THE EFFECT OF INTERIOR SHAPE AND SIZE OF CLARINET MOUTHPIECES
ON INTONATION AND TONE QUALITY

by

Walter L. Wehner
B. M. E., 1949; M. M. E., 1950
University of Wichita

Submitted to the Department of Music
Education and to the Faculty of the
Graduate School of the University of
Kansas in partial fulfillment of the
requirements for the degree of
Doctor of Education.

Diss
1961
Wehner
c.2

Advisory Committee:

May, 1961

Redacted Signature

Redacted Signature

Redacted Signature

R00056 66801

ACKNOWLEDGMENTS

Throughout the preparation and writing of this dissertation, the writer has received valuable advice and encouragement from many people. In particular the writer is indebted to his adviser, Dr. Marcus E. Hahn, for his sympathetic understanding of the nature of this study and his many excellent suggestions. The other members of his committee, Dr. E. Thayer Gaston, and Dr. William C. Cottle have offered cogent criticisms, suggestions, and advice during the course of this work. The writer also wishes to express his appreciation to his wife, Merle Lorraine Wehner, who is, as always, the chief sustainer of his efforts.

W. L. W.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vii
 CHAPTER	
I. INTRODUCTION AND PROBLEM	1
The Problem of the Clarinet Mouthpiece	1
The Clarinet and the Music Education Program	1
Factors Affecting Clarinet Tone Quality	5
The Clarinet Mouthpiece Facing	9
Factors Affecting the Choice of Clarinet Mouthpieces	14
The Concept of Desired Tone Quality	14
The Embouchure of the Performer	16
The Amount of Air Passed Through the Mouthpiece	19
The Maintenance of Correct Intonation, Responsiveness, and Security	21
The Importance of the Mouthpiece in Clarinet Performance	23
The Problem of the Study	27
II. THE CLARINET	30
History and Construction	30
The Modern Clarinet	40
The Modern Clarinet Mouthpiece	44
III. EXPERIMENTAL DESIGN	46
Bore Taper Analyses	46
Bore Size Analyses	47
Bore Length Analyses	47
Tone Chamber Analyses	48
Improvement of Student Clarinetist's Performance	49

IV. EVALUATION OF THE DATA	51
Bore Taper Analyses	51
Bore Size Analyses	54
Bore Length Analyses	56
Intonation Analyses of Tone Chamber Taper	58
Intonation Analyses of Tone Chamber Depth	60
Tone Quality Analyses of Tone Chamber Taper	62
Tone Quality Analyses of Tone Chamber Depth	68
Mouthpiece Tone Chamber Tone Quality Perception Tests	73
Evaluation of Student Clarinetist's Performances . . .	86
V. SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS . . .	92
Summary	92
Summary of Procedures	94
Findings	96
The Internal Dimensions and Intonation	96
The Internal Dimensions and Tone Quality	99
Conclusions	101
Recommendations	103
BIBLIOGRAPHY	107
APPENDIX A: Forms used in Tone Quality Perception Tests	111

LIST OF TABLES

Table	Page
1. Mouthpiece Facing Chart (Measurement of the Control Section)	11
2. Mouthpiece Facing Chart (Measurement of the Vent Section)	12
3. Average Medium "French" Mouthpiece Facing	19
4. The Effect of Mouthpiece Bore Taper Size on Intonation of Two Clarinets Having a Bore of 0.591 and 0.585 Inch	53
5. The Effect of Mouthpiece Bore Size on Intonation of Two Clarinets Having a Bore of 0.591 and 0.585 Inch	55
6. The Effect of Mouthpiece Bore Length on Intonation of Two Clarinets Having a Bore of 0.591 and 0.585 Inch	57
7. The Effect of Mouthpiece Tone Chamber Taper on Intonation of Two Clarinets Having a Bore of 0.591 and 0.585 Inch	59
8. The Effect of Mouthpiece Tone Chamber Depth on Intonation of Two Clarinets Having a Bore of 0.591 and 0.585 Inch	61
9. The Effect of Mouthpiece Tone Chamber Taper on the Relative Strength of a Series of Partial with a Fundamental of f	64
10. The Effect of Mouthpiece Tone Chamber Taper on the Relative Strength of a Series of Partial with a Fundamental of f'	65
11. The Effect of Mouthpiece Tone Chamber Taper on the Relative Strength of a Series of Partial with a Fundamental of f''	66
12. The Effect of Mouthpiece Tone Chamber Taper on the Relative Strength of a Series of Partial with a Fundamental of c'''	67
13. The Effect of Mouthpiece Tone Chamber Depth on the Relative Strength of a Series of Partial with a Fundamental of f	69
14. The Effect of Mouthpiece Tone Chamber Depth on the Relative Strength of a Series of Partial with a Fundamental of f'	70
15. The Effect of Mouthpiece Tone Chamber Depth on the Relative Strength of a Series of Partial with a Fundamental of f''	71
16. The Effect of Mouthpiece Tone Chamber Depth on the Relative Strength of a Series of Partial with a Fundamental of c'''	72

17.	Tape Recording of Tone Chamber Taper Changes	75
18.	Tape Recording of Tone Chamber Depth Changes	77
19.	Test Scores Made with Tape Recordings of Tone Chamber Taper and Depth Changes	79
20.	Tape Recording of Tone Chamber Taper Changes with Mouthpiece D Serving as the Mean Size	82
21.	Tape Recording of Tone Chamber Depth Changes with Mouthpiece D Serving as the Mean Size	83
22.	Choices by Selected Judges when Comparing the Tone Quality Produced with a Mean Size Tone Chamber Taper with the Tone Quality Produced with Seven Other Sizes of Taper	84
23.	Choices by Selected Judges when Comparing the Tone Quality Produced with a Mean Size Tone Chamber Depth with the Tone Quality Produced with with Six Other Sizes of Depth	85
24.	Tape Recording of Student Clarinetist's Performances	88
25.	Choices by Judges when Comparing Student Performances with Original and Correct Mouthpieces	90

LIST OF FIGURES

Figure	Page
1. Mouthpiece Construction	9
2. Musical Excerpt used in Tape Recording	73

CHAPTER I

INTRODUCTION AND PROBLEM

The Problem of the Clarinet Mouthpiece

The selection of correct mouthpieces for clarinet students is of major importance to the clarinet teacher and the music educator. It is generally assumed that the mouthpiece is instrumental in the development of fine clarinet players. Many factors are involved in the choice of mouthpiece. Some of the factors contributing to correct intonation and tone quality are known and others are unknown at present. The internal dimensions are presumed to have some effect on intonation and tone quality, but precisely what this effect may be remains a mystery. Most music educators and clarinet teachers select mouthpieces for their students by considering the facing measurements only, ignoring the internal dimensions. There is some empirical evidence that the internal measurements are critical and should be considered along with the facing. This study is an attempt to determine what effect variations in internal dimensions have upon the development of correct intonation and tone quality.

The Clarinet and the Music Education Program

The clarinet has been in use in the public schools since the earliest beginnings of the instrumental music education program. The instrument serves a need in the concert and marching bands, the orchestra, woodwind ensembles, dance and stage bands, and for the student who desires to perform as a soloist. It is a valuable instrument for the musical

training of the elementary school child because of the simplicity of the fingering. Many notes can be played with the addition or subtraction of only one finger. In addition, it is relatively simple to produce a tone--especially in the early stages of learning.

Many more clarinets are needed than any other single wind instrument to properly balance other instruments in the modern band. The woodwind instruments form the largest section and, of this group, the soprano b-flat clarinets constitute the greatest percentage. In addition to the prominent role it plays in the music education program, the clarinet is popular with school children. The popularity of the clarinet is shown in a survey which was made by the editors of the national magazine, Boys Life, and reported in the magazine, The Instrumentalist. This survey indicated that 40.9 per cent of their readers played musical instruments and that, of these, 12.8 per cent preferred the clarinet, a proportion which was second only to the piano.¹

Although the clarinet remains a popular and necessary instrument in the music education program, it presents a challenging problem to the teacher. Because of the large number of clarinets used in the modern band, it is essential that good tone quality is developed and correct intonation is maintained. The overall sound of the band is affected by the performance of the clarinet section. The lower register of the clarinet is usually more controllable, thereby permitting the student especially to play well in tune; however, the tuning in the upper register is usually poor and it is very difficult for the student to

¹"Instruments Boys Like." The Instrumentalist, Volume V, Number 4 (January-February, 1951), Evanston, Ill., p. 41.

maintain accurate intonation for even a short period of time. At festivals, contests, and concerts, the tone quality of the clarinet section usually receives criticism, and the intonation in the high register is always in need of improvement. Low, a clarinet teacher of many years experience, sums up the situation when he writes as follows:

There certainly is nothing worse in all musicland than a cackling, out-of-tune clarinet section. It is usually the chief headache [sic] of the school band director. It is quite amazing that an instrument that has such wonderful possibilities for musical beauty and expression is also capable of emitting a coarse, reedy, soggy tone excruciatingly out of tune.²

Gee, in an article written for music educators, reports that "there is a need to improve the tone quality and intonation of clarinet sections on all levels of school bands."³ Waln⁴ reports that questions asked by band directors are concerned mainly with the intonation of the clarinet.

To add to the difficulty encountered with student clarinetists in the achievement of accurate tuning, the instrument, being a compromise of intonations, generates some problems of its own. McGinnis and Pepper⁵ reporting on an analysis made of the intonation of the clarinet, remark upon its faults of construction. When the clarinet is tuned accurately

²Floyd E. Low. "Keep that pitch up." The Instrumentalist, Volume IV, Number 2 (November-December, 1949), Evanston, Ill., p. 38

³Harry R. Gee. "Clarinet Mouthpieces." The Instrumentalist, Volume XI, Number 8 (April, 1947), Evanston, Ill., p. 50.

⁴George E. Waln. "Clarinet Mouthpieces and Tuning Problems." The Instrumentalist, Volume III, Number 4 (March-April, 1949), Evanston, Ill., p. 39.

⁵C. S. McGinnis, and R. Pepper. "The Intonation of the Boehm Clarinet." The Journal of the Acoustical Society of America, Volume 16 (1945), pp. 188-193.

in the chalumeau register, the clarion and acute registers are affected greatly, and vice versa. Therefore, each register must be mistuned to a certain extent to maintain an overall balance. Further corroboration of the difficulty of playing the clarinet in tune is stated by Bonade:

To play the clarinet in tune is a very difficult task. Usually, it is the concern of only the advanced student and professional, and it gives the former a few uneasy years. By playing in tune, I do not mean the simple act of tuning to a given note and then forgetting all about the matter. It is a practical measure in a large ensemble to tune to a given note, but the problem of intonation merely begins at this point.⁶

It is evident that clarinet teachers and music educators are aware of the problems involved in the teaching of the clarinet. Articles concerning the problems can be found in periodicals intended for the various teachers involved with clarinet instruction. The usual attempts made to improve intonation and tone quality are as follows: cutting the reed and thereby making it harder and more resistant, shortening of the barrel joint which is the immediate section below the mouthpiece, improving the embouchure of the student, and lengthening the instrument by extending each section. However, the mouthpiece is usually neglected. Possibly, because many school music educators are not clarinetists, they hesitate to investigate this possibility or are unaware of how the mouthpiece can affect intonation.

In an subjective report concerning the factors which contribute to the improvement of clarinet tone quality and intonation, Low⁷ mentions

⁶Daniel Bonade. "Playing in Tune." The Clarinet, 17 (Winter, 1954-1955), Symphony, New York, p. 10.

⁷Low. op. cit., p. 38.

posture, breathing, angle at which the instrument is held, lips, cheeks, lower jaw, chin, tongue, throat, and the right-hand thumb. Exactly how each of these elements affect tone quality and intonation is not shown. Parker⁸ states that the following have important effects on the tone quality of clarinets: the pressure on the reed and the position at which pressure is exerted, the blowing pressure, and the position of the pitch in the register. However, if professional clarinetists are correct in their beliefs, the mouthpiece is critical in this respect. If a good mouthpiece is essential for the development of good tone quality and accurate intonation, perhaps what is critical in this respect can be measured and evaluated. The music educator should be able to evaluate each student's mouthpiece, make improvements on it, or recommend a better one for the performer.

