69-8598

HARDIN, Burton Ervin, 1936-

A COMPARISON OF TWO METHODS OF ARRIVING AT THE MOST SUITABLE THICKNESSES OF VIOLIN PLATES.

The University of Oklahoma, D.Mus.Ed., 1969
Music

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

A COMPARISON OF TWO METHODS OF ARRIVING AT THE MOST SUITABLE THICKNESSES OF VIOLIN PLATES

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF MUSIC EDUCATION

BY

BURTON ERVIN HARDIN

Norman, Oklahoma

1968

A COMPARISON OF TWO METHODS OF ARRIVING AT THE MOST SUITABLE THICKNESSES OF VIOLIN PLATES

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

The writer wishes to thank Dr. Robert C. Smith, who directed this study, for his excellent guidance and assistance, and professors Spencer H. Norton, Donn L. Mills and David P. French for their encouragement and advice.

Gratitude is expressed to the judges who rated the violins, all of whom patiently and generously donated their time.

Special thanks is due my wife, Barbara, who aided by being the first to evaluate the instruments, proof-reading each draft and offering many valuable suggestions. I am grateful to my parents, Dr. and Mrs. Robert A. Hardin, who also read the copy. The skills and techniques necessary for constructing the instruments were largely conveyed to me by my father, who made the first violin to bear the Hardin name in the year 1927.

TABLE OF CONTENTS

ACKNOWLEDGMENTS iii

LIST OF TABLES v

LIST OF ILLUSTRATIONS vi

Chapter

I. THE PROBLEM 1

II. A SURVEY OF THE METHODS OF GRADUATION OF VIOLIN PLATES 20

III. THE CONSTRUCTION OF THE TEST VIOLINS. 66

IV. THE EVALUATION OF THE VIOLINS 101

V. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDIES 120

BIBLIOGRAPHY. 129

LIST OF TABLES

Table		Page
1.	Measurements Commonly Used in Violin Graduations	22
2.	Fundamental Frequency of Violin Plates. . . .	50
3.	Judges' Evaluations of the Tone Quality of the Violins.	109
4.	Judges' Evaluations of the Responsiveness of the Violins.	110
5.	Judges' Numerical Rating of the Violins . . .	112
6.	K (Judges) By N (Objects)	114
7.	Aural Evaluations of the Violins.	119

LIST OF ILLUSTRATIONS

Figure		Page
1.	Heron-Allen diagram of graduations of old backs, given in fractions of an inch	23
2.	Heron-Allen diagram of graduation of old tops, given in fractions of an inch.	23
3.	Heron-Allen diagram for preliminary regulation of thicknesses of the back.	25
4.	Heron-Allen final thicknesses of a new back. .	26
5.	Heron-Allen final thicknesses of a new top . .	27
6.	Batts top graduation diagram, given in millimeters.	29
7.	Batts back graduation diagram, given in millimeters.	30
8.	Hutchins "dark" tone diagram, given in millimeters.	31
9.	Hutchins "brilliant" tone diagram, given in millimeters	31
10.	Henley dimensions of Gasparo da Salo violin of 1580, given in millimeters.	36
11.	Dimensions of back of 1703 Stradivarius violin, "DeRougemont," given in tenths of millimeters	38
12.	Dimensions of top of 1703 Stradivarius violin, "DeRougemont," given in tenths of millimeters	39
13.	Dimensions of back of 1682 Stradivarius violin, given in tenths of millimeters . . .	41

Figure		Page

14. Dimensions of lower half of top of 1962 Stradivarius violin, given in tenths of millimeters. 42

15. Pattern derived from 1703 Stradivarius violin top, given in tenths of millimeters. 43

16. Pattern derived from 1703 Stradivarius violin back, given in tenths of millimeters. 43

17. Pitch name definitions. 46

18. Loudness curves of Stradivarius violins . . . 57

19. Cross section of a log of wood showing slab and quarter cut portions. 72

20. Cross section of a one-piece back showing the removal of excess wood. 72

21. Zinc half outline of the plate, with the form of the mold also exhibited 73

22. Violin arching templates. 75

23. Violin scroll and neck template 78

24. Dimensions of back of violin C, given in tenths of millimeters 82

25. Dimensions of top of violin C, given in tenths of millimeters 83

26. Dimensions of back of violin D, given in tenths of millimeters 84

27. Dimensions of top of violin D, given in tenths of millimeters 85

28. Loudness curves of tops and backs of violins A, B, C, and D. 91

29. Loudness curves of completed violins A, B, C, and D. 93

Figure | Page

30. Directions for use of the scoring instrument for the evaluation of the test violins 106

31. Scoring instrument for the evaluation of the test violins. 107

A COMPARISON OF TWO METHODS OF ARRIVING AT THE MOST SUITABLE THICKNESSES OF VIOLIN PLATES

CHAPTER I

THE PROBLEM

Introduction

After 1750, the demands of society increasingly caused craftsmen and artists to work with an emphasis on volume and numbers in order to earn an acceptable living, and finally to abandon their benches altogether. The craft of violin making (and the making of the other members of the stringed instrument family as well) has not been spared in this industrial movement. By the time it was realized that violins could not be satisfactorily made using mass production methods, much of the accumulated skill and knowledge of the craft had been lost. As a consequence excellent stringed instruments have become extremely difficult to obtain. It is generally felt that students who use poor instruments are working under an unnecessary disadvantage and are more likely to become discouraged and give up the study of stringed instruments than are those who are fortunate enough to possess superior instruments.

Violins have been made for some four hundred years. During the first two centuries of their manufacture, beginning with early craftsmen in northern Italy, and culminating with Antonio Stradivari and Giuseppi Guarneri in Cremona, which is in the same general region, the finest violins and other stringed instruments were made.

For the ensuing two hundred years, violin makers have been trying to discover what elements in the production of these earlier craftsmen caused their instruments to be so consistently superior, and what particular elements have been missing in the productions of makers since 1750.

Communication in our present-day society has developed to such an extent that the person who has not heard of the great violin makers of Italy of centuries past, and the works of art with exceptional reputations produced by them, is rare indeed. In any circle of humanity the utterance of the name, "Stradivarius," produces a response of awe and respect.[1] This famous craftsman's dominance of the musical world in the production of fine instruments is unquestioned. The name has become so popular, in fact, that professional violinists and instrument makers, dealers and restorers are continually besieged by hopeful persons clutching battered violins equipped with spurious

---

[1]Throughout this dissertation the Italian form of the name, Stradivari, refers to the person, whereas the Latin form, Stradivarius, refers to instruments made by that craftsman.

Stradivarius labels. The story is usually the same: the instrument was bought by a grandfather from a gypsy, and has been in the family over one hundred years, and the bearer is always convinced of its great value. Unfortunately the violin in question usually turns out to be factory made, and often of the cheapest construction.

This respect for Stradivari and his fifteenth, sixteenth and seventeenth century Italian colleagues is by no means confined to laymen, nor is it belittled by the professional musicians who own and play the authentic instruments. In fact, the persons who stand in awe to the highest degree, and who respect Stradivari's name more than all others, are the hundreds of professional and amateur makers who are constantly striving to emulate the quality established by these earlier makers.

Variation in any of several characteristics of violin construction will cause a variation in the tonal and playing characteristics of the instrument. The thickness of the top and back; the model; the arching; the size, shape and position of the sound holes; the length of the strings; the angle at which the neck is set; the height, thickness and texture of the wood in relationship to the other factors--all these characteristics will affect the ultimate quality of the instrument. The first of these (thickness of the plates) is felt to be most critical by many violin makers. This is also the most frequently neglected characteristic in the production of low-priced instruments. Often the top and back plates in such instruments are only roughly worked out.

In journals devoted to the articles of violin makers one finds that there are a number of individual elements discussed as perhaps being the craftsmen's elusive secret, not the least of which are the selection and drying of the wood, the varnish, and the method of arriving at the thicknesses of the plates of the instrument--and in each case multiple choices are presented.

The journals describe several methods of arriving at the final thicknesses of the plates. Unfortunately very little objectivity is to be found even there, since each maker seems to be convinced that his method is the final answer to the question and excludes all others, and all join in enthusiastically attacking one anothers' theories.

Some methods involve tuning the plates by discovering their fundamental frequencies through artificial vibration of the plate with a blow of the hand, with a bow drawn across the edge, or by using electronic means. Others simply use measurements, often with the vague recommendation that the measurements be altered depending on the characteristics of the wood employed.

Obviously objectivity is impossible in such an atmosphere. Further investigation indicates that very little in the way of objective experimentation has been done to try to isolate elements which may aid in the production of instruments of high merit.

This is serious, perhaps even critical, for the ancient productions are two to four hundred years old. Because of the fact that the instruments are made of wood, and wood being perishable, they cannot last forever. Many have already been consigned to museums, some of these having been brought to a ruined condition from the player's standpoint, and those still in circulation have become so highly priced that they are beyond the reach of most musicians. The solution to this plight lies in objective development to weed out the myth from the truth. One element must be isolated at a time, and each alternative must be tried and compared in finished instruments evaluated by competent professional musicians.

The Study

The element under study here is the thickness of the top and back of the violin. Various methods have been expounded concerning methods of establishing the thickness of each of these components, but in no case examined by the present writer has a previous study dealt with a comparison of methods, rather than to one method or another embraced to the exclusion of all others. Successful professional makers, with very few exceptions, are reluctant to reveal their methods, preferring to surround them with the mysterious aura of "trade secrets." No academic work in this field has been discovered.

Delimitation

This study is limited to two methods of achieving the final thicknesses of the plates, a process known as "graduation." Two violins were constructed to the specifications of each of the two methods. In an effort to eliminate as many uncontrolled variables as possible in the production of the test instruments, all of the violins were constructed on the same model using templates to control the arching. The wood was as nearly matched as possible in texture and grain. The various components of each violin were constructed at the same time to minimize variations in workmanship. The varnish is the same for all instruments, even to the color, and was applied to all four at the same time. Fittings such as the bridges, sound posts and strings were chosen with the intent of eliminating variations in quality and texture.

The survey of the literature revealed the methods available from which the methods of graduation of the test models were chosen. Most sources were periodicals, although some books and correspondence with authorities in the field were also used. The amount of available literature of value in this field is relatively small.

The project involved the construction of the instruments, all elements of which were done by the writer.

The evaluation of the violins was done according to a pre-prepared questionnaire which was submitted to a limited number of musicians and artists along with the violins. Questions were asked about the tone quality and playing qualities of each violin, and the artists were asked to rate each violin against the others. Comments were invited.

It is hoped that future studies will be made dealing with other elements with the hope of further isolation of factors influencing the quality of violins, perhaps eventually defining limitations within which violin makers may work with the expectation of producing consistently excellent instruments.

Historical Background

Because the earliest history of the violin is vague, it is difficult to trace the exact ancestry of the instrument or even to name the first maker. One may examine ancient artifacts made of stone or metal in museums of today by virtue of the durability of these materials. Few wooden objects survive more than a few centuries, having been destroyed by fire, physical damage, insects, or even by use and abuse by man himself.

Even in relatively recent history (i.e., the past thousand years) very little in the way of information about wooden instruments has been preserved. Prior to the beginning of the Baroque era in music, composers seldom specified instrumentation in their compositions, leaving the choice of orchestration to the option of the performers. In most cases the instruments were used simply to double the vocal line, one instrument to a part, utilizing whatever instruments happened to be available at the moment.[2] The earliest extant music written specifically for the violin dates from 1581, "Circe ou le Ballet Comique de la Reine," by Lambert de Beaulieu and Jaques Salmon, which was written for dancing at a royal wedding in France.[3]

As a consequence, the earliest records of stringed instruments are contained in paintings. Heron-Allen describes the panels on the roof of the Peterborough Cathedral, which depict grotesque figures playing violin-like instruments. The roof is considered to be from the year 1194, but the instruments appear to be violins, with f-holes, scrolls and bows. The bodies and fittings of the instrument are typical of those of the viol.[4]

Boyden, however, contends that the first evidence of the existence of violins in frescoes and paintings is to be found in the works of the Italian painter, Guadenquio

---

[2]Donald Jay Grout, A History of Western Music (New York: W. W. Norton and Company, 1960), 250.

[3]David D. Boyden, The History of Violin Playing from Its Origins to 1761 (London: Oxford University Press, 1965), 56.

[4]Edward Heron-Allen, Violin Making as It Is and Was (2nd ed.; London: Ward, Lock and Company, Ltd., 1885), 30.

Ferrari (c. 1480-1566) in the churches of Milan.[5] The earliest of these, "La Madonna Degli Aronici," which was painted about 1529-1530, shows a child with a primitive three-stringed violin. A reproduction of this painting is carried as the frontispiece to Boyden's book.

Several interesting examples of early art depicting instruments played with the bow are contained in the volume by Buchner, particularly plates 93 (from the thirteenth century), 98, 99 and 228.[6] The first three examples show either musicians or angels playing upon viols and other instruments, whereas plate 228 is a photograph of a lira da braccio which is displayed in the Museum of Art in Vienna. Sachs indicates that evidence of the existence of instruments played with the bow is to be found in tenth and eleventh century Spanish manuscripts.[7]

"Viol" is the generic term for a family of instruments played with a bow that was of great importance in the European countries during the fifteenth, sixteenth and seventeenth centuries. The instruments, unlike the present day violins, were not standardized and consequently are found in a variety of forms. Common characteristics of the

---

[5]Boyden, 7.

[6]Alexander Buchner, Musical Instruments Through the Ages, trans. Iris Urwin (London: Batchworth Press, Ltd., 1961), Plates 93, 98, 99, 228.

[7]Curt Sachs, The History of Musical Instruments (New York: W. W. Norton and Co., Inc., 1940), 275.

instruments of this family are the number of strings (six or seven), the presence of frets on the fingerboard (improvized out of gut and placed there and adjusted by the performer), and the technique with which the bow was held, with the hand under the bow, rather than over it as is the case with the instruments of the violin family. The early viols were played while being held between the knees similarly to the modern violoncello. By the sixteenth century the viols had evolved into two distinct branches: the <u>viole da gamba</u> (leg viol), and the <u>viole da braccio</u> (arm viol). When the latter instrument was too large to be held against the breast, it was held over the shoulder.[8] In comparison with the dimensions of violins, the necks of the viols were broader to accommodate the large number of strings, and were cut to a rather thin dimension. In addition, the neck was longer than in the case of the instruments of the violin family, making the string length greater. The strings were tuned in fourths with one major third and were lighter and less tense than with the modern instrument. The wood of the viol was thinner throughout, the sides were much deeper, and, perhaps most characteristic, the back was flat rather than being arched and the shoulders were sloped.[9] In all periods, however, some

---

[8] <u>Ibid</u>., 374.

[9] Gerald Hayes, "Viol," <u>Grove's Dictionary of Music and Musicians</u> (5th ed.; London: Macmillan and Co., Ltd., 1954), VII, 803.

specimens contradicted one, some, or most of these characteristics.

Other early stringed instruments played with the bow were the Welsh crwth, the rebec and the pochette. The crwth had the appearance of a lyra or a small harp, but was played with a bow. The origin is not known, but it was still being used as late as the nineteenth century in Wales.[10]

The rebec was a pear-shaped viol which was held to the breast rather than between the knees as was the case with other viols. The body was carved from a solid piece of wood, and the top was a flat piece, glued in place. Visually it appears similar to the lute in construction.

The pochette, or "kit," is believed to be a more refined form of the rebec. It was known as early as the first half of the sixteenth century, and may have been older. By the eighteenth century it had taken on the form of a small violin, and was known as _Tanzmeistergeige_ ("Dancing-master's fiddle"), or pochette, since it could be carried in the pocket. In the Rococo period the design of the instrument was such that the bow could be placed inside the instrument for additional convenience in transport.[11]

---

[10] Sachs, 268.

[11] Karl Geiringer, _Musical Instruments; Their History in Western Culture from the Stone Age to the Present Day_, trans. Bernard Mialle (2nd ed.; London: George Allen and Unwin, Ltd., 1945), 157.

Viols were built with indentations at the waist as early as the twelfth century in order to facilitate bowing, although unwaisted varieties were still being built in the fifteenth century, showing that there existed no direct line of evolution; several types existed contemporaneously, and the varieties were intermingled.[12]

The members of the violin family suddenly assumed their present shapes--with comparatively shallow sides, arched back and narrow neck (but with only three strings)--about 1530, or soon after the birth of Palestrina and the death of Josquin des Pres.[13] However, only one or two violins have survived which were made prior to 1550, and in the case of these instruments, the exact dates and makers are not known.[14] One theory is that the viola evolved first, followed by the violin and cello. Evidence does not seem to substantiate this theory, however. A fresco in Saronno Cathedral, painted about 1535-1536, shows a violin, viola and cello in the same scene, leading one to the belief that all three were in use at that date.[15]

The question of the identity of the inventor of the violin has long been the subject of controversy. At one time it was thought that a viol maker named Gaspard

---

[12]Sachs, 227.

[13]Boyden, 3.

[14]Boyden, 6.

[15]Boyden, 15 and plate 1.

Tieffenbrucher (or Duiffopruggard or Duiffobruggard) was the inventor, for several inlaid violins bearing his name and dates of about 1520 were in circulation in the nineteenth century. It was discovered, however, that these instruments were actually forgeries made by the French maker, J. B. Vuillaume, whose records were made public after his death.[16]

The term, "violino," first appears in 1538 in the official records of Pope Paul III (1534-1549), who brought "violini Milanesi" (violinists from Milan) with him to a peace conference in Nice in June of that year.[17] It is interesting to note that Milan is in the same area of Northern Italy as are Brescia and Cremona, where so much of the development of the violin occurred.

Fully developed violins with four strings were in existence by the middle of the sixteenth century, for such instruments are described in detail and painstakingly differentiated from viols in a work of 1556 by Jambe de Fer, called Epitome Musical.[18] De Fer indicates that at that time viols were played by gentlemen, whereas violins were used by professionals in leading dancing. The violins were tuned in fifths because that interval is easier to hear and

---

[16]William Henley, Universal Dictionary of Violin and Bow Makers (5 vols.; Brighton, England: Amati Publishing Company, Ltd., 1959), II, 80.

[17]Boyden, 26.

[18]Boyden, 31-32.

tune than is the fourth. Apparently the additional resonance gained by tuning in fifths was either not recognized at this time, or dismissed as being unimportant.

Gasparo Bertolotti, known as Gasparo da Salo, as he indicated on his label, was born in Salo in 1542, and died in Brescia, where he practiced, in 1609. Da Salo was credited with the origin of the violin for some time because of the fact that he produced both violin and viol forms. But with the knowledge that three-stringed violins were in existence about 1530, it would seem that the Brescian master could not have produced the first ones twelve years before his birth.[19] Gasparo seems to have produced many more violas than violins, a fact which has contributed to the theory stated previously that the viola was developed earlier than was the violin. The larger production of violas was due to the purely functional fact that singing voices were relatively low in pitch by modern standards, so it was natural that the instrument which more closely approximated the voice would be in greater demand.[20]

Andrea Amati's birth and death dates were accepted as being 1523 and 1611 until recently. On the basis of the discovery of official documents which name his sons as his heirs in January of 1580, Boyden feels that Amati was born not later than 1511, and died before 1580. Amati would,

---

[19]Boyden, 19.

[20]Boyden, 33.

then, have the proper dates to have been a possible originator of the violin form.[21] In any event, this master is accepted as being the founder of the Cremona center of violin making, just as Gasparo da Salo is accepted as being the father of the Brescian school.

The work of Giovanni Paolo Maggini (1580-1630) a student of Gasparo da Salo, indicates a continuation of the same style with revisions and improvements. The productions of the Brescian makers of this period have a rugged appearance with blunt corners and long sound holes which are often rather wide open. The patterns are large and broad.[22] Dimensions and graduations of Gasparo da Salo and several other Italian makers will be found in Chapter II.

The fittings and appliances of the violins in their first two hundred years differed from those of today. The neck was shorter and was not mortised into the neck block, but was instead glued to the outside of the instrument and affixed there by three or four nails driven from the inside of the instrument through the block and into the base of the neck. This practice dated from the earliest instruments and was continued until about 1800.[23] The neck was

---

[21] Boyden, 19.

[22] Heron-Allen, 73.

[23] W. Henry Hill, et al., Antonio Stradivari; His Life and Work (2nd ed.; New York: Dover Publications, Inc., 1963), 188.

set in such a way that its top surface was approximately on a level with the edge of the upper plate, the necessary angle being achieved by the insertion of a wedge of wood between the neck and the fingerboard.[24] The bass bars of the old instruments were smaller in every dimension than those of modern instruments. Practically all of these instruments have had their necks lengthened and mortised into the body of the instrument and have had the bass bar removed and a new one inserted in order to withstand the increased pressure of the strings brought about by the increased angle of the neck, the higher bridge, and the rise in standard musical pitch.

Following Andreas Amati in Cremona were his sons, Antonius and Hieronymus. The son of Hieronymus, Nicholas Amati (1596-1684), is considered to be the best maker of the Amati family. It was to him that Antonio Stradivari (1644-1737), was apprenticed. Stradivari was an excellent craftsman and is considered the non plus ultra of violin makers.

Several makers of the Guarneri family are considered to be first-rank artists too, culminating in Joseph Guarneri, called "del Gesu," because of the device on his labels which included a cross and the letters, "IHS."

Carlo Bergonzi (1718-1755) incorporated features of both Stradivari and Guarneri and also worked in Cremona. At one time he was thought to have been apprenticed to

---

[24] *Ibid.*, 202.

Stradivari, as he took possession of Stradivari's tools some time after his death. This view was taken even by authorities such as the Hill family of London.[25] However, in a later work they re-refute their earlier statement and state that Bergonzi was apprenticed to the father of Guarneri del Gesu, that is, Joseph Guarneri, son of Andrea.[26]

Nicholas Lupot (1758-1824) was an excellent craftsman who worked in Paris and is known as the "French Stradivarius." Another Frenchman, Jean Baptiste Vuillaume (1798-1875), was one of the most celebrated makers of the nineteenth century. He specialized in copying the Italian makers and apparently did so with fraudulant intent at the beginning of his career, as evidenced by the "Tieffenbrucher" forgeries mentioned earlier.

After the passing of the great Italian violin makers, later generations, recognizing the excellence of the productions of these makers, began trying to rediscover precisely what it was that made them superior. The first and most obvious theory was that the adjustments of the thicknesses of the top and back were of paramount importance.[27]

---

[25]W. Henry Hill, et al., Antonio Stradivari; His Life and Work (2nd ed.; New York: Dover Publications, Inc., 1963), 86.

[26]William Henry Hill, et al., The Violin Makers of the Guarneri Family (3rd printing; London: Holland Press, Ltd., 1965), 60.

[27]W. Henry Hill, et al., Antonio Stradivari; His Life and Work (2nd ed.; New York: Dover Publications, Inc., 1963), 183.

It is not difficult to demonstrate that leaving the wood too thick in a violin will produce an instrument whose tone is pinched and nasal, lacking in body and projection. The same violin regraduated to normal dimensions will produce a reasonably satisfactory instrument. If the instrument is worked too thin the tone will sound loud near the player, but will not project. Frequently "wolf-tones" (i.e., tones which warble from one pitch to another) will be a result.

Violin makers of the nineteenth century began attempting to reproduce the fine violins by duplicating the graduations of the older makers, on the assumption that copying the dimensions would reproduce the quality of a given instrument.[28] Although this met with a certain amount of success (for the reproductions of makers such as Lupot and Vuillaume are held in high regard now), it was nevertheless felt that the efforts produced instruments which tonally fell short of the standard set by the Italians, so other elements were sought as being potentially the "lost secret" of Cremona.

One of the more popular methods involved tapping the front or back of the violin to determine its fundamental frequency, or "tap-tone." A related method involved application of a rosined bow to the edge of the plate, taking the pitch thus produced as being the frequency of the plate.

---

[28] Heron-Allen, 83.

Recently a refinement of the tap-tone method, called "microtone" was introduced--the difference being that the area of the plate vibrated was much smaller than in the earlier method. Another method upon which some research has been carried out is one in which the plate is set into vibration using a contact speaker and electronic amplifiers, microphone and sound meter. Each of these will be discussed in detail in later chapters.

