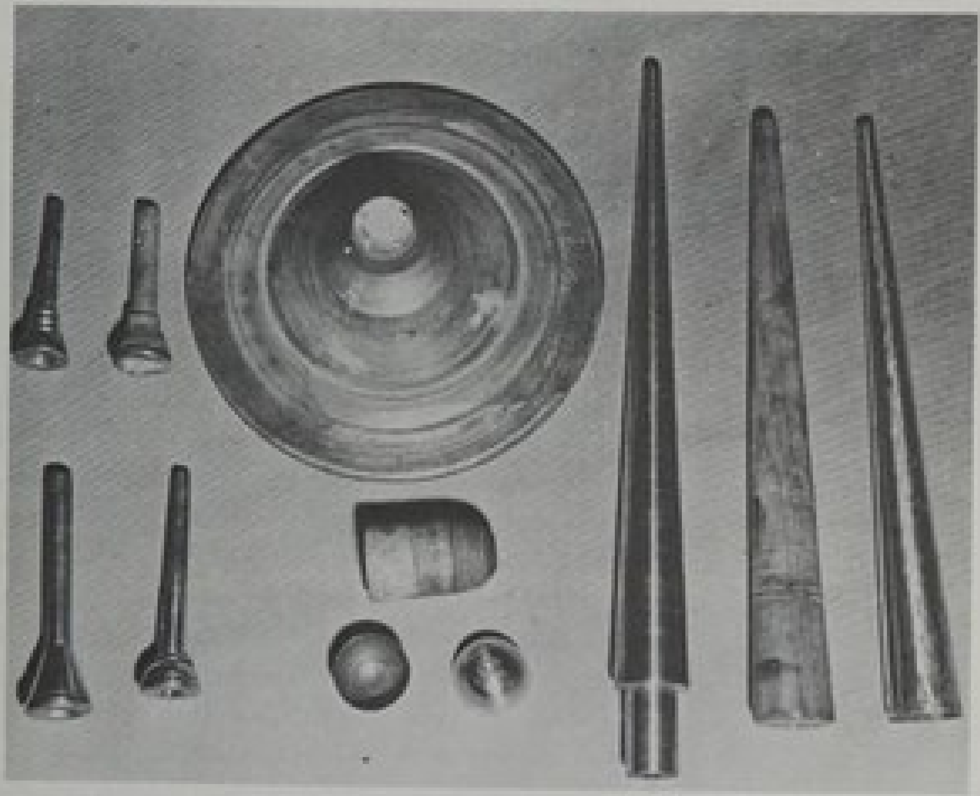


FIGURE 35. Brass instrument tools and parts: *left*, mouthpieces and a rough mouthpiece casting; *center*, forms for spinning bell and ball; *right*, steel and wooden mandrels and a seamed cone.

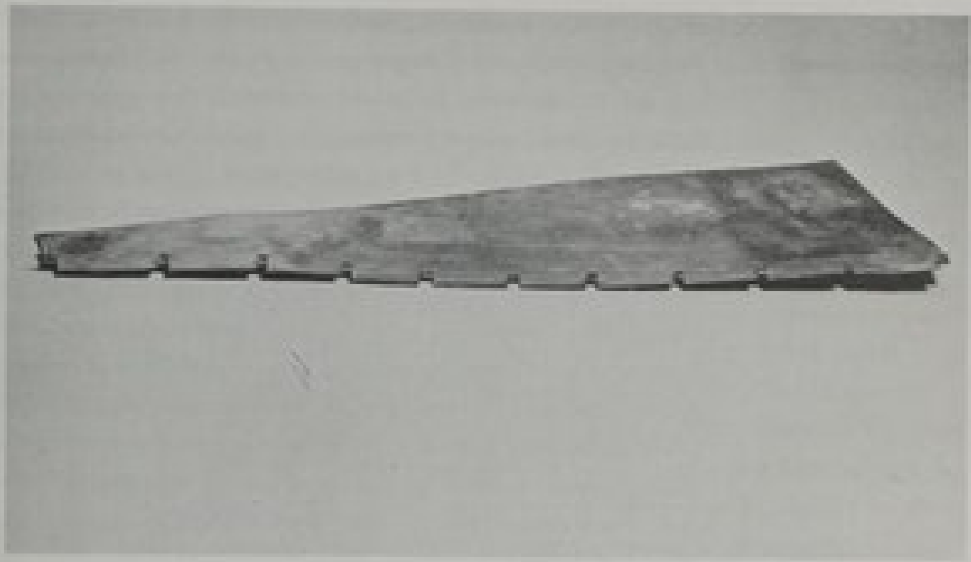
permanent mold bored out of steel can be used. A simpler approach is to drill a hole through the center of a short length of large-diameter rod and solder a length of smaller diameter rod into it. When the mouthpiece is turned from this assembly, the solder joint will be inconspicuous.

General Construction

My approach to the general construction of brass instruments departs from tradition in that I make the bell and conical sections separately. As described in *The Making of Musical Instruments* by Young, these two parts were usually made of one piece of metal seamed along its length and then planished over a mandrel before spinning the bell to its final shape. This procedure is inconvenient for the amateur for several reasons, the chief one being that brazing is required. The approach I have adopted is used to some extent in industry today. For simplicity I have also decided to make the cylindrical part of the trumpet from only two pieces of tubing, whereas old trumpets normally used separate U-shaped pieces to join the ends of the straight tubes. The following very useful articles should be consulted for details on the construction of old trumpets: "William Bull and the English Baroque Trumpet," "Early British Trumpet Mouthpieces," and "Four Seventeenth Century British Trumpets," by E. Halfpenny; "Further Notes on the British Trumpets," by J. Wheeler; and "The Trumpets of J. W. Haas," by D. Smithers.

Spinning the Bell

For basic information on the technique of metal spinning, the beginner should consult one of a number of instruction books dealing with lathe operation or metalworking. As a word of encouragement, though, it may be remarked that trumpet and horn bells are



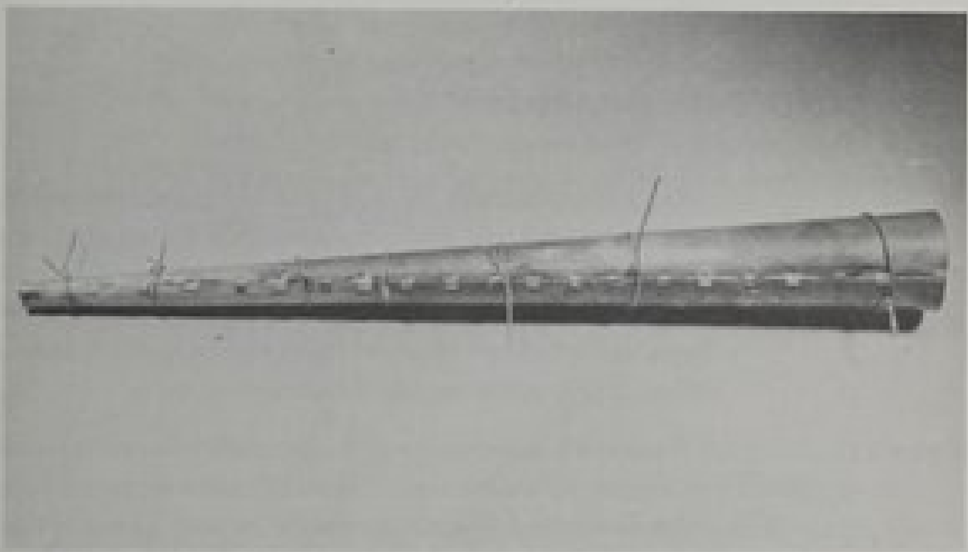


FIGURE 36. Steps in forming and seaming a cone.