Factors Affecting Clarinet Tone Quality

Several factors affecting the tone quality of the clarinet have been previously recorded. Probably the first recorded clarinet tone analyses were attempted by Blaikley.⁹ He held an opposite view from Helmholtz and Rayleigh who had concluded that the clarinet acted as a stopped cylindrical tube and emitted only odd harmonics. More recent studies made by McGinnis, Hawkins, and Sher¹⁰ have proved the presence

⁸Sam E. Parker. "Analyses of the Tones of Wooden and Metal Clarinets." The Journal of the Acoustical Society of America, Volume 19, Number 3 (May, 1947), p. 417.

⁹Ibid., p. 415.

¹⁰C. S. McGinnis, C. Gallagher, and N. Sher. "An Experimental Study of the Tone Quality of the Boehm Clarinet." The Journal of the Acoustical Society of America, Volume 14 (1943), pp. 228-237.

of even-numbered harmonics and, although the strength of these harmonics vary, they tend to be stronger in the higher register.

Various studies have been made concerning the influence of the material used in the construction of instruments on tone quality. Tone quality analyses were made by Miller¹¹ concerning the effect of various materials in flute construction. He concluded that the material used in construction was of great importance and that certain metals, such as gold, were superior to others in tone production. In a study made by Parker concerning tone quality production on metal and wooden clarinets, it was found that "all comparative analyses using wooden and metal resonating tubes were essentially identical."¹² However, although identical results were obtained on the metal and wooden clarinets when measured by physical means, it is possible that a psychological difference exists which is evident to the performer. Richardson¹³ also investigated the influence of the material used in the clarinet tube on tone quality. He found that the rigidity of the tube could have a damping effect upon tone quality, and that various materials have a tendency to enhance certain regions of the clarinet scale.

Other methods have been utilized in attempting to analyse the tone quality of the clarinet. Redfield¹⁴ considered the effects of a

¹¹ D. C. Miller. The Science of Musical Sounds. Macmillan Co., New York, 1926, p. 182.

¹² Parker. op. cit., p. 416

¹³ E. G. Richardson. The Acoustics of Orchestral Instruments and of the Organ. Oxford University Press, New York, 1929, p. 57.

¹⁴ J. Redfield. "Air Column Behavior in Orchestral Wind Instruments." The Journal of the Acoustical Society of America, Volume 6 (1934), pp. 34-36.

player's respiratory tract on clarinet tone quality. His method involved the use of a stethoscope in the examination of several players' necks and throats. His subjects visualized notes from the various registers of the clarinet before playing them and Redfield attempted to determine whether a physiological change was produced which could be measured by the stethoscope. He concluded that a change takes place when playing a tone which corresponds with the impression the subject has of the sound of the particular note.

Concerning the function of the clarinet reed, it was generally believed that the reed remained a distance away from the lay of the mouthpiece at all times during its vibratory cycle. This was the assumption accepted in the studies of Das¹⁵ and Ghosh¹⁶ in their mathematical explanations regarding the presence of even partials. In a more recent study, McGinnis and Gallagher¹⁷ have shown that the flow of air is completely shut off by the clarinet reed during a large part of the cycle. This study demonstrates the need for having an unwarped and exact mouthpiece facing which would permit the reed to close completely. Actual control and responsiveness would be limited if the reed was hindered in its closing action.

¹⁵P. Das. "Theory of the Clarinet." Indian Journal of Physics, Volume 6, Part I (1931), p. 225.

¹⁶R. N. Ghosh. "The Theory of the Clarinet." The Journal of the Acoustical Society of America, Volume 9 (1938), pp. 255-264.

¹⁷C. S. McGinnis, and C. Gallagher. "The Mode of Vibration of a Clarinet Reed." The Journal of the Acoustical Society of America, Volume 12 (1941), pp. 529-531.

The studies which have been cited have considered materials in clarinet construction, the function of the reed, the bore of the clarinet tube, and an examination of the respiratory tract. None of these studies have considered the role of the mouthpiece in tone quality production. Notwithstanding the fact that many professional clarinetists and some music educators consider the mouthpiece as being essential for good tone production and the maintenance of accurate intonation.

It is common knowledge that clarinetists are continually looking for more desirable mouthpieces and are usually dissatisfied with their present models. Brymer reports that a student calling at the home of the English clarinetist, Henry Lazarus, found his drawing room table "groaning under the weight of not less than fifty mouthpieces, all complete with reeds, which the great man used in turn as he felt necessary."¹⁸ Stein demonstrates the attitude held by the professional clarinetist when he states:

Accomplished clarinetists, given the choice of performing with a poor mouthpiece on a fine clarinet or a fine mouthpiece on an unsatisfactory clarinet, would be forced to choose the latter, since the mouthpiece is the first point of contact and its reaction greatly affects the response of the clarinet. No matter how fine the instrument, only meager results are possible if the mouthpiece does not respond correctly.¹⁹

Willaman, an author of a recent book on the clarinet, protests against the attitude of some clarinetists when he mentions that "players frantically searching for the best mouthpiece forget the all-important matter

¹⁸ Jack Brymer. "Henry Lazarus." The Clarinet, 2 (Summer, 1950), Symphony, New York, p. 16.

¹⁹ Keith Stein. The Art of Clarinet Playing. Summy-Birchard Publishing Company, Evanston, Ill., 1958, p. 5.

of human adaptability, and they go on for years, blowing every mouthpiece they see, and condemning them all. Their friends call this 'mouthpiece disease'."²⁰

The Clarinet Mouthpiece Facing

There are many factors present in the construction of the clarinet mouthpiece which should be considered when the selection is made for the student. The following figure shows the various parts of the clarinet mouthpiece:

FIGURE 1

MOUTHPIECE CONSTRUCTION

The facing, which permits the opening between the reed and mouthpiece, is selected by the performer in consideration of the pressure exerted against the reed by the lower lip and teeth, and the amount of air passed through the mouthpiece. The player cannot use the mouthpiece if the facing is placed on the mouthpiece in such a way as to allow insufficient air to pass through it, and at the same time allow the performer to breathe normally in relation to the amount of air needed to maintain a good tone quality. When playing a reed instrument the air

²⁰Robert Willaman. The Clarinet and Clarinet Playing. Carl Fischer, Inc., New York, 1949, p. 39 .

pressure generated through deep breathing must be maintained constantly against the reed. Although the player must hold his breath longer than normal when playing a wind instrument, the normal amount of air needed by the human body must be present. Therefore, the performer will select the mouthpiece facing which will enable him to perform with the minimum amount of exertion needed to produce a satisfactory sound on his instrument.

Various mouthpiece facings are considered applicable in the production of certain results when combined with the normal, or rather, most popular embouchure. Richardson,²¹ a mouthpiece expert of many years experience, reports the following results obtainable when using the various facings:

²¹Arlie Richardson. "The Clarinet Mouthpiece in Relation to Tone and Pitch." Leblanc Educational Series Publication, Kenosha, Wisconsin, p. 5.

TABLE 1
MOUTHPIECE FACING CHART

Measurement of the control section (nearest table).

- A. a. gauge: 0.0015"
b. length: 9/16" or less
c. possible result: less "bite" used; less power and projection
- B. a. gauge: 0.010"
b. length: 6/16" or less
c. possible result: stuffy

A and B lengths are considered short.

- C. a. gauge: 0.0015"
b. length: 10/16"
c. possible result: firm embouchure produces projection;
brilliant tone
- D. a. gauge: 0.010"
b. length: 7/16"
c. possible result: same as letter C

C and D lengths are considered medium.

- E. a. gauge: 0.0015"
b. length: 11/16" or more
c. possible result: long "bite" used; control difficult; strong
embouchure needed
- F. a. gauge: 0.010"
b. length: 8/16" or more
c. possible result: tiring to use; blows hard; rough tone

E and F lengths are considered long.

TABLE 2
MOUTHPIECE FACING CHART

Measurement of the vent section (nearest tip).

- A. a. gauge: 0.024"
b. length: 3/16" or less
c. possible result: great resistance; small tone
- B. a. gauge: 0.034"
b. length: 3/32" or less
c. possible result: stuffy tone; requires stiff reed

A and B lengths are considered close.

- C. a. gauge: 0.024"
b. length: 4/16"
c. possible result: some resistance; projected tone in all ranges

- D. a. gauge: 0.034"
b. length: 2/16"
c. possible result: brilliant, fluid tone; medium reed used

C and D lengths are considered medium.

- E. a. gauge: 0.024"
b. length: 5/16" or more
c. possible result: little resistance; control difficult

- F. a. gauge: 0.034"
b. length: 5/32" or more
c. possible result: strong embouchure needed; soft reed used

E and F lengths are considered open.

Measurements of the facings above are made with the use of feeler gauges which are inserted between a flat glass plate, marked in inches, and the lay of the mouthpiece. Combinations of any of the measurements stated above can and may make a difference in actual

performance qualities. Richardson goes further in his analysis to state that "great differences in tone chamber and/or bore can nullify results."²² As can be seen by an examination of the tables presented above, the choice of a clarinet mouthpiece facing will be determined by a number of factors. In addition, the tone chamber and bore measurements must be considered in relation to the same factors. The facing is a matter of individual choice after the preliminary steps have been passed and the embouchure formed. The object of the curve facing is to permit the performer, by altering the pressure against the reed, to vary the length of reed which is free to vibrate making the natural frequency of the reed more nearly equal to the frequency of each note.

When a mouthpiece facing is considered by the performer, it is essential that the measurements of the facing are identical on both sides. The feeler gauges of various sizes must stop at right angles to the bore when inserted between the mouthpiece and the glass plate. If one side is slightly lower than the other, the mouthpiece will produce increased resistance because the reed will not only vibrate back and forth but will also have to twist somewhat to meet the facing on the lower side. Since the vibrations of the reed occur several hundred times per second, it is understandable why a correct facing is important.

²²Richardson. op. cit., p. 5

Factors Affecting the Choice of Clarinet Mouthpieces

The Concept of Desired Tone Quality

Many adjectives have been used to describe the clarinet tone quality. It is generally agreed that by "quality" is meant those characteristics which enable one to distinguish the tone of one instrument from that of other instruments even though the frequency and amplitude remain the same. In scientific terms, quality is referred to as harmonic structure, waveform, or pattern of partials. The tone quality of the clarinet has been considered as representative of one of three, or perhaps four, schools of clarinet playing: French, German, Italian, and American. Rendall considers the concept of tone quality as being of utmost importance to the performer when he writes that "a player will as a rule obtain on any system of clarinet the tone which he admires, which he strives to cultivate, or in which he has been schooled."²³

In a chapter devoted to the various tone qualities, Willaman²⁴ reports that the "German" facing is very long, in some cases as much as twenty-eight millimeters. It requires a reed which is longer than the ordinary reed used by the clarinetists in the United States, England, and France. The tone quality is dark, tubby, thick, and heavy. The "Italian" facing is very short. It permits a length between reed and mouthpiece, as short as thirteen millimeters and opening, between reed

²³F. G. Rendall. The Clarinet. Ernest Benn, Limited, London, 1954, p. 106.

²⁴Willaman. op. cit., pp. 31-39.

and mouthpiece, of only a half-millimeter at the tip. The tone quality of the "Italian" facing is reported as being light, nasal-sounding, and thin. The "French" style mouthpiece, which is in general use in the United States today, is midway between the "German" and the "Italian." Its length is usually about sixteen millimeters and the tone quality produced is generally considered light, bright, liquid, flexible, and sweet.

Another viewpoint is expressed which differs from the information provided by Willaman. In an article by Gigliotti, the observation is made that "of the several schools of thought on this subject [clarinet tone quality] the German and English schools are the most influential."²⁵ He then mentions that the American tone quality is a combination of the "German" and the "French" tone qualities.