CHAPTER II

A SURVEY OF THE METHODS OF GRADUATION OF VIOLIN PLATES

Methods Involving Measurement

The methods published and commented on in journals and books for arriving at the final thicknesses of the tops and backs of violins fall into two large categories: that which involves simple measurement with calipers, and that involving manipulation of the natural vibrating resonance points of the plates. Of these, the first category is far more prevalent. One of the problems encountered, however, is that of determining which sources of information are reliable and which sources must be dismissed, either wholly or in part, because of inaccuracy of information. One example found in a widely accepted volume is a conflict between the text and the plate given as the model from which the violin is to be constructed. The text refers to the violin as having a length of fourteen and one-eighths inches and gives instructions and other figures based on that length, but the plate referred to has a length of only thirteen and seven-eighths inches, or one-fourth inch shorter.[1,2]

Published graduation diagrams usually are in the form of a full-size outline of the violin upon which the prescribed thicknesses are represented, separated by lines similar to those on a topographical map, which are meant to show where the thicknesses merge into one another. Since different systems of measurement are used in the various sources of information about violin graduation a table of conversion is included in order to make comparison easier (Table 1).

The Heron-Allen work has been the standard textbook of violin making since 1882. Edward Heron-Allen (1861-1943) was an amateur who studied violin making with Georges Chanot, son of the celebrated Georges Chanot of Paris, under whose guidance he made two violins, one on a Stradivarius pattern and one on a Guarnerius pattern.[3] After completing these instruments, he wrote an account of the procedures in serialized form, which was published in the journal Amateur Work Illustrated from 1882 through 1884. After adding a section on the history of the violin, he published his work

---

[1]Edward Heron-Allen, Violin Making as It Is and Was (2nd ed.; London: Ward, Lock and Company, Ltd., 1885), 253.

[2]Heron-Allen, Plate IV.

[3]William Henley, Universal Dictionary of Violin and Bow Makers (5 vols.; Brighton, England: Amati Publishing Company, Ltd., 1959), I, 21.

in book form in 1884 and again in a revised and corrected edition in 1885.

TABLE 1

MEASUREMENTS COMMONLY USED IN VIOLIN GRADUATIONS

Sixty-fourths of an Inch	Conventional Fractions	Decimal Equivalents	Millimeters
-	-	.0393	1
3	-	.0468	1.19
-	-	.0590	1.5
4	1/16	.0625	1.58
5	-	.0781	1.97
-	-	.0787	2
6	3/32	.0937	2.38
-	5/48	.1041	2.64
7	-	.1093	2.76
-	-	.1181	3
8	1/8	.1250	3.17
-	-	.1377	3.5
9	-	.1406	3.75
10	5/32	.1562	3.96
-	-	.1574	4
11	-	.1718	4.36
12	3/16	.1875	4.76
-	-	.1968	5
-	7/40	.1999	5.07
-	1/5	.2000	5.08
13	-	.2031	5.15
14	7/32	.2187	5.55

The book gives two series of graduation diagrams. The first series, given in Figs. 1 and 2, is described as being an average of excellent old violins.[4]

The thickest part of the back is in a heart-shaped area in the center of the place encompassing an

[4]Heron-Allen, 141.

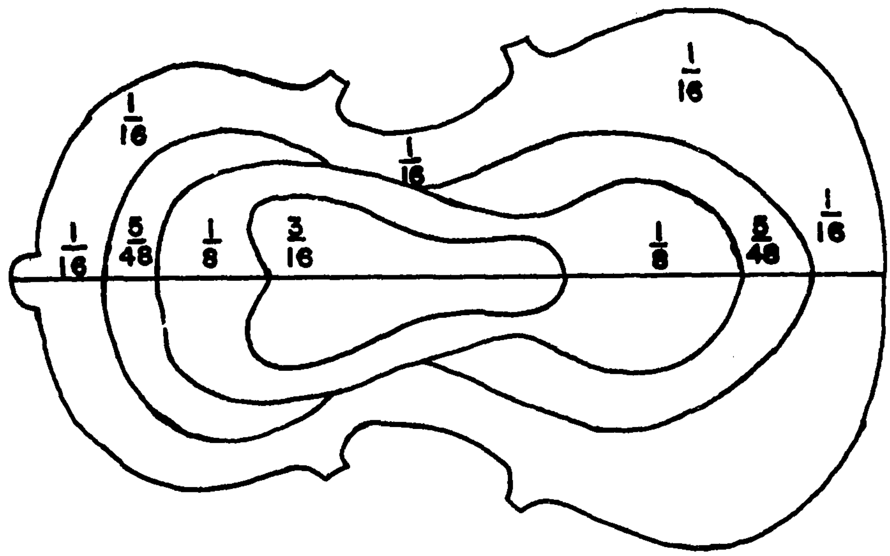

Fig. 1.--Heron-Allen diagram of graduations of old backs, given in fractions of an inch.

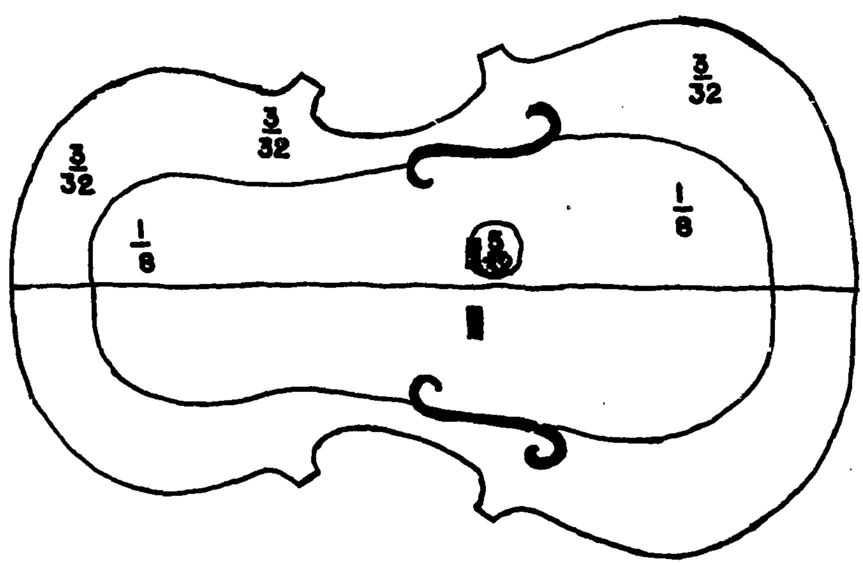

Fig. 2.--Heron-Allen diagram of graduation of old tops, given in fractions of an inch.

area of more than one-third of the length of the plate and nearly half the width of the plate in the areas it covers. It is represented as being 3/16 of an inch thick in this central area, graduating down to a thickness of 1/16 all the way around the edge of the plate including the ends and waist.

In Fig. 2 the top is shown as being 1/8 of an inch thick in the largest part of the center area, being bounded by the sound holes on the sides and carried almost to both ends of the plate with the exception of the area where the sound post stands, which is 5/32 thick. All the way around the edges, including the ends and waist, it is said to be 3/32 thick.

Heron-Allen recommends that the thicknesses be varied according to the properties of the wood. The closer the grain and the harder the wood, the thinner the violin maker must leave the plate in order to achieve good results, but the caution is given that it is better to err on the side of excess material than to leave insufficient wood.[5]

The second set of thicknesses given by Heron-Allen is said to be the correct thicknesses for a newly made violin.[6] The implication seems to be that shrinkage of the wood after manufacture is expected, making it necessary to

---

[5]Heron-Allen, 140.

[6]Heron-Allen, 248.

have a different set of graduations for a new instrument, even though wood used in violin manufacture is aged until it is stable.

Fig. 3 shows the diagram given for preliminary gouging of the back.[7] The thickest part is in the center of the back, graduating in this case toward the ends, with the edges of the waist being thicker than the ends.

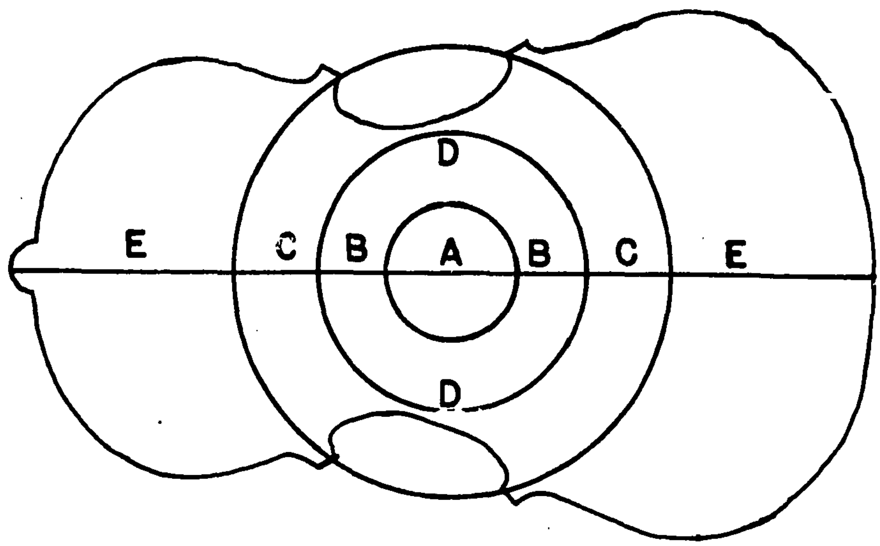

Fig. 3.--Heron-Allen diagram for preliminary regulation of thickness of the back.

The diagram of the final thicknesses for a new back is given in a separate diagram, shown here in Fig. 4. The text gives the final thicknesses at point A, 7/40 of an inch; at B, 1/5; at C, a shade thinner than at A; and at the points D, 9/64.[8] (The unconventional units of measurement

---

[7]Heron-Allen, 255.

[8]Heron-Allen, 248.

used by Heron-Allen are included in Table 1). The directions are that the wood will be left slightly thicker in the upper than in the lower ends, and similarly slightly thicker at the point where the sound post rests.

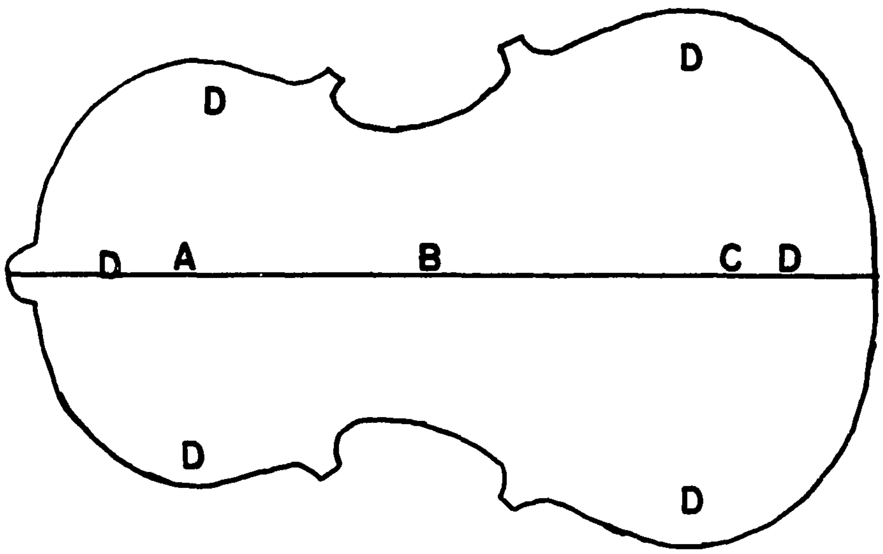

Fig. 4.--Heron-Allen final thicknesses of a new back.

The final diagram in Heron-Allen is for the thicknesses of the top of a new violin, shown below in Fig. 5. Material relating to the placement of the bass bar is deleted from this figure. The dimensions given are: at the center (points A), 9/64 of an inch, thinning to about 6/64 at the edges marked C, but slightly thicker at the area of the sound post, B.

Several graduation diagrams are given in the Jalovec book, two typical examples of which are represented as having been taken from a Guarnerius del Gesu of 1739 and a Gasparo da Salo.

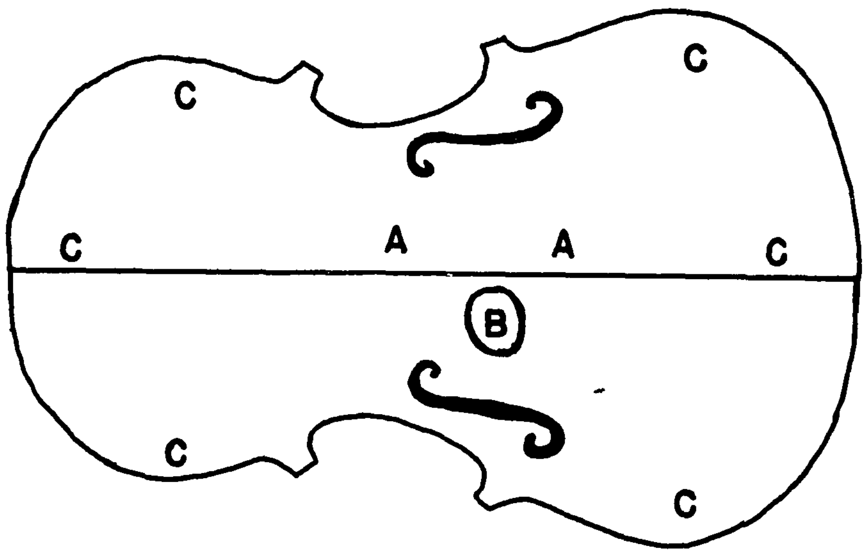

Fig. 5.--Heron-Allen final thicknesses of a new top.

The Guarnerius is shown having the thickest part of the back at the center joint in line with the sound post and is 5 millimeters (hereafter abbreviated "mm") over an area the diameter of which is as large as the distance from the center of one bridge foot to the center of the other, or about 1 1/4 inches.[9] Lines are given which generally follow the outline of the plate and represent progressive diminution of the thicknesses until 2 mm is reached all the way around the plate, including the edge of the waist. The thickest portion of the top is 4 mm centered on the bridge,

---

[9]Karel Jalovec, Italian Violin Makers (Rev. ed; London: Paul Hamlyn, Ltd., 1964), Plate IX.

and the graduation progresses in the same manner until a thickness of 2 1/2 mm is reached all around, including the wings of the sound holes.

The Gasparo da Salo back is represented as having a thickness of 5 mm centered over the center joint in line with the post, graduating in concentric circles down to 2 1/2 mm in the ends.[10] In the area of the edges of the waist the thickness is 3 mm. The top is represented as being 4 mm in an area centered at the bridge, and graduating in the same manner to 2 1/2 mm in the ends. The wings of the sound holes are 3 mm.

Instructions which vary a great deal from the above are given by Batts.[11] The top (Fig. 6) in this case follows to geometrical pattern but, instead, dimensions are given for areas of the plate. The thickness recommended is an even 2.5 mm over most of the plate, but is slightly thicker in the area of the sound holes (2.9 mm), and tapers to a thicker dimension next to the edges leading to the increased substance of the edges. The taper begins about 15 mm from the edge of the plate. The author recommends that the area of the soundpost be left about .5 mm thicker than the surrounding area for the sake of added strength and indicates that no tonal harm will result.

---

[10]Karel Jalovec, Italian Violin Makers (Rev. ed.; London: Paul Hamlyn, Ltd., 1964), Plate V.

[11]Jack Batts, "The Arching of Plates," The Violin Makers Journal, V (Feb.-Mar., 1962), 14.

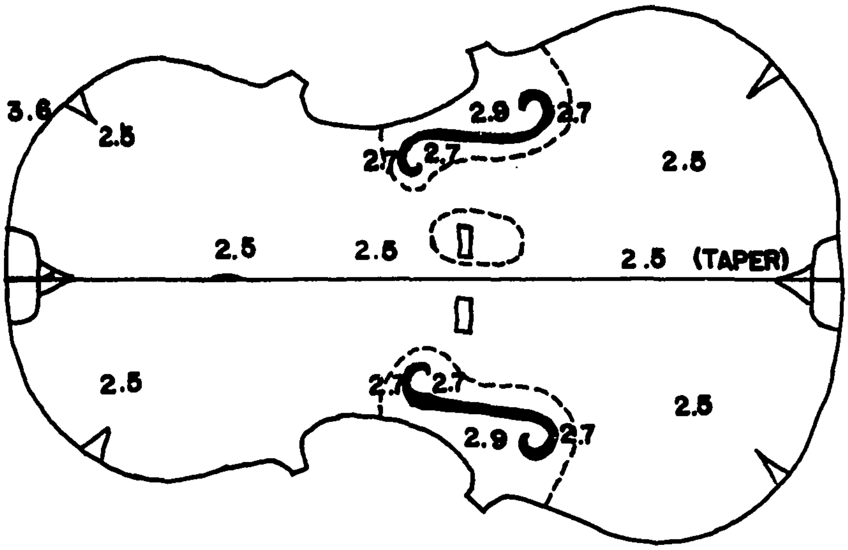

Fig. 6.--Batts top graduation diagram, given in millimeters.

For the back Batts recommends that the thickest area be at the center joint in line with the sound post. The dimension at this spot is to be 4.5 mm in a small area, graduating in a circular pattern down to the thinnest areas (2.3 mm) which are located at both ends of the plate (Fig. 7).

Two graduation diagrams recommended by Carleen Hutchins are intended as approximations with the final thickness of the plates being determined electronically, utilizing a system which will be discussed later.[12] Although these diagrams were intended for the viola, they are of some interest because this is the only instance in which

---

[12]Carleen Hutchins, "Tuning Top and Back Plates Electronically," Catgut Acoustical Society Newsletter, VI (November, 1966), 15.

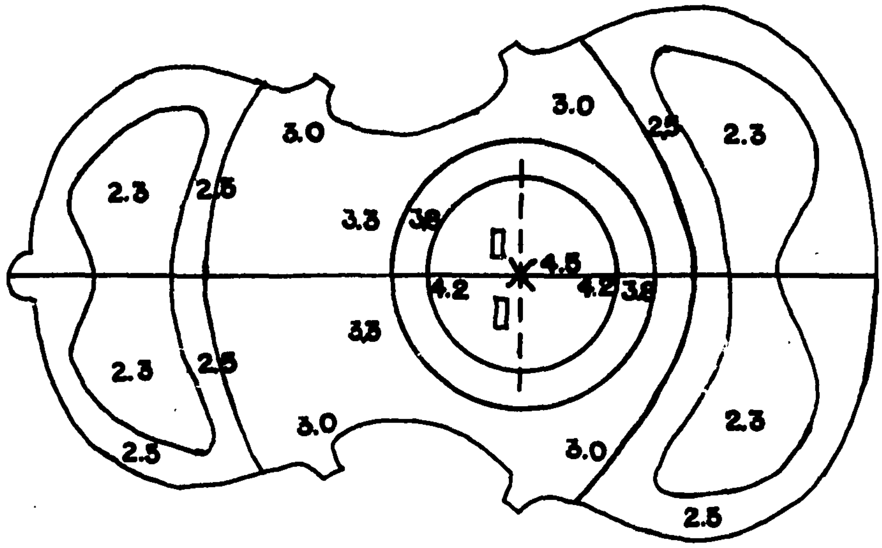

Fig. 7.--Batts back graduation diagram, given in millimeters.

an author refers to different characteristics of sound being obtainable through the use of different types of graduation of the back of the instrument. Patterns are not given for the top in this article. Fig. 8 shows the characteristics of the pattern used to produce a "dark" tone quality. The entire central area is left thick, from 4 to 5 mm, with an abrupt slope at about the location of the corner blocks leading to thin upper and lower parts of the plate, from 2 to 2.5 mm in the upper and 2 to 3 mm in the lower part.

In the second pattern (Fig. 9) the thickest portion is in the center, where it is 4 to 5 mm, graduating to 2 mm in the ends of the plate. The slope in this case is gradual. This method is said to produce a "brilliant" tone in an instrument.

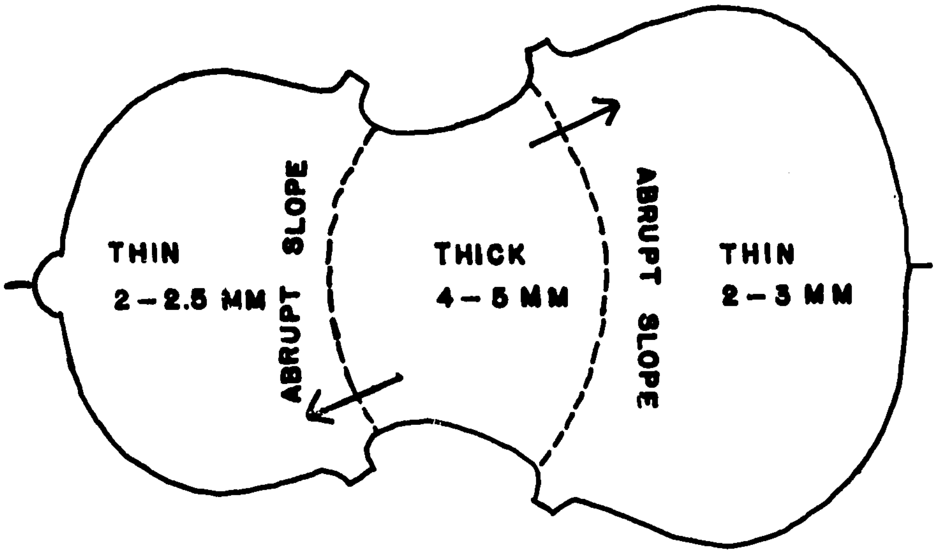

Fig. 8.--Hutchins "dark" tone diagram, given in millimeters.

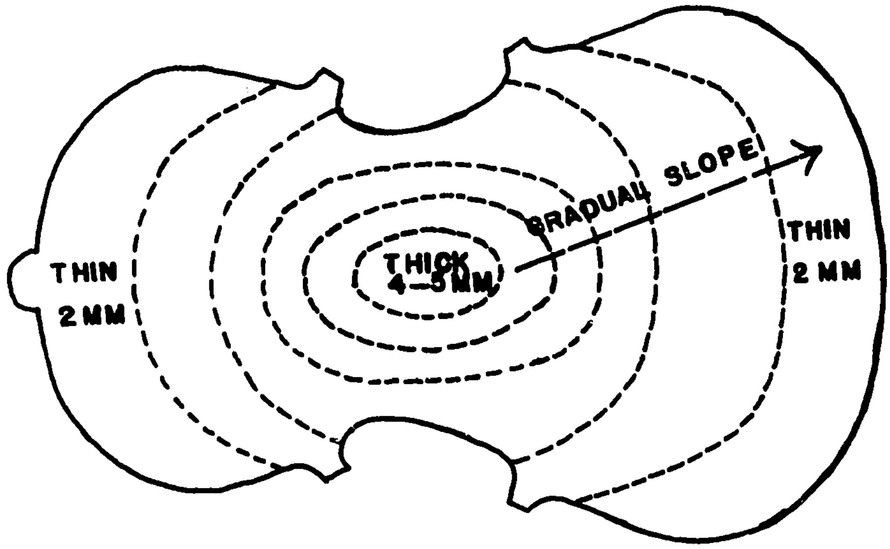

Fig. 9.--Hutchins "brilliant" tone diagram, given in millimeters.

Several sources give only verbal dimensions without recourse to pictorial diagrams. E. H. Sangster offers the following thicknesses: top, 6.5/64 (13/128) of an inch in the center and 6/64 at the purfling; back, 10/64 in the center to 6/64 at the purfling.[13] In a later article the same author gives a slightly different set of graduations, the center thickness of the top being increased to 7/64.[14] All other dimensions remain the same as were given in the earlier article.

The William E. Hill Company of London, in continuous business for two centuries under the leadership of the same family, has over the course of time examined, repaired and adjusted most of the finest Italian instruments. Besides being makers and dealers, members of the family have from time to time published works about several of the more well-known Italian makers. Although these works discuss the makers and their instruments mainly as historical or art objects, some information pertinent to the subject is contained within their works. The Hill book on Stradivari gives some observations on graduation:

> If we take the interior construction and examine more especially that important point--the thicknesses of the backs and bellies--we find that the principles left to us by Stradivari are those of Gasparo [da Salo]

---

[13]E. H. Sangster, "Fifty years of Violin Making," The Violin Makers Journal, I (July, 1958), 5.