relatively easy as metal spinning projects go. A wooden chuck must first be made from a fine-grained hardwood such as maple (see fig. 35) and soaped or waxed with beeswax. Both copper and brass bells require frequent annealing during the spinning process by heating them red hot and quenching them in cold water. I like to work on two bells at the same time so that one can be heating while I spin the other. It is a good idea to make a small scratch on the metal to line up with a mark on the chuck, because if the chuck is just slightly unsymmetrical, wrinkles will appear in the metal if it is put back with a different orientation. When the bell has been spun to its full size the edge is trued up with the diamond tool and rolled over with the beading tool. Before the bead is closed the rim can be strengthened by inserting a circle of copper wire into it. If this is done the wire must be prevented from rattling by running in solder or epoxy cement.

Forming the Cone

A seamless cone can be formed by spinning, either by starting with a disc and gradually spinning it down over a series of successively smaller diameter mandrels or by starting with a cylindrical tube which has a diameter equal to that of the large end of the finished cone and spinning it down around a conical mandrel. However, a seamed cone seems best for the amateur to make.

The simplest seamed cone is shaped around a wooden mandrel turned to the correct taper. The metal can be cut to size by wrapping brown paper tightly around the mandrel, gluing or taping it together, then cutting it square at top and bottom and slitting down its length. The paper pattern can then be traced on the metal adding about 5 mm. of width along one edge for the overlapping seam. A neater seam can be made if a narrow step is made along the mandrel so that one edge of the metal can be set against it. Both copper and brass should be thoroughly annealed before bending them around the mandrel. To hold the metal in place for soldering the seam, a series of steel rings is forced around it so that they are about 2 in. apart. Before forming the cone the surfaces to be soldered together should have been well cleaned and fluxed. Finally, with the heat from a torch, solder is run into the seam. For greater strength silver solder can be used, but even on cones that are to be curved later a good, soft soldered joint will hold. Finally, when the solder has hardened, the joint must be filed, ground, and buffed.

A stronger and smoother seam can be made by workers who can braze it with an oxygen torch. For this work a steel mandrel is required. The metal is cut to size just as before. Then a series of square notches is cut along one edge and the teeth raised. When the cone is formed around the mandrel the other edge butts against the raised teeth, which are hammered down over it to hold it in place (fig. 36). The seam is now brazed, washed to remove excess flux, and hammered down smoothly against the mandrel. Since the cone made in this way is essentially a homogeneous piece of metal, final smoothing of the seam can be done by putting the cone on its mandrel in the lathe and applying the flat spinning tool to it, then polishing it with abrasive cloth and buffing. The large end of the cone is finally hammered out into a smooth flare to meet the curve on the small end of the bell.

The Cylindrical Tube

For a straight herald's trumpet the only thing that must be done to the cylindrical tube is to enlarge one end into a short flare into which the conical portion will fit to a depth of an inch or so. This is done by annealing the end of the tube and driving in a steel mandrel that has the correct taper.

Most brass (or copper) instruments require bending of the tubing to achieve their final form. If brass is used, it must be well annealed even for bends of large diameter. Flexible copper water pipe does not require annealing.

Bends of large diameter, such as those in hunting horns, can be made easily with no danger of the tubing becoming flattened. For tight bends, however, it is necessary to fill the tubing with some material that will prevent collapse of the walls during the bending and can be readily removed later. Low melting alloys such as Wood's metal are used industrially for this purpose, but they are expensive. Pitch was one material used classically, and it is available quite cheaply from some suppliers of industrial chemicals or from tanners, since it is used for dehairing hides. The tubing is filled with melted pitch and, when the pitch has hardened, bent around a wooden form cut to the correct radius. The tube is then reheated so that the pitch melts and runs out. Thorough heating is required to insure complete removal of the pitch.

Assembly of the Parts

When the three sections described above have been made it is a simple matter to solder them together. The bell should fit into the cone about ¼ in. to ⅜ in. and the cone into the tube about 1 in. The instrument is assembled with the bell pointing up, a weight put on to hold the joints tightly together, and solder run in with heat from a torch. If a soldered cone is used, the upper end must be tightly wrapped with steel wire to prevent it from spreading open when the solder melts. I think it is better to use soft solder for this assembly even if facilities for brazing are available, because disassembly for any later corrections is much simpler.

The Mouthpiece

The first principle of making a mouthpiece is the same as that for turning wooden instruments, that is, the bore is made first and the outside then turned to be concentric with it. A piece of brass, preferably shaped roughly as described earlier, is drilled straight through its center with a drill equal in diameter to the smallest part of the finished bore. The contour of the cup can be shaped roughly using larger drills but not given its final form until the last operation. A conical back bore can be reamed all the way, but it is faster to make it by using increasingly larger drills to give a series of steps that are then smoothed out with a tapered reamer. After this boring has been done, the exterior of the mouthpiece is turned between centers in the lathe. Finally the cup is given its final shape by chucking the shank either in the drill press or lathe and working on the cup with a rotary file held in a suitable handle. Polishing is completed with rubber-bonded abrasive wheels in the high-speed hand grinder and a buffing wheel loaded with Tripoli compound.

Finishing

It is a good idea to polish individual parts to some extent before final assembly, since it may be easier to get at them separately; but an overall polishing operation will surely be needed at the end, and it is a matter of working down from files through successively finer grades of abrasive cloth, rubber-bonded abrasive wheels, and finally buffing on a cloth wheel with Tripoli compound. After that an occasional polishing with brass polish will keep the instrument shiny. For those who wish to avoid the polishing chore, a brass lacquer is available from instrument shops.