In view of the descriptive terms used to differentiate between the various clarinet tone qualities, it seems that most writers on the subject of the clarinet are of the opinion that differences do exist. Therefore, the training of the clarinetist and the school to which he has been subject would play an important part in the development of the concept of tone quality which he accepts. The performer will undoubtedly attempt to obtain a mouthpiece which will enable him to achieve the type of tone quality he desires, and this concept will be determined by his schooling.

²⁵Anthony Gigliotti. "Playing Legato." The Clarinet, 17 (Winter, 1954-1955), Symphony, New York, p. 4.

The Embouchure of the Performer

Another factor important in tone quality production and the maintenance of correct intonation on the clarinet is the embouchure. By embouchure is meant the formation of the lips and teeth against the mouthpiece and reed which maintains the pressure needed in the production of a musical tone. Portnoy, when writing about the clarinet embouchure, states:

The embouchure must be considered in two parts: the first is the amount of pressure and where it is applied against the reed; and the second is the quality of the pressure. The quality of the pressure is determined by the degree of muscular tension present in the lip, and this can be varied in the same manner as one can vary the tension (or state of contraction and relaxation) of the bicep muscles in the arm . . . It is the degree of contraction and relaxation of these muscles that produces the various tone colors needed by the player.²⁶

The primary object in the exertion of lip pressure is to force the reed closer to the facing section of the mouthpiece. Pressure is needed to control the volume of tone rather than quality, but the point on the reed at which the pressure is exerted is quite important. This is directly related to the facing of the mouthpiece as the lip pressure is regulated by the space between the reed and the facing of the mouthpiece. In the case of the long lay, or facing, more pressure is needed because the opening between the reed and mouthpiece extends to or beyond the point where the lower lip rests on the reed. The opposite would be true when using the short lay.

²⁶ Bernard Portnoy. "The Embouchure and Tone Color." The Clarinet, 23 (Summer, 1956), Symphony, New York, p. 6.

The single-lip embouchure, the most common, is the type in which the upper teeth rest on top of the mouthpiece and the lower lip covers the lower teeth. When the upper and lower lips cover the teeth it is called a double embouchure. Because of the varying degrees of jaw pressure exerted in the utilization of either embouchure, a different mouthpiece for each is available. However, there are many clarinetists using different embouchures who perform well on similar mouthpieces. In general a mouthpiece which will function well for one embouchure will function well for the other providing the performers have similar concepts of desired tone quality. The selection of a specific mouthpiece facing is made usually because the embouchure and tone quality concept are combined.

Many teachers maintain that the development of a certain type of tone quality is dependent upon a specific embouchure. For example, Ralph McLane, former solo clarinetist of the Philadelphia Symphony Orchestra, considered the use of the double embouchure essential in the production of the type of tone quality which he thought desirable. In an article, he considers the benefits of the double embouchure to be as follows:²⁷

1. It is a very sensitive gauge of lip and jaw pressure.
2. It makes for greater ease in playing.
3. Drawing the upper lip down over the teeth opens the oral chamber, or sound box resonator, which produces a free, fuller, and more mellow tone. Different shadings of tone are made with greater ease.
4. It automatically supports the tone from one interval to another.

²⁷Ralph McLane. "Single or Double Lip." The Clarinet, Symphony Supplement, Symphony, New York, p. 8.

5. It allows adjustments in intonation without changing the quality of tone. It holds pitch in forte passages.
6. One can take more mouthpiece in the mouth with complete control.
7. Endurance is just as good after good muscular development.

A similar list of benefits credited to the single-lip embouchure can be found in articles by Bonade²⁸ and Arey.²⁹ The reasons for using either embouchure are similar and the benefits of each are concerned mainly with tone quality, control, and artistry.

The evolution of the clarinet embouchures combined with the various concepts of tone quality has led to the development of a multitude of facings produced by manufacturers of clarinets and clarinet mouthpieces. Mouthpieces are produced which vary in length between the extreme "German" lay to the short "Italian" lay and utilize all of the degrees of measurement in between. In addition, the opening of the facings vary from a close facing of one-half millimeter to one and one-half millimeters. The favored lay in the United States and the Western European countries is the "French" lay which is considered as medium. The majority of clarinet reeds made available to the clarinetist and clarinet student will function well on the medium facing modeled after the "French" lay. At least, they require the least work in the preparation needed to make them function well for performing. The metric measurements of the average medium "French" facing are presented in the

²⁸Daniel Bonade. "Tone Production." The Clarinet, 15 (Summer 1954), Symphony, New York, pp. 4-7.

²⁹Rufus M. Arey. "Tone and Tune." The Clarinet, 1 (Spring, 1950), Symphony, New York, pp. 5-6.

following figure.*

TABLE 3
AVERAGE MEDIUM "FRENCH" MOUTHPIECE FACING

Gauge	Length
0.034"	3 mm.
0.024"	6 mm.
0.010"	11 mm.
0.0015"	16 mm.
Tip opening	1 mm.

The Amount of Air Passed Through the Mouthpiece

The clarinet generates sound by means of a single reed which vibrates against the tip rails of the mouthpiece; these vibrations being controlled and imparted to the air by the body tube. The body has a somewhat cylindrical bore although the mouthpiece is slightly conical, the barrel is also conical but inverted when compared to the taper of the mouthpiece, and the lower joint flares out into a conical bell. The keys and finger holes vary the resonance of the interior column of air and thus control the pitch. Galper explains the action of the air in the production of a tone as follows:

*The measurements above are made with the use of feeler gauges of various sizes and a glass plate marked in millimeters. The glass plate is placed against the table of the mouthpiece and the feeler gauges are placed between the mouthpiece and the plate. The tip opening is measured with a taper gauge marked off in 1/100 millimeters.

In the clarinet the initial impulse works like this; the first puff of air causes a condensation to travel down the tube to the first outlet (open hole or opened key) where it resolves itself and turns into a rarefaction which goes up the tube and reaches the reed which in the meantime has closed. The rarefaction is reflected at this closed end and goes down the tube to the outlet where it turns into a condensation which goes up the tube. This time the force of condensation plus the restitution force of the reed itself causes the reed to move away from the mouthpiece, and thus one cycle of operations by the reed is completed. During one closing and opening of the reed, a pulse travels four times the length of the tube.³⁰

It can be assumed that only a small amount of air is needed to produce a tone on the clarinet. However, the small amount of air must be accompanied by pressure which is forced into the mouthpiece by the releasing of the tongue held against the reed. The tongue serves as a valve releasing the pressurized air which is sent out of the mouth by the movement of the contracting abdominal muscles. The result of this movement is increased intra-abdominal pressure which forces the diaphragm upward.

The manner in which the clarinet tone is produced would indicate that the breathing habits and training of the student clarinetist should have a great effect upon his choice of mouthpiece. His selection would be determined, in part at least, by the amount of pressurized air he made available while performing. Children therefore, differing from adults as to the amount of pressurized air they are capable of developing, would need a different facing on their mouthpiece.

³⁰Abe Galper. "The Clarinet Air Column." The Clarinet, 3 (Fall, 1950), Symphony, New York, pp. 15-16.

The Maintenance of Correct Intonation, Responsiveness, and Security

The role of the clarinet mouthpiece in maintaining correct intonation is considered by many professional clarinetists and clarinet teachers as being of utmost importance. In the development of criteria for the selection of a mouthpiece, Stein states that "a mouthpiece which plays out of tune is worthless, no matter how well it responds."³¹

O'Brien reports that:

. . . if the taper in the bore is graduated to tune middle C (c') and the octave above correctly, all tones above high C (c''') should be correct. Most clarinets that are flat or sharp in the third register are fitted with an improperly designed mouthpiece. The fault of tuning is usually in the mouthpiece and not the instrument. Too few realize this and condemn the instrument. The bore of the clarinet passes on into the mouthpiece and must be correct according to the design of the maker of the instrument.³²

Although the internal dimensions of the mouthpiece seem to be important for the maintenance of correct intonation, the inner space is a mystery to most clarinet players. Volpe reports that "there are clarinet players who believe that if you scoop out the inside of the mouthpiece at a particular spot, or that if you were to make the slot (opening between tone chamber and bore) so thin that only a dime could pass through, the perfect mouthpiece would be theirs."³³ However, since

³¹Keith Stein. The Art of Clarinet Playing. Summy-Birchard Publishing Co., Evanston, Ill., p. 5.

³²Harry E. O'Brien. "The Mouthpiece Bore." The Clarinet, 13 (Winter, 1953-1954), Symphony, New York, p. 12.

³³Gennaro Volpe. "Clarinetists and Mouthpieces." The Clarinet, 20 (Fall, 1955), Symphony, New York, p. 19.

the ideal bore measurement as stated by O'Brien³⁴ is 0.591 inch, and the diameter of a dime measures 0.705 inch, it is unlikely that a dime would fit into any standard clarinet mouthpiece.

Willaman³⁵ mentions that the intonation of the clarinet is largely governed by the diameter and taper of the circular bore and the tone quality is influenced by the shape of the tone chamber. When considering the effects of bore dimensions, Rendall³⁶ states that when a cylindrically bored mouthpiece is coupled with a large bore clarinet (15 millimeters or more) it will give excellent twelfths, but is less kind to the higher harmonics which are apt to be rather sharp and piercing. If the performer desires to replace a conical mouthpiece with a cylindrical one without upsetting the general intonation, it is usually necessary to shorten the barrel by the width of a ring (about one-fourth inch).

Of great importance to the clarinetist is the manner in which the mouthpiece responds in the actual production of a musical sound. Clarinetists usually consider this as the "speaking" quality of the mouthpiece. Many mouthpieces which have good qualities do not respond well to blowing or to the attack made when the tongue is released from the reed.

Willaman³⁷ mentions that the cause for this is unknown owing to our imperfect understanding of acoustics. Stein³⁸ includes responsiveness as one of his criteria for the selection of a clarinet mouthpiece, and

³⁴O'Brien. op. cit., p. 12.

³⁵Willaman. op. cit., Chapter II.

³⁶Rendall. op. cit., pp. 56-61.

³⁷Willaman. op. cit., Chapter II.

³⁸Stein. op. cit., p. 5.

indicates that the selected mouthpiece must and should be free-flowing.

Security in performance is also of great importance. The performer must feel free to interpret the content of the music without restrictions of any kind. Security in performance is evident in the freedom from "squeaks," the ability to change pitch and tone color with slight gradations of embouchure pressure, and adequate dynamic control. Usually, security is considered in a mouthpiece only after one has been found which is satisfactory in tone quality and intonation, but it is important in the final selection.

The Importance of the Mouthpiece in Clarinet Performance

Clarinetists have investigated various sizes, shapes, and materials of mouthpiece construction in an attempt to produce a more desirable tone quality and to improve intonation. O'Brien, in an article concerning the clarinet bore dimensions, mentions that "the clarinet player is in constant search for the perfect mouthpiece."³⁹ Link⁴⁰ believes that volume and tone "edge" can be controlled by refacing techniques. He attempts to inform the performer as to what can be accomplished in the refacing process. The refacing process takes place usually when the performer is dissatisfied with his present mouthpiece facing and desires a more or less open lay, or a greater or lesser length. Link also associates the facing with the bore dimensions when he states

³⁹Harry E. O'Brien. "Mouthpiece Bores & Tone Chambers." The Clarinet, 9 (Spring, 1952), Symphony, New York, p. 7.

⁴⁰Otto Link. "Refacing Mouthpieces." The Clarinet, 2 (Summer, 1950), Symphony, New York, p. 7.

that if the bore is too small an unpleasant, piercing tone will result and if too large, a tubby tone quality will be produced. Clarinetists generally accept the fact that if a student can gain a concept of clarinet tone quality, which the teacher and student consider as satisfactory, he may then attempt to locate the mouthpiece which will have the right qualities to enable him to produce that tone.

Manufacturers and mouthpiece experts have tried to satisfy the performers by producing a vast number of mouthpiece facings, and mouthpieces with varied internal dimensions. The over-production of different mouthpieces has led to confusion on the part of student clarinetists. In more recent years a movement has evolved, through the efforts of a number of teachers, to produce one mouthpiece facing suitable to all students. The assumption is that the student should adapt his embouchure to the mouthpiece rather than attempting to adapt the mouthpiece to his embouchure and style of playing.