[14]E. H. Sangster, "Forty Years of Violin Making," The Violin Makers Journal, IV (March, 1961), 9.

> plus the result of a gradual progression, in which Maggini and the Amatis had a large share.[15]

The thicknesses of the backs of Maggini's instruments are said to vary from 1/8 to 11/64 of an inch in the center, diminishing to 5/64 at the extremes of the flanks. The tops vary from 7/64 in the center, diminishing to 5/64 and 1/8 at the flanks. In the five violins of the Amati family which are discussed the thicknesses of the backs vary from 10/64 to 12/64 of an inch in the center, and diminish to 4/64 at the flanks. The tops vary from 6/64 to 1/8 in the center, graduating to from 4/64 to 6/64 at the flanks. In one example the top is an even 7/64 all over.[16]

Thicknesses of eighteen violins made by Stradivari are also given. The backs in the center vary from as little as 9/64 of an inch to as much as 14/64 with one example given as 1/4 of an inch. At the flanks they vary from 5/64 to 7/64, and in one case, 1/8 of an inch. When the dimensions of the extremes of the flanks are given, they are invariably the thinnest. Generally the thickest backs are the earlier ones, although 10/64 and 11/64 are dimensions common to all periods. Dimensions of the tops vary from 1/8 to 5/64. When separate dimensions are given for the center and the flanks, the flanks are always thinner. In

---

[15] W. Henry Hill, et al., Antonio Stradivari; His Life and Work (2nd ed.; New York: Dover Publications, Inc., 1963), 183.

[16] Hill, Antonio Stradivari, 184.

five cases the tops are said to be the same thickness all over, and in all of these cases the dimension is 6/64. Only two examples are said to diminish to the flanks. In these cases the taper is of 1/64 of an inch, one being from 1/8 to 6/64 and the other from 7/64 to 6/64. Both of these are early examples from the 1680 decade. In the remaining eleven examples two dimensions are given and the thicknesses are said to vary from one to the other, presumably as the result of unevenness. The two exceptions to this are from the year 1736, the year before Stradivari's death, and 1704. The first example varies between 1/8 and 6/64 of an inch; the second, between 7/64 and 5/64. In the violins with graduating dimensions, the taper is between either 5/64 and 6/64 or between 6/64 and 7/64 of an inch.

Thicknesses of eight violins of Joseph Guarneri del Gesu are given in the Hill book about that maker.[17] Dimensions are given at the center of the back, the area of the post and the flanks. Five of the examples measure 12/64 of an inch in the center, one 11/64 and two 10/64. Three of the examples which are 12/64 in the center are still 12/64 at the post, whereas the other two have reduced to 11/64. The example which is 11/64 in the center is the same dimension at the post. The two violins measuring 10/64 at the center are thicker at the post: 13/64 in each case.

---

[17]William H. Hill, et al., Violin Makers of the Guarneri Family (2nd ed.; London: Holland Press, Ltd., 1965), 159.

Both of the latter are from 1742, two years before the master's death. Dimensions at the flanks vary widely from 10/64 to 6/64. The tops vary from 6/64 to 8/64 of an inch, the dimension being applied to the whole plate, except in two cases, where the extremes of the flanks are less; in both cases from 8/64 to 6/64. Guarneri del Gesu was a less meticulous workman than Stradivari; consequently his work shows more variation than that of Stradivari.

The detailed measurements of a violin made by Gasparo da Salo, about the year 1580, appear in the five volume work by Henley. The thickness of the top by the bridge is between 2.8 mm and 3 mm; between the bridge and lower block, 2.8 mm; between the bridge and upper block, 3 mm; upper cheeks, 2.1 mm; lower cheeks, 2.2 mm; near the edge, 2.6 mm to 2.8 mm; by the upper and lower curves of the sound holes, 3.1 mm to 3.4 mm. The back at the middle, 4.3 mm; by the sound post, 4.1 mm; between the post and lower block, 3.4 mm; upper part, 2.7 mm; lower part, 2.7 mm; near the edge, 2.5 mm.[18] Resonance points of the top, back, and the air contained within the instrument are also given. This will be referred to later in this chapter where more direct application will be made. Henley also gives the graduations of a violin made by Nicolo Amati in 1648. The back is 10/64 of an inch in the center diminishing to 5/64

---

[18]William Henley, Universal Dictionary of Violin and Bow Makers (5 vols.; Brighton, England: Amati Publishing Company, Ltd., 1959), II, 189.

at the ends. The top measures 7/64 at the center and 5/64 at the extremes.[19] The description of the Gasparo da Salo violin is complete enough to derive a diagram of the thicknesses of this instrument. (Fig. 10).

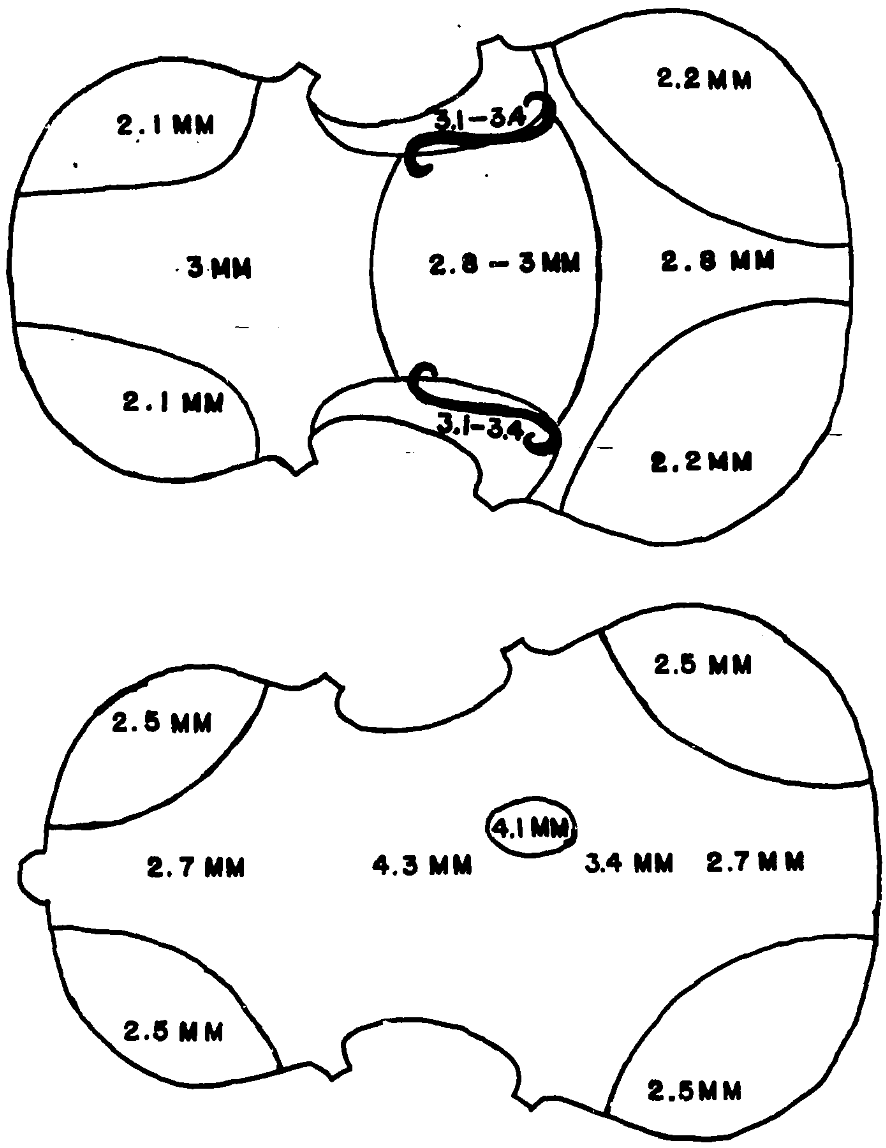

Fig. 10.--Henley dimensions of Gasparo da Salo violin of 1580, given in millimeters.

---

[19]Henley, I, 30.

Two unique sets of diagrams, each plate of which contains nearly five hundred caliper readings, were provided for the present study by Mr. Eugene Knapik, a violin maker in Chicago, and were authenticated by him as having been taken from the master instruments indicated in each case. The first of these is the DeRougemont Stradivarius of 1703, which Hill refers to as being a "fine example."[20] The back (Fig. 11) is thickest in the center, or more specifically, 47% of the length of the plate from the upper edge, and covers an area of no more than 3/8 of an inch in width and 1 inch in length. At this spot the thickness is 4.5 mm. At the edge of the waist the thickness has diminished to between 3.4 and 3.6 mm. Between the center and the upper block the thickness has reduced to 2.6 mm and in the corresponding position toward the lower block, 2.4 mm. In the upper and lower extremes the thickness is between 2.2 and 2.3 mm. A tendency to taper can be seen toward the edges, where after being thin, the substance has increased. This is also present at the ends near the upper and lower blocks, tapering out farther than at the edges. No particular thickening is seen under the post.

The top (Fig. 12) is less even than the back in its thicknesses. It is between 2.5 and 2.7 mm (predominantly the latter dimension) in the area between the sound holes with the post area .1 mm thicker than the surrounding area,

---

[20]Hill, <u>Antonio Stradivari</u>, 50.

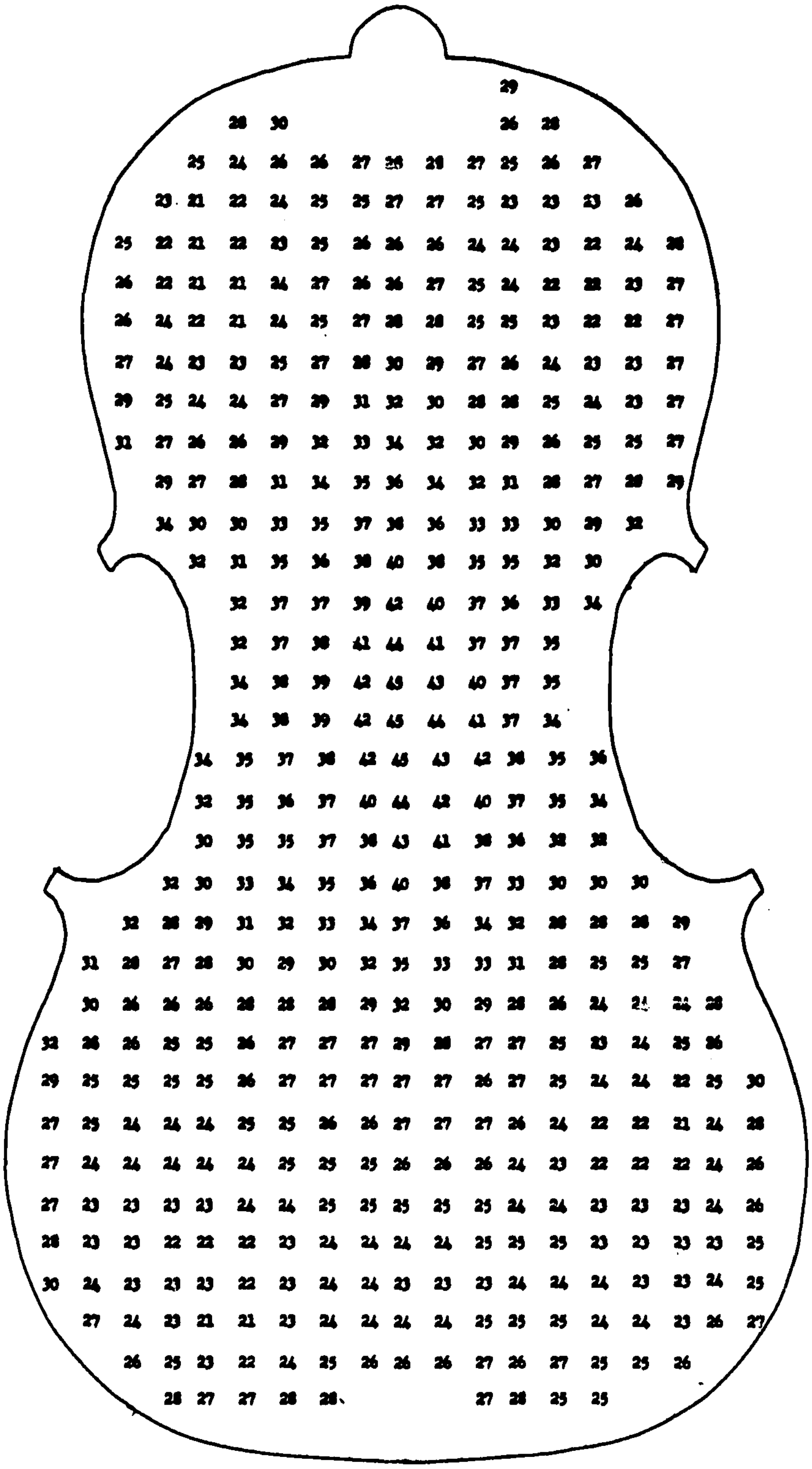

Fig. 11.--Dimensions of back of 1703 Stradivarius violin, "DeRougemont," given in tenths of millimeters.

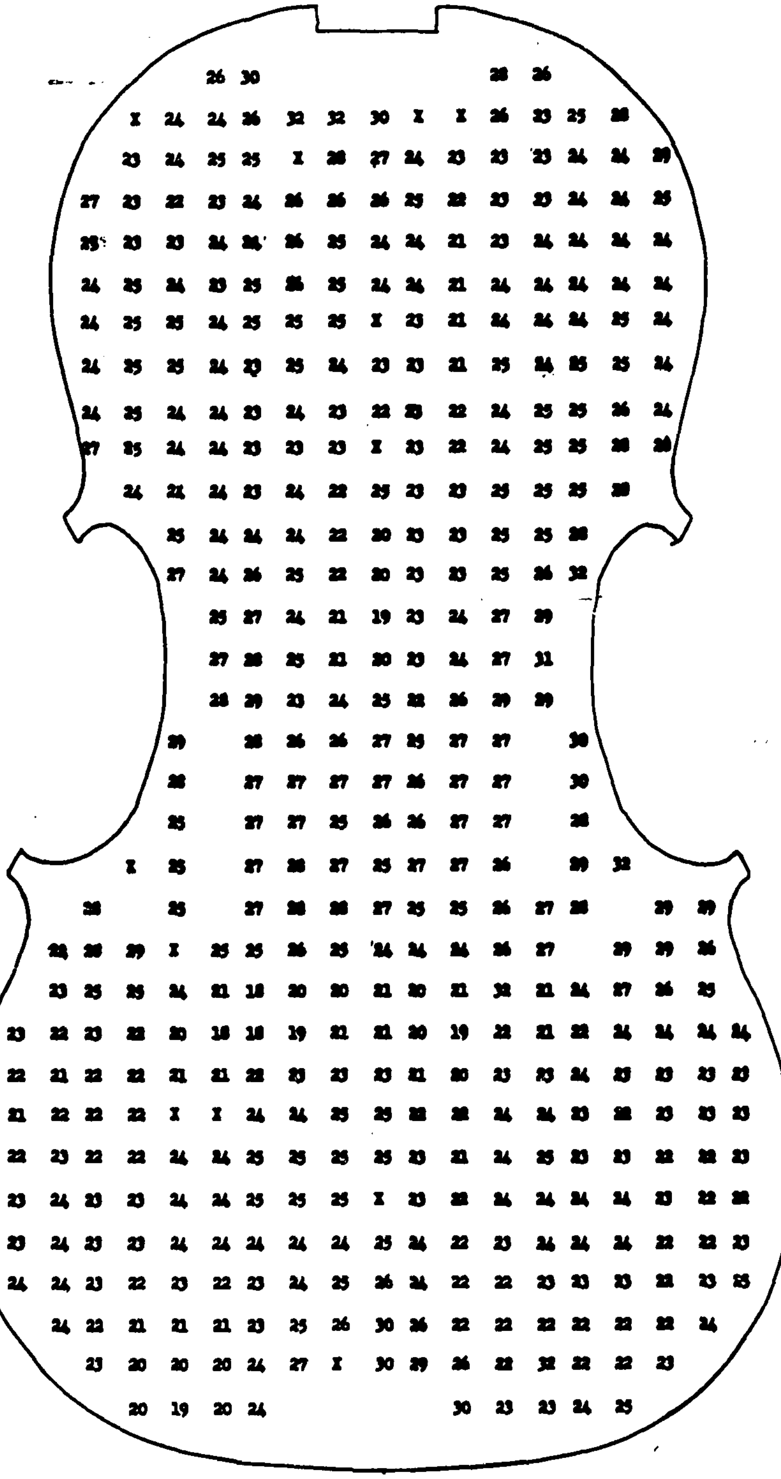

Fig. 12.--Dimensions of top of 1703 Stradivarius violin, "DeRougemont," given in tenths of millimeters.

or 2.8 mm in thickness. The wings of the sound holes are between 2.5 and 3.0 mm, the thicker dimension being on the bass side. The dimensions reduce to 2.5 mm in the upper and lower ends, with 2.4 mm being reached in the upper extremes and 2.3 mm in the lower extremes, with a tendency to thicken to 3.0 at the upper and lower blocks. The thinness along the line of the bass bar is probably due to that part having been removed and replaced repeatedly.

The second violin is an unnamed Stradivarius made in 1682 (Fig. 13). The back is thickest in the same area as that of the 1703 example. At this spot it is 4.6 mm. It shows a tendency to remain thick under the post, being 4.5 mm at this spot. At the edge of the waist on the treble side, it is between 3.0 and 3.2 mm. On the bass side it is between 3.4 and 4.0 mm, excluding one thin area where it is 3.0 mm. The central strip, running from the upper block to the lower block, in only one spot is thinner than 2.8 mm, and shows a tendency to regain thickness toward the ends after thinning from the center. The extremes are between 2.6 and 2.9 mm.

Unfortunately Mr. Knapik could furnish only the lower half of the diagram of the top in this case (Fig. 14). The thickness of the top between the sound holes varies between 2.5 and 2.9 mm. On the treble side, between 2.4 and 2.8 mm. Moving toward the lower block, this plate shows a progressive thickening to 3.1 mm, with an additional

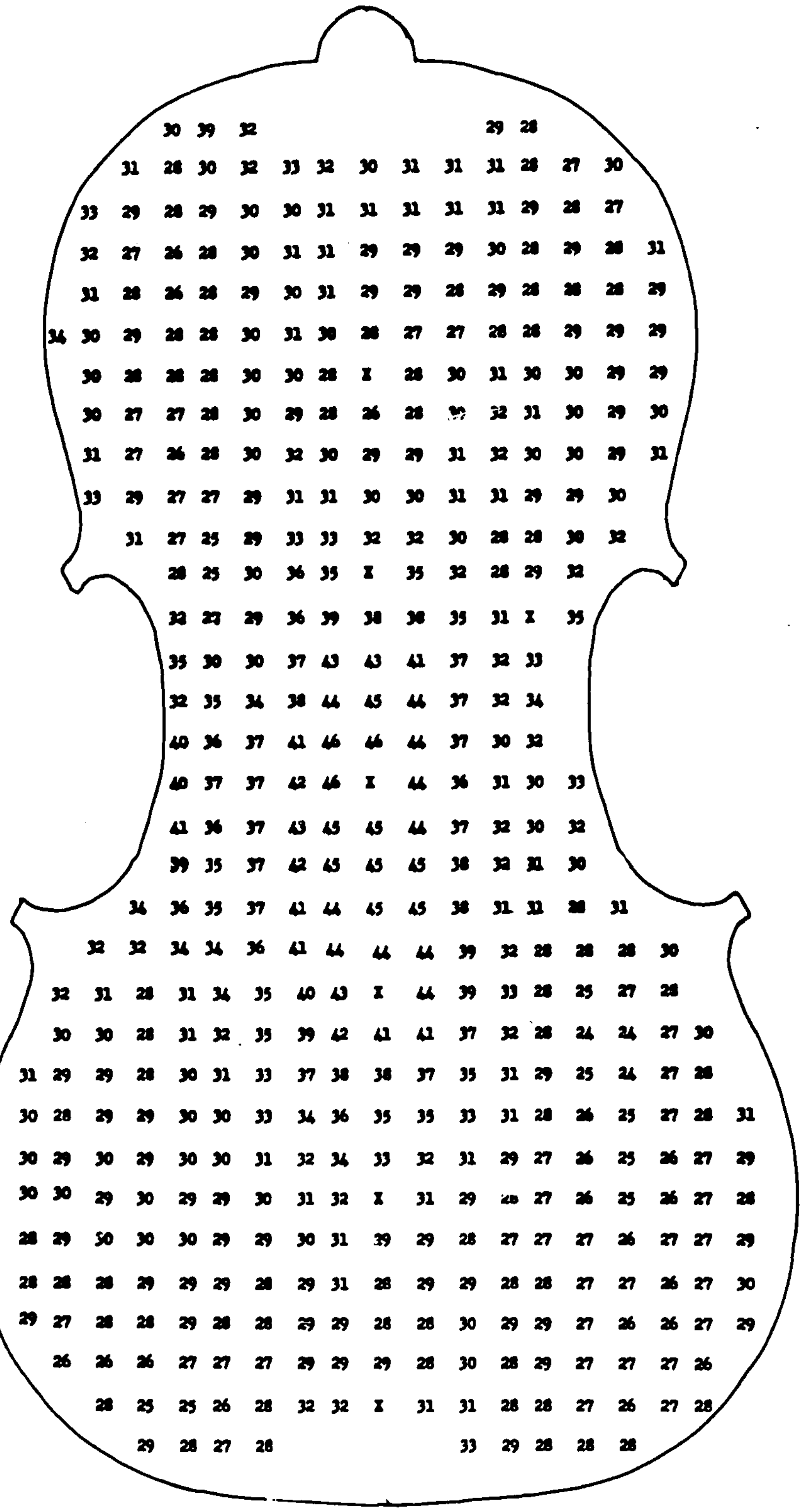

Fig. 13.--Dimensions of back of 1682 Stradivarius violin, given in tenths of millimeters.

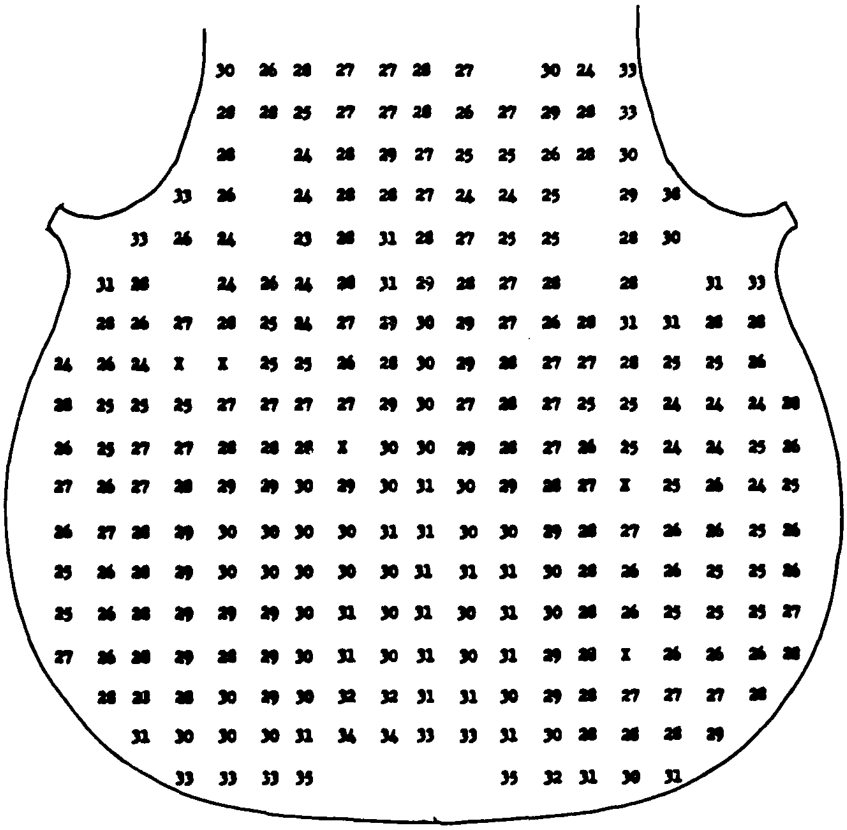

Fig. 14.--Dimensions of lower half of top of 1682 Stradivarius violin, given in tenths of millimeters.

taper to 3.4 next to the block. The extremes are thinner, from 2.4 to 2.6 mm, again tapering to the heavier substance of the edges.