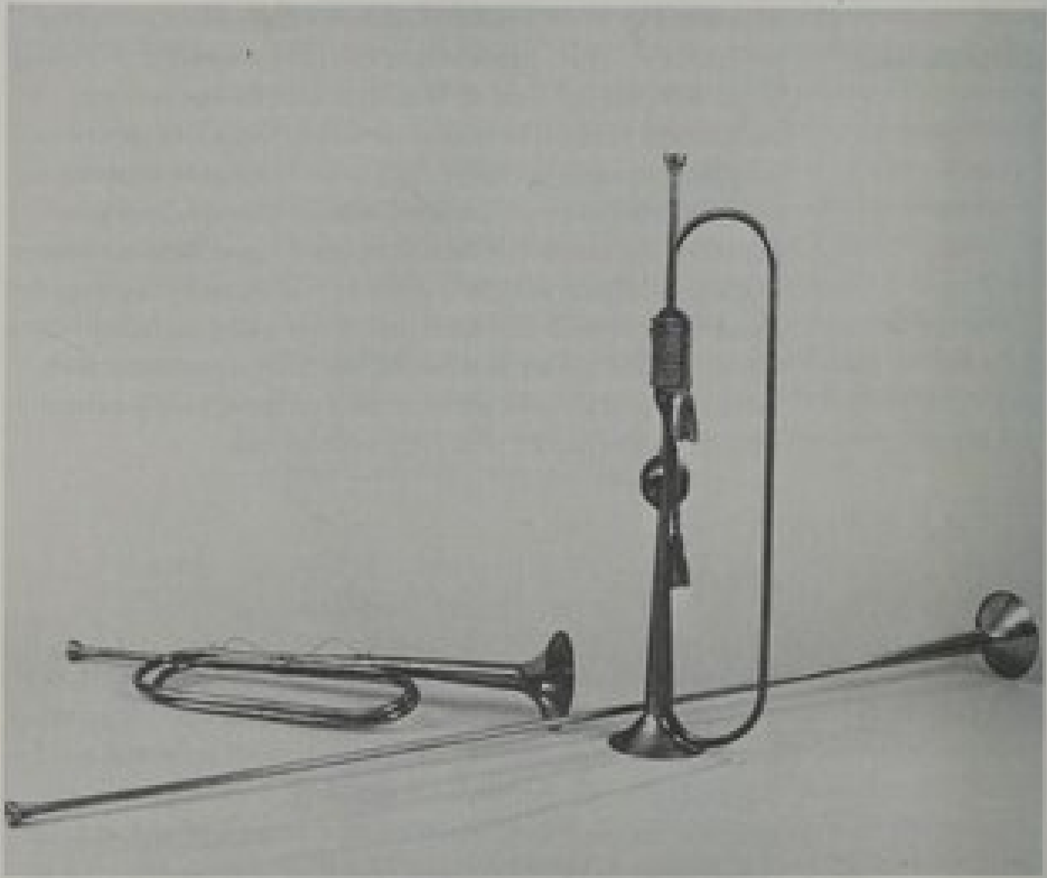


FIGURE 37. Some trumpets.

11 Trumpets

The trumpet is an instrument of great antiquity and widespread occurrence in one form or another. The special type that is considered here had its beginnings in Europe in the thirteenth and fourteenth centuries where it took the form of a flattened S. By the sixteenth century the twice-folded form of the tube had been standardized and remained mostly unchanged until the end of the eighteenth century. This twice-folded form is the design presented here in figure 38. The three parallel tubes are commonly designated *mouthpipe, middle pipe*, and *bell pipe*. Aside from the peculiarities of the mouthpiece (to be dealt with later), two things should be pointed out. The mouthpipe and bell pipe were usually not soldered together rigidly but held together only by the wooden block and wrapping towards the back end. Some believe that the tone is improved by this lack of rigidity. The ball in the middle of the bell pipe is also a standard feature of old trumpets. In the instrument shown in figures 37 and 38, as in some historical ones, it serves to cover a joint. It also serves as a handle for pressing the instrument firmly against the lips.

The construction procedure follows mostly without any special problems from the general methods discussed in chapter 10. There are several possible ways of fastening together the two J-shaped cylindrical sections. One can be flared slightly and the other fitted into it for soldering. A joint made in this way is weak by itself, and a reinforcing garnish should be soldered over the joint. If there is to be an extra garnish at this joint, the flaring might as well be dispensed with and a closely fitting section of tubing soldered over the joint.

The ball is spun as two hemispheres with a short, flaring skirt on one half into which the other half fits snugly (see fig. 35). Before soldering the halves together the holes for passage of the tubing should be drilled at the ends, starting the drill on the inside. Notice that the hole towards the bell must be larger than the hole towards the mouthpiece, but its final diameter can be adjusted with a reamer after the ball has been soldered together. Attachment of the ball to the tubing must be done by sliding the ball and the two reinforcing washers onto the cylindrical tube, flaring the end to receive the conical tube, soldering the two tubes together, and finally sliding the ball over the joint and soldering it in place. The other joints at the bell and in the middle pipe can be soldered at any time. The piece of wood between the bell and mouthpiece pipes is grooved along the edges with a gouge or router. The cord is wrapped around it following the same pattern illustrated in figure 4 for wrapping thread around the joints of woodwind instruments.

The dimensions given in figure 38 are for a trumpet in D, the most common of the baroque period. For a C trumpet it is necessary merely to increase the length of the cylindrical tubing by 1 ft., that is, by adding 4 in. to each of the three parallel sections of tubing. Small adjustments in pitch can be achieved by preparing a number of short lengths of tubing (called *bits*) that can be fitted between the mouthpiece and the mouthpiece pipe and held in place by a ferrule soldered either to the bit or to the end of the mouthpiece pipe. A loop of tubing can also be made for insertion here to lower the D trumpet to C; but since the diameter of such a loop is only about 3 in., it must be made of quite thin-walled tubing.

Three ranges of trumpet parts have been distinguished to take note of the differences between players and instruments so that if a composition was required to cover the full range of harmonics in the key of C, three instruments and three players might be required as follows:

Principal e'-e''
Clarino I g'-g''
Clarino II c''-c''' or higher

Most authors agree that the mouthpiece was of crucial importance in the design of the old trumpets, but they disagree on what its essential characteristics were. The most general agreement that can be reached is that the shape of the cup was a flattened hemisphere, not chamfered at the rim or at the grain, and that the rim was rather broad and flat. The volume of the cup, the diameter of the grain, and the shape of the back bore were apparently not standardized by any means. Cup diameters measured by Halfpenny as recorded in his articles, "William Bull and the English Baroque Trumpet," and "Early British Trumpet Mouthpieces," for a dozen old mouthpieces ranged from 16 mm. to 21 mm. and depths from 8.5 mm. to

13.2 mm. H. Eichborn, in *Die Trompete*, stresses the requirement for a narrow back bore for clarino playing, but grain diameters measured by Halfpenny ranged from 4 mm. to 7 mm., and that for a modern mouthpiece falls within this range. The taper of the back bore was also quite variable. Some instruments measured by Halfpenny carried the grain diameter in a cylindrical section for about 20 mm. before starting to expand into a cone. Others had the shank formed of sheet metal and therefore no conical back bore at all. In *Encyclopaedia Britannica* (11th ed., s.v. "Trumpet") V. Mahillon describes a mouthpiece in which the grain diameter was carried through in a cylindrical bore for 10 cm., ending abruptly at the main bore; and he found that with such a mouthpiece extra notes could be obtained—indeed a continuous glissando from c to e'' could be played. Mahillon regards a mouthpiece of this type as probably a secret of the trumpeters' guilds, allowing initiates to play seemingly impossible passages. From his consideration of the subject Halfpenny arrived at the simple conclusion that "anyone determined enough could learn to blow any note with any mouthpiece" (*Galpin Society Journal*, p. 78), but he agrees with Eichborn that the fullness of tone is directly related to the volume of the cup (*Die Trompete*, p. 30).

J. E. Altenburg, one of the last of the great clarino players, wrote an excellent book on the trumpet in which he discusses the mouthpiece at some length, but sadly he does not give any precise measurements. The drawing he presents of the end view of his favorite mouthpiece cannot be interpreted as if it were an engineering drawing, but it does conform to the general characteristics of a broad rim and shallow cup. Some of Altenburg's general discussion from his book, *Versuch einer Einleitung zur heroisch-musikalischen Trompeter-und Pauker-Kunst*, seems well worth reproducing here in English translation.