Attempts to find a "more perfect" tone quality is indicated by the variety of materials used in their manufacture. Wood was the material used for all clarinet mouthpieces at the time of J. C. Denner (ca. 1690), and this material continued to be used well into the present century. J. C. Denner is generally given the credit for the creation of the separate mouthpiece which was attached to the then-existing chalumeau. The most suitable wood for the purpose of mouthpiece construction was hard, well-seasoned cocus wood (*Brya ebenus*). Rendall asserts that "some German players are still faithful to wood, thinking no doubt that a more beautiful tone may be obtained from it, and content to tolerate its many

disadvantages."⁴¹ Wood mouthpieces do have their disadvantages because the material warps badly from the action of saliva, and the lay is seldom the same two days in succession. Because the taper of the tip of the mouthpiece is across the grain it can be broken easily, and the wood can be worn down at the table where the reed is placed.

Glass was used quite early in the last century in the manufacture of clarinet mouthpieces. This material was probably suggested by the experimental work done by Laurent and Breton in the manufacture of glass flutes.⁴² Because of the hardness of this material, the lay of the mouthpiece can be immutable. This would give it quite an advantage over wood. However, because glass is naturally brittle, it is difficult to work with and consequently its use in the manufacture of mouthpieces has been limited. The use of glass mouthpieces for beginning and young students has not been recommended because the material is easily broken. Willaman, a performer using glass mouthpieces for many years, contends that "the lay wears so slowly that no reed track is visible after twenty or thirty years of constant use."⁴³

Various metals have also been used in the construction of clarinet mouthpieces. J. S. Hermstedt (1778-1846), the virtuoso for whom Spohr wrote his concerti, played upon a gold mouthpiece with a silver lay.⁴⁴ Aluminum and brass have also been experimented with but metals, in general,

⁴¹Rendall. op. cit., p. 7.

⁴²Ibid.

⁴³Willaman. op. cit., p. 37.

⁴⁴Rendall. op. cit., p. 7.

have found little favor with clarinetists because it was believed that the tone quality they produced was harsh and rough.

Other materials used for the manufacture of clarinet mouthpieces have included ivory, porcelain, and more recently, ebonite and plastics. After ebonite was first utilized in mouthpiece construction, around 1851, it was accepted as a better material than wood. Because it is sufficiently stable for all practical purposes and is less easily broken, it is the material used by most manufacturers today. The most popular are those made from hard-rod rubber, rather than molded rubber. The only disadvantage found in the use of ebonite is that the material is affected by extreme heat, therefore, care must be given in its use.

In addition to the experimental work concerning the materials used in mouthpiece construction, efforts have been made to improve the design. The early mouthpieces designed by J. C. Denner were very narrow and long. Since that time they have gradually broadened and shortened. An examination of the diagram of early mouthpieces, as included in the book by Rendall,⁴⁵ will demonstrate that the present size was fixed more than a century ago. The interior throat or tone chamber remains much the same as it was in its earliest forms although minor changes in shape have been introduced from time to time by many manufacturers searching for better, or at least different, tone quality.

That experimentation continues at the present time is indicated by the vast number of mouthpieces available. Many professional clarinetists and teachers have collaborated with various manufacturers in the

⁴⁵Rendall. op. cit., p. 6.

construction of mouthpieces which are suitable. An examination of the advertising literature concerning clarinet mouthpieces reveals that the manufacturer's products will insure "acoustical correctness and rich, full tone; a quality of tone which will amaze and delight the performer; easier played high notes." One manufacturer advances the statement that his mouthpiece will "instantly make you a finer clarinet player."⁴⁶

The Problem of the Study

After reviewing the studies made in the attempt to determine the factors which contribute to good tone quality and correct intonation, it can be seen that many variables are present. The mouthpiece itself combines a number of elements which contribute to whatever tone quality is to be produced. The facing, as considered in an earlier section, is selected because of personal considerations. Perhaps the internal dimensions should be considered by each individual also, but at the present time, they are usually neglected. O'Brien maintains that "too much importance is given to the facing. The interior definitely must be properly proportioned to produce quality of tone such as density, carrying power, and a bright or dark tone quality."⁴⁷ The question may be asked as to what is meant by "properly proportioned."

When measuring twenty-two mouthpieces which were selected at random, the writer found a great variance in bore specifications. The

⁴⁶Cited from an advertisement. The Clarinet, 16 (Fall, 1954), Symphony, New York, p. 6.

⁴⁷Harry E. O'Brien. "On Clarinet Mouthpieces." The Clarinet, 1 Symphony Supplement, Symphony, New York, p. 12.

taper of the bores of seven mouthpieces, made by the same manufacturer and having the same price range and facing measurements, varied from 0.046 inch to 0.061 inch. In addition, the lower bore measurements varied from 0.589 inch to 0.597 inch. This last measurement should be critical because it is at this point that the mouthpiece enters the body of the clarinet. It has been considered that for best results the measurements at this location should be exactly the same. Rendall mentions that "the bore of the mouthpiece must be identical with that of the instrument, not a hair's breadth more or less."⁴⁸ What is the effect produced when using these various mouthpieces when they are intended for the same clarinet?

Concerning the taper of the bore, Willaman states that "this taper is as much as 0.015 of an inch in some makes, in the two inches of its length."⁴⁹ The writer found that of the tapers of the twenty-two mouthpieces selected at random, the smallest taper measurement was 0.026 inch and the largest, 0.061 inch.

Willaman⁵⁰ also alleges that the intonation is largely governed by the diameter and taper of the circular bore and the tone quality is influenced by the shape of the tone chamber. When the tone chambers of the mouthpieces were measured, it was found that they varied in their tapers from 0.034 inch to 0.122 inch. When the bore lengths were measured, it was found that the lengths varied from 2 1/16 inches to 2 1/4 inches.

⁴⁸Rendall. op. cit., p. 5.

⁴⁹Willaman. op. cit., p. 38.

⁵⁰Ibid.

It is evident that the mouthpieces measured by the writer varied a great deal. Therefore, the question may be asked as to what effect this variance found in clarinet mouthpieces has upon intonation and tone quality. This study will attempt to analyse the internal portion of the clarinet mouthpiece and will endeavor to answer the following questions:

1. What effect do various taper sizes, bore sizes, and bore lengths have upon intonation when the tone chamber and facing remain unchanged?
2. What effect do various tone chamber sizes have upon tone quality and intonation when the bore taper, bore size, and facing remain unchanged?
3. Will the changes in tone quality produced with tone chamber sizes be perceptible to expert clarinetists?

CHAPTER II

THE CLARINET

History and Construction

A cylindrical bored tube of cane on which a single reed is placed is of very ancient origin. Such instruments are recorded as being in use in Egypt as early as the third millennium and it is possible that Egypt may have been the country of its origin. In its most ancient form, a flexible tongue was cut in a piece of rush or cane and thinned down at either of its ends to facilitate vibrations. This primitive instrument was known as the idioglot.

A later development is found in the formation of a sounding generator, which included the beating reed, from a short separate piece of cane inserted into a longer body. The resonating pipes were usually doubled to strengthen the sound or to produce a beat-tone when the tubes were intentionally mistuned. Instruments of this type, the arghul and the zummarah, are still in use in the Near East. A more elaborate form consisting of a triple pipe is found in Sardinia, called the launeddas. A capsule was later provided which was used to enclose the reed. It is possible that this was added as a protective device but eventually came to be used as a wind chamber. This enabled the performer to sustain the tone for longer periods of time. Instruments of this nature are the Basque alboquea and the Slav brelka.

With the development of the Welsh hornpipe or pibgorn, an instrument somewhat closer to the modern clarinet came into existence.

This is a folk instrument which survived well into the eighteenth century in the Northern section of the British Isle, especially Wales. Rendall mentions that this instrument was "provided with a bell of cowhorn at the lower end, cut up in front and finished with a serrated edge, and the body was made of bone or elderwood and provided with seven finger-holes."¹ One of these finger-holes was provided for the thumb and placed on the underside of the instrument. A number of these instruments included twin pipes, some had single pipes, but all contained wind-chambers, detachable resonators, and a definite bell.

A somewhat similar instrument is found in Scotland where it was known as the stock-and-horn. This instrument also had a resonator of wood or bone, and was pierced with eight finger-holes. It also included a separate bell. It is generally assumed that instruments of this type probably originated in the East and could have been introduced into the British Isles during the Celtic immigrations. Sachs² mentions that double clarinets of this type existed in China in very ancient times but that there are no specimens extant. Until the late seventeenth century and early eighteenth century, instruments of the single reed type were confined to the music making of peasants. Because these early single reed instruments could not be over-blown without a speaker key, and because keys were needed to bridge the blank spaces in their scales, they were not used to any extent in the performance of serious music. The cylindrically bored instruments used were all equipped with a double reed.

¹F. G. Rendall. The Clarinet. Ernest Benn Ltd., London, 1954, pp. 62-63.

²Curt Sachs. The History of Musical Instruments. W. W. Norton and Company, New York, 1940. p. 212.

The immediate predecessor of the modern clarinet is generally considered to be the chalumeau. In the seventeenth century this word meant either a chanter of a bagpipe, or a simple rustic reed-pipe with a single reed cut in a corn stem. The name chalumeau was not used in relation to the clarinet until sometime after 1700. The description of this simple instrument is given by Baines³ as being eight to nine inches long, with six holes and thumb-hole, and a reed tongue cut in the upper side of the cane.

The first part of the eighteenth century was a period of great importance in the development of the clarinet. In 1706, an Amsterdam publisher by the name of Roger was advertising music for the chalumeau. Two years earlier, 1704, chalumeau parts began to appear in musical scores. Some of the early composers for the chalumeau were Marco Antonio Ziani (ca. 1653-1715), Giovanni Bononcini (1670-1747), and Attilio Ariosti (1666-ca. 1740). The parts written for this early instrument were usually of short duration and were confined within an interval of a ninth or tenth. Rendall states that this instrument was a "two-piece pipe, consisting of a cylindrical body without a bell, and pierced with eight finger-holes and a detachable mouthpiece with a single reed."⁴

The improvement of the chalumeau is usually credited to J. C. Denner at approximately 1690. However, there is a lack of definite evidence concerning his inventions relating to the clarinet or chalumeau.

³Anthony Baines. Woodwind Instruments and their History. Faber. and Faber Limited, London, 1957, p. 296.

⁴Rendall. op. cit., p. 66.

Possibly he was the first to apply improvements to the chalumeau which led to the development of the clarinet. The improvements which appeared on the chalumeau during the late seventeenth century were as follows: the instrument was given a separate mouthpiece, the bell was developed into a more conical shape, and two keys were added to the instrument--one of which was a speaker key. With the addition of the speaker key, the clarion register was added to the instrument. It could be overblown to produce an interval of a twelfth which extended its range one complete octave. However, the improved instrument was not used extensively because of the imperfections in its scale. In addition, the occasional chalumeau parts were given to oboists or flutists, who, finding no latent possibilities in the new instrument, did not bother to acquire a new technique.

The Denner instrument resembled a recorder and was twice the length of the chalumeau. This early instrument was built in three pieces: a mouthpiece and barrel joint in one section, an undivided main piece with six spaced holes in the front of the instrument and one in the back, and a small joint at the bottom with two small holes placed side by side. Placed above the first hole were two keys. When one of these keys were opened, the pitch produced was a¹. When both were opened, b¹ would be produced. Either of the keys could be used as a speaker key to enable the performer to overblow the twelfth.

The mouthpieces of these instruments were slightly larger in external measurements than the modern type, and the reed which was intended for use on these mouthpieces was probably at least fifteen

millimeters wide. Rendall⁵ reports that the facing was long and wide with little curve, and the bore was cylindrical. The reed was placed against the upper lip. This practice continued for many years and was still followed in some European countries and the United States in the present century.