By generalizing and dismissing minor variations in thicknesses, it is possible to produce diagrams of the same nature as previous examples, as shown in Figs. 15 and 16.

<u>Summary and Appraisal of the Patterns</u>

The diagrams given by Heron-Allen do not agree with the authenticated material in some aspects. The thinness of

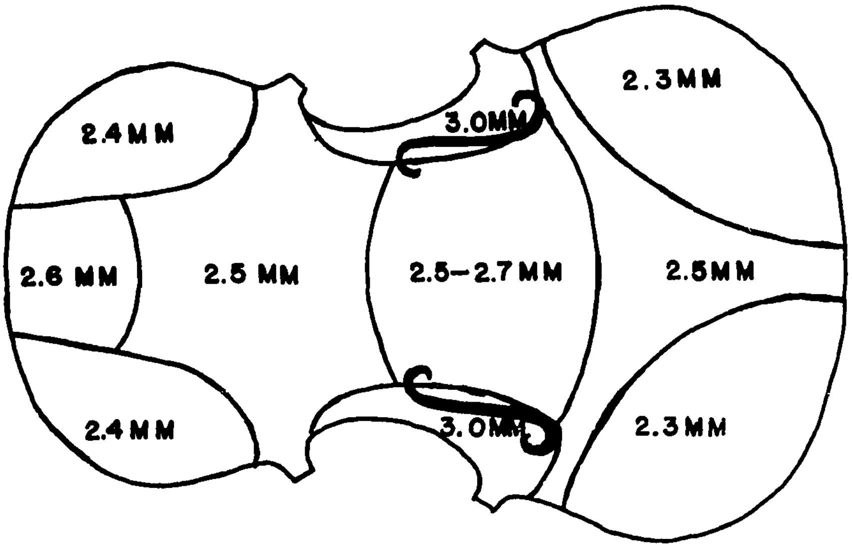

Fig. 15.--Pattern derived from 1703 Stradivarius violin top, given in tenths of millimeters.

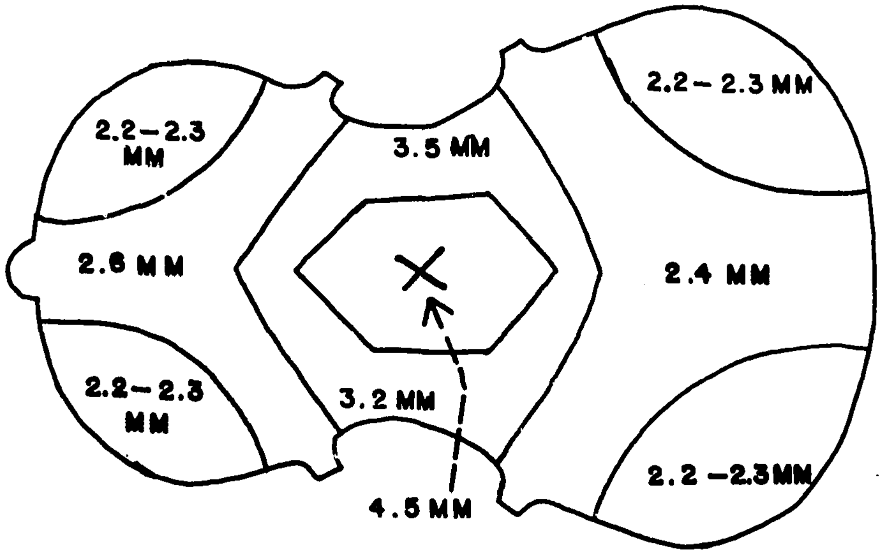

Fig. 16.--Pattern derived from 1703 Stradivarius violin back, given in tenths of millimeters.

the plates in the area of the edge of the waist seems to be the most noticeable difference, but the substance of the main portion of both top and back would produce a rather heavy plate in each case, because of the thick portions covering such a large area. His presentation of different thicknesses for new and old violins has been refuted by Mertzanoff and Westall, who have shown that shrinkage in these dimensions would be a maximum of no more than four percent, an amount hardly measurable, and unlikely to account for great differences in tone (although the possibility cannot be dismissed entirely).[21]

The back of the Gasparo da Salo in Jalovec's book shows some resemblance to the patterns of the Stradivarius violins, except for the position of the thickest portion. The back of the Guarneri diagram is similar to the diagram of Heron-Allen. Neither top agrees with the Stradivari diagrams or the Hill books.

It is not known whether or not there is any significance in the fact that the lower areas of the waist of both top and back plates are thinner on the treble side than on the bass side in both authenticated Stradivari examples. In other than this characteristic there is agreement between these samples and the principles of Henley's quotation of dimensions of da Salo in areas of relative thickness and

---

[21] C. E. Mertzanoff and J. Westall, "Thickness of Violin Plates, Old and New," <u>Violins and Violinists</u>, V (April, 1944), 474.

thinness. The example given by Jack Batts is also very similar, except for the location of the thickest area of the back. Both Hutchins examples are also similar. The dimensions given by Hill are so general that it is difficult to tell the extent of agreement. Terminology may be confusing in this case. If by "flanks" Hill means the extremes of the upper and lower ends, his dimensions agree with the authenticated examples. But on several examples the term "extremes" is used, which leaves the point open to question. If on those particular examples the term is taken to mean the portions of the upper and lower ends of the plates nearest the outer edges, the dimensions would seem to agree.

Methods Involving Tuning the Plates

Various methods have been advocated for arriving at the final thicknesses of a violin's plates by adjusting the fundamental frequencies of the top and the back. The principles of most of these are similar, the chief differences being the method used to determine the frequency and the pitches recommended.

In discussing the properties of materials for use in *violin* making, Heron-Allen relates experiments which have some interest in relation to methods involving the tuning of the plates.[22] Rods were made 7 3/4 of an inch long, 3/4

---

[22] Heron-Allen, 132.

broad and 1/5 thick from fragments of ruined Stradivarius instruments of various dates. The rods of maple, when struck, all gave an identical note, while the rods taken from the softer top wood all gave identically another higher note.

This experiment was repeated in substance and confirmed in principle by the present writer using ordinary maple and spruce, the customary materials used in violin making. The rods were the same length and breadth, but instead of being 1/5 of an inch in thickness, both were 3/16 thick. Each was suspended between thumb and forefinger 1 3/4 inches from the upper end, and tapped with a pencil at a point one inch from the bottom edge. The pitch emitted by the maple rod was A3, whereas that of the spruce rod was flat of E4, almost a perfect fifth higher. (Pitch name definitions are shown in Fig. 17.)

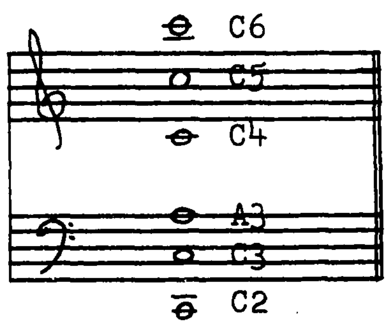

Fig. 17.--Pitch name definitions

The reason given for this phenomenon is that maple, being more dense than spruce, vibrates more slowly;

consequently in samples of the same mass and shape it produces a lower tone. If the top and back of a violin were the same thickness, the maple back, when struck or vibrated alone with the bow, would produce a lower note than the spruce top. The hypothesis is that the reason that the back is made thicker is to compensate for this effect, the recommendation being that the back be left a tone higher than the top. It is further indicated that an interval of less than a tone would produce an instrument with a throbbing tone and a larger interval would produce an even less satisfactory result.

The Tap-Tone Method

Heron-Allen mentions two methods of obtaining the fundamental frequency of the plate: the first by striking the plate, the second by drawing a bow along the edge of the plate, which has been clamped in a vise at a point where two nodal lines cross, determined by placing sand on the plate and bowing it, which causes the sand to collect at nodal points.[23] Further instructions indicate that the top, when finished, but without sound holes or bass bar, should produce the note, "C." Cutting of the sound holes should lower the note to "B," and the addition of the rough bass bar will raise the note to "D." Final trimming of the bar to its proper dimensions will again lower the pitch to the

[23] Heron-Allen, 133.

same note the top gave originally.[24] The pitch recommended for the back is "D."[25] No indication is given of the octave in which each of the recommended notes is to be found.

Gilbert takes issue with the method of deriving the pitch of the plate through the use of the bow, the reason being that it is unreliable due to the variety of pitches which can be evoked in this manner.[26] In its place, he suggests holding the plate by the edges of the waist with the thumb and forefinger, the plate being held with the upper portion down, and tapping about two and one-half inches from the edge nearest the floor. The present writer has duplicated the experiment of determining the pitch of the plate using the bowing method, and produced a variety of pitches. The pressure exerted upon the bow and the speed of travel of the bow seemed to produce more change in pitch than the removal of wood. The removal of wood from the center of the plate had little effect, although thinning the area near the edges altered the pitches produced somewhat.

When adjusting the plates using Gilbert's system, by reference to the tone produced by striking the plate, it is necessary to maintain a balance between the pitch of the tone (usually called the "tap-tone") and the weight of the

---

[24]Heron-Allen, 153.

[25]Heron-Allen, 249.

[26]Justin Gilbert, Cremona Violin Technique (Seattle: Lowman and Hanford Company, 1937), 10.

plate. The pitch of the back plate when finally adjusted should be between .83 and .875 of a major second higher than that of the top, the optimum being .85.[27] The top should be within .1 ounce of 2.5 ounces, and the back should be between 2.5 and 3.3 ounces when varnished. Reducing the thickness in the center of the plate is said to raise the pitch of the plate, whereas removal of wood from near the edges lowers the pitch.[28] Removal of wood from a certain area between the two extremes produces no change.

Plate frequencies for several master violins are given by G. Sanborn of Sweden.[29] Of twenty-six old Italian instruments, the pitch of the back is higher than that of the top in nineteen cases. Of these, the difference is a quarter tone in two cases, a semitone in five cases, three-quarters of a tone in three cases, and a full tone in one case. The same note occurs between the top and back in only one case. Of the six examples in which the pitch of the top is higher than the pitch of the back, in four cases the difference is a semitone or less. Extreme differences in which the back is a minor third higher occur in five cases and a major third in two.

---

[27] Justin Gilbert, 11.

[28] Justin Gilbert, 25.

[29] G. Sanborn, "Who Was Right?," International Violin and Guitar Makers Journal, X (September, 1966), 10.

This list includes second and third rank makers. Taking only the first rank makers as examples the incidence of wide intervals is reduced greatly. Of the six Stradivarius violins included in Table 2 there occur three cases in which the back is higher in pitch than the top, two cases in which the top is higher than the back, and one case in which the pitch is the same. The specific octave of occurrence is not given. In the Bergonzi example the top is higher than the back, and in the remaining examples the back is higher than the top. It would be interesting to compare this list with the height of arching, graduation and tonal characteristics of each instrument. Unfortunately this information is not available.

TABLE 2

FUNDAMENTAL FREQUENCY OF VIOLIN PLATES

Maker	Year	Top (+ indicates	Back 1/4 tone higher)
Amati, Niccolo	-	d sharp	f
Amati, Niccolo	-	f	g+
Bergonzi, Carlo	-	e	d sharp
Salo, Gasparo da	-	f	f sharp
Stradivari, Antonio	1701	e	e+
Stradivari, Antonio	1708	f	e+
Stradivari, Antonio	1709	f sharp +	g
Stradivari, Antonio	1712	g+	g
Stradivari, Antonio	1726	e	f+
Stradivari, Antonio	1720	f+	f+

Another author commenting on Sanborn's article gives two methods of tapping.[30] In the first, the plate is grasped between the thumb and forefinger at the soundpost position and tapped in the lower part of the plate. In the second, the plate is held at a nodal line in the upper third of the plate and tapped in the lower part. It is recommended that the knuckles not be used as their hardness tends to accentuate harmonics of the fundamental, rather than the fundamental. The ball of the finger is said to achieve better results and more consistency. The pitch of the plate is usually to be found in the second octave of the piano between D2 and G2.

The fundamental pitch of the plates of a violin by Joseph Guarneri of 1733, the "Consolo," is given by Henley.[31] The top with the bass bar is one quarter tone higher than "f." The pitch of the back is "g."

The pitches of the plates of the violin of Gasparo da Salo, the measurements of which were given earlier, also are referred to by Henley.[32] The top with the bass bar gives the note, "f." The back is one-quarter tone higher than "f sharp."

---

[30]Fred Artindale, "On Tone and Pitch of Violin Plates," International Violin and Guitar Makers Journal, X (November, 1966), 9a.

[31]William Henley, II, 254.

[32]William Henley, II, 189.

H. S. Wake recommends that the finished top with bass bar should give the note "d" when tapped.[33] The back in this case is tuned to "f," giving an interval relationship of a minor third. Carmen White cautions makers to check the tap tones at a consistent temperature, as a higher temperature results in a lower tap-tone.[34]

Hutchins, Hopping and Saunders report that empirical observation of violin makers has indicated that most present day makers who use a tap-tone method hold their instruments at a point about one-fifth of the length of the plate from either end and tap in the center.[35]

The Microtone Method

The Microtone method was developed by Kristian Skou, of Denmark, after finding certain characteristics present in Italian instruments he examined.[36] By tapping the plates very lightly and at the same time damping the surrounding area, a pitch can be discerned which involves only about one square centimeter of surface, as opposed to

---

[33]H. S. Wake, "Keep Your Weight Down," The Violin Makers Journal, VII (Dec., Jan., Feb., 1964), 27.

[34]Carmen White, "Thoughts About Tap Tones," International Violin and Guitar Makers Journal, X (February, 1967), 13.

[35]C. M. Hutchins, et al., "Subharmonics and Plate Tap Tones in Violin Acoustics," Journal of the Acoustical Society of America, XXXII (November, 1960), 1448.

[36]Kristian Skou, Personal Correspondence (October 4, 1966).

the tap-tone method, which involves the entire plate. It is necessary to excite the pitches in such a way that they originate from a very small area. The tap-tone, in contrast, is an average of all the microtones, therefore is not regarded as being sufficiently accurate to produce consistent results. The technique involves comparing pitches from each area of the top with the pitches from each area of the back, adjusting the plates by thinning the involved areas until given areas of the top have the same pitch as the corresponding areas of the back. The best instruments are said to have the lowest pitch in the central area, rising slightly and evenly toward the edge.[37] Variations in the pattern cause variations in the timbre of the finished violin.

The microtones are produced by tapping the plate gently with the back of a fingernail, a bit of insulated wire, or a small piece of wood. They can also be produced by means other than tapping, by simply stroking the wood with a light, brushing motion with the finger, or with a short stroke of a scraper. The surrounding plate area is muffled with the fingers of the non-active hand. Two principles are attempted; first, to achieve agreement between the top and back, so that the microtone in any one spot of the top is the same as that of the point on the back directly beneath

---

[37]Edmund Daggit, "Some Suggestions on Microtoning, Part 2," International Violin and Guitar Makers Journal, IX (March, 1965), 22.

it, and second, to try to achieve a balance so that the microtones of one side of the plate are approximately the same as the corresponding place on the other side. The process takes a great deal of time, as after each tuning the plate must be laid aside for a period of from two weeks to six months, for the pitch of the plates will change as hardening of the newly exposed wood occurs. Therefore it is necessary to repeat the process of microtoning several times, until the pitches remain the same after a period of aging.[38]

Electronic Research

The first of several articles reporting electronic experiments dealing with violins was published in 1937 by F. A. Saunders, Professor Emeritus of Physics at Harvard University.[39] In an effort to discover elements which influence the tone of the violin, a harmonic analyzer was constructed which registered the relative strength of overtones in the range from 0 to 10,000 cycles per second. In early experiments the sounds were obtained by applying a revolving celluloid disk attached to a silent, variable speed motor to the violin strings in turn, thereby producing

---

[38] Edmund Daggit, "Some Suggestions on Microtoning, Part I," International Violin and Guitar Makers Journal, IX (February, 1965), 20.

[39] F. A. Saunders, "The Mechanical Action of Violins," Journal of the Acoustical Society of America, IX (October, 1937), 81.

the sound in a manner similar to the application of the violinist's bow. The pressure of the disk as well as the speed at which it traveled could be varied to produce a variety of conditions.

There was a certain amount of reluctance on the part of artists to accept the results of mechanical bowing, so hand bowing was thereafter employed. An even tone of about three seconds duration was all that was required for analysis, and in each specimen it was repeated to check for variations in bowing. It was soon learned that the results of the measurements were the same regardless of which method of activating the string was employed.

On each violin sixty-four notes were played with a total of forty-six separate frequencies, the duplications occurring on different strings. The results from the analyzer were plotted and a response curve was constructed by a graphical method for each violin. It was found that even though the power of the violins was thought to be consistent throughout all registers, a great deal of variation in volume of sound occurred. Certain frequencies were loud and certain frequencies soft, the graphical representation of which was a series of peaks and valleys.

Later experimentation by the same author disclosed that the same results were obtainable more simply by playing a chromatic scale at an even level, measuring the decibel intensity of each note in comparison to the others and graphically representing the sequence of intensities in a manner similar to that described above. This eliminated the complex process of averaging the strength of overtones. Evenness was obtained by either playing all the notes as loudly or as softly as possible without distortion of the tone. The graphs thus obtained were called, "loudness curves."[40]

Several well-known Italian instruments were tested in this manner, as well as a cheap, factory-made violin, valued by Saunders at five dollars, which was used as an example of an undesirable violin. An average of the best violins identified five main resonances at C sharp 4 or D4, C sharp 5, A sharp 5, A sharp 6, and G sharp 7. A valley occurs between 1,000 and 1.700 cycles. The first peak is at the natural frequency of the volume of air contained within the violin, known as the "air-peak." The position of the body peak varies somewhat between even the best violins.[41] Fig. 18 shows loudness curves of five Stradivarius violins in addition to the average of the five. Each band runs from twenty to forty decibels. The cycles per second are given at the bottom, and the related musical scale at the top.

---

[40] C. M. Hutchins, et al., "Subharmonics and Plate Tap Tones in Violin Acoustics," Journal of the Acoustical Society of America, XXXII (November, 1960), 1443.

[41] F. A. Saunders, "Scientific Search for the Secret of Stradivarius," Journal of the Franklin Institute, CCXXIX (January, 1940), 10.

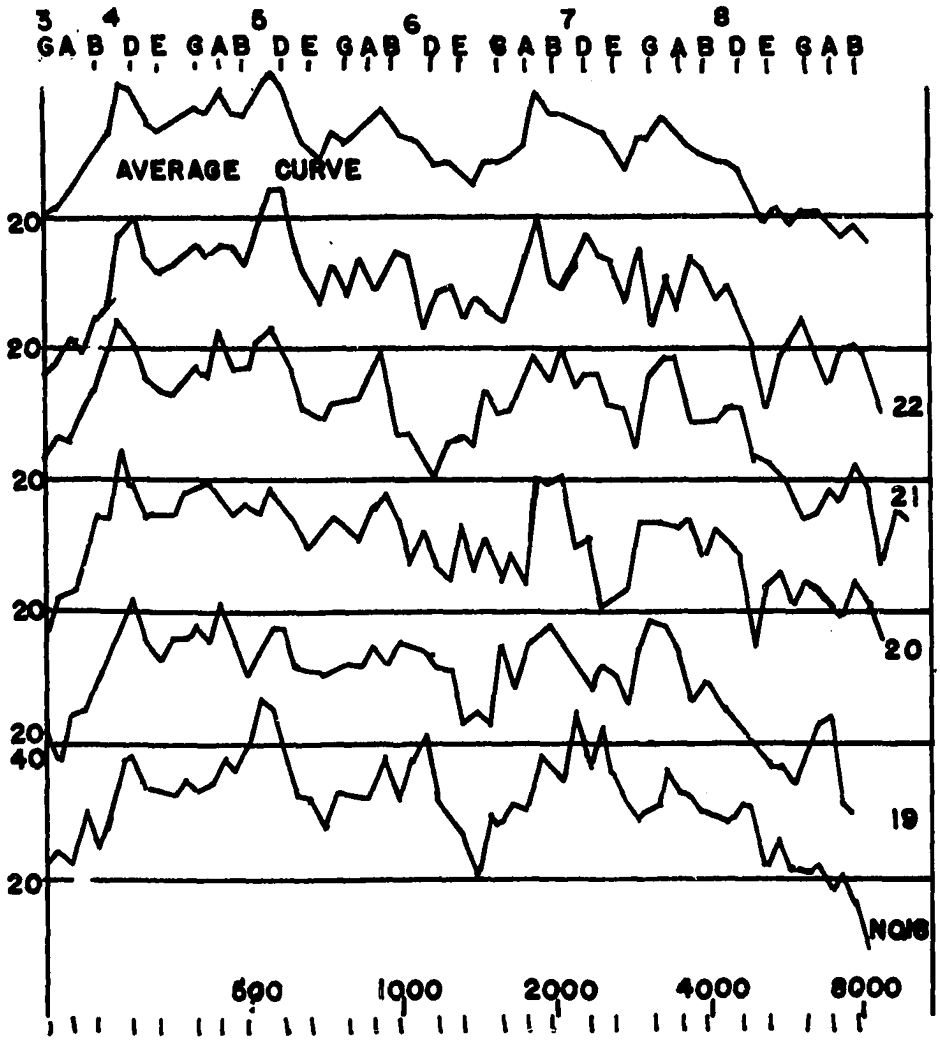

Fig. 18.--Loudness curves of Stradivarius violins.

Generally the best violins have a fairly uniform response over most of the range, with a valley low on the E string and with a stronger response near the top of the E string, dropping to nothing at pitches above the range of the violin. This is indicative of a tone rich in partials on the lower strings, but with comparatively few partials in the higher register. In the case of the five-dollar violin, the peaks were strong in the higher register indicating too much strength in the highest harmonics, which accounts for the shrillness of that instrument.

During the course of experimentation, "blindfold" tests were made in which a group of listeners were asked to identify by sound a Stradivarius violin played in alternation with two others of good quality. Less than one third of the audience correctly identified the Stradivarius.[42] Those of the audience who had had musical training did no better than the rest.

After the death of Saunders in 1963, Carleen Hutchins and a group founded by Saunders, the "Catgut Acoustical Society," carried on his work. The efforts of the group have been primarily concerned with the development of a new family of violin-derived instruments, the size of the members of which are based on their acoustically correct length.[43]

The Electronic Tuning Method

Hutchins provides a complete description of the process of graduating plates using electronic devices.[44]

---

[42]F. A. Saunders, "Scientific Search for the Secret of Stradivarius," Journal of the Franklin Institute, CCXXIX (January, 1940), 14.

[43]Carleen Hutchins, "Physics of Violins," Scientific American, CCVII (November, 1962), 78.

[44]Carleen Hutchins, "Tuning Top and Back Plates

The work on the plates must be completed on the outside, except in the case of the top in which the sound holes have not been cut. The thickness of the top is brought to an even thickness of 3 mm through the center section between the sound holes, reducing to 2.8 mm or even 2.5 mm toward the edges of the upper and lower ends. The plate is suspended on a frame by rubber bands, which are attached to each of the four corners. A loud speaker, from which the cone has been removed, is prepared so that the coil is extended by an elongated center pole. This pole, which is long enough that the coil does not touch the violin plate, is attached to the inside of the plate with sealing wax. This apparatus is fed by the signal from a variable sinewave generator. The amplification is set to get as loud a response as is possible without overloading the coil. The wood of the plate then acts as a speaker cone, vibrating in sympathy with and further amplifying the signal. The wood responds with more or less vigor, depending on the frequency, the stronger responses being at those frequencies where resonances occur within the plates. A microphone is placed one plate length (approximately 14 inches) from the outside of the vibrating plate and the output of the microphone is displayed on an oscilloscope, a vacuum tube voltmeter, a sound level meter, or a recorded strip chart syncronized

---

Electronically," Catgut Acoustical Society Newsletter, VI (November, 1966), 15.

with the input sweep frequency. Reverberation and extraneous noise are critical, so adequate damping material must surround the area.