. . . A rim that is too broad hinders the attack somewhat, since it takes away freedom of the lips and covers them too much. On the contrary a rim that is too narrow does not demand a precise and consistent attack and tires the lips in a short time.

The so-called cup contributes much to the strength and weakness of the sound accordingly as it is deep or shallow, wide or narrow.

One can strengthen the sound by a deep and wide cup which gives good service especially in field pieces and in the principal range. On the other hand a cup that is too shallow and narrow will not produce the required strength.

The interior opening brings forth, according to its narrowness or width, a corresponding height or depth of sound. If the air that is forced in is compressed in a small opening, it is able, because of its elasticity, to vibrate at the same time the resonant body and make it sound. On the other hand, if it spreads out into a wide opening and with little strength and pressure it will also bring forth only the low tones. . . .

Many provide themselves with a mouthpiece having a narrow cup and small hole with the intention of being able to reach the very high range. However, with this it is probably impossible to have a pure and bright tone in the high region as well as the low for heroic field pieces and the principal range. Therefore this kind of mouthpiece is not recommended to either the clarino or the principal player.

It is an especially important rule to accustom oneself only to a particular mouthpiece, because one can spoil his attack by frequent changes. Each must select a suitable mouthpiece according to the way his lips are formed and the range that he plays. That is, it would be out of place if a person with strong lips or [one] *who plays the principal range were to choose a mouthpiece with a narrow cup and small opening. . . .*
[*pp.* 81–82, *my translation*]

The design given here (fig. 39) is a kind of average based on Halfpenny's measurements and other descriptions. Following the general principles presented by Altenburg, it can be modified to suit particular needs.

For the final word here on trumpet mouthpiece design, Benade has suggested to me that a properly made mouthpiece will sound at about a'' (880Hz) when the rim is slapped on the palm of the hand. This pitch is controlled by cup volume, grain diameter and backbore and can therefore be adjusted by varying any one of these dimensions.

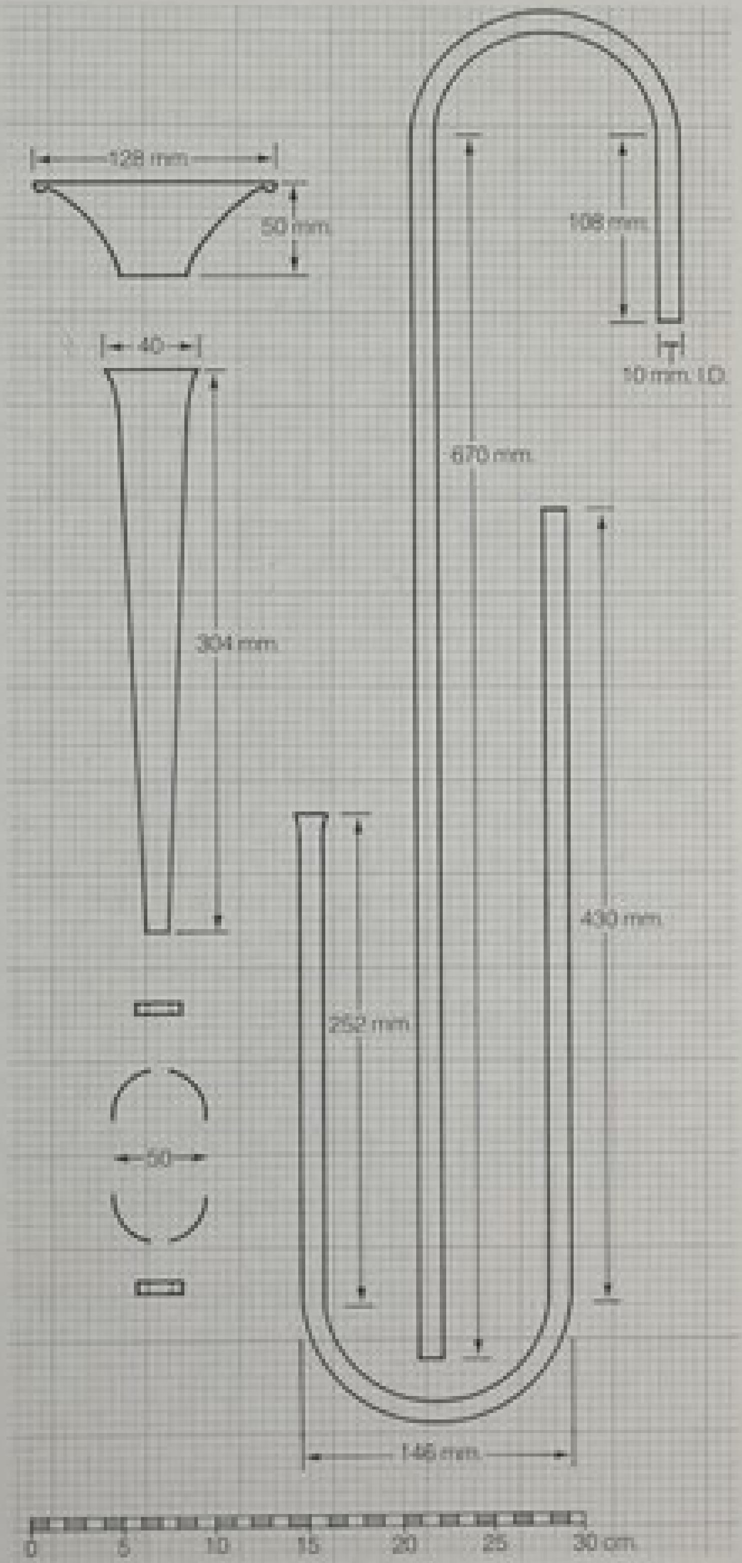


FIGURE 38. Trumpet in the key of D.