The next improvements made to the clarinet were concerned with the moving of the speaker key closer to the mouthpiece and in making the hole which it covered smaller. This improvement enabled the performer to play b-flat⁶ with both keys open rather than by slackening the embouchure as was necessary with the older system. A flared bell of larger size was also developed and the mouthpiece was reduced in its external dimensions. These improvements are usually credited to Jacob Denner in 1720. Two-keyed clarinets of this type were introduced into France by German clarinetists who performed on them in combination with horns. Music for this combination of instruments was written by Thomas Arne in 1760, and an Overture in D was composed by Handel in 1740. These instruments were usually made in the keys of D and C, and the tone was considered to be very strident and unsatisfactory.

In the mid-eighteenth century the clarinet moved quite close to its final basic form. The bell was made longer so it could utilize the b⁷ key, which also enabled the performer to produce an e, below the treble staff. With the addition of the e-flat⁸ and the c-sharp⁹ keys, the classical five-keyed clarinet was developed.

⁵Rendall. op. cit., p. 69.

This was probably the instrument on which Joseph Beer (1744-1811), for whom Karl Stamitz wrote a number of concerti, and Anton Stadler (1753-1812), for whom Mozart wrote the Quintet and the Concerto, played and raised to the rank of a solo instrument. The material used in the construction of these instruments was usually boxwood, retaining its natural color, or stained a dark brown. The mouthpieces were made from wood, either cocus or ebony.

By 1770, these instruments were made in five or six sections as follows:

1. Mouthpiece: this was reduced in width, tapered, and fitted with a reed which was more narrow and shorter than now in use.
2. Barrel or socket: in France and Germany these were usually made separately but in England they were made in one piece with the mouthpiece.
3. Upper joint: four finger-holes were placed in this joint for the left hand and an a' key and speaker key were placed above the first hole.
4. Right hand joint: this section had three finger-holes for the right hand.
5. Lower joint: this section contained a small hole for the right little finger, and three keys. These keys were mounted on a swelling in the wood which enabled the finger-hole to be bored obliquely. This mechanism was used to aid the intonation and at the same time to bring it within reach of the finger.
6. Bell: This was sometimes made in one piece with the preceding part.

Geiringer⁶ mentions that these refinements made on the clarinet were largely transferred from the double reed instrument which were considered satisfactory in their development.

⁶Karl Geiringer. Musical Instruments. Oxford University Press, New York, 1943, p. 174.

The next key to be added to the clarinet was the c-sharp¹ key. This improvement was made around 1790 and the range of this instrument was from d, in the chalumeau register, to g^{'''} in the acute. The clarinet family served a need in the military bands in the latter part of the eighteenth century and has remained an essential instrument for band instrumentation to the present day. This instrument was still made most often of boxwood, some models had six keys, but the five-keyed clarinet was the most common. Intonation was poor in the chalumeau register, and only slightly better in the clarion and acute. Early in the nineteenth century, clarinets were included in the instrumentation of many orchestras and its place in chamber music was assured by Mozart. As a solo instrument, it had already had a successful career.

The nineteenth century was a period when great strides were taken in the construction of musical instruments. Great improvements in mechanism were made because of the demands of the virtuosi. Simiot of Lyons, France, claimed to have made a twelve-keyed clarinet as early as 1803, and thirteen keys were placed on a bass clarinet by the same maker in 1807. Forsyth states that Iwan Müller (1786-1854) was making "thirteen-keyed clarinets in Paris as early as 1810."⁷ The great Heinrich Bärmann (1784-1847) was performing, at the height of his career, on a ten-keyed clarinet made by Griessling and Schlott of Berlin in 1810.

The additional keys which were added to the six-keyed instrument were the g-sharp¹, the f¹ (this was a key placed crosswise just under

⁷Cecil Forsyth. Orchestration. The Macmillan Company, New York, 1947, p. 252.

the first finger-hole or against the right side of the right side of the joint), and a cross or side key for e-flat'. These additions were placed on the upper joint. On the lower section, a cross-key or b-flat was placed. Another key, added to the upper joint, was optional and enabled the performer to trill from a' to b'. All of these improvements are credited to Iwan Müller, a virtuoso of Russian extraction. His successful experiments formed the basis for modern clarinet manufacture.

Rendall⁸ reports that these additions were applied to a clarinet as early as 1808 but that this improved instrument was not popular. Clarinetists felt that the instrument had lost its distinctive tone color. However, the improvements made by Müller became widely known, whereas those made by Simiot of Lyons were not known beyond the maker's province. When the new instrument was adopted by Frederic Berr (1793-1838), Professor of Clarinet at the Paris Conservatoire from 1831 to 1838, it was also soon adopted by students and other clarinetists. Berr was also instrumental in moving the reed from against the upper lip and placing it on the lower, which is the manner in which the clarinet is universally played today.

A change in the clarinet mechanism of great importance developed between the years 1835 and 1850. It was during this period that H. Klose¹ (1808-1880) collaborating with August Buffet (? - 1885) produced a clarinet based on the principles which Theobald Boehm (1794-1881) had applied to the flute. Boehm placed the tone holes where the acoustical laws demanded they should be, and then constructed a suitable mechanism

⁸Rendall. op. cit., p. 92.

to cover these holes. This instrument was called the "clarinet with movable rings" and was patented in 1844. It had twenty-four tone holes which were governed by seventeen keys (ordinary Boehm) and six rings. H. Klose⁹ wrote his instruction book for this model in 1843, and it is interesting to note that a diagram of the mouthpiece appearing in this tutor is the same in shape and construction as our present type. The mouthpiece of the clarinet was fairly well standardized at this early date, and Rendall¹⁰ states that very little change has taken place since that time.

The improvements incorporated in the Boehm clarinet eliminated some of the problems which remained in the Müller instrument. The keys controlling the lowest tone holes were duplicated and interlocked which eliminated sliding from key to key by the little fingers. Above the duplicate keys were placed the four tone-holes, one of which was covered by a padded cup. This permitted the playing of the four semitones, a, b, b-flat, and c', with three fingers. On the upper joint a rearrangement of the tone-holes was made. This placement aided in the correction of the intonation. A ring was added for the left thumb, and an extra trill key was placed on the upper joint.

The Boehm clarinet became popular in France but was less favored in other countries. In Germany, Spain, and the Slavic countries, the Müller clarinet was preferred, and the new instrument did not become

⁹H. Klose. Method for the Clarinet. Meissomnier, 1843. English edition, Hawkes, London, 1906.

¹⁰Rendall. op. cit., p. 5.

popular in England until within the last forty years. This instrument differs very little from the modern Boehm system clarinet. The most popular is the ordinary system which is mentioned above. Additional keys which are available on this system are the e-flat, a-flat/e-flat', articulated g-sharp', and the forked b-flat''.

The Oehler system clarinet, which is popular in Germany, has a total of twenty-one keys. The Müller system clarinet had eighteen or nineteen keys when it was used by Carl Bärmann (1811-1885), and Richard Mühlfeld (1856-1907), virtuosos of the nineteenth century. The Albert system was an outgrowth of the Müller system with slight improvements. The Albert system clarinet was basically a thirteen-keyed instrument, and with the addition of the c-sharp' key, was the clarinet preferred by Henry Lazarus (1815-1895). Later in his life, through the influence of the Boehm clarinet, he added the side key for e-flat', and the trill key for a' to b-flat', both of which were included on the first Boehm instrument.

Other systems which have developed through attempts to improve intonation and tone quality were the Romero system (ca. 1860), which did not become popular because of an unreliable mechanism; the Barret system (ca. 1870), which was adopted from the oboe; and the Schaffner system (ca. 1890), which was too complex in its mechanism for practical use. More recent improvements made in the construction of the clarinet have been by Potter,* who added additional holes and covered keys to the

*The Charles E. Potter clarinet (ca. 1915).

side of the instrument in an attempt to correct the intonation of the upper joint.

Improvements have also been made in fingering by the placement of keys at different angles and at different locations on the two joints. Some fingerings are simplified and certain passages in the music can be performed with ease. The Mazzeo system (H. Selmer & Company, Elkhart, Indiana) clarinet is an example of this type. This is a very recent development and, as yet, none of these changes have become a permanent part of the mechanism of the modern clarinet.

The Modern Clarinet

The modern clarinet is made in five sections: bell, lower joint, upper joint, barrel or socket, and mouthpiece. The instrument is usually described as being cylindrical, which is a rough generalization and not completely accurate. The mouthpiece is conical, being wider at the point where it enters the barrel than it is at the top. The barrel is built in a reversed cone which extends from the barrel to the point in the upper joint where the speaker key is placed; a cylindrical portion then begins and continues until about midway through the lower joint where a cone develops and flares out to meet the conical bell. The measurements of the modern clarinet are as follows:¹¹

1. Total overall length: 67 centimeters.
2. Length of the conical mouthpieces: 7 centimeters.
3. Length of barrel and inverted cone in upper joint: 8.5 centimeters.

¹¹Rendall. op. cit., p. 42.

4. Cylindrical portion of bore: 36.5 centimeters.
5. Length of conical portion of lower joint and bell:
15 centimeters.

The conical portions of the instrument total 30.5 centimeters, and the cylindrical section totals 36.5 centimeters, which is slightly more than half of its overall length.

The internal diameter of the instrument has changed slightly in the course of its development. The early clarinets had a bore measurement of thirteen millimeters (approximately 0.5 inch), but by the early part of the nineteenth century the diameter had been increased by a millimeter. By 1850, the bore measurement had increased to 14.75 or 14.85 millimeters (0.581 or 0.585 inch). Later, in the same century, the bore diameter was increased to fifteen millimeters (0.591 inch), and this latter measurement may be taken as the most prevalent in the modern clarinet although some are still manufactured with a bore measurement of 0.585 inch.

The manufacturer usually selects the bore measurement which will give the performer maximum responsiveness, evenness of tone quality, and purity of intonation throughout the entire register. As may be expected, this must be a compromise because of the extreme compass of the instrument. The written range of the clarinet is from e to c'''' , a total of slightly over three and one-half octaves. When the selection of a bore diameter is made which is excellent for the notes of the chalumeau register, an intonation problem exists in the higher registers. Therefore, the maker attempts to build an instrument which will be relatively satisfactory throughout its entire range.

The placing of the tone holes is generally considered to be the primary duty of the conscientious maker. The basic problem is to tune the twelfths to the fundamental because it is in the clarion register where the manufacturer finds his source of trouble. The problem lies with the placement of the speaker key. The air column cannot be divided into the segments necessary to produce the twelfths without a speaker key, and if correct intonation is the desired end, every note would require a different position for the placement of the speaker key. This would involve a mechanism too complex to be practical, so the maker compromises in the placement of this key to produce results within a given span of pitches.

The modern clarinet is usually made from African blackwood (Mozambique grenadilla), which has replaced cocus; ebonite, which is a black variety of hard rubber; various metals, usually brass with silver plating and sometimes sterling silver; and various other compositions, including plastics. However, the choice of the professional clarinetist greatly favors the instrument made from wood. The effects of the various materials on pitch and tone quality have been studied and are reported in an earlier section of this paper. Parker¹² found the tone to be identical when measuring the strength of the partials in relation to each fundamental tone. This analysis was of a quantitative nature which compared the strength of various notes on metal and wood clarinets as measured in millivolts. Nevertheless, the qualitative effect, or how the tone quality is evaluated by the listener, is another matter. Professional clarinetists are entirely satisfied with the wooden tube of the clarinet

¹²Parker. op. cit., pp. 415-417.

because of the timbre, which they consider to be superior to all other materials. At the present time, the qualitative effects of the various materials have not been measured satisfactorily.

The various clarinets which are in general use today are as follows:

1. Soprano, E-flat clarinet: this is a small instrument which sounds a minor third higher than written. This instrument performs a valuable service in the symphony orchestra but has been neglected in the band instrumentation in recent years.
2. Soprano, B-flat and A clarinets: the B-flat clarinet sounds a major second lower than written and is an important instrument in our present symphony orchestra and band. The A clarinet, which sounds a minor third lower than written, is used exclusively as a solo instrument, in chamber music, and in the symphony orchestra.
3. Alto, E-flat and F clarinets: the E-flat clarinet is used almost entirely in the band and sounds a major sixth lower than written. Recently, a few manufacturers have produced alto clarinets in F. This instrument sounds a perfect fifth lower than written and has not been included in the instrumentation of either the band or orchestra.
4. Bass, clarinet in B-flat and A: the B-flat bass clarinet sounds one octave and a major second lower than written in American and English notation. This instrument plays an important role in both the band and orchestra. The bass clarinet in A sounds one octave and a minor third lower than written and is used exclusively in the orchestra, especially in the performance of nineteenth century German music.
5. Contrabass, clarinets in B-flat and E-flat: the contrabass clarinet in E-flat sounds an octave and a major sixth lower than written and is used in the modern concert band. The contrabass clarinet in B-flat sounds two octaves and a major second lower than written and is also used in the modern band.