In Hutchins' process the top plate is graduated following traditional violin making practice. The back is to be adjusted to complement the top. After the resonance points are charted, the sound holes are cut and the bass bar affixed, with its outer edge straight and square. The bar is planed down gradually, again following traditional shaping, observing changes in both resonance frequency and amplitude. At a certain point the amplitude increases suddenly followed by a leveling off. The bar is left at this stage, because soon after this stage removal of even a little wood will cause the amplitude to decrease. The data about the top are then carefully recorded.

The back is prepared for the operation in the same manner, except that it is left thicker than was the top. In graduating operations the back is left thickest in the center, with the wood thinning out toward the edges according to one of two patterns (Figs. 8 and 9), but being careful that the edges of the plate at the waist are left relatively thick. The procedure is to remove wood from various areas of the back, constantly testing for resonances and amplitudes. The optimum situation is to achieve the desired frequency and at the same time the maximum amplitude. Frequency changes occur most rapidly with thinning near the edges of the upper and lower ends, as well as in front of the blocks. The wider and thinner these areas, the lower are the fundamental frequencies. Thinning the center of the plate can raise slightly the frequency of the plate. The most desirable frequency relationship for violins and violas is to have the main resonance of the top between a tone and a semitone lower than the resonance point of the back. In violoncellos and basses the top should be a semitone higher than the back.

Miscellaneous Methods

Several other theories have been advanced to account for the excellence of some violins. Not all are concerned with graduation *per se*, but have some bearing on the problem, therefore are included as a matter of interest.

The conclusion that the balance of air contained within the violin is of importance was advanced by Wright.[45] The theory is that the mass of air contained within the violin above the bridge line should be exactly the same in volume as the mass of air contained below the bridge line. The measurement is accomplished by covering the soundholes below the bridge line with cellophane tape and filling the violin to this point with dry rice. The remainder of the holes are then covered and the violin inverted. If the

[45] G. R. Wright, "Balancing the Air Volume of the Violin," *International Violin and Guitar Makers Journal*, VIII (April, 1965), 29.

level of rice is again at the bridge line there is a perfect balance between the upper and lower portions. Instances are cited of adding wood to the blocks in violins which did not conform to the standard with resulting improvement in the instruments.

An author identified only as Smiley gives a related method.[46] The outline of the 1722 Stradivarius violin, "the Earl," is given. By cutting this outline out of paper and folding it along the center line, the point at which it will balance is found. This is called the center of gravity and is located 7 5/16 inches from the upper edge of the plate, or 5/16 of an inch in front of the bridge. The nonvibrating area of the plate pattern is then cut away--the area of the blocks and edges--after which the gravity point is found to be in the same place. In construction of an actual violin the top and back and the bass bar are all adjusted so that when finished, the balance points of each will be found at this spot.

Castle offers a method of adjusting the final thicknesses of the plates using the transluscency of wood as a guide.[47] Each plate is held with its outer surface toward a strong light source. The violin maker examines the inner surface. The light shining through the wood outlines

---

[46]Smiley, "Science for the Maker," Violin Makers Journal, IV (June, 1961), S12.

[47]Frederick Castle, Violin Tone Peculiarities (Lowell, Indiana: H. H. Ragon and Son, 1906), 29.

any areas which are out of balance, the thick areas being seen as shadows. Enough wood is removed from these areas to achieve an even shading when the test is repeated. The contention is that slight irregularities produce impurities in the violin tone in the form of increased intensity of the overtones above 4,000 cycles per second, and these areas are so subtle that they cannot be located using simple measurement, but can be seen in this candling process.

One violin maker recommends that the violin, after preliminary graduation, be strung up prior to varnishing.[48] The tone is tested and final graduation is judiciously carried out from the outside. The wood is left about .5 mm thicker than normal in the preliminary graduation. After assembly the instrument is allowed to season approximately one week before it is tested for tone. If the violin is hard to play, the top is thinned. If the lower notes are deficient, the back is thinned. The top and back are worked upon alternately until the desired effect has been achieved. Finally the fittings are removed and the instrument is varnished.

Summary and Appraisal of Tuning Methods

The various recommendations of intervals at which to tune the plates encompass only slightly more than a

[48] Robert F. McGowan, "My Method of Tuning Plates," Violin Makers Journal, VI (Jan.-Feb., 1963), 31.

fourth. The intervals from a quarter tone to a major second are most recommended.

The Gilbert method of tapping the plate at the end nearest to the floor while holding the plates at the edge of the waist produces the lowest pitch, so it seems reasonable that the tone thus produced is the fundamental. Tapping at the bridge line produces a higher pitch. Holding at the upper end of the plate and tapping at the bridge also produces a higher note.

The microtone method has the disadvantage of being so time consuming that the time necessary for the production of a finished violin makes it impractical.

Research done with electronic devices has added interesting data to the field. It appears to have been carefully done and specific directions are given for the process of tuning instrument plates. All of the research has been with loudness peaks. The question is whether the tone quality and power of the instrument are controlled by this variable. Saunders' results from blindfold tests show a lack of ability in listeners to differentiate between the instruments, which leads to the belief that evaluation must be left to the professional violinist to be effective.

Castle's candling method may have some use. It is possible that spots of concentrated density which would not effect direct measurement would be observable using this method.

The two methods involving balance may be important. It is not known, however, whether Italian instruments have been examined for these characteristics. More published research by reputable sources is needed.

CHAPTER III

THE CONSTRUCTION OF THE TEST VIOLINS

Selection of the Methods

From the methods of determining the final thicknesses of violin plates reported in Chapter II, two were selected to be used in this experiment: the traditional method of measuring the thicknesses, and the recently developed electronic method.

Graduation with reference to a set of fixed thicknesses has been a traditional method of adjusting plate thicknesses in violins. It was necessary to select a diagram which was known to be reliable. Of the diagrams given in Chapter II, the only complete diagram which is known to have been taken from a master violin is that of the 1703 DeRougemont Stradivarius; therefore, it was the choice from among the methods involving direct measurement. Although the diagrams from the 1682 Stradivarius were also certified, a portion of the top diagram of that instrument was missing, so that only conjecture and estimation could complete it. The 1703 instrument is from the period of Stradivari's life commonly called the "golden period," during which he is said to have produced his best instruments.[1] This particular instrument is highly regarded also, strengthening the recommendation for its use as the model for the violins to be constructed according to direct measurement.

The published data concerning the electronic tuning method are more voluminous than those of any of the other methods of tuning the plates. The electronic instruments that are used diminish the chance of error which might be more likely in some of the other methods. In addition, the research has been carried on by more persons which leads to the expectation that there would be more objectivity than if only one person had carried on the research. These methods, therefore, were chosen for this experiment.

It was determined that two violins would be made following the specifications of each of the two methods with the hope that the comparison would aid in discovering whether consistent results would be achieved through the use of either method. The violins graduated using the measurement method were given the identifying letter designations, "A" and "B," whereas the electronically graduated violins were designated "C" and "D." After the backs of

---

[1]W. Henry Hill, et al., Antonio Stradivari; His Life and Work (2nd ed.; New York: Dover Publications, Inc., 1963), 49.

each violin had been graduated, labels were inserted in each, bearing the name of the maker (the present writer), the place of manufacture (Norman, Oklahoma) and the year of construction (1967). These labels were placed so that they could be seen by looking through the left sound hole in each completed instrument. In addition, small labels were placed on the opposite side so that they could be seen through the right sound hole which carried the identifying letter, A, B, C, or D. No information was offered concerning the details of construction to avoid compromising the objectivity of the judges.

Preliminary Construction

Even though the diagrams of the Stradivari instruments contained an outline of each instrument, each of the diagrams had been slightly reduced in size in the photographic reproduction process. The possibility of distortion in the photographic process made reenlargement of dubious value; therefore, it was considered desirable to select a different instrument with an outstanding reputation from which the outline (as distinguished from the graduation diagram) could be traced by the present writer as the model upon which the test violins would be constructed, while continuing to use the previously selected graduation diagrams.

Several instruments by Italian makers are part of the collection of the Library of Congress in Washington, D.C. Although several by Stradivari are in the collection, it was not possible to remove these instruments from their display cases owing to a complicated alarm system which takes some time to deactivate; however, a violin by the brothers Amati and one by Guarneri del Gesu were available. The Guarnerius, which was donated to the Library of Congress by Fritz Kreisler, was chosen for its pattern, the outline of which was taken by placing the violin on a sheet of paper on a firm surface, and scribing with a pencil closely around the edge of the instrument. The Guarnerius is in excellent condition, with 90% of its original varnish, a deep transparent red color, preserved. The sound holes are very well cut and bear a resemblance to those of Stradivari. The label reads, "Joseph Guarnerius fecit Cremona Anno 1733," and bears the "IHS" and cross symbol which appears on all of this maker's labels. The measurements are: length, 13 15/16 inches; upper bouts, 6 17/32; middle bouts, 4 5/16 full; lower bouts, 8; sides 29 mm in the shoulders, 30 mm in the middle and 30 1/2 mm in the lower bouts. These measurements were taken over the modeling with a flexible steel ruler. The instrument, known as the "Kreisler ex Junot, ex Mountford," is felt by authorities to be one of Guarneri's finest productions.

> . . . We feel, and feel strongly that no specimen can exemplify del Gesu in his mature youth more strikingly than that dated 1733 (Kreisler), which conceivably was made some years previous to that year. It stands on the threshold of the master's emancipation from the past; the f - holes still reveal his indebtedness to Stradivari, but model and form are his own, timid of conception, perhaps, when contrasted with the audacity

> of later years, yet admirably typifying those closely knit examples which, from a tonal point of view, stand up to the greatest.[2]

It was considered desirable, in order to minimize effects of unknown variables, to use wood which was as nearly identical for each of the four violins as was possible to obtain. A letter specifying the requirements was sent to Metropolitan Music Company in New York City, a large supplier of violin making and repairing equipment and materials. It was necessary for the staff of that company to examine their stock at some length before satisfactory material was obtained.

The wood thus selected was very well matched. All the top wood was taken from adjacent positions in the same log of spruce; the wood for the scrolls was cut from the same piece of maple and all the sides from another. It was not possible to obtain four backs cut from adjacent positions in the same log of wood, but these were matched very closely in grain, texture, color and figure. The wood for the interior framing (the linings and blocks) was not obtained from Metropolitan, but was willow of local growth, cut from a tree which had grown in the southern part of Norman, Oklahoma.

In both the back and the top the wood was in wedge-shaped pieces cut on the quarter, i.e. with vertical grain.

---

[2]William Henry Hill, _et al_., _The Violin Makers of the Guarneri Family_ (3rd printing; London: Holland Press, Ltd., 1965), 103.

In the growth of any tree, each year a more dense, often more highly pigmented section is produced during the winter months when growth is slight, which contrasts to the lighter, less dense growth of the summer months. This may be seen in the cross section of the log as a series of circular lines, hence the name, "growth rings." When the wood is cut so that the lines run in the same direction as the cut, the wood is said to be cut "on the slab." When the wood is cut so that the grains are perpendicular to the cut, the wood is said to be cut "on the quarter."

Fig. 19 represents the cross section of a log of wood, showing the two methods by which wood for violin making purposes is cut. The wedge-shaped section, A, has been cut on the quarter, and the vertical grain is evident. The grain in the sections B, cut on the slab, deviates from perpendicular at various angles from approximately 45 degrees to horizontal. Tops are always cut on the quarter in violin making, whereas the cut of the backs may be cut either on the quarter or on the slab. Quarter cut wood for the back also is generally felt to be preferable because, while offering equal resistance to the sound post, it tends to produce a brighter sound.[3]

In the quarter cut wood, the wedge thus cut from the tree is again divided down the middle and joined at the thick edge. In the case of the backs for this study the

---

[3]Hill, Antonio Stradivari, 160.

latter was unnecessary because the wood had come from a tree broad enough to yield quarter cut backs in one piece. It was necessary only to cut the excess wood from the wide end of the wedge to prepare the wood for the next step. (Fig. 20).

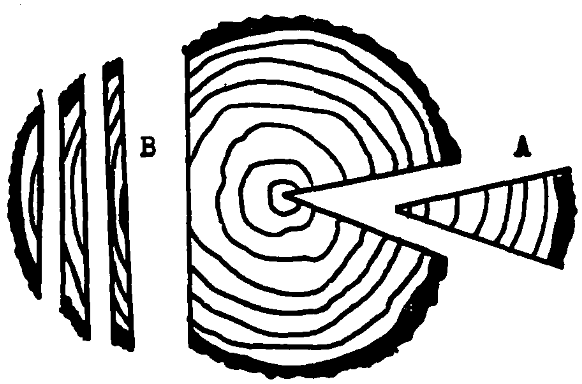

Fig. 19.--Cross section of a log of wood showing slab and quarter cut portions.

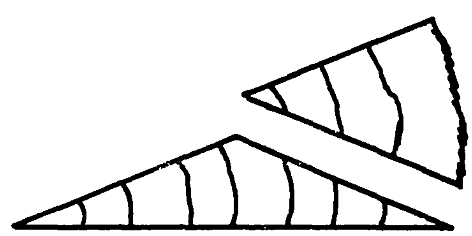

Fig. 20.--Cross section of a one-piece back showing the removal of excess wood.

The outline of the Guarnerius violin was transferred to a sheet of zinc which was then cut to conform with that outline. A half outline was used rather than a full one to assure that the two halves of each plate would be in exact contrafacsimile (Fig. 21).

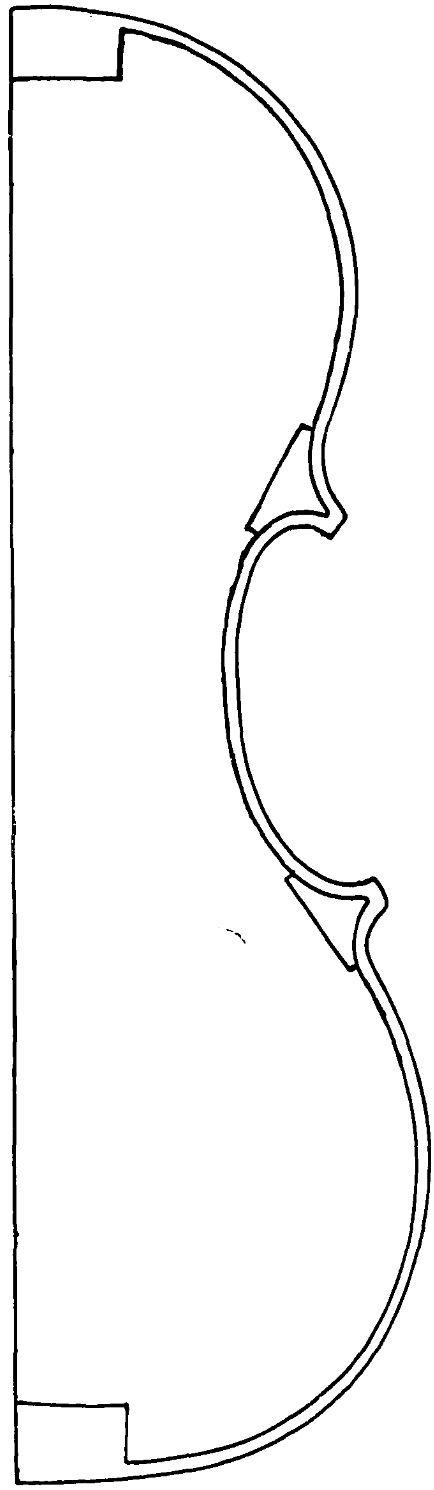

Fig. 21.--Zinc half outline of the plate, with the form of the mold also exhibited.

In the entire construction process work upon each component part of the violins was carried on simultaneously in all the instruments in order to reduce the chance of variation in workmanship.

After finding and marking the center line of each plate, top and back, the zinc half-outline was placed on the flat side of the wood and cut around with a bandsaw, leaving a rough outline of the shape of the instrument in wood. The outline was then clamped in place to avoid movement and placed in a vise. A wood file was used to bring about the final shaping of the wood and to cause it to conform to the shape of the half outline.

The modeling of the outside of each plate was accomplished by first marking the edges of the wood to indicate the final thickness of that point, then removing wood using gouges, chisels, and small, round bottom, oval-shaped wood planes. In the last stages of this operation frequent reference was made to the modeling templates (Fig. 22) to insure that the arching of the instruments would be as nearly alike as possible. These consisted of strips of wood into which the lines of modeling of the violin had been cut. The long curved lines are the tracings of the templates of the arching of the length of the violin, and the shorter lines are tracings of templates of the arching from side to middle. These cross-arching tracings are located in their proper positions in relation to the long

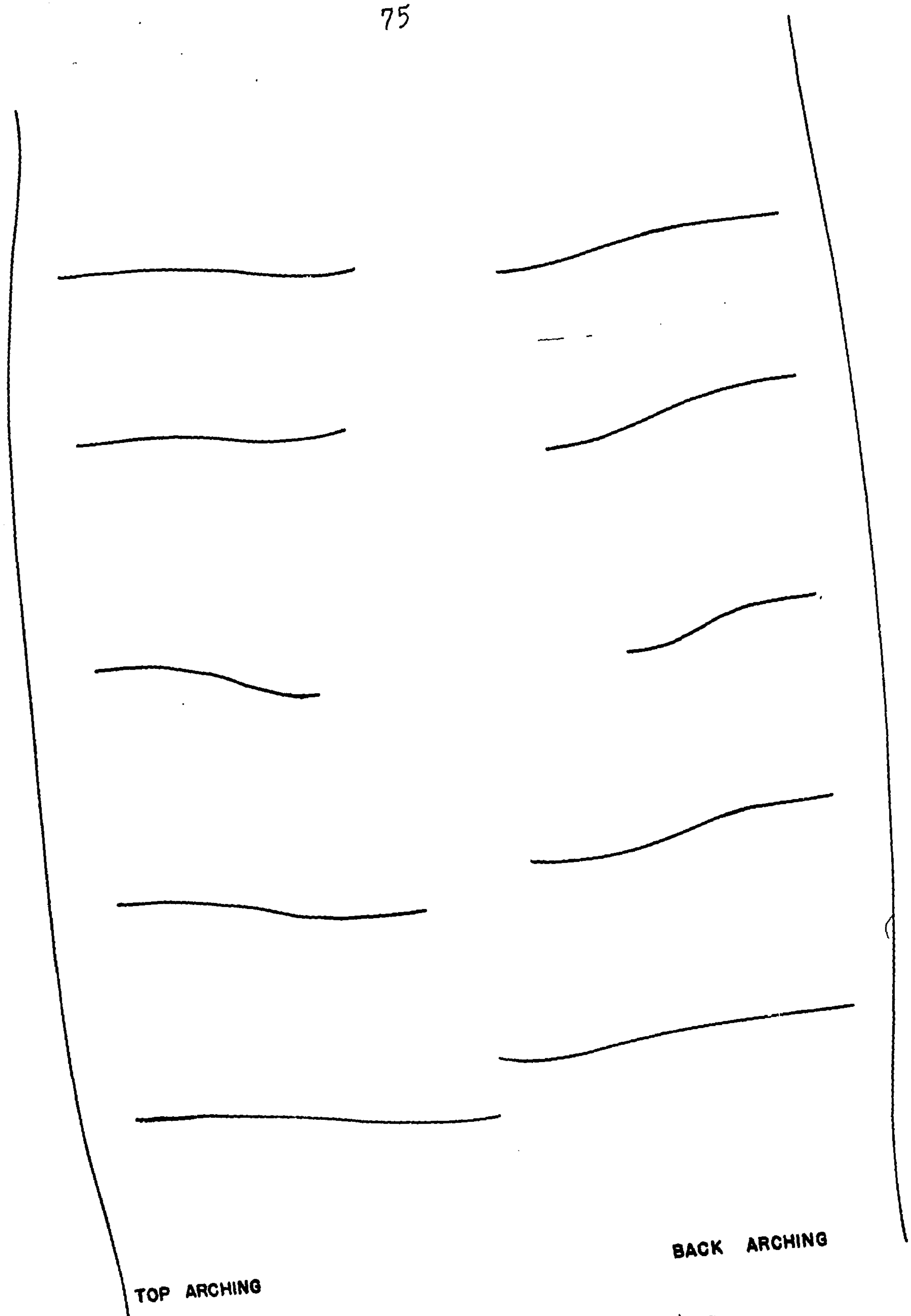

Fig. 22.--Violin arching templates.

arching tracing, the neck end of the violin being at the top of Fig. 22. Experienced violin makers ordinarily do not use these templates, rather relying on their judgment guided by experience in determining the shape of the arching. As a result one rarely sees two instruments of the same maker with precisely the same arching. For this experiment it was deemed desirable to utilize the templates in order to reduce the number of uncontrolled variables. The thickness of the edge was cut and made even with a milling cutter bit in a drill press adjusted to leave a constant thickness.

After the external modeling was completed using scrapers and garnet paper, the purfling was inlaid. Two parallel grooves were marked around the edges using a tool designed for that purpose, then were deepened with a knife. Finally, the wood between the two grooves was removed with a picking tool. Purfling is made up of three thin pieces of wood, two black and one white. It is extremely brittle and difficult to shape without breaking; therefore, it is necessary to dampen the purfling and bend it to the desired shape over a hot piece of metal known as a "bending iron." The bending iron used in this case was made from a one-inch aluminum pipe using an alcohol burner as a heating element.

After the purfling is shaped, hot animal glue is applied to the purfling and the grooves. Then the purfling is inserted in the pre-prepared grooves and squeezed into place with a pair of pliers. This last operation has a tendency to compensate for any slight variation in the width of the groove, contributing to the attractiveness of the purfling by expanding it to fill any irregularities. Spring clothes pins are used as clamps to hold the purfling securely until the glue dries. After the glue is dry the protruding portion of the purfling is cut off, scraped and sanded.

The frames of the violins were constructed over a wooden form which reproduces the contour of the sides with cutaway slots for the introduction of the supporting blocks, called a "mold," which may be seen as the inner lines in Fig. 21. Blocks of willow wood were lightly glued into the cut out sections and shaped properly to conform to the model. Wood for the sides was cut from a single block of maple. After sawing, one side of each piece was smoothed with scraper and garnet paper. Then, with a milling cutter bit in a drill press, the sides were thinned to 1.3 mm, then scraped and sanded to an even 1 mm. The sides were then soaked for approximately fifteen minutes in water and bent to conform to the model using the same equipment which was utilized in the preparation of the purfling, and finally clamped in place on the mold, glued to the blocks and allowed to dry.

Next, strips of willow 3/8 of an inch wide, 3/32 thick, and several inches long were cut, scraped, and sanded. Following the same procedure that had been used with the sides and the purfling, the strips were bent to match the inner surface of the sides, becoming "liners" or "lining strips." In the case of the liner for the center bouts, the ends were spliced into the corner blocks to give the frame added strength and resist the tendency of the liners to straighten. The liners were then trimmed and sanded so that the inside of the frame presented a clean and smooth surface.

The scrolls were also hand made from blocks of maple. A piece of sheet zinc was again used as a pattern for scribing the outline of the neck and scroll on the wood (Fig. 23). The profile outline was cut out first on the band saw, leaving a piece of wood looking similar to the scroll as viewed from the side, but which was the same width in all parts. The turns of the scroll were traced onto the side of the wood, and through a series of saw cuts, the rough outline was made. Finally, the scroll was finished with chisels and knives, then with scraper and garnet paper.

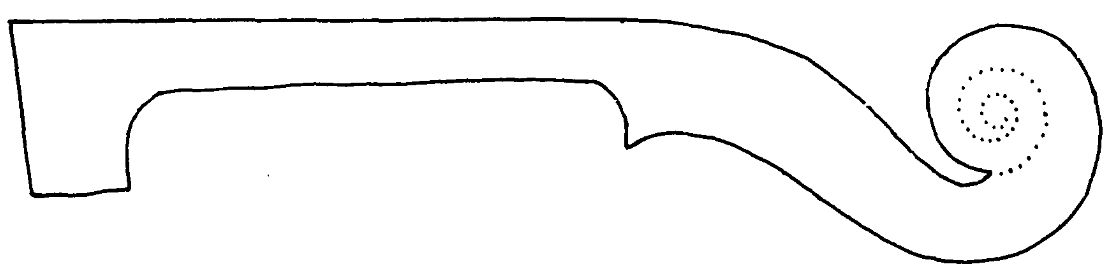

Fig. 23.--Violin scroll and neck template.