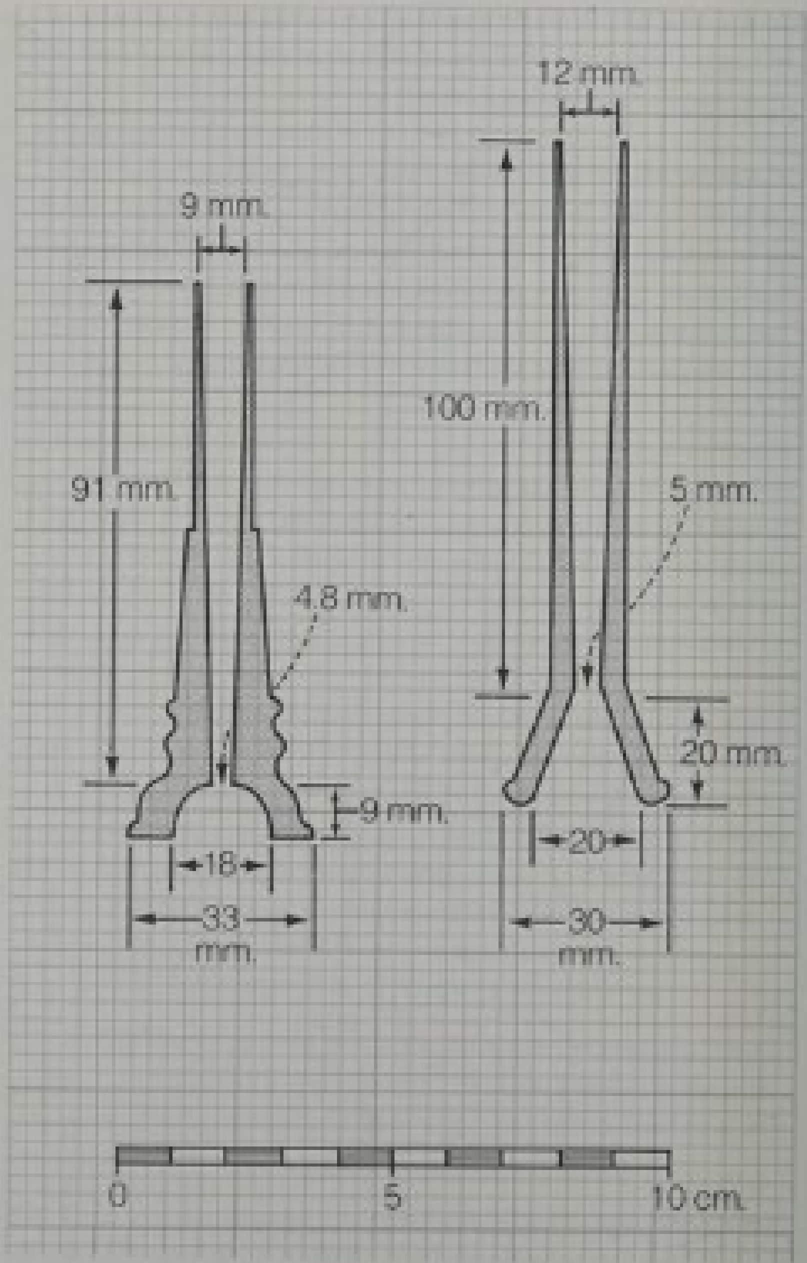


FIGURE 39. *Left*, trumpet mouthpiece; *right*, horn mouthpiece.

12 Horns

The ancestry of today's horns can be traced back to instruments made of animal horns. The clearest distinction between the horn family and the trumpet family is that instruments of the former have a conical bore throughout their length, whereas the trumpets start flaring into a cone only near the open end. For at least the last two centuries there has also been a distinction in the shape of the mouthpiece: trumpets have a cup whose bottom makes a distinct angle with the start of the backbore, while horn mouthpieces have an elongated funnel shape blending rather unobtrusively into the backbore. The European hunting horn was first accepted into the orchestra in the eighteenth century and began its development towards the sophisticated French horn of today.

The simple hunting horn shown in figure 40 is nothing more than a conical tube 17 in. long with a small bell made as described in chapter 10. It has a shallow trumpet type of mouthpiece and can sound only two or three notes. The bend was made (after filling it with pitch) so that the soldered seam was along the concave side of the curve.

The larger hoop-shaped horn shown in figure 40 is not strictly speaking a true horn, since its bore is cylindrical for most of the length; but as a result of the form of the mouthpiece its tone is distinctly that of a horn. For a horn in F (the most usual key) the main tube consists of 11 ft. of ½-in. copper tubing, the conical part is 15½ in. long expanding to a diameter of 1½ in., and the bell has a diameter of 7½ in. The outside diameter of the loop is 18 in. The mouthpiece is made with a very long conical backbore. The dimensions given in figure 39 can be achieved by reaming the backbore with a so-called repairman's reamer obtainable in most hardware stores. In order to conserve brass and avoid making a special casting, the mouthpiece shown was made in two parts soldered together as described in chapter 10.

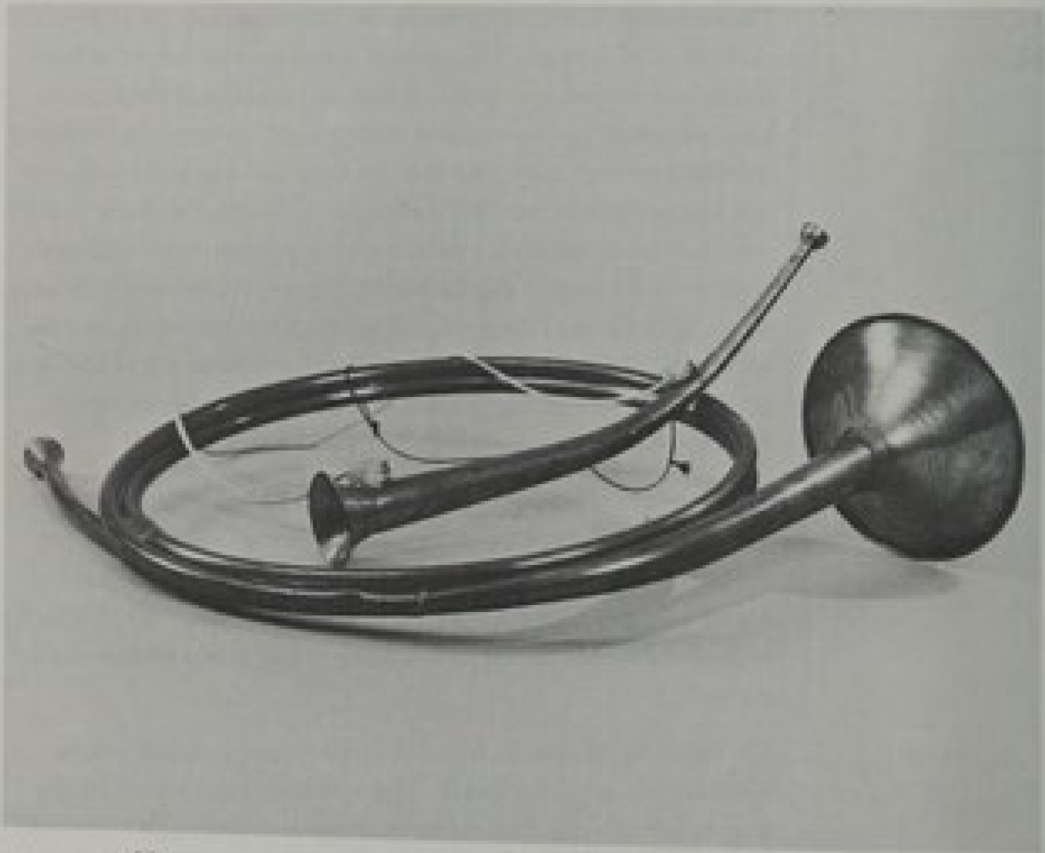


FIGURE 40. Horns.

Appendix A Some Museum Collections of Instruments

There are two published directories of instrument collections. One by Lichtenwanger *et al.* covers the U.S. and Canada. The other by Jenkins is international. Anyone who plans to visit any of the collections listed here should write ahead, since many of the museums are open to the public for only short periods and at unusual times.

Catalogs:* A catalog is available or in preparation;† A catalog has been published but is out of print;§ Instrument plans are sold.