All of the members of the clarinet family have the same written range and read their parts in the treble clef. An exception is music written for the bass clarinet in French notation where the notes are sounded a major second lower than notated for the B-flat instrument, and a minor third lower for the A instrument.

The fingering is the same on all of these instruments. The Boehm system clarinet is preferred in United States, France, England, and Italy, and the Oehler and Müller systems are more popular in Germany, Russia, and other Slavic countries.

The Modern Clarinet Mouthpiece

The bore of the modern clarinet mouthpiece is usually conical, and just what effect the various tapers within the mouthpiece have upon tone quality and intonation has not been explained. The bore length varies from 2 1/6 inches to 2 1/4 inches, and the average bore length is slightly less than 2 1/4 inches. The tone chamber is slightly conical but varies to such a degree that every mouthpiece measured by the writer had a different size taper. The facings are placed on the mouthpiece in a great number of combinations and are intended to satisfy the performer on an individual and personal basis.

Concerning the materials used in mouthpiece construction, ebonite is the most popular although glass, wood, and plastics are used. Where measurements of extreme exactness and accuracy are involved, the importance of a durable and immutable material is essential. When using a material such as wood, differences in quality are likely, but in the case of ebonite it is difficult to understand why the mouthpieces should vary as much as they do. However, the fact remains that standardized mouthpieces do differ and when selecting a number of mouthpieces which are supposedly the same, made by the same manufacturer to the same specifications, each will respond in a different manner.

The modern clarinet mouthpiece is usually 8.9 centimeters (3 1/2 inches) in overall length. The bore is 2 1/4 inches in length and the tone chamber is 1 1/4 inches. The tapers of the bore vary from 0.020 inch to 0.065 inch, and the tone chamber measurements are between 0.406 inch and 0.570 inch. The depth measurements, at the bottom of the tone chamber vary from 0.490 inch to 0.555 inch.

The reed, which produces the vibrations and hence generates the sound, is placed on the table of the mouthpiece and held in place with a screw ligature. In Germany, a string is preferred for the purpose of holding the reed because a string exerts somewhat less pressure. The player puts the uppermost half-inch, or so, of the mouthpiece in the mouth. The reed is placed downwards between the lips, with the lower lip drawn back to form a cushion between the reed and the teeth. Some performers also draw the upper lip back to form a cushion on top of the mouthpiece as well. These are the double and the single-lip embouchures.

CHAPTER III

EXPERIMENTAL DESIGN

Bore Taper Analyses

Preliminary studies made by the writer have shown that various tapers, bore sizes, and lengths appear to have no effect upon tone quality when measured physically, or when judged psychologically, in the latter case by expert clarinetists. Therefore, the analyses made of taper changes, bore sizes, and bore lengths will be made in regard to intonation. It was found that the various sizes have a great effect upon introducing pitch deviations into the clarinet scale. The procedure used in this section of the study will be as follows:

1. Two mouthpieces having the popular medium facing (described on page 19) will be selected. The bottom bore sizes of these mouthpieces are 0.585 inch, and 0.591 inch. These are the common sizes used in clarinet construction today. Two clarinets having the same bore measurements as stated above will be used in combination with the mouthpieces.
2. Brass shim stock will be used in the bore of the mouthpieces to form the various tapers. Brass shim stock of the thickness of 0.005 inch will be used to form the cones and these will be made airtight with the use of rubber cement.
3. The tapers to be tested will vary from 0.000 inch, and gradually increase to 0.100 inch. These sizes are undersize and oversize in relation to the standard clarinet mouthpieces used today.
4. An expert clarinetist will play several tones from each register of the clarinet; chalumeau, throat, clarion, and acute. The analyses of the various sizes will be made with a Strobocomm* which registers the deviations of pitch from the equal-tempered scale in which $A=440$ cycles per second.

*Strobocomm, C. G. Conn, Ltd., Elkhart, Indiana

5. The results of the taper analyses will be presented in tables indicating the pitch deviations, as measured in cents, and showing which taper is best in regard to intonation for each bore size tested.

Bore Size Analyses

To determine the effect of various bore sizes on intonation, the following procedure will be followed:

1. A standard ebonite clarinet mouthpiece will be selected having a bottom bore measurement of 0.581 inch. This mouthpiece will have the same facing used in the first portion of the study.
2. Two clarinets will be used in combination with the above mentioned mouthpiece. These instruments have the two common bore measurements of 0.585 inch and 0.591 inch.
3. This mouthpiece will be tested on each clarinet using the Strobocomm. All registers of the instrument will be tested as notes are played by an expert clarinetist.
4. The bore of the mouthpiece will be increased in size until it reaches an oversize measurement of 0.595 inch. The size will be increased by filing and the bore will be measured from several angles to make certain that the opening remains circular.
5. In this section of the study, an attempt will be made to discover what effect the various bore sizes have upon intonation. Tables will be presented which will show the pitch deviations as measured in cents on the Strobocomm. This part of the study should indicate which bore size is best in regard to intonation when combined with the two clarinets used in the study.

Bore Length Analyses

The bore lengths will be analysed as follows:

1. A standard ebonite clarinet mouthpiece will be cut lengthwise. The bore of this mouthpiece will be reamed out to an oversize length of $2 \frac{3}{8}$ inches. This will be accomplished by using a steel reamer mounted in an electric drill. The taper will be maintained between 0.040 inch and 0.050 inch, which is the average taper used today.

2. Red dental wax will be used to control the length of the bore. This material is pliable and provides a reasonably hard surface, and will be placed in the upper portion of the bore. The bore length will be varied beginning at 1 3/4 inches and gradually increased to 2 3/8 inches. These sizes are under-size and oversize to the standard lengths used today. The average is 2 1/4 inches.
4. Notes will be played from each register of the clarinet using each of the two clarinets in combination with the various bore lengths. These will be played by an expert clarinetist and will be analysed with the Strobocorn to determine what effect the various bore lengths have upon intonation.
5. Tables will be presented showing the results of the analyses. The ideal bore length for each clarinet bore size will be indicated.

Tone Chamber Analyses

When making analyses of the various changes introduced into the tone chamber, the bore size, taper, length, and facing will remain unchanged. The following procedure will be followed:

1. A standard ebonite clarinet mouthpiece will be selected having the medium facing (described on page 19). The bore size of this mouthpiece will be the most common used today-- 0.591 inch.
2. This mouthpiece will be used in combination with a clarinet having the same bore measurement. The tone chamber size is 0.030 inch, which is undersize. The average taper measurement used today is about 0.070 inch.
3. The tone chamber will be gradually increased in size until an oversize measurement of 0.135 inch is reached. As each change is made in the tone chamber, a tape loop will be made of a note from each register of the clarinet. An expert clarinetist will make these loops using an Ampex tape recorder, Model No. 600, and a Unidyne unidirectional microphone, Model No. 5565. The performer will stand ten feet from the microphone when making the recordings. The same volume setting will be used for all tape loops.
4. The changes in tone chamber will be made by filing at the outer end to increase the taper. Care will be given so that the facing is not damaged.

5. The tape loops will be used in an analysis to determine the effects of the changes introduced into the tone chamber on tone quality. The effect on the wave forms will be analysed on a harmonic wave analyser.* The wave analyser measures the strength of each partial present in each tone in millivolts.
6. As each change is introduced into the tone chamber the mouthpiece will be tested by an expert clarinet player on the Strobocorn to determine if any pitch deviations occur.
7. Various depth sizes will also be analysed. A mouthpiece will be selected having a depth size of 0.495 inch, and this will be increased gradually to a size of 0.555 inch. This is undersize and oversize to the standard mouthpiece in use today. The size will be increased by filing and the procedure will follow the tone chamber analyses. A Strobocorn and a harmonic wave analyser will be used in this section also.
8. In addition to the analyses made physically, the tape loops will be played for expert clarinetists to determine if a difference can be perceived in tone quality.
9. Tables will be prepared showing the results of the tone chamber analyses, the depth size analyses, and the results of the deviations in intonation. These tables should indicate what the ideal taper and depth size is when analysed physically, and psychologically, when evaluated by expert clarinetists.

The tools used in making the measurements of the mouthpieces are as follows: two telescope gauges, 1/4 inch to 1/2 inch, and 1/2 inch to 3/4 inch; a micrometer which measures in thousands of an inch.

Improvement of Student Clarinetist's Performance

After the above information is gathered and some conclusions reached, music educators who are working with school bands will be asked to recommend several advanced clarinetists who are having tone quality

*Harmonic Wave Analyzer, Model 300 A, Hewlett Packard, Palo Alto, California.

and/or intonation difficulties. The experimental study used with the clarinet students will be as follows:

1. Each student will be asked to play an excerpt which will be recorded by tape recorder. This excerpt will be selected in view of the performer's ability and will be at least eight measures long.
2. The student's mouthpiece will be tested by an expert clarinetist and evaluated subjectively as to tone quality potential and accuracy of intonation.
3. The mouthpiece will also be measured and evaluated in terms of the conclusions reached in this study.
4. If a mouthpiece change is indicated, a corrected mouthpiece will be given to the student. A new recording will then be made having the student repeat the excerpt played on the first mouthpiece.
5. These recordings will then be played for selected judges, made up of expert clarinetists and experienced music educators, to determine if a difference can be detected in the student's performances. The recordings will be divided into pairs, made by the same person, and the judges will be asked to select the better recording of the two in regard to tone quality and intonation.
6. A binomial expansion $(p + q)^n$ will be used to determine if the choices of the judges are significant at the 0.01 or 0.05 level of confidence.

Following the conclusion of the study, it is hoped that recommendations can be made which will be of value to the music educator and clarinet teacher. With the use of a few simple tools, the music educator and clarinet teacher may be able to evaluate the student's mouthpiece more objectively. With the use of this information, the teacher may be able to solve the common problems of clarinet students in the production of good tone quality and the maintenance of correct intonation, especially as they may be related to the mouthpiece.

CHAPTER IV

EVALUATION OF THE DATA

Bore Taper Analyses

When making the mouthpiece taper intonation analyses with the two clarinets used in the study, the clarinet range was divided into four divisions. The divisions were arrived at in a preliminary study which indicated that the deviations from equi-tempered tuning remained relatively constant between the extreme notes in each. The first division included the tones between written e to e'. The preliminary study demonstrated that the tones between these extremes were slightly sharp and remained so throughout the division. The second division included tones between f' and b', which were slightly flat. The third division contained the notes between c'' to g'''. It was found that these tones were slightly flat but not as much so as the notes in the second division. The fourth division included the tones between a'' to g'''. These tones were slightly sharp throughout the division.

Each tone in the divisions was tested on the Strobocomm, and the total deviations as measured in cents from their corresponding pitches in equi-tempered tuning were averaged. In this way, if the trend within a division was toward deviations which were sharp, the average deviation of all of the tones within a division would indicate the general degree of deviation within that division. By selecting the divisions as stated above, the trend toward either flat or sharp deviations remained constant within each. This would eliminate the possibility of having both flat and sharp notes in a division.