The tops and backs, already finished on the outside, were roughly cut out on the inner surfaces with the drill press and a Forstner bit, designed for quick removal of excess wood. Plenty of wood was left in the plates so that there would be no danger of leaving traces of the roughing out process after the final graduation. This ended the preliminary work. The processes used in graduating, tuning, and comparing the four violins are described immediately below.

Graduating Using Direct Measurement

In preparation for the graduation of violins A and B, the graduation diagrams of the 1703 Stradivarius given in Figs. 11 and 12, Chapter II, were transferred full size to a lightweight paper in which holes had been punched each centimeter in each direction, which was the interval of measurement on the original diagrams. Each dimension was transferred to this paper directly above the hole which was at the point of measurement. The holes were large enough that the thickness of the plate could be measured through them with the caliper. A direct comparison between the caliper reading and the desired dimension was facilitated through this approach when the diagram was taped to the inside of the violin plate, front or back.

The caliper used was equipped with a sensitive dial indicator calibrated in tenths of a millimeter. One tenth of that amount was easily discernible. The frame was large enough so that all portions of the violin plate could be reached for measurement.

The plates were brought to within .5 mm of the proper dimensions with chisels, gouges and round-bottom planes commonly used in the violin making process. In the final stages each measurement was taken frequently through the appropriate hole in the pattern and directions for the amount of further adjustment were penciled directly onto the plate through the same hole. When the dimensions were within .2 mm of the final thickness, only a finely sharpened scraper was used for further adjustment. When the plates were the proper thickness (i.e., identical with the thicknesses indicated in the 1703 Stradivarius diagram) the adjustment was complete. The wood as left by the scraping process was sufficiently smooth that neither sandpaper nor garnet paper was used subsequently for fear of altering the dimensions.

It was found that adhering to this method of graduating the plates in detail was extremely time-consuming. Attention was directed to smaller areas of the plates than the areas normally considered in the graduation process, in that minute variations in the thicknesses of the instrument from which the diagram was taken made it necessary to measure each square centimeter several times in the course of removing one tenth of one millimeter from the thickness of the wood.

After the thicknesses of the other pair of violins, <u>C</u> and <u>D</u>, were adjusted electronically (which will be described in detail later), for the sake of completeness of information each violin was measured minutely with the caliper (Figs. 24, 25, 26 and 27). Even though the graduation of these instruments has not yet been discussed, it is appropriate that the information concerning their measurements be given here. The measurement was carried out by taping a thin piece of tracing paper to the inside of each completed plate. Marks had been made on the paper at the position of the intersection of each square centimeter. The caliper was adjusted to read zero when one thickness of the paper was between the measuring points, thus neutralizing the effect of the thickness of the paper on the subsequent measurements. The paper had been measured in several places and was found to be of a uniform thickness. The plates were then measured and each thickness marked upon the paper at the spot at which it occurred.

Graduating Using the Electronic Tuning Method

The basis of the electronic equipment used in graduating violins C and D was a sine wave generator as described by Hutchins.[4] The particular instrument used was equipped to produce a signal from 20 cycles to 200 kilocycles per second in four bands. Only a small portion of this was needed to establish the frequencies of the plate resonance.

---

[4]Carleen Hutchins, "Tuning Top and Back Plates Electronically," Catgut Acoustical Society Newsletter, VI (November, 1966), 15.

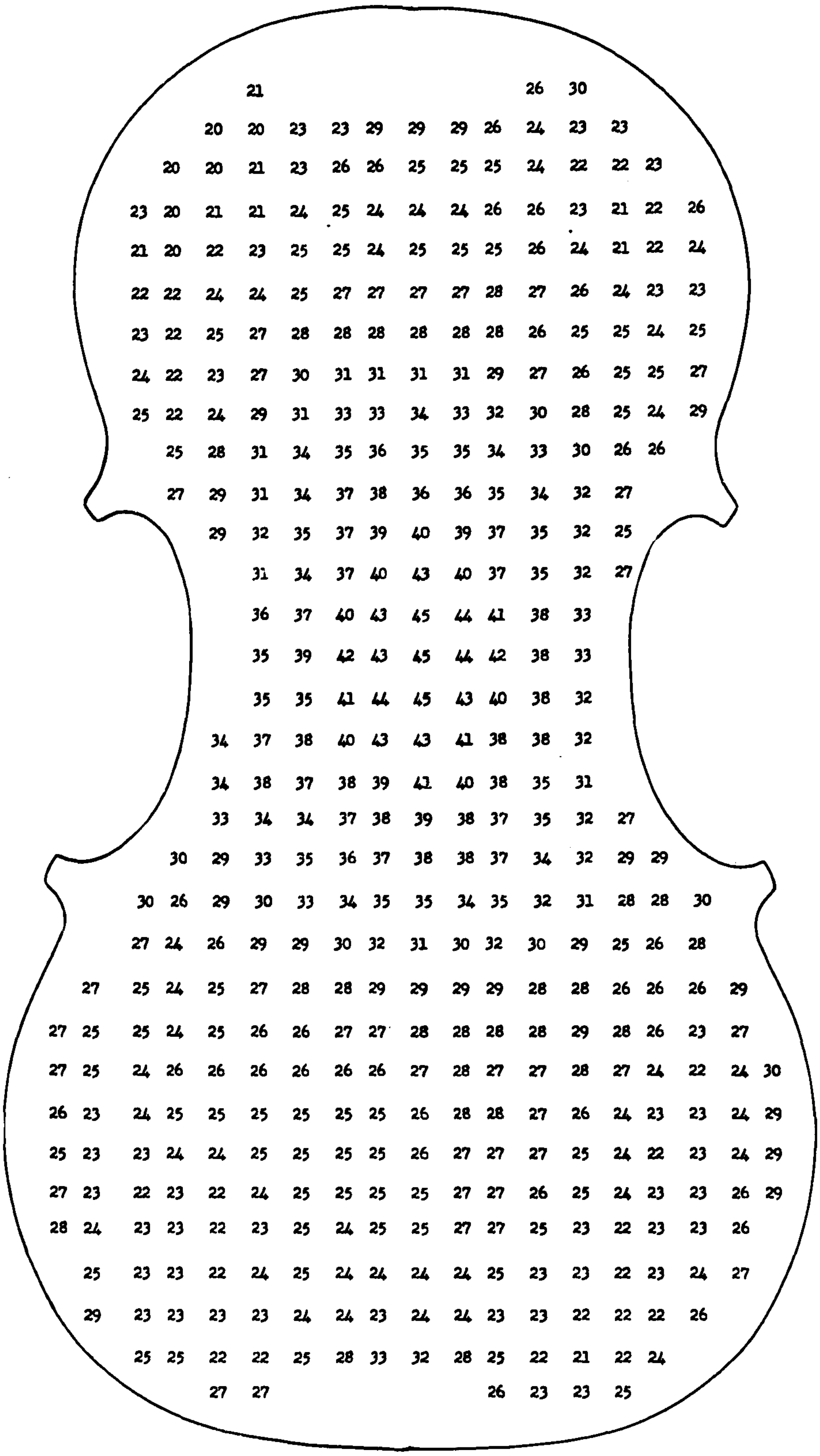

Fig. 24.--Dimensions of back of violin C, given in tenths of millimeters.

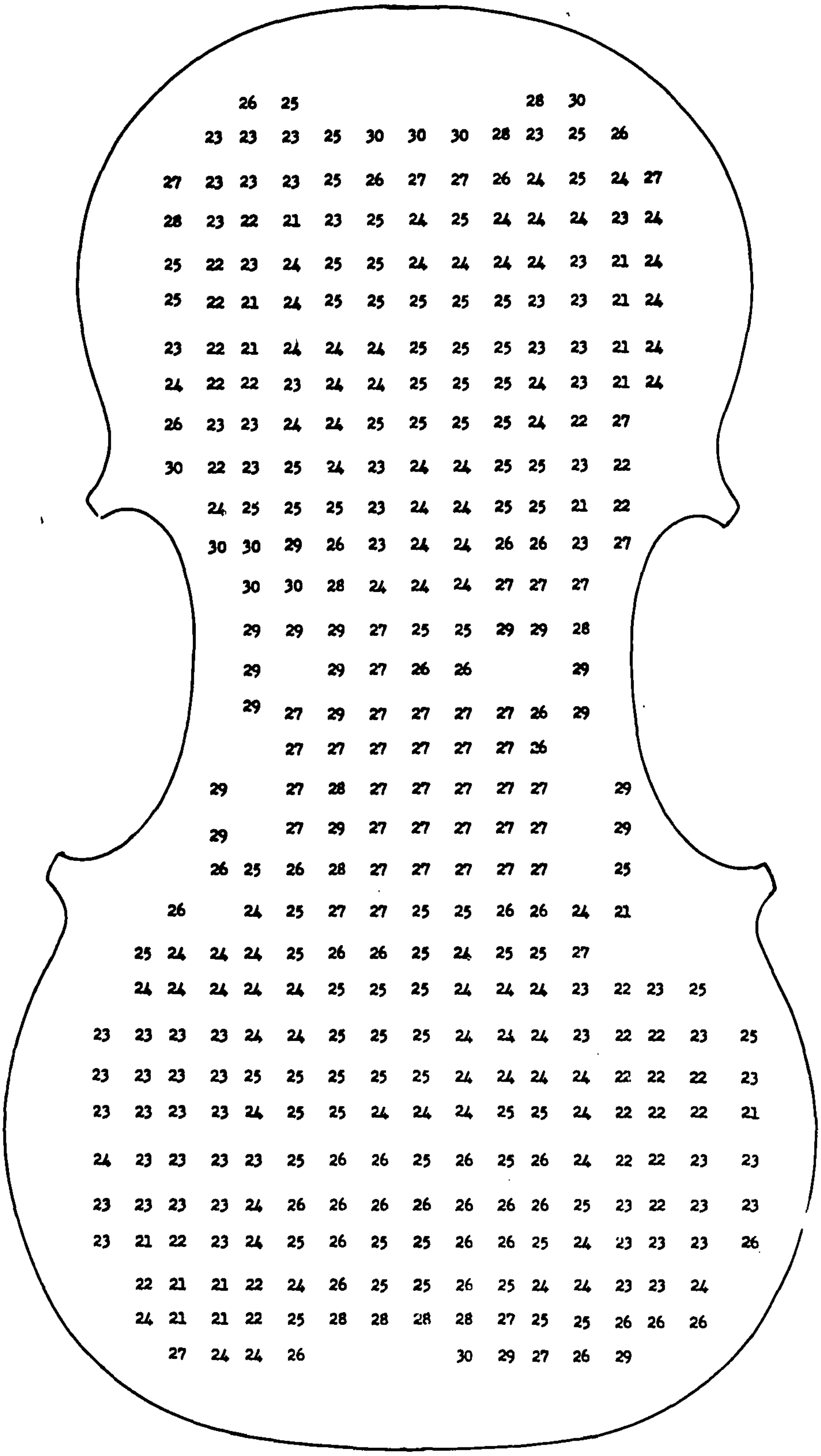

Fig. 25.--Dimensions of top of violin C, given in tenths of millimeters.

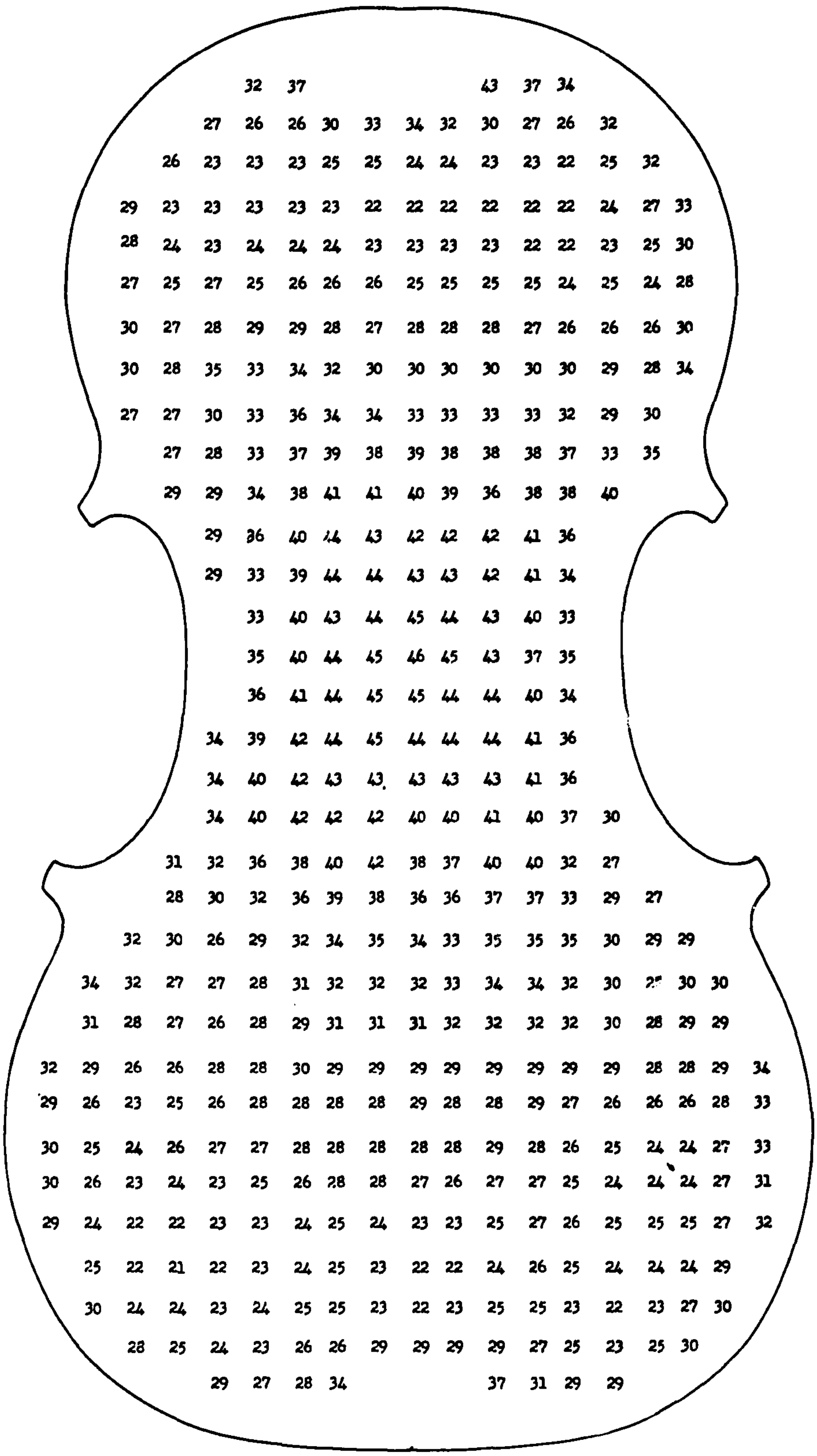

Fig. 26.--Dimensions of back of violin D, given in tenths of millimeters.

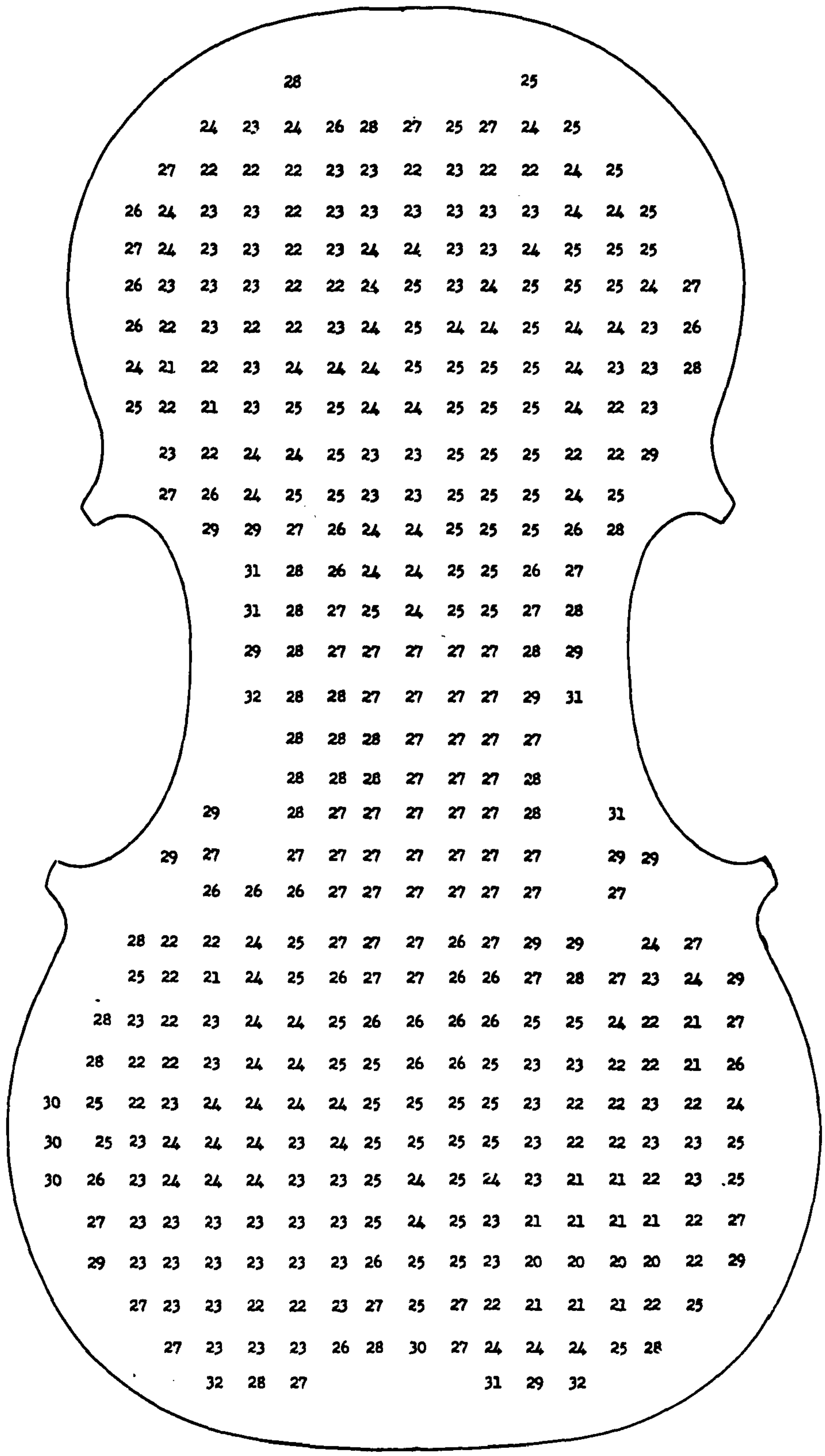

Fig. 27.--Dimensions of top of violin D, given in tenths of millimeters.

The signal was fed into an audio amplifier which, in turn, drove an especially prepared loud speaker. The cone of the speaker was removed and a four-inch extension was attached to the speaker coil with epoxy resin cement. The length was sufficient so that no part of the speaker assembly except the elongated center pole could come into contact with any surface that might cause extraneous vibration.

The receiving and evaluating instrumentation consisted of a dynamic microphone, the signal from which was received by a pre-amplifier-amplifier combination, and finally displayed on a vacuum tube volt meter.

Prior to its use in conjunction with violin plates, this apparatus was tested to see whether any peaks or valleys were inherent in the equipment by moving the frequency of the sine wave generator through the entire range to be used in the experiment. None was found.

A frame was constructed to hold the violin plate, consisting of two vertical columns of wood bridged by a cross-beam at the top and with a broad base cushioned by several layers of soft cloth material. Nails were placed in the columns at the necessary positions to facilitate the suspension of the plate within the frame. Rubber bands were fastened between the nails and the corners of the plate as recommended by Hutchins.

The elongated center pole of the speaker was affixed to the plate in the center of the inside of the plate with sealing wax. The microphone was placed 14 inches from the center of the outside of the plate.

It became immediately apparent that the rubber bands from which the plate was suspended were vibrating in sympathy with the plate, causing an erroneous reading of the amplitude of the peaks. Experimentation revealed that the speaker could be laid on its back with the elongated pole extending vertically from it with the plate attached. No distortion of the signal was detected with the equipment assembled in this manner, so the frame with rubber bands was not used. In the first stages of experimentation it was discovered that the presence of a human body within the same room with the vibrating plate produced varying effects upon the amplitude of the signal depending upon its location in relationship to the plate and the microphone. Simple noises created by breathing or slight movements also affected the readings. Thereafter, the controls were operated from a separate room.

The recommendation of Hutchins was that the tops of the violins be graduated by measurement following good violin-making practice and subsequently to tune the back in sympathy with the top. It was decided to start with the tops 2.7 mm thick in the center, reducing the thickness to about 2.3 at the extremes with the wings of the sound holes being slightly thicker, 2.9 mm.

The top of violin C, when completed without soundholes or bass bar exhibited loudness peaks on each C sharp and G throughout the range of the instrument. The sound holes were then cut and the bass bar glued in. The amplitude was checked often as the dimension of the bass bar was reduced following a standard form. When the amplitude ceased to be increased with the removal of wood the process was halted. At that time the strongest resonance peak was a double peak which was found to be on C 4, with a smaller, yet major peak approximately one quarter tone below F sharp 4. Other lesser peaks were also found.

The back of violin C, when first tested was rather thick; about .5 mm thicker than its final thickness. At that time resonances and valleys were found to be rather extreme, with several of each within the octave. As the plate was thinned the differences between the amplitudes of the peaks and valleys became less extreme, and those loudness peaks which remained moved gradually down the scale as wood was removed from the plate. The main resonance of the back was tuned one quarter tone higher than C sharp 4 in order to bring the relationship of the back and top within a major second. A less strong resonance was found at G sharp 4. Thus the relationship between the back and top was three quarters of a full tone, the back being higher than the top as was recommended by Hutchins, as well as indicated by other authorities.

The principal loudness peak of the top in violin D was manipulated to bring it to the same pitch as that of violin C. It was found that the loudness peaks of the spruce top moved less with the removal of a given amount of material than those of the maple back. It would have been possible to let the main peak frequency in this plate deviate from that of C, for it was recommended by Hutchins that the back receive the adjusting action, but for the sake of repeating the experiment it was felt that the resonance peaks in the plates of both instruments should be the same. Therefore, the top plate with sound holes and completed bass bar had a main resonance frequency of C 4, and a secondary resonance one quarter tone below F sharp 4. The back of violin D was adjusted to place the principal resonance one quarter tone higher than C sharp 4.

Loudness Curves of the Plates

As violins C and D were adjusted, the positions of the resonance peaks were observed displayed on the vacuum tube volt meter. When the optimum positions had been achieved a graph was constructed for each plate showing where all peaks or areas of maximum resonance were located as well as the positions of the valleys or areas of minimum resonance. In addition, violins A and B, after having been completed by adjustment of the thicknesses by direct measurement with no reference to the electronic instrumentation, were tested with the electronic equipment to discover where the peaks and valleys of resonance were located on those violins (Fig. 28).

The principal and secondary resonances of the violins are graphically represented as large and less large peaks. The resonances of violins C and D are not identical even though the principal resonances lie in the same positions, as the relative amplitude of each is different than that of its counterpart in the other violin. Many of the minor resonances are in slightly different positions.

After being adjusted to match the Stradivari diagrams, violins A and B were found to have resonance peaks which differed from those of violins C and D.

The top plate of violin A, when complete with sound holes and bass bar, was found to have its principal resonance one quarter-tone below B 3. This is the lowest main resonance pitch found in the tops of any of the violins. The principal resonance of the back was found at E 4, which is the highest of any of the backs. The interval difference between the top and the back of this violin is more than a fourth, which is consequently the widest interval to be found between the back and front plates in any of the violins.