AUSTRIA

Kunsthistorische Museum* §
Neue Burg
Vienna

Museum Carolino Augusteum*
Salzburg, Postfach 525
Museumplatz 6

Oberösterreichischen Landesmuseum*
Linz

BELGIUM

Gruuthusemuseum
Brugge (Bruges)

Musée Instrumental*§
Conservatoire Royal de Musique
17 Petit Sablon
Brussels

Vleeshuis Museum*
Antwerp

CZECHOSLOVAKIA

Národní Museum
Velkop řevorské námestí 4
Malá Strana
Prague I

DENMARK

Musikhistorisk Museet†
Aabenraa 32–34
1124 Copenhagen K

FRANCE

Musée du Conservatoire National de Musique†§
rue de Madrid
Paris

GERMANY

Bavarian National Museum†
Munich

Deutsches Museum*
Munich

Germanisches Museum§
Untere Grasergasse 18
Nuremberg

Leipzig Musikinstrumenten-Museum*
Karl Marx Universität
Leipzig

Staatliches Institut für Musikforschung*§
1 Berlin 15
Bundesallee 1–12

Stadtisches Museum†
Braunschweig

GREAT BRITAIN

Ashmolean Museum
Oxford

Donaldson Collection
Royal College of Music
London

The Galpin Society Collection
Reid School of Music
Park Place
Edinburg 8

Horniman Museum†
London Road
Forest Hill
London S.E.23

Philip Bate Collection*
The Music Faculty
Oxford University
33 Holywell Street
Oxford

Pitt Rivers Museum*
Oxford

Royal College of Music
London

Sheffield City Museum*
Sheffield

Victoria and Albert Museum*
Cromwell Road
London S.W.7

HUNGARY

Nemzeti Múzeum
Múzeum kit 14–16
Budapest

ITALY

Accademia Filharmonica
Via dei Mutilati 4/L
Verona

Biblioteca Capitolare*
Verona

Conservatorio Benedetto Marcello
Venice

Museo Civico
Bologna

Museo Civico*
Modena

Museo del Conservatorio Luigi Cherubini*§
Florence

Museo Nazionale Scienza e Tecnica
Via S. Vittore 21
Milan

Museo Strumenti Musicali*
Castello Sforzesco
Milan

NETHERLANDS

Gemeente Museum*
Kon. Emma Kade
The Hague

POLAND

Museum of Musical Instruments
Old Market Square
Poznan

SOVIET UNION

Institute of Theater, Music, and Cinematography†
Leningrad

SPAIN

Municipal Museum of Music
School of Music
110 Bruch Avenue
Barcelona

SWEDEN

Musikhistoriska Museet†§
Slottsbacken 6
Stockholm

SWITZERLAND

Bernoulli Music Instrument Collection
Greifensee

Sammlung Alter Musikinstrumente†
Leonhardstrasse
Basel

UNITED STATES

Casadesus Collection†
Symphony Hall
Boston, Massachusetts 02115

The Dayton C. Miller Flute Collection*
The Library of Congress
Washington, D.C. 20540

Division of Musical Instruments*
National Museum of History and Technology
Smithsonian Institution
Washington, D.C. 20560

The Metropolitan Museum of Art†§
5th Avenue and 82nd Street
New York, New York 10028

Museum of Fine Arts†
Huntington Avenue
Boston, Massachusetts 02115

Stearns Collection of Musical Instruments†
University of Michigan
Ann Arbor, Michigan 48104

Yale Collection of Musical Instruments*
Yale University
New Haven, Connecticut 06511

Appendix B Sources of Materials

WOODS

Many dealers in rare woods advertise in the magazines *Fine Woodworking* and *Woodworker*. The following list contains only dealers with whom I have had personal experience or recommendations from friends.

Albert Constantine and Son, Inc.
2050 Eastchester Road
Bronx, New York 10461

Craftsman Wood Service Co.
2727 South Mary Street
Chicago, Illinois 60608

A.I. Eppler
1921 Fifth Avenue
Seattle, Washington 98101

General Woodwork Supplies
76–80 Stoke Newington High Street
London N.16
England

Joseph Gardner Hardwoods, Ltd.
25–37 Rothbury Road
London E9 5HA
England

Penberthy Lumber Co.
5800 South Boyle Avenue
Los Angeles, California 90058

TOOLS

Allcraft Tool and Supply Co.
215 Park Avenue
Hicksville, New York 11801
(*metal spinning tools and buffing supplies*)

Brookstone Company
127 Vose Farm Road
Peterborough, New Hampshire 03458
(*fine small tools, files, and silver solder*)

Kitts Surplus Sales
Box 141, 21724 Albion
Farmington, Michigan 48024
(*machinists' tools, drills, and reamers*)

William Ridgway and Sons Ltd.
Oscar Works, Meadow Street
Sheffield S3 7BP
England
(*shell augers for long hole boring*)

Woodcraft Supply Corp.
313 Montvale Avenue
Woburn, Massachusetts 01801
(*fine woodworking tools, turning and carving chisels*)

METALS
(tubing, rods, and sheet)

Small Parts Inc.
6901 NE Third Avenue
Miami, Florida 33138
(*tubing in 1-ft. lengths only*)

FOUNDRY

Kansas City Specialties Co.
2805 Middleton Beach Road
Middleton, Wisconsin 53562
(*several sizes of small gas-fired furnaces excellent for brass casting or steel forging*)

IVORY AND SUBSTITUTES

Angus Campbell Inc.
4417 South Soto Street
Vernon, California 90058
(*#454 imitation ivory*)

C. Dietrich
1 Berlin 15
Bundesallee 221
West Germany

A.I. Eppler
1921 Fifth Avenue
Seattle, Washington 98101

F. Friedlein and Co., Ltd.
Kudu House
60 Minories
London E.C.3
England

MUSICAL INSTRUMENT SUPPLIES

Erick Brand
1117 W. Beardsley Avenue
Elkhart, Indiana 46514
(tools and repair supplies)

A. Glotin
15 rue du Progrès
95460 Ezanville, France
(reeds)

Kelhorn Corp.
Brasstown, North Carolina 28902
(plastic reeds)

Phillip Levin
112 First Avenue
New York, New York 10009
(reeds)

Scottish and Irish Crafts Ltd.
Rte. 3
Trenton, Maine 04605
(bagpipe supplies)

Sterling Music Co.
505 So. Harrison Road
Sterling, Virginia 22170
(electronic tuning aids)