The mouthpieces selected for the study were made of hard-rod rubber and each had a bore length of $2 \frac{1}{8}$ inches. One of the mouthpieces had a bore diameter of 0.585 inch, and the other had a bore diameter of 0.591 inch. These were identical with the clarinets used in the study. The bore taper was varied with the use of brass shim stock, as stated in Chapter III, and the taper dimensions tested varied from 0.000 inch to 0.100 inch, in measurements of 0.010 inch. The following table demonstrates the results of these analyses:

TABLE 4

THE EFFECT OF MOUTHPIECE BORE TAPER SIZE ON INTONATION OF
TWO CLARINETS HAVING A BORE OF 0.591 AND 0.585 INCH

Bore Taper Size	Register and Cents, Flat or Sharp*							
	Chalumeau		Throat		Clarion		Acute	
	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"
.000"	0	0	-25	-23	-5	-10	+12	-3
.010"	0	0	-21	-10	-4	- 6	+ 8	-2
.020"	+ 2	0	-18	- 7	-4	- 2	+ 1	0
.030"	+ 3	+ 2	-11	- 2	-1	+ 2	+ 1	+2
.040"	+ 5	+ 4	- 4	- 1	0	+ 3	+ 2	+1
.050"	+ 5	+ 4	- 4	0	-4	+ 4	+ 5	+2
.060"	+12	+ 5	- 6	+ 1	-6	+ 8	+ 4	+6
.070"	+15	+ 7	0	+ 1	+5	+10	+ 8	+7
.080"	+15	+10	+ 3	+ 2	+10	+12	+11	+10
.090"	+15	+11	+ 5	+ 3	+12	+15	+15	+12
.100"	+17	+12	+18	+ 3	+15	+16	+17	+14

*The notes contained in the first division are included in the column under the heading, chalumeau; those in division two under the heading, throat; those in the third division under the name, clarion; and those notes in the fourth division are included in the column named acute.

The table presented above shows that intonation in the chalumeau register was favored when using the smaller tapered mouthpiece bore but that the upper registers were quite flat. The pitch was gradually raised throughout all registers of the clarinet as the size of the taper was increased. The best taper for the clarinet having a bore size of 0.591 inch was found to be from 0.030 inch to 0.050 inch. When using a mouthpiece having these taper measurements on the two clarinets used in the study, the pitch deviations were found to be smallest. Generally, when using a mouthpiece taper size of less than 0.030 inch, the pitch deviations were greater, causing the clarinets to be flat. When using a mouthpiece taper size greater than 0.050 inch, the pitch deviations increased and, consequently, caused the clarinets to be sharp.

Bore Size Analyses

When making the bore size analyses, one mouthpiece was used having a bore size of 0.581 inch. The bore taper size was 0.030 inch, and the bore length was 2 1/8 inches. The bore size was gradually enlarged to a size of 0.595 inch, and the taper was maintained between 0.030 inch and 0.050 inch. The effects of the various bore sizes on intonation when used with clarinets having bore sizes of 0.585 inch and 0.591 inch was determined. The range of the clarinet was divided in the same manner as had been done in the bore taper analyses. The total deviations from equi-tempered tuning for each division of range were averaged after each tone was tested on a Strobocomm. Table 5 shows the effects of the changes in pitch introduced by the various sizes of the bore of the mouthpiece.

TABLE 5

THE EFFECT OF MOUTHPIECE BORE SIZE ON INTONATION OF TWO
CLARINETS HAVING A BORE OF 0.591 AND 0.585 INCH

Mouthpiece Bore Size	Register and Cents, Flat or Sharp							
	Chalumeau		Throat		Clarion		Acute	
	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"
.581"	+2	+3	-10	- 6	-3	0	0	+1
.583"	+8	0	- 5	- 6	0	0	+ 2	+3
.585"	+8	0	- 9	- 5	0	0	+10	+2
.587"	+5	+1	- 8	-10	-1	0	+ 5	+4
.589"	+4	+2	- 6	-12	+1	0	+ 4	+2
.591"	+2	+4	- 1	-16	0	-1	0	+2
.593"	+5	+5	- 4	-17	+2	-4	+ 6	+3
.595"	+6	+5	- 7	-19	+3	-8	+ 7	+3

In general, the intonation improved as the mouthpiece bore size approached the bore size of the clarinet. In both cases the best intonation was found to be at the point in the testing where the bore size of the mouthpiece was the same as the bore size of the clarinet. This would indicate that the matching of mouthpiece bore and clarinet bore measurements to be of utmost importance. Where an oversize or undersize exists, intonation will be adversely affected. In addition, mouthpieces having a bore size larger than the clarinet with which they are used have a more pronounced effect on intonation than do those whose bore sizes are smaller, raising the pitch in all registers except throat.

Bore Length Analyses

When making analyses of the effects of changes introduced into the bore length of the clarinet mouthpiece, the divisions of the clarinet range used in the two earlier studies were maintained. The same two clarinets were also used. Two mouthpieces were selected for this section of the study, each having bore measurements which precisely matched the clarinet with which it was used. The bore taper size in each mouthpiece was 0.030 inch and, although the lengthening of the bore increased the taper size, a maximum taper size of 0.040 inch was maintained.

The mouthpieces had bore lengths of $1 \frac{3}{4}$ inches and this was increased gradually until an oversize dimension of $2 \frac{3}{8}$ inches was reached. The intonation for each note of all divisions of the clarinet range was measured on a Stroboscopes and the pitch deviations from equitempered tuning were recorded. The following table demonstrates the effect of mouthpiece bore length on intonation:

TABLE 6

THE EFFECT OF MOUTHPIECE BORE LENGTH ON INTONATION OF TWO
CLARINETS HAVING A BORE OF 0.591 AND 0.585 INCH

Bore Length	Register and Cents, Flat or Sharp							
	Chalumeau		Throat		Clarion		Acute	
	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"
1 3/4"	+7	+8	-7	-5	+1	+4	+4	+1
1 7/8"	+6	+6	-6	-5	+4	+6	+4	+2
2"	+4	+5	-3	-6	+5	+4	+6	+3
2 1/8"	+3	+5	-2	-6	0	+1	+1	+1
2 1/4"	+3	+5	-6	-6	-3	-3	-2	-2
2 3/8"	0	+5	-9	-6	-4	-4	-2	-2

The deviations in intonation, as measured on a Strobocorr, were not as variable when the bore length was changed as were the deviations found when the bore taper and bore size were varied. However, in the case of each of the clarinets tested, at least one dimension was better in regard to intonation than the others. On both clarinets used in the study the least deviations in intonation were found when a mouthpiece was used which contained a bore length measurement of 2 1/8 inches. Since the deviations are not extreme when using any of the bore lengths tested in the study, the bore length of the mouthpiece would not appear to be as critical as the taper or the bore size with its effect on intonation accuracy.

Intonation Analyses of Tone Chamber Taper

When the tone chamber of the clarinet mouthpiece was analysed as to the effects of changes introduced into it on pitch deviations, the bore size, bore length, and bore taper remained unchanged. Two mouthpieces were selected having bore lengths of 2 1/8 inches, bore tapers of 0.040 inch, and bore sizes of 0.585 inch and 0.591 inch to match the clarinet bore sizes used in the study. The taper of the tone chamber begins underneath the tip of the reed, when the latter is placed on the mouthpiece, and extends to the point in the mouthpiece where the bore begins. The dimensions are least at the top of the mouthpiece and greatest at the lowest point in the tone chamber. An undersize tone chamber measurement of 0.030 inch was used and this taper size was gradually increased until an oversize measurement of 0.135 inch was reached.

The divisions of the clarinet range, as used in the mouthpiece bore analyses, were maintained in this study and the total deviations from equi-tempered tuning were averaged for each division. The Stroboscopes were used to indicate the deviations as measured in cents. Table 7 illustrates the effects on intonation when changes are made in the mouthpiece tone chamber taper size.

TABLE 7

THE EFFECT OF MOUTHPIECE TONE CHAMBER TAPER ON INTONATION OF
TWO CLARINETS HAVING A BORE OF 0.591 AND 0.585 INCH

Taper Size	Register and Cents, Flat or Sharp							
	Chalumeau		Throat		Clarion		Acute	
	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"
.030"	+5	+2	- 7	- 7	0	0	+ 2	- 1
.045"	+5	+2	- 7	- 7	0	0	+ 2	- 1
.060"	+5	+2	- 7	- 7	0	0	0	- 1
.075"	+4	+2	- 7	- 7	0	0	0	- 1
.090"	+2	0	- 7	- 7	0	0	- 1	- 3
.105"	0	-2	- 7	- 9	0	- 2	- 1	- 3
.120"	-2	-6	- 9	-13	-5	-10	- 7	- 8
.135"	-6	-6	-12	-18	-6	-12	-10	-11

The pitch deviations appearing when the tone chamber taper was changed varied slightly until a measurement of 0.120 inch was reached. On both clarinets used in this study, the intonation remained relatively constant up until that point. A taper size over 0.120 inch causes the pitch to become flat in all registers; therefore, a tone chamber taper size between 0.030 inch and 0.105 inch should be satisfactory for the clarinetist in maintaining intonation accuracy.

Intonation Analyses of Tone Chamber Depth

When measuring the effects of changes caused by variations in the depth of the tone chamber, two mouthpieces were selected having depth measurements of 0.495 inch. This measurement was made at the bottom portion of the tone chamber at the extreme end of the taper. A telescopic gauge was used to measure the distance from the top to bottom where the depth is greatest and before the bore section begins. A micrometer was used to obtain the measurement in thousands of an inch. The depth was gradually increased in measurements of 0.010 inch, and the effect of each change on pitch was then measured with the Strobocorr. Each of the mouthpieces used in this study had a bore size measurement to match the clarinet used, the bore length was 2 1/8 inches, and the bore taper size was between 0.030 inch and 0.040 inch. These data appear in table 8.

TABLE 8

THE EFFECT OF MOUTHPIECE TONE CHAMBER DEPTH ON INTONATION OF
TWO CLARINETS HAVING A BORE OF 0.591 AND 0.585 INCH

Depth Size	Register and Cents, Flat or Sharp							
	Chalumeau		Throat		Clarion		Acute	
	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"	0.591"	0.585"
.495"	-1	0	-5	-6	0	+ 2	+ 2	+ 4
.505"	0	+3	-5	-4	+ 3	+ 6	+ 5	+ 7
.515"	+3	+5	-1	-2	+ 9	+ 9	+11	+10
.525"	+7	+5	+3	+2	+14	+12	+13	+14
.535"	+7	+5	+3	+2	+16	+12	+16	+14
.545"	+9	+8	+3	+3	+16	+15	+16	+19
.555"	+9	+8	+3	+3	+16	+15	+16	+19

In general, as the depth of the tone chamber was increased, the pitch was raised. The best depth measurement for both clarinets used in the study was found to be between the dimensions of 0.495 inch and 0.505 inch. It was between these measurements that the least deviations from equi-tempered tuning was noted. Although the pitch was raised in all registers, the least deviations in intonation were noted in the chalumeau register. In each of the upper registers, the pitch was raised to a greater extent as the depth measurements were increased.

Tone Quality Analyses of Tone Chamber Taper

The effect of various tone chamber tapers on wave form was measured with a harmonic wave analyser. Tape loops were made of a tone from each register of the clarinet; chalumeau, throat, clarion, and acute. When these were made, a sound level meter was used to measure the intensity and each tape loop was recorded at precisely the same volume level. In this way, deviations introduced into the wave forms would be kept at a minimum because it was found in a study reported by McGinnis, Gallagher, and Sher¹ that the wave form may be affected by producing a variance in the intensity level.

The harmonic wave analyser, which measures the strength of the fundamental tone and its partials in millivolts, produced a span of readings due to the fluctuations occurring in the strengths of the various partials. The highest and lowest readings were made and the mean of each partial strength was selected to be used in this study. The tapers made in the mouthpiece tone chamber started at 0.030 inch and were gradually increased to a measurement of 0.135 inch. The bore size of the mouthpiece matched the bore size of the clarinet used. The bore length of the mouthpiece was 2 1/8 inches, and the bore taper size was 0.040 inch. The facing was the ideal "French" model. The measurements of this facing are included in Table 3. The only dimension which was changed throughout this portion of the experiment was the tone chamber taper.

¹C. S. McGinnis, C. Gallagher, and N. Sher. "An Experimental Study of the Tone Quality of the Boehm Clarinet." The Journal of the Acoustical Society of America, Volume 14 (1943), pp. 228-237.