The top plate of violin B, when complete with sound holes and bass bar was found to have a principal resonance approximately 1/8 tone higher than B 3. The main resonance of the back was on D 4. The consequent interval difference

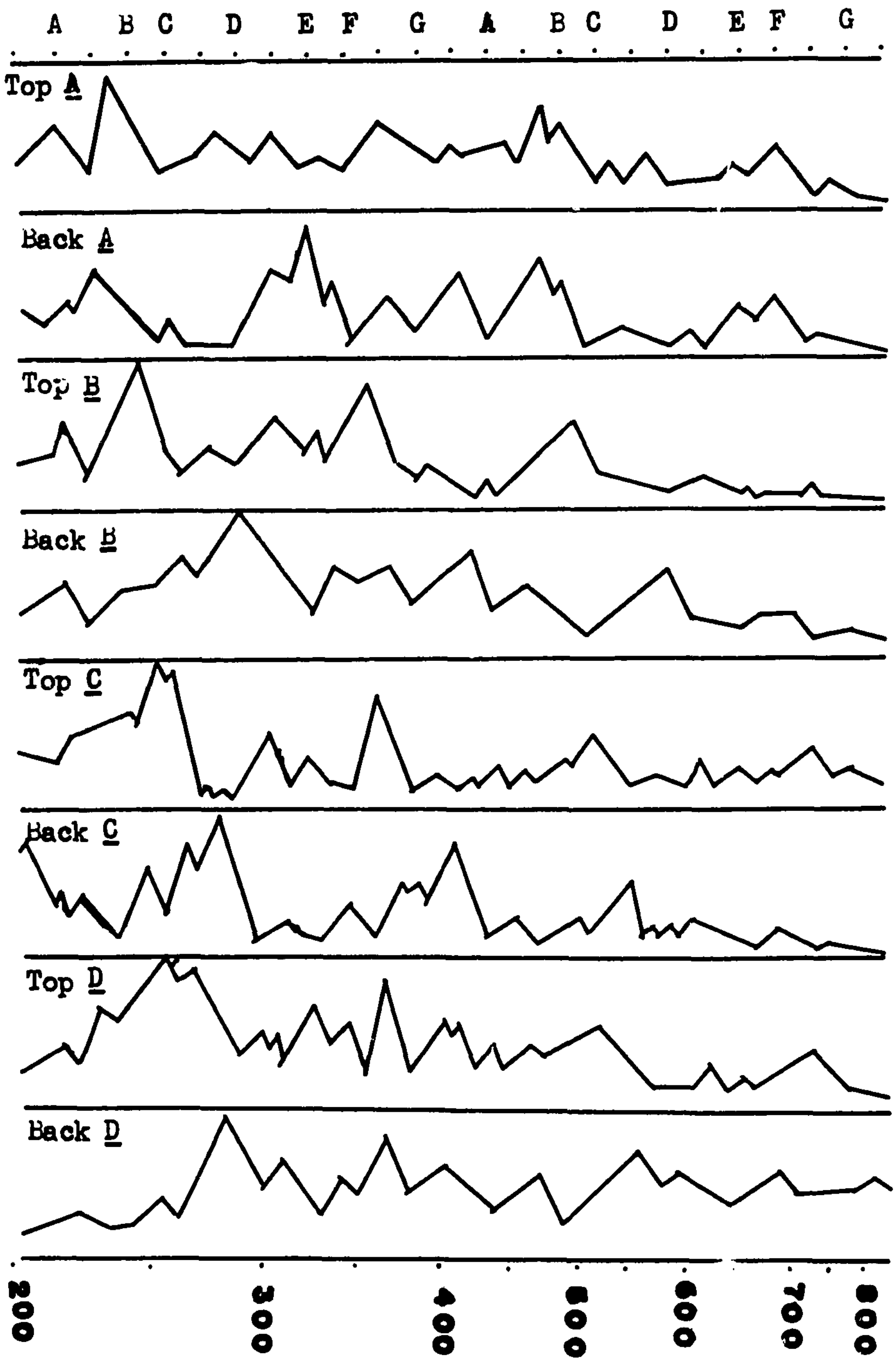

Fig. 28.--Loudness curves of tops and backs of violins A, B, C and D.

between the top and the back was a minor third, or 1/8 tone less.

In all cases a secondary resonance was found slightly less than an augmented fourth above the main resonance. Such an interval is found in the overtone series between tone eight and tone eleven. If the secondary resonance is accepted as being tone eleven, this would place the location of the true fundamental frequency of the plate three octaves below the principal resonance point concentrated on in the electronic method. All of the plates were tapped following Gilbert's method, given earlier, and invariably emitted a pitch two octaves below the primary resonance found electronically. Following the same line of reasoning, the tap-tone may be tone two of the series.

Loudness Curves of the Finished Violins

After all the violins had been assembled, varnished and fitted with strings and appliances, they were subjected to an additional test with the electronic equipment. The extended center pole of the loud-speaker used in previous tests was affixed with sealing wax to the top of the bridge of each instrument in turn. The signal from the variable frequency sine wave generator was fed through the equipment and transferred to the bridge and consequently by conduction to the entire vibrating body of the instrument. Cloth was inserted between the strings and the fingerboard to preclude any possibility of exciting sympathetic vibration which might interfere with the test. The results of these tests may be seen portrayed graphically in Fig. 29.

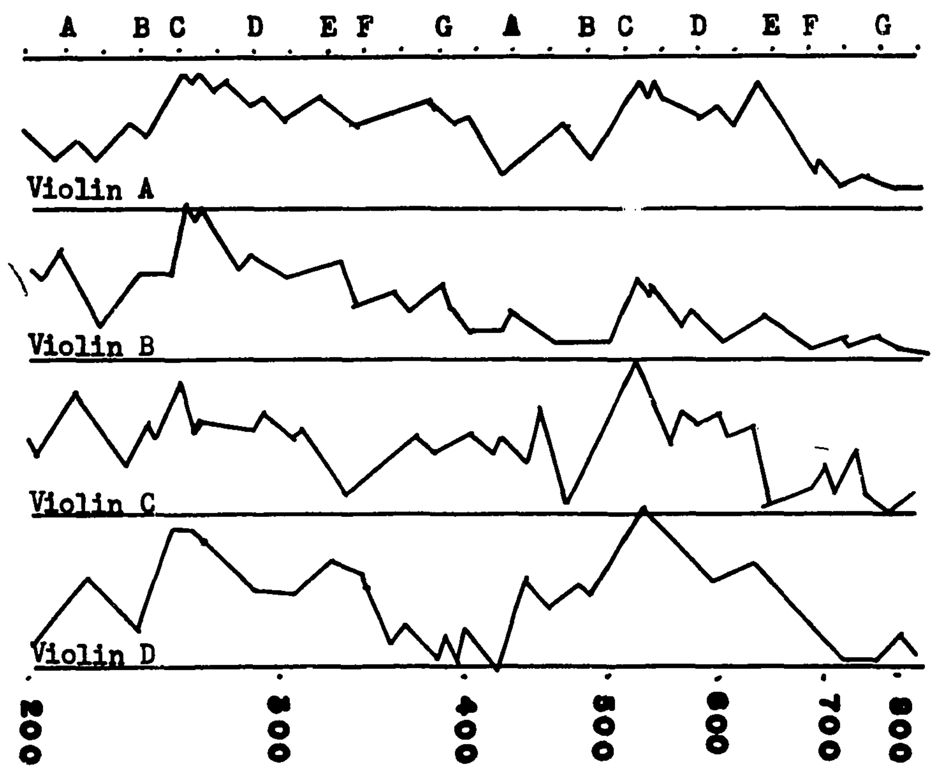

Fig. 29.--Loudness curves of completed violins A, B, C and D.

Violin A exhibits several strong resonance points. Those peaks between C and C sharp in both octaves are probably the resonance point of the air contained within the body of the instrument (cavity resonance) and its first overtone. The small peak on E 4 reflects the very large peak found in the back plate. The peak between A sharp 4 and B 4 may be an overtone of the principal resonance of the top. It can be seen that this graph is less angular than those of the top and back alone, indicating some averaging of peaks of one plate with valleys of the other.

Of the resonance peaks graphically representing violin _B_, the cavity resonance between C 4 and C-sharp 4 is the most pronounced. The principal resonance point of the top is seen as a plateau between B 3 and C 4. The principal resonance point of the back can be seen in a slight peak at D 4 and an octave higher, D 5.

In violin _C_ the largest loudness peak is seen an octave above the cavity resonance, which itself is quite strong. The peaks of the top and back can also be seen in the contour of the graph.

The octave above the cavity resonance of violin _D_, like that of violin _C_, is the strongest peak, with, in this case, also a strong cavity resonance. In both violin _C_ and violin _D_ the strong octave above the cavity resonance may be due to the fact that the main resonance of the top is in the same place as the cavity resonance, causing a reinforcement of that partial.

The Varnish

Commercially manufactured violin varnishes are available which fall into two large categories--those with an alcohol base in which a soft resin is dissolved, and those with an oil base, usually with a harder resin, the oil acting to modify the hardness of the resins, thus producing a softer finish than does the spirit varnish.

The varnishes of the old Italian violin makers, especially those of Cremona, have long been considered superior to all others, and many attempts have been made to reproduce this varnish which had a soft texture, was highly colored and at the same time was very transparent. Many formulas are given in Heron-Allen and other books for converting highly colored resins into varnish. It is not within the purpose of this report to attempt to make a value judgment about varnishes or varnish formulas. It was considered desirable, however, in order to have as much knowledge about the experiment as possible, as well as to make it possible for the experiment to be reproduced, that commercially made varnishes would not be used. Even the supplier rarely knows the ingredients of these varnishes, and often purchases stock from different sources, increasing the chance of variation in the formulas.

A commercial consulting chemist, Joseph Michelman, inductively produced a formula for the recreation of the Italian varnishes.[5] By isolating the ingredients that were available during the period in which the Italian varnish was being used, and applying techniques used in the textile and varnish industries and other techniques of chemistry, it seemed feasible to produce a resin that would resemble the

---

[5]Joseph Michelman, Violin Varnish; A Plausible Re-Creation of the Italian Violin Makers Between the Years 1550 and 1750, A.D. (Cincinnati: Joseph Michelman, 1946).

resin produced by the Italian violin makers of the sixteenth and seventeenth centuries.

The basic ingredients recommended are rosin (which is the resin of conifer trees), turpentine, a dilute potassium-lye solution, alum and linseed oil, with ferrous sulfate and tincture of the madder plant as coloring matter.[6]

Rosin was chosen as the basis because it has other applications relating to violins and was easily obtainable at the time of the Italian craftsmen. Turpentine was not used as a thinner during the time of these violin makers, but its use as a solvent had been known even to the ancient Egyptians.[7] Potassium-lye solutions are a by-product of the process of soap making. Madder root has been used as coloring matter for centuries, as have iron solutions.[8]

The original process of producing the varnish as it appeared in Michelman's book involved dissolving the rosin in the potassium-lye solution, the resulting compound being called potassium rosinate solution. The highly acid rosin is then precipitated with the base, alum, which neutralizes the acidity and forms a viscous liquid which is washed to remove any excess water-soluble base, then dried to form the basic resin. Red or yellow coloring is added by the use

---

[6]Michelman, Violin Varnish, 32.

[7]Ibid., 33.

[8]Ibid., 36.

of varying strengths of madder solution prior to precipitation. Brown coloring is imparted by adding varying amounts of ferrous sulfate to the precipitating solution. The dry resin is then dissolved in turpentine and linseed oil and applied to the instrument. Ultraviolet light, which is present in large amounts in sunlight, is necessary to the drying process.

After the publication of Michelman's book in 1946, it became possible to make spectrographic and chemical analyses of known specimens of old Italian violin varnish.[9] The presence of metallic elements in large quantities were taken as evidence for the hypothesis, and repeated analyses of other Italian varnish specimens were consistent with the first. In addition, the presence of madder was definitely established. Slight changes were made in the formula to adjust the relative proportions, and the discovery that the formula using sulfates produced a varnish which had a tendency to remain too soft in warm and humid climates led to the formulation and publication of a new formula using modern chemicals to simplify the process and replacing the sulfates with chlorides.[10] Because in modern times the cultivation and use of madder has been practically

---

[9] Joseph Michelman, "Confirmatory Evidence of the Rediscovery of the 'Lost' Italian Violin Varnish," American Paint Journal (Feb., 1948), 62.

[10] Joseph Michelman, "Modernized Violin Varnishes," Violins and Violinists (Jan.-Feb., 1958), 28.

discontinued, alizarine, the now-synthesized coloring matter in madder, is recommended in connection with the modern production of the varnish.

The use of such a mordant dye in connection with metallic oxide lakes had previously been used successfully in the textile industry.[11] No previous application of this technique has been discovered with reference to the coloring of varnishes.

The formula is quite adaptable, and resins other than rosin have been used, as well as oils other than linseed. Michelman discourages the use of substitute materials, however, in the interest of retaining a degree of authenticity.[12]

The varnish used on the test violins was prepared according to the modernized version of the formula. 13.8 grams potassium carbonate and 34.8 grams of WW grade rosin were dissolved in 600 cubic centimeters distilled water. The product was 600 cc potassium rosinate solution. 200 cc of this solution was placed in a separate container and 5 cc of 2% alizarine suspension was added as coloring matter. Separately, 5% solutions of aluminum chloride, calcium chloride and ferric chloride were prepared. The precipitating solution was made up of 90 cc of the 5% aluminum

---

[11]Michelman, Violin Varnish, 149.

[12]Joseph Michelman, Personal Correspondence. November 11, 1967.

chloride solution, 20 cc of the 5% calcium chloride solution, and 10 cc of the 5% ferric chloride solution, the latter being added to impart a degree of brownness to the color of the varnish.

The precipitating solution was poured into the potassium rosinate solution, the resulting reaction being accompanied by a decided thickening and color change in the solutions. The resin thus produced was placed on a piece of filter paper on a funnel and washed three times with distilled water. Finally it was removed to a dark area and allowed to dry naturally. Having dried completely, the resin was ground with a mortar and pestle and the varnish resin needed for one application to all four violins was measured.

Four grams of resin were weighed and added to 12 cc turpentine. After all the resin had dissolved, 6 cc artist grade linseed oil were added and mixed thoroughly. The varnish was then filtered through two thicknesses of nylon hosiery and applied to the violins with a sable brush. Only enough varnish could be made each time to apply one coat to the four violins, for the varnish is not stable and will gel in a matter of hours.

The first three coats of varnish, which were applied to the violins on December 2, 3 and 6, 1967, were clear. The subsequent eight coats, which were applied on December 14, 15, 16, 19, 20, 21, 22 and 23, 1967, contained coloring matter. Four large ultraviolet lamps were used to dry the varnish so that identical conditions would be present in the drying of all the instruments. The violins were suspended in front of the lamps and turned hourly for even exposure. The resulting varnish film was a deep golden orange color. Polishing with rubbing compound imparted a high luster to the finish.

After the varnish was completely dry the finger-board, pegs, bridge, sound post, tailpiece and strings were fitted and adjusted to the instruments, thus preparing them for evaluation.

CHAPTER IV

THE EVALUATION OF THE VIOLINS

Fifteen judges were selected to evaluate the four test violins. The group consisted of concert artists, orchestral concert masters, college professors of stringed instruments, professional musicians, and advanced students. The judges were (alphabetically) Vivian Adams, Stuart Canin, James Ceasar, Douglas Cone, Jean Crosby, Josef Gingold, Karl Greenshields, Barbara Hardin, Jacqueline Leonard, Theodore Madsen, Joshua Missal, Linda Terry, Bernard Rosenthal, Roberta Sellon and Diane Spognardi.

The difficulties inherent in evaluating violins are many. It is seldom, if ever, that a violin can be judged as having no bad qualities, or conversely as having no good qualities. Therefore, two violins may have differing strong and weak points, making it necessary for the judge to make a decision as to whether a particular weakness in one violin renders the violin less desirable than does the presence of a different weakness in another violin. A violin may be superior in all respects except for one glaring fault. In this case, the judge is faced with deciding whether or not the fault is severe enough to impair the quality of the violin when regarded as a whole.

Inevitably the judge's previous experience enters into his decision. If his own instrument has a particular flaw which he has learned to compensate for, he may find that he will attempt to make the same compensation on other instruments, which, if he is not aware of this fact, would tend to influence him into believing a fault existed which, in fact, was brought about by the compensating factor in his own technique.

Differences in stature of the judges, the type of playing each does (orchestral vs. solo), and personal preferences in tone quality and response will also have some influence on the standards by which each evaluates violins. The high degree of subjectivity involved in choosing a violin can be easily perceived.

Another difficulty to be dealt with in the same area is the tendency of some professional violinists to attempt to placate a violin maker. Artists are accustomed to violin makers who bring their creations to them ostensibly for evaluation, but quite often with only the desire that the artist assure them that the violin is excellent, and react unfavorably when the artist attempts to offer constructive criticism. To avoid such a confrontation, the artist is tempted to give a favorable criticism of the violin in question regardless of its actual qualities.

One such case was encountered in gathering the evaluations for this study. The reaction of the judge was that all the violins were so superior that all must be evaluated in the highest position. No true evaluation occurred, so this case was dismissed. The violinist in question therefore was not included as one of the judges, nor was the result of his inspection of the violins included in the tabulation of the results.

However, it is felt that the factors of the tone quality and response of the violins themselves are the major consideration in the process of evaluation.

The Scoring Instrument

In the evaluation of the test violins in this study, it was desired that the four violins be ranked in order of their relative merits. Artists would assign them the ranks 1, 2, 3 and 4. At the same time, the desirability of evaluations of specific characteristics was recognized. Through the artists' ratings on specific characteristics, additional information regarding weaknesses and strengths could be obtained.

For the evaluation of the violins a rating scale known as the "Semantic Differential," developed by Osgood, Suci and Tannenbaum, was used.[1] Basically the semantic differential is a scale offering multiple choices between

---

[1]Charles E. Osgood, et al., The Measurement of Meaning (Urbana: University of Illinois Press, 1967).

adjectives of opposite meaning. It is possible to make a judgment of degree graphically by selecting a space on the scale close to either term, in a neutral position, or showing tendencies in either direction. It has an advantage over scales in which all the positions within the scale are given adjectives, in that the differences in position are even, whereas in some cases it may not be possible to select adjectives evenly spaced across the scale. For the purpose of this study the direction of the scale was alternated (good-bad; bad-good).[2]

The specific characteristics to be judged were divided into two general categories: tone quality and responsiveness. Polarized adjectives were selected which were appropriate to each characteristic, and a scale of five positions was placed between them. It was therefore possible for each judge to place a check mark in the space adjacent to an adjective if he felt that the quality of a concept in relation to the violin to be closely identified with that adjective, in the middle if he felt it to be average, or in the second or fourth spaces if he felt the quality to be above or below average, but not to the degree that it should be closely identified with the adjective.

A simple rating scale was used for the overall evaluation of the violins, since numerical ranking was possible. The judges were asked simply to circle the

---

[2] Ibid., 156.

appropriate number which reflected their rating of the violin. Space was reserved for comments after each section.

The evaluation packet submitted to each judge with the four violins included a set of directions (Fig. 30), and four evaluation sheets (Fig. 31), one for each violin. In each case the judges were orally requested to make their judgments in as objective a manner as possible. It was emphasized that praise was unnecessary. The judges were assured that their evaluations would remain anonymous to allay any fears that their names might be used in connection with the sale of the violins, or that their evaluations might be used as endorsements.

The evaluations took from one hour to one and one-half hours for each judge to test all the violins. All of the judges played each of the violins at least twice, often three or four times. The entire range of the violin was covered and each violinist utilized his own tests to determine the relative merits of the various qualities of the instruments.

Results of the Evaluations

In order to facilitate examination of the evaluations, the responses to each pair of adjectives in the scoring instrument were dealt with separately. The number of responses in each position were totaled. The directions of the scales were reversed where necessary so that all the positive adjectives were on the left and the negative on

SCORING INSTRUMENT
FOR
EVALUATION OF VIOLINS

PURPOSE

The purpose of this evaluation is to measure as objectively as possible the tone and playing qualities of four test violins and then rate them, one against the others, in over-all quality.

DIRECTIONS

After you play each violin, evaluate it on the scales in parts I and II. If you feel that the quality in a given concept is good or bad, place a check mark as follows:

Good __X__ _____ _____ _____ _____ Bad

or

Good _____ _____ _____ _____ __X__ Bad

If the quality is average or neutral on the scale, place a check mark in the middle blank:

Good _____ _____ __X__ _____ _____ Bad

If the quality is above or below average, but not average, place a check mark as follows:

Good _____ __X__ _____ _____ _____ Bad

or

Good _____ _____ _____ __X__ _____ Bad

After you have played all the violins, rate the overall quality of each against the others by circling the number in part III: 1, 2, 3 or 4, which describes that violin. The number, 1, indicates the best; 4 indicates the least. The violins may be played any number of times desired.

Fig. 30.--Directions for use of the scoring instrument for the evaluation of the test violins.

Name of judge _______________	Violin identification letter _______________

Date _______________

I. Tone Quality

Ideal	___	___	___	___	___	Unacceptable
Poor	___	___	___	___	___	Excellent
Sweet	___	___	___	___	___	Harsh
Uneven	___	___	___	___	___	Even
Powerful	___	___	___	___	___	Weak
Soft	___	___	___	___	___	Strident
Penetrating	___	___	___	___	___	Tubby

Comments: (Back of sheet may be used)

II. Responsiveness

Ideal	___	___	___	___	___	Unacceptable
Poor	___	___	___	___	___	Excellent
Immediate	___	___	___	___	___	Sluggish
Demanding	___	___	___	___	___	Effortless
Even	___	___	___	___	___	Uneven
Uncomfortable	___	___	___	___	___	Comfortable
Quick	___	___	___	___	___	Slow

Comments:

III. Rating of this violin (Circle one): 1 2 3 4

Fig. 31.--Scoring instrument for the evaluation of the test violins.

the right. The responses on the column next to the negative adjective were weighted with a value of 20, and each column progressing toward the positive adjective was similarly weighted in increments of 20, until the column next to the positive adjective was reached, which was weighted with a value of 100. Because of lack of response the number of responses was not always fifteen in each case. The lack of response to some parts of the questionnaire was never total on the part of any judge, but several judges did omit one to four responses. The mean response was computed for the responses to each set of adjectives. The judges tended to avoid rating the tone quality or response of the violins in the extremes, with very few completely negative responses (Tables III and IV).

Examination of the means in Table III shows that, from the larger category of tone quality, the judges have chosen violin A most nearly ideal of the four and D most unacceptable; A most excellent, D poorest; A sweetest, D harshest; B most even, D most uneven; C most powerful, D weakest; A most strident, D softest; and C most penetrating, D most tubby.

Table IV indicates that in the category of response, B is most nearly ideal and D least; B is most excellent, D poorest; C is most immediate in response, D most sluggish; B is most effortless, D most demanding; A is most even, C along with D most uneven; A and B are most

TABLE 3

JUDGES' EVALUATIONS OF THE TONE QUALITY OF THE VIOLINS

Positive (Weight)	100	80	60	40	20	Negative	Mean
			Violin A				
Ideal	4	5	4	0	0	Unacceptable	80
Excellent	4	5	4	0	0	Poor	80
Sweet	3	2	6	0	0	Harsh	75
Even	2	7	1	2	1	Uneven	71
Powerful	3	6	4	1	0	Weak	76
Strident	2	1	6	1	0	Soft	68
Penetrating	2	4	3	2	0	Tubby	71
			Violin B				
Ideal	3	6	3	1	0	Unacceptable	77
Excellent	5	7	3	0	0	Poor	83
Sweet	1	6	2	2	0	Harsh	71
Even	4	4	3	2	0	Uneven	75
Powerful	4	7	1	1	1	Weak	77
Strident	2	2	3	3	0	Soft	66
Penetrating	1	4	4	1	0	Tubby	70
			Violin C				
Ideal	2	6	4	1	0	Unacceptable	74
Excellent	3	5	6	0	0	Poor	76
Sweet	1	4	5	2	0	Harsh	67
Even	2	6	0	4	2	Uneven	63
Powerful	5	5	2	0	0	Weak	85
Strident	0	4	5	1	0	Soft	66
Penetrating	3	3	2	2	0	Tubby	74
			Violin D				
Ideal	0	5	6	2	0	Unacceptable	65
Excellent	0	4	7	1	1	Poor	62
Sweet	1	3	4	3	1	Harsh	60
Even	2	2	6	4	1	Uneven	60
Powerful	1	3	5	1	1	Weak	64
Strident	1	3	3	4	0	Soft	62
Penetrating	2	1	6	2	0	Tubby	65

TABLE 4

JUDGES' EVALUATIONS OF THE RESPONSIVENESS OF THE VIOLINS

Positive (Weight)	100	80	60	40	20	Negative	Mean
			Violin A				
Ideal	2	7	4	0	0	Unacceptable	77
Excellent	2	7	3	1	0	Poor	75
Immediate	3	9	1	1	0	Sluggish	80
Effortless	1	8	1	2	0	Demanding	73
Even	2	6	1	3	0	Uneven	72
Comfortable	7	3	3	0	0	Uncomfortable	86
Quick	3	7	1	1	0	Slow	80
			Violin B				
Ideal	6	2	4	1	0	Unacceptable	80
Excellent	6	5	2	1	0	Poor	83
Immediate	5	7	0	2	0	Sluggish	81
Effortless	4	7	1	2	0	Demanding	79
Even	4	2	3	4	0	Uneven	69
Comfortable	6	5	2	0	0	Uncomfortable	86
Quick	7	3	1	1	0	Slow	87
			Violin C				
Ideal	2	7	3	1	0	Unacceptable	75
Excellent	2	9	1	1	0	Poor	78
Immediate	4	5	3	0	0	Sluggish	82
Effortless	1	8	2	3	0	Demanding	70
Even	2	5	2	1	2	Uneven	67
Comfortable	5	5	1	1	1	Uncomfortable	78
Quick	3	7	1	1	0	Slow	80
			Violin D				
Ideal	0	7	3	1	1	Unacceptable	67
Excellent	0	6	5	0	1	Poor	67
Immediate	1	7	2	1	2	Sluggish	66
Effortless	0	6	4	0	1	Demanding	67
Even	1	5	4	1	1	Uneven	67
Comfortable	1	5	2	2	1	Uncomfortable	65
Quick	2	5	3	0	1	Slow	73

comfortable whereas D is most uncomfortable; and B is quickest and D is slowest.