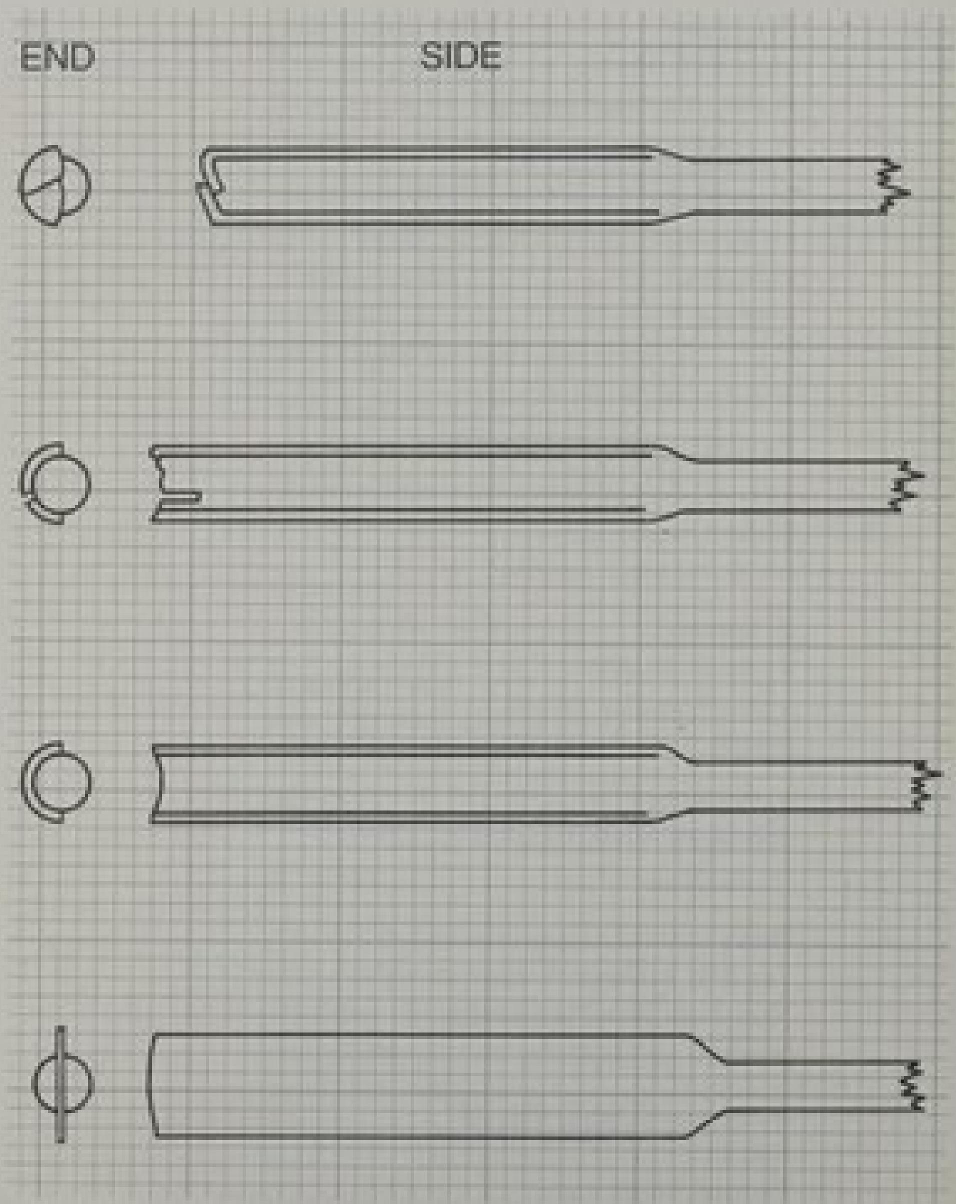


FIGURE 41. Making a shell auger.

Appendix C Making Shell Augers

A reasonable substitute for the commercial shell auger for boring long, straight holes can be made with some effort if it is too inconvenient to obtain the others. The stages of manufacture are sketched in figure 41. A length of drill rod 1/16 in. to ⅛ in. less in diameter than the diameter of the desired hole is used, heated red hot, and flattened on the anvil for a distance of 3½ in. to 4 in. back from the end. The flattened section is again heated and hammered around an anvil of the proper radius. After this operation, the end view should show a half-circle section with the center of the arc in line with the center of the main piece of rod. A longitudinal slit is next made for a distance about equal to the diameter of the arc and dividing it in the ratio of 1:2. The tip is again heated red hot and the two sections bent in almost to a right angle with the narrower piece overlapping the wider one. The overlapping edge will be the cutting edge of the bit, and it should be ground and sharpened so that its leading point is at the axis of the auger. Finally the tip should be reheated, quenched, and tempered.

A flat-tipped bit, which will not bore straight by itself but is useful for enlarging a hole made by one of the others, is made by starting the process as above. Then, when the end has been hammered flat, the tip is simply ground to a 60° V-shape with the cutting edges slightly relieved.

Appendix D Miscellaneous Useful Addresses

American Musical Instrument Society
Secretary, Alan G. Moore
10 Waterside Plaza, Apt. 22K
New York, New York 10010

Fellowship of Makers and Restorers of Historical Instruments
c/o Jeremy Montagu
7 Pickwick Road, Dulwich Village
London SE21 7JN
England

Galpin Society
Secretary, Margaret Cranmer
116 Tenison Road
Cambridge CB1 2DW
England

NRI Design Service
722 Main Street
Burton Joyce
Nottinghamshire NG14 5EH
England

Appendix E Table of Decimal Inches and Metric Equivalents

Inch	Decimal inch	Millimeter	Inch	Decimal inch	Millimeter
1/64	0.015625	0.396785	17/64	0.265625	6.746875
1/32	0.03125	0.79375	9/32	0.28125	7.14375
3/64	0.046875	1.190625	19/64	0.296875	7.540625
1/16	0.0625	1.5875	5/16	0.3125	7.9375
5/64	0.078125	1.984375	21/64	0.328125	8.334375
3/32	0.09375	2.38125	11/32	0.34375	8.73125
7/64	0.109375	2.778125	23/64	0.359375	9.128125
1/8	0.125	3.175	3/8	0.375	9.525
9/64	0.140625	3.571875	25/64	0.390625	9.921875
5/32	0.15625	3.96875	13/32	0.40625	10.31875
11/64	0.171875	4.365625	27/64	0.421875	10.715625
3/16	0.1875	4.7625	7/16	0.4375	11.1125
13/64	0.203125	5.159375	29/64	0.453125	11.509375
7/32	0.21875	5.55625	15/32	0.46875	11.90625
15/64	0.234375	5.953125	31/64	0.484375	12.303125
1/4	0.25	6.35001	1/2	0.50	12.7

Table of Decimal Inches and Metric Equivalents (*cont.*)

Inch	Decimal inch	Millimeter	Inch	Decimal inch	Millimeter
33/64	0.515625	13.096875	49/64	0.765625	19.446875
17/32	0.53125	13.49375	25/32	0.78125	19.84375
35/64	0.546875	13.890625	51/64	0.796875	20.240625
9/16	0.5625	14.2875	13/16	0.8125	20.6375
37/64	0.578125	14.684375	53/64	0.828125	21.034375
19/32	0.59375	15.08125	27/32	0.84375	21.43125
39/64	0.609375	15.478125	55/64	0.859375	21.828125
5/8	0.625	15.875	7/8	0.875	22.225
41/64	0.640625	16.271875	57/64	0.890625	22.621875
21/32	0.65625	16.66875	29/32	0.90625	23.01875
43/64	0.671875	17.065625	59/64	0.921875	23.415625
11/16	0.6875	17.4625	15/16	0.9375	23.8125
45/64	0.703125	17.859375	61/64	0.953125	24.209375
23/32	0.71875	18.25625	31/32	0.96875	24.60625
47/64	0.734375	18.653125	63/64	0.984375	25.003125
3/4	0.75	19.05	1	1.00000	25.4

Bibliography

Works Cited in the Text

ALTENBURG, J. E. *Versuch einer Einleitung zur heroisch-musikalischen Trompeter- und Pauker-Kunst.* Halle: J. C. Hendel, 1795.