The Ratings of the Violins

At the beginning of this study it was anticipated that the evaluations would be quite one-sided; that almost all of the artists would choose one of the violins in first place, and with equal decisiveness in each of the other positions on the scale. It was entirely unexpected that each of the four violins would be chosen in first place at least once. As a matter of fact all the violins were chosen at least once in every position, with the exception of violin B, which was never chosen fourth, and violin D, which was never chosen in second place.

Interestingly enough, violin B was chosen in first place by nine of the fifteen judges, violin A was chosen in second place by nine judges and violin D was chosen in fourth place by nine judges. Violin C was chosen in third place by only seven judges, but in first place by five judges. Most of the judges commented orally to the writer that choosing the first place and last place violins was relatively easy, but that it was very difficult to choose which of the two remaining violins should be in second, and which should be in third place. This was true regardless of which two violins were in the middle. Two judges chose two violins in first place.

Because only four rankings were available to the judges for the numerical ranking of the instruments, the four positions were weighted with the values of 25, 50, 75 and 100, the latter being given for the rating of first position.

TABLE 5

JUDGES' NUMERICAL RATING OF THE VIOLINS

Rating	1st	2nd	3rd	4th
Weight	100	75	50	25
Violin <u>A</u>	1	9	1	4
Violin <u>B</u>	9	4	2	0
Violin <u>C</u>	5	1	7	2
Violin <u>D</u>	2	0	4	9

Five of those judges selecting violin <u>B</u> in first place selected the violins in the order, <u>B</u>, <u>A</u>, <u>C</u>, <u>D</u>. No other similar trends were seen.

In observing the evaluation of the violins, the present writer noted that, no matter which violin was chosen in first place, that was the violin upon which the judge himself sounded best according to the present writer's subjective rating. This may be indicative of a certain amount of individuality in approach to playing, requiring that some players be fitted with instruments having characteristics other than those required by other players.

The ranking of the violins by the fifteen judges was tested to determine the amount of agreement of the judges using the Kendall Coefficient of Concordance W formula.[3] In this case the rankings 1, 2, 3 and 4 were used for ease of computation, the lowest number indicating the highest rating. To compute the Kendal W, the sum of the ranks (Rj) in each column of a k (judges) by N (objects) table is taken (Table 6). The mean value of Rj is found. Each Rj is then expressed as a deviation from the mean value. Finally the squares of the deviation from the mean are computed and summed, yielding s. The value of W is then computed using the formula,

$$W = \frac{s}{\frac{1}{12} k^2 (N^3 - N)}$$

where s equals the sum of squares of the deviations from the mean of Rj, that is, $s = \Sigma (Rj - \frac{\Sigma Rj}{N})^2$ where k equals the number of judges N equals the number of objects ranked and $\frac{1}{12} k^2 (N^3 - N)$ is the maximum possible sums of the squared deviations, that is, the sum s which would occur with perfect agreement among k rankings.

At the .01 level, a critical value greater than 269.8 is necessary in this case to reject the null hypothesis. The calculated value of s is 366.75, therefore the null hypothesis is confidently rejected. A value of 366.75

---

[3]Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, Inc.), 229.

TABLE 6

K (JUDGES) BY N (OBJECTS)

	Violin			
	A	B	C	D
Judge				
1	4	2	1	3
2	4	1	3	1
3	2	1	1	4
4	2	3	1	4
5	2	1	3	4
6	1	2	4	3
7	2	1	3	4
8	2	1	3	4
9	2	1	3	4
10	4	2	1	3
11	2	3	1	4
12	3	2	4	1
13	2	1	3	4
14	4	1	2	3
15	2	1	3	4
RJ	38	23	36	50

is highly significant at the .01 level.[4]

The obtained coefficient, W = .33, expresses a high degree of agreement among the fifteen judges in ranking the four violins, indicating that the judges are applying essentially the same standard in ranking the instruments under study. Computations of the W were carried out by Mr. Jerry Carrol of the Statistics Laboratory, College of Education, University of Oklahoma.

[4]*Ibid.*, 286.

Comments By the Judges

The comments by the judges relative to specific violins are given here separated by violin:

Violin A

"This has a better G string than violin B."

"Tone color nasal. E string less brilliant. This violin has a deeper tone quality than all the rest. Sound leans toward the viola timbre."

"Fairly even tone on all strings, but a little hard to obtain good sound on the upper strings."

"Has a resonant quality and is very brilliant. The G and A strings are so rich they sound like a viola."

"The top two strings respond more easily. I do not like the bottom strings."

"The two lower strings are best. The E string is somewhat 'Wolfey.'"

"The E string is tight. The top of the G string is uncomfortable and hard to draw out tone."

"E string doesn't come out. Top of G is difficult."

Violin B

"The D is ever so slightly less loud than the other three--takes a bit of compensation."

"The G and D strings are ideal, the A and E less so, but still good."

"The E string is very bright in the upper register."

"The lower two strings speak slowly. Bright and singing on A and E."

"Good tone quality; needs to project more, though."

"Dark tone. I like the G string more. Built much on the bass side."

"Tone more clouded than A. Top two strings have a different tone quality; the difference is hard to detect, however."

Violin C

"The D string holds it back. A and E are nice."

"This violin has a harshness which is probably due to newness."

"This one has more quality than A and B."

"D string is less ideal than others, but overall, quality is excellent. D string crackles under pressure."

"The D and G strings are more responsive than the A and E. There is more substance to the D and G."

"This is the brightest of the four. It has a good ring to it. Not as mellow as it is brilliant. Even in tone quality."

"A string quite unresponsive."

"Harder quality than A and B but not as much depth."

Violin D

"This is not half as good as C."

"Sound comes from the surface rather than from within. The E string has the best sound."

"Pinches up on the E string. Seems to be too muffled--not brilliant enough."

"Stiff and open sounding."

"This is the most responsive of the four for me, but I don't care for the sound."

"Nasal tone quality. Nice 'G' string."

"E string very good--better than violin B."

"A string is weakest of the four violins."

General Comments

"If you get a player who plays lightly he will not like these fiddles--you have to dig in."

"Commendable workmanship on all four. Compares favorably with most modern instruments I've played."

"The most useful doctoral dissertation material I have run across in a long time."

"I've never played four violins that were so all alike, but craftsmanship of the instruments is too excellent for such a boxy scroll."

Aural Evaluation

April 23, 1968, the violins were evaluated by forty-six students at Bemidji State College, Minnesota. The group included majors from all areas of music, plus a few students electing music courses whose majors lay outside the field of music.

Mrs. Roberta Sellon, the violin instructor at the college carried out the experiment. The following was read aloud: "The purpose of this evaluation is to determine the relative merit of each of four violins. A passage will be played on each of the violins in order, then the process will be repeated. Each violin will be identified by the performer prior to each playing with a letter name: A, B, C or D. After the second playing, please indicate which violin you feel is best tonally by placing a figure '1' next to the violin's identification letter. Rate the second best instrument '2,' the third best '3,' and the least good '4.' Do not discuss your choice with others prior to marking it on paper." (The passage played was from the Bruch Violin Concerto.)

The responses were weighted in increments of 25 and the means computed (Table 7). The standard deviations are large, indicating a lack of reliability in this form of evaluation. This tends to confirm Saunders' similar findings.[5] In addition, the only agreement between the aural and playing evaluations is in the selection of violin D in last place.

The judges were all very generous with their time and none was superficial in his approach. The present writer

[5]F. A. Saunders, "Scientific Search for the Secret of Stradivarius," Journal of the Franklin Institute, CCXXIX

felt that as soon as each understood the purpose and scope of the project, full energies were directed toward as objective as evaluation as was possible in each instance.

TABLE 7

AURAL EVALUATIONS OF THE VIOLINS

Rating	1	2	3	4		
Weight	100	75	50	25	Mean	σ
Violin						
A	19	13	10	4	76	25
B	8	16	13	9	63	25
C	13	8	11	14	61	30
D	6	10	11	19	52	27

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDIES

In previous chapters various methods of graduation were reported and two were selected for use in the present experiment. Two violins were made following the specifications of each method and were evaluated by fifteen judges to determine whether there is any advantage to the use of either method of graduation.

The most consistent element in all the evaluations is the placing of violin D in last place of preference. In the first two parts of the evaluating instrument, dealing with tone quality and response, violins A and B are chosen in first place in all elements except those dealing with power, in which violin C, and sometimes violin D, are chosen in first place.

Many of the evaluations are mirrored in the graphs of the loudness curves of the completed instruments (Fig. 29). The harshness of violin D may be related to the extreme peaks of loudness near the air tone as contrasted with the extreme valleys an augmented fourth away. The valley may account for the tubbiness of that instrument and the fact that, from a standpoint of responsiveness, it makes more demands upon the performer than is the case with the other violins. The unevenness of C and D are reflected in their extreme peaks and valleys as graphically depicted in Fig. 29. The recommendations of Hutchins were that the top was to be made simply following good violin making practice. The back was then to be adjusted so that its peak resonance was within a major second above that of the top. In this case, the peak resonance of the top was so near that of the air tone that the pitch became an extreme peak, while an extreme valley occurred between the peaks in the finished violin, contributing to the unevenness of the loudness curve.

The rating of violin B in first and violin D in last place is well established. The positions of A and C are more difficult to establish, being so close in the sums of the ratings. When all the votes are considered, the slightly larger number of first place votes cast for C brings it to second place by a small margin. Therefore, the relative places of the violins in order of preference is B, C, A, and D. The first three are comparatively close in quality, whereas the ratings of D indicate that it is decidedly inferior.

From the data the conclusion must be drawn in this experiment (using the graduations, intervals and resonance points as recommended) that, while the electronic method seems to have the advantage of producing a violin with more volume, it has a disadvantage in that evenness and tone quality of the violins so treated are inferior, especially as exemplified in violin D. On the basis of this experiment the conclusion must be that no real, generalizable advantage has been found in either method of graduation.

It is possible that placement of the resonance points at different positions in relation to the air tone would produce a more satisfactory result. This seems to have happened in the case of violin B, if strictly by chance. Certainly, if the resonance points are largely responsible for the tone quality and response of the violin, the electronic method gives the maker greater control over their placement than does the traditional graduation method, in which the placement of the resonance frequencies is subject to chance.

Suggestions for Further Studies

It is felt that the experiment of comparing electronic tuning of the plates with graduation by measurement, which is described in these pages, could be profitably repeated several times in differing climates or with other factors different from those of this particular experiment. But, in addition, the present writer wishes to suggest several factors that should be studied and reported in print to further aid in isolating elements influencing the quality of violins and other stringed instruments and defining the limits within which the violin maker may work and be assured of producing successful instruments.

The present study, as well as each of the other possible studies which will be suggested here, could and should be repeated with the viola, violoncello and double bass. These instruments have been largely neglected in the literature and by violin makers in general and should receive concentrated attention. It is important that all experiments be comparative and that electronically derived data be recorded in all cases.

Electronic Tuning

Further experimentation is suggested using electronic equipment to determine the principal and minor resonance points. Other different intervals between the top and back plates should be tried. The fundamental resonance of the frame of the violin should be measured and it should be determined what elements are influenced when the resonance of the frame is changed. It should be determined whether the minor resonance points play a larger role than has been formerly assumed in the sound of the instrument: Can these minor resonances be isolated as coming from a certain part of the instrument, and/or can their amplitude be influenced independently of the other resonance points? It should be determined whether a different result is produced if the violin plates, traditionally tuned before varnishing, are tuned after varnishing instead.

Graduations

The study of graduation as a technique deserves further study. It is suspected that the range of usable dimensions as seen in the survey of the literature may be further narrowed through experimentation and study.

A study should be made of the effects of thinning various parts of each plate other than the traditional spots, to determine what effect unusual thinness in each portion of the plate does to tone quality, volume, evenness and other aspects of violin quality. With this experiment as with the others, data should be carefully notated, and reference made to various electronic instrumentation.

It would be profitable, when a procedure becomes available permitting alteration of specific qualities through specific techniques, to determine the advantages and disadvantages of disassembling completed instruments and altering them after discovering their deficiencies in the assembled state.

The presence of a slight thinness on the treble side of the plates in the graduation diagrams of the Stradivarius violins offers further material for experimentation. It should be determined what effects are obtained with an unbalanced graduation with thicker dimensions on one side, and what advantages are caused thereby.

Comparative experiments should be carried out testing other methods of graduation than were the subject of this dissertation. The fact that the tap-tones taken from the test violins were the same note name (if a different octave) as the main resonance, gives the tap-tone technique some credence, and certainly indicates the necessity for further experimentation with the technique. The effects of the microtone technique, the candling technique, and the methods involving balance and balance of air should also be explored.

Model

Experiments with the model should include alterations of the shape of the outline, various types of arching and their relation to the graduations, and alterations to the shape and position of the sound holes.

Wood

Comparative experiments are needed in relation to the wood used in building the violin. A complete survey should be made of the treatment of the wood, including not only the seasoning of the wood, but also impregnation of the wood with chemicals and preservatives to see what effects are caused by various treatments.

Generalizations need to be established about the characteristics of wood as they effect the graduation process. It should be determined whether harder wood should be left thicker or thinner than softer wood of the same species, or whether the contrast between the thickest and thinnest portions of the plate should be greater or smaller with harder wood. It should be determined whether the spruce should be treated in the same or opposite manner as the maple in this respect.

It should be determined what effect the width of the grain has on the elasticity, strength and acoustical qualities of the wood, and how these qualities should effect graduation.

Varnish

The effects that various types of varnish have on violins of similar wood and model should be studied. The foundation coat that is applied to the violin prior to the application of the color varnish should be studied to determine what materials are available, and what effect (if any) each has on the ultimate tone qualities of violins. Study should be made of the effect of varnishing the interior of the violin to determine if a violin so treated would resist changes brought about by changes in the atmosphere, and whether any harmful effect is caused thereby. Studies of the effects of varnishing should include before-and-after studies of loudness curves and overtone production.

Fittings

Differing types of bridges, sound posts and bass bars have been known to have decided effects on the tone and response of violins, but alterations have been largely empirical, with no firm generalizations having been established. Experimentation in this field is needed. Effects of extremes of hardness and softness of material should be tried, and varying settings of position.

Repairs

Minute effects of various repairs could be easily examined with before-and-after tests with various electronic equipment, even when the effects are too minute to be detected by the human ear. Experimentation of this type may help define the useful life of violins, as well as help discover which techniques of making a given repair are tonally superior to other techniques.

Age

If the chemical and physical changes which occur in wood and varnish in aging can be discovered, it is possible that any beneficial effects of aging may be reproduced artificially. If sound is an important factor in maturing the violin, experiments of artificially inducing this maturation could be carried out by using a specially prepared speaker such as was used in the experiment carried out for this dissertation. The elongated center pole could be brought in contact with the bridge, and sound projected into the instrument by means of phonograph records or electronic equipment. Results of experiments using "white noise" could be compared with results of experiments using musical sound. Sound could be projected into the instrument twenty-four hours a day, whereas playing in the normal manner would cause sound to be projected into the instrument only a fraction of that time. If successful, it could have the effect of maturing the instrument in a much shorter span of time than is usually the case.

Electronic equipment should be used to discover if any change occurs in violins played by professionals over a period of years, and what those effects are.

Experiments such as those suggested above would not always produce instruments exhibiting positive qualities, but even by producing negative qualities, the experimenters would be performing the service of further defining the limitations within which the violin maker may work.

BIBLIOGRAPHY

Books

Abele, Hyacinth. The Violin and Its Story. London: The Strad Office, 1905.

Boyden, David D. The History of Violin Playing from Its Origins to 1761. London: Oxford University Press, 1965.

Buchner, Alexander. Musical Instruments Through the Ages. Trans. by Iris Urwin; London: Batchworth Press, Ltd., 1961.

Castle, Frederick. Violin Tone Peculiarities. Lowell, Indiana: H. H. Ragon and Son, 1906.

Farga, Franz. Violins and Violinists. London: Rockliff Publishing Corporation, Ltd., 1950.

Geiringer, Karl. Musical Instruments; Their History in Western Culture from the Stone Age to the Present Day. Trans. by Bernard Miall; 2nd ed.; London: George Allen and Unwin, Ltd., 1945.

Gilbert, Justin. Cremona Violin Technique. Seattle: Lowman and Hanford Company, 1937.

Grout, Donald Jay. A History of Western Music. New York: W. W. Norton and Company, 1960.

Henley, William. Universal Dictionary of Violin and Bow Makers. 5 vols.; Brighton, England: Amati Publishing Co., Ltd., 1959.

Heron-Allen, Edward. Violin Making As It Is and Was. 2nd ed.; London: Ward, Lock and Company, Ltd., 1885.

Hill, W. Henry, et al. Antonio Stradivari; His Life and Work. 2nd ed.; New York: Dover Publications, Inc., 1963.

Hill, William H., et al. Violin Makers of the Guarneri Family. 2nd ed.; London: Holland Press, Ltd., 1965.

Jalovec, Karel. Italian Violin Makers. Rev. ed.; London: Paul Hamlyn, Ltd., 1964.

Michelman, Joseph. Violin Varnish; A Plausible Re-creation of the Varnish Used by the Italian Violin Makers Between the Years 1550 and 1750, A.D. Cincinnati: Joseph Michelman, 1946.

Osgood, Charles E., et al. The Measurement of Meaning. Urbana: University of Illinois Press, 1967.

Sachs, Curt. The History of Musical Instruments. New York: W. W. Norton and Company, Inc., 1940.

Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956.

Articles

Artindale, Fred. "On Tone and Pitch of Violin Plates." International Violin and Guitar Makers Journal, X (November, 1966), 9a.

Batts, Jack. "The Arching of Plates." The Violin Makers Journal. V (February-March, 1962), 14.

Conner, Karl. "The Michelman Varnish and Drying Cabinet." The Strad. (January, 1966), 327.

Daggit, Edmund. "Some Suggestions on Micro-toning." International Violin and Guitar Makers Journal. IX (February, 1965), 20.

________. "Some Suggestions on Micro-toning." International Violin and Guitar Makers Journal. IX (March, 1965), 19.

________. "Some Suggestions on Micro-toning." International Violin and Guitar Makers Journal. IX (April, 1965), 7.

________. "Some Suggestions on Micro-toning." International Violin and Guitar Makers Journal. IX (June, 1965), 19.

________. "Some Suggestions on Micro-toning." International Violin and Guitar Makers Journal. IX (July, 1965), 19.

Hayes, Gerald. "Viol." Groves Dictionary of Music and Musicians. 5th ed.; London: Macmillan and Company, Ltd., 1954, VII, 803.

Hutchins, C. M. "The Physics of Violins." Scientific American. CCVII (November, 1962), 78.

Hutchins, Carleen. "Tuning Top and Back Plates Electronically." Catgut Acoustical Society Newsletter. VI (November, 1966), 15.

Hutchins, C. M., et al. "Subharmonics and Plate Tap Tones in Violin Acoustics." Journal of the Acoustical Society of America. XXXII (November, 1960), 1443.

McGowan, Robert F. "Comments on Michelman Varnish." The Violin Makers Journal. V (April-May, 1962), 29.

________. "My Method of Tuning Plates." The Violin Makers Journal. VI (January-February, 1963), 31.

Meinel, H. "Regarding the Sound Quality of Violins and a Scientific Basis for Violin Construction." Journal of the Acoustical Society of America. XXIX (July, 1957), 617.

Mertzanoff, C. E. and J. Westall. "Thickness of Violin Plates Old and New." Violins and Violinists. V (April, 1944), 474.

Michelman, Joseph. "Additional Confirmatory Evidence of the Rediscovery of the Old Italian Varnish." Science. CXII (September 22, 1950), 337.

________. "Analysis of a Varnish Used by Stradivarius." Journal of the Franklin Institute. CCXLVII (June, 1949), 569.

________. "Chemical Research on the Violin." The Strad. (October, 1965), 205.

________. "Confirmatory Analysis of the 'Lost' Italian Varnish." Science. CVII (June 25, 1948), 679.

________. "Confirmatory Evidence of the Rediscovery of the 'Lost' Italian Violin Varnish." American Paint Journal. (February, 1948), 62.

________. "Lost Art of Strad Varnish." The Scientific Monthly. LXXXI (November, 1955), 221.

________. "Modernized Violin Varnishes." Violins and Violinists. (January-February, 1958), 28.

Michelman, Joseph. "Successful Use of the Michelman Violin Finish (Part 2, New Drying Equipment)." The Strad. (March, 1963), 401.

Sanborn, G. "Who Was Right?" International Violin and Guitar Makers Journal. X (September, 1966), 10.

Sangster, E. H. "Fifty Years of Violin Making." The Violin Makers Journal. I (July, 1958), 5.

________. "Forty Years of Violin Making." The Violin Makers Journal. IV (March, 1961), 5. (sic)

Saunders, F. A. "The Mechanical Action of Instruments of the Violin Family." Journal of the Acoustical Society of America. XVII (January, 1946), 169.

________. "The Mechanical Action of Violins." Journal of the Acoustical Society of America. IX (October, 1937), 81.

________. "Recent Work on Violins." Journal of the Acoustical Society of America. XXV (May, 1953), 491.

________. "Scientific Search for the Secret of Stradivarius." Journal of the Franklin Institute. CCXXIX (January, 1941), 1.

________. "Violins, Old and New." American String Teacher. (Summer, 1966), 36.

________. "Violins, Old and New." American String Teacher. (Fall, 1966), 9.

________ and Hutchins, C. M. "On Improving Violins." Violins and Violinists. XIII (November, 1952).

Skou, Kristian. "How to Rebuild a Violin from the Microtone System." Violin Makers Journal. (April-May, 1961), 17.

Smiley, ___. "Science for the Maker." The Violin Makers Journal. IV (June, 1961), S 12.

________. "Science for the Maker." The Violin Makers Journal. V (December-January, 1962), S 27.

Wake, H. S. "Keep Your Weight Down." The Violin Makers Journal. VII (December-January-February, 1964), 27.

White, Carmen. "Thoughts About Tap-tones." International Violin and Guitar Makers Journal. X (February, 1967), 13.

Wright, G. R. "Balancing the Air Volume of the Violin." International Violin and Guitar Makers Journal. VIII (April, 1965), 29.

Unpublished Material

Heffelfinger, E. R. Violin Appraisal. Unpublished Masters Thesis. University of Michigan, 1949.

Knapik, Eugene. Personal Correspondence. November 12, 1966.

Michelman, Joseph. Personal Correspondence. November 11, 1967.

Skou, Kristian. Personal Correspondence. (October, 1966).

Stetler, Z. R. Influence of Design and Construction of Violins Upon the Interest and Progress of School Violin Pupils. Unpublished Masters Thesis. Boston University, 1950.