BENADE, A. H. *Fundamentals of Musical Acoustics.* New York: Oxford University Press, 1976.

———. *Horns, Strings, and Harmony.* New York: Doubleday Anchor Books, 1960.

BESSARABOFF, N. *Ancient European Musical Instruments.* Cambridge, Mass.: Harvard University Press, 1941.

BRAND, E. D. *Band Instrument Repairing Manual.* Elkhart, Ind.: E. D. Brand (1117 W. Beardsley Ave, Elkhart, Indiana 46514).

BROUGH, J. C. S. *Timbers for Woodwork.* London: Evans Brothers, 1967.

CONSTANTINE, A., Jr. *Know Your Woods.* New York: Albert Constantine and Son, 1969.

DIDEROT, D., ed. *L'Encyclopédie.* Volumes of plates. Paris: Briasson, David, LeBreton and Durand, 1762–72. Facsimile edition, 5 vols. New York: Redex Microprint Corporation, 1969.

EDLIN, H. L. *What Wood is That?* New York: Viking Press, 1969.

EICHBORN, H. *Die Trompete.* Leipzig: Breitkopf and Härtel, 1881.

FIRTH, I. *Directory of Suppliers to Craftsmen Musical Instrument Makers.* Edinburgh: Small Business Division, Scottish Development Agency, 1975.

HALFPENNY, E. "William Bull and the English Baroque Trumpet." *Galpin Society Journal* 15(1962):18–24.

———. "Early British Trumpet Mouthpieces." *Galpin Society Journal* 20(1967):76–88.

———. "Four Seventeenth Century British Trumpets." *Galpin Society Journal* 22(1969):51–57.

HAYNES, B. "Making Reeds for the Baroque Oboe." *Early Music* 4(1976):31–34, 173–79.

JENKINS, J., ed. *International Directory of Musical Instrument Collections.* New York: Heinman, 1978.

KARP, C. "Woodwind Instrument Bore Measurement." *Galpin Society Journal* 31(1978):9–28.

KOTTICK, E. L. *The Collegium: A Handbook.* Stonington, Conn.: October House, 1977.

KUKACHKA, B. F. *Properties of Imported Tropical Woods.* Washington: U. S. Department of Agriculture, 1971.

LICHTENWANGER, W., HIGBEE, D., HOOVER, C. A., and YOUNG, P. T. *A Survey of Musical Instrument Collections in the United States and Canada.* Philadelphia: Music Library Association, 1974.

LORETTO, A. "Recorder Modifications." *Early Music* 1(1973): 107–9, 147–51, 229–31.

MACMILLAN, D. "The Mysterious Cornamuse." *Early Music* 6(1978):75–77.

MARVIN, R. "Recorders and English Flutes in European Collections." *Galpin Society Journal* 25(1972):30–57.

———. "Making Reamers on a Shoestring." *The FOMRHI Quarterly*, January 1979, 37–38.

MERSENNE, M. *Harmonie Universelle.* 1636. Reprint, Paris: Centre National de la Recherche Scientifique, 1965. English translation by R. E. Chapman, The Hague: Nijhoff, 1957.

MEYER, K. T. and KOTTICK, E. L. "Making Double Reeds for Renaissance Wind Instruments." *The FOMRHI Quarterly*, July 1979, 52–58.

RENDLE, B. J. *World Timbers.* 3 vols. London: Ernest Benn, 1969.

SMITHERS, D. "The Trumpets of J. W. Haas." *Galpin Society Journal* 18(1965):23–41.

STERN, C. "A Brief Workshop Manual for Recorders." *Early Music* 7(1979):359–65.

TOMLIN, P. "Woodwind Instruments." *Woodworker* 75(1971): 118, 131, 199, 234, 303, 326, 344; 82(1978):202, 266; 83(1979):168, 250.

WHEELER, J. "Further Notes on the British Trumpet." *Galpin Society Journal* 18(1965):14–22.

YOUNG, T. C. *The Making of Musical Instruments.* Oxford: Oxford University Press, 1939. Reprint. Freeport, N. Y.: Books for Libraries, 1969.

General Books on the History of Musical Instruments

BAINES, A. *Woodwind Instsruments and their History,* 3d ed. New York: W.W. Norton, 1967.

———. *European and American Musical Instruments.* London: Batsford, 1966.

———, ed. *Musical Instruments Through the Ages.* Harmondsworth, Eng.: Penguin Books, 1961.

BATE, P. *The Flute.* New York: W. W. Norton, 1969.

———. *The Oboe,* 2d ed. New York: W. W. Norton, 1962.

———. *The Trumpet and Trombone.* New York: W. W. Norton, 1966.

BOEHM, T. *The Flute and Flute-Playing.* Translated by D. C. Miller. New York: Dover Publications, 1964.

BRAGARD, R. and DEHEN, F. J. *Musical Instruments in Art and History.* London: Barrie and Rockliff, 1968.

BUCHNER, A. *Musical Instruments Through the Ages.* London: Spring Books, 1961.

CARSE, A. *Musical Wind Instruments.* New York: Da Capo Press, 1965.

GALPIN, F. W. *Old English Instruments of Music,* 3d ed. London: Methuen, 1965.

HARRISON, F. and RIMMER, J. *European Musical Instruments.* New York: W. W. Norton, 1964.

HUNT, E. *The Crumhorn.* London: Schott and Company, 1975.

———. *The Recorder and Its Music.* New York: W. W. Norton, 1963.

KROLL, O. *The Clarinet.* London: Batsford, 1968.

LANGWILL, L. G. *The Bassoon and Contrabasoon.* New York: W. W. Norton, 1966.

MARCUSE, S. *Musical Instruments, A Comprehensive Dictionary.* New York: Doubleday, 1964.

MELVILLE-MASON, G., ed. *An Exhibition of European Musical Instruments.* London: The Galpin Society, 1968.

RENDALL, F. G. *The Clarinet,* 2d ed. New York: W. W. Norton, 1967.

ROCKSTRO, R. S. *A Treatise on the Flute.* London: Musica Rara, 1967.

SACHS, C. *Real-Lexicon der Musikinstrumente.* 1913. Reprint. New York: Dover Publications, 1964.

WINTERNITZ, E. *Musical Instruments of the Western World.* New York: McGraw Hill, 1966.

The Amateur Wind Instrument Maker (Revised Edition)
Trevor Robinson

First published in 1973, *The Amateur Wind Instrument Maker* has now been thoroughly revised by its author. This revised edition contains new sources of design and adds three more instruments to the impressive number of construction possibilities—a Renaissance-type alto recorder, Renaissance flute, and a Baroque bass rackett. The alto krumhorn has been redesigned, and Robinson adds a new reamer design and expands his earlier comments about reed making. This revised edition contains an essential, updated appendix listing dealers of materials and tools used in the construction of instruments, and another updated listing of museums displaying early instruments.

"Robinson has put together an excellent guide, both for craftsmen and for musicians. The book includes lucid descriptions of the materials and methods for making a number of wind instruments. . . . This is not a handbook for whittling hobbyists, but a how-to-do-it manual for serious craftsmen"—*Whole Earth Epilog.*

ISBN 312-2