It was found that the clarinet bore measurement of 0.591 inch, or 0.585 inch made no noticeable difference in the wave form when measured with a harmonic wave analyser or when evaluated by expert clarinetists. Therefore, a clarinet mouthpiece having a bore measurement of 0.591 inch was matched with a wood clarinet having identical bore dimensions. This combination was used to make the tape loops which were used in the study. The results of the analyses when using a harmonic wave analyser are as follows:

TABLE 9

THE EFFECT OF MOUTHPIECE TONE CHAMBER TAPER ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH A FUNDAMENTAL OF f

Taper Size and Relative Harmonic Strength in Millivolts								
Partial	.030"	.045"	.060"	.075"	.090"	.105"	.120"	.135"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.02	.02	.08	.06	.06	.04	.04	.02
3	.7	.7	.7	.8	.9	.9	.8	.8
4	.03	.1	.1	.1	.24	.24	.2	.2
5	.9	.7	.7	.9	.9	.8	.7	.7
6	.12	.1	.1	.1	.14	.12	.1	.1
7	.6	.7	.7	.7	.8	.6	.6	.4
8	.2	.16	.14	.2	.12	.1	.1	.1
9	.1	.1	.2	.2	.2	.2	.26	.34
10	.02	.02	.02	.02	.06	.06	.06	.06

TABLE 10

THE EFFECT OF MOUTHPIECE TONE CHAMBER TAPER ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH A FUNDAMENTAL OF f'

Taper Size and Relative Harmonic Strength in Millivolts								
Partial	.030"	.045"	.060"	.075"	.090"	.105"	.120"	.135"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.04	.02	.04	.06	.08	.1	.1	.1
3	.9	.9	.9	.9	.9	.9	.9	.9
4	.02	.02	.02	.1	.13	.2	.1	.1
5	.7	.7	.7	.7	.8	.6	.6	.6
6	.1	.1	.16	.12	.1	.1	.06	.06
7	.5	.5	.5	.5	.5	.5	.5	.4
8	.1	.1	.2	.16	.1	.2	.2	.12
9	.3	.3	.3	.3	.3	.3	.3	.3
10	.1	.08	.16	.2	.14	.2	.06	.06

TABLE 11

THE EFFECT OF MOUTHPIECE TONE CHAMBER TAPER ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH
A FUNDAMENTAL OF f''

Taper Size and Relative Harmonic Strength in Millivolts								
Partial	.030"	.045"	.060"	.075"	.090"	.105"	.120"	.135"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.16	.14	.14	.12	.2	.2	.14	.1
3	.9	.9	.9	.9	.9	.9	.9	.9
4	.12	.1	.14	.14	.14	.2	.14	.12
5	.7	.7	.8	.8	.8	.8	.8	.7
6	.1	.08	.08	.08	.1	.14	.08	.08
7	.4	.7	.7	.7	.7	.6	.5	.5
8	.14	.1	.12	.12	.2	.1	.1	.06
9	.3	.3	.2	.2	.2	.18	.18	.14
10	.02	.04	.04	.04	.02	.01	.01	.005

TABLE 12

THE EFFECT OF MOUTHPIECE TONE CHAMBER TAPER ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH
A FUNDAMENTAL OF c^{111}

Taper Size and Relative Harmonic Strength in Millivolts								
Partial	.030"	.045"	.060"	.075"	.090"	.105"	.120"	.135"
1	.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.3	.34	.38	.42	.5	.5	.4	.4
3	.5	.8	.8	.9	.9	.9	.9	.9
4	.3	.5	.6	.46	.4	.4	.3	.2
5	.1	.6	.6	.7	.7	.7	.5	.4
6	.01	.4	.4	.26	.2	.2	.1	.04
7	.32	.5	.5	.5	.46	.42	.4	.38
8	.1	.2	.2	.22	.2	.2	.12	.1
9	.08	.12	.14	.1	.1	.06	.01	.01
10	-	.01	.01	.02	.02	.01	-	-

The wave forms as measured in millivolts show a similarity throughout. The changes made in the taper of the tone chamber do not show a great difference in the notes, f and f^1 . However, on f^{11} and c^{111} there are some differences. The taper measurements between 0.045 inch and 0.105 inch show that the upper partials, in general, are stronger. In the case of c^{111} the partials are stronger and, in some cases, present only between these measurements. The taper measurement

of 0.030 inch and above 0.120 inch indicate a weaker strength level as indicated in millivolts. Therefore, it would indicate that the selection of a mouthpiece between 0.045 inch and 0.105 inch, in tone chamber taper measurements, would be desirable.

Tone Quality Analyses of Tone Chamber Depth

In the case of the depth analyses, a mouthpiece was selected which had a depth measurement of 0.495 inch. This mouthpiece depth was gradually increased until a measurement of 0.555 inch was reached. These sizes are undersize and oversize to the standard clarinet mouthpiece in use today. The length of the bore was $2 \frac{1}{8}$ inches, the bore taper was 0.040 inch, and the bore size was identical to the clarinet used, 0.591 inch.

Tape loops were made of a tone from each register of the clarinet in the manner mentioned above, and the harmonic wave analyser was used to indicate the strength of the partials in each tone. A sound level meter was used when recording to maintain precisely the same intensity. The following tables show the results of these analyses:

TABLE 13

THE EFFECT OF MOUTHPIECE TONE CHAMBER DEPTH ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH A FUNDAMENTAL OF f

Depth Size and Relative Harmonic Strength in Millivolts							
Partial	.495"	.505"	.515"	.525"	.535"	.545"	.555"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.16	.18	.16	.14	.14	.12	.12
3	.9	.9	.9	.9	.9	.9	.9
4	.16	.14	.18	.18	.18	.18	.12
5	.7	.7	.6	.7	.7	.6	.6
6	.06	.06	.08	.08	.08	.06	.06
7	.5	.5	.5	.5	.4	.4	.4
8	.02	.06	.06	.04	.04	.04	.04
9	.3	.28	.3	.32	.4	.44	.5
10	.01	.02	.02	.02	.06	.06	.08

TABLE 14

THE EFFECT OF MOUTHPIECE TONE CHAMBER DEPTH ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH A FUNDAMENTAL OF f^1

Depth Size and Relative Harmonic Strength in Millivolts							
Partial	.495"	.505"	.515"	.525"	.535"	.545"	.555"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.18	.1	.04	.06	.06	.08	.08
3	.9	.9	.7	.6	.6	.78	.9
4	.1	.08	.1	.12	.06	.06	.06
5	.7	.7	.7	.5	.5	.6	.8
6	.08	.12	.08	.08	.06	.08	.1
7	.5	.4	.3	.26	.3	.4	.4
8	.06	.06	.04	.06	.04	.06	.06
9	.3	.26	.18	.18	.24	.2	.3
10	.02	.04	.04	.06	.02	.04	.06

TABLE 15

THE EFFECT OF MOUTHPIECE TONE CHAMBER DEPTH ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH
A FUNDAMENTAL OF f^{11}

Depth Size and Relative Harmonic Strength in Millivolts							
Partial	.495"	.505"	.515"	.525"	.535"	.545"	.555"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.2	.18	.16	.12	.12	.12	.06
3	.7	.7	.74	.74	.7	.7	.7
4	.32	.3	.34	.3	.22	.22	.16
5	.9	.9	.8	.8	.8	.8	.8
6	.08	.08	.06	.08	.1	.1	.06
7	.4	.5	.5	.6	.5	.5	.5
8	.04	.04	.04	.04	.02	.02	.02
9	.3	.3	.24	.24	.22	.2	.2
10	.01	.01	.01	.01	.01	.01	.01

TABLE 16

THE EFFECT OF MOUTHPIECE TONE CHAMBER DEPTH ON THE RELATIVE
STRENGTH OF A SERIES OF PARTIALS WITH
A FUNDAMENTAL OF c^{111}

Depth Size and Relative Harmonic Strength in Millivolts							
Partial	.495"	.505"	.515	.525"	.535"	.545"	.555"
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	.5	.6	.6	.5	.4	.5	.5
3	.7	.7	.6	.6	.6	.6	.6
4	.34	.4	.3	.4	.3	.3	.26
5	.2	.3	.26	.2	.14	.1	.1
6	.04	.04	.02	.02	.005	.005	.005
7	.02	.02	-	-	-	-	-
8	.01	.01	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-

When the analyses were recorded of the changes in wave form caused by changes in depth dimensions, it was found that a great similarity of partial strength was evident. This was especially noticeable in the first three tones analysed. In the case of c^{111} , the partial strength was slightly greater with the tone chamber depth measurements of 0.505 inch and 0.495 inch. When the depth sizes of 0.515 inch to 0.555 inch were measured, the seventh and eighth partials were missing. In general

the depth changes did not change the wave forms significantly; however, perhaps the selection of tone chamber depth sizes of 0.495 inch or 0.505 inch should be considered because of the slight increase in partial strength.

Mouthpiece Tone Chamber Tone Quality Perception Tests

In addition to the analyses made of changes in the mouthpiece tone chamber with a harmonic wave analyser, tape recordings were made of a musical phrase using the same mouthpiece each time a change in dimensions was made. The mouthpiece was a hard-rod rubber type with a bore size matching the clarinet bore, which was 0.591 inch. The bore length was 2 1/8 inches, and the bore taper was 0.040 inch. The musical excerpt used in the study included tones from each register of the clarinet range. The musical excerpt used in the study is as follows:

FIGURE 2

MUSICAL EXCERPT USED IN TAPE RECORDINGS

An expert clarinetist made two separate tape recordings, the first of which contained the musical excerpt which was played while changes were introduced into the tone chamber taper size. The second recording was made with the same musical phrase while changes were made in the mouthpiece tone chamber depth sizes.

On the first tape recording, fifteen pairs of performances of the musical excerpt were made. Eight of these pairs were repetitions made when using the same mouthpiece with identical measurements in the tone chamber taper sizes. Seven pairs of performances were recorded using the same mouthpiece but with different size taper measurements introduced in the tone chamber. For example, mouthpiece tone chamber taper measurement 0.030 inch was paired with a tone chamber taper measurement of 0.045 inch. Taper measurement 0.045 inch was then paired with 0.060 inch in the next pair of performances on the recording. This process was continued until all taper sizes were included. The pairs of recordings were mixed so that a logical order could not be detected. Table 17 shows the mouthpiece tone chamber taper sizes and the order in which they were used on the recording.

TABLE 17
TAPE RECORDING OF TONE CHAMBER TAPER CHANGES

Tone Chamber Taper Size		Recording Pair Number	Taper Size Order	
A	0.030"	1	A	A
B	0.045"	2	C	D
C	0.060"	3	A	B
D	0.075"	4	E	E
E	0.090"	5	F	G
F	0.105"	6	B	B
G	0.120"	7	G	H
H	0.135"	8	B	C
		9	G	G
		10	D	D
		11	F	E
		12	H	H
		13	F	F
		14	E	D
		15	C	C

Fifteen pairs of recordings were also made, using the procedure outlined above, with changes made in the mouthpiece tone chamber depth sizes. One mouthpiece was selected, which was made of ebonite, having a bore size of 0.591 inch to match the clarinet with which it was used.

The bore specifications were the same as those in the mouthpiece which was used for the tone chamber taper recordings. The musical excerpt was the same as used previously. Nine of the pairs of recordings were repetitions of performances using the same mouthpiece tone chamber depth size. Six of the pairs of recordings were made of performances using different tone chamber depth sizes. Depth size 0.495 inch was paired with 0.505 inch, and 0.505 inch depth size was paired with 0.515 inch. This procedure was continued until all of the various depth sizes were included in the recording. Table 18 shows the order of the recordings in regard to depth size and the manner in which they were paired.

TABLE 18
TAPE RECORDING OF TONE CHAMBER DEPTH CHANGES

Tone Chamber Depth Size		Recording Pair Number	Depth Size Order	
A	0.495"	1	A	B
B	0.505"	2	D	C
C	0.515"	3	B	B
D	0.525"	4	D	E
E	0.535"	5	F	F
F	0.545"	6	G	G
G	0.555"	7	E	F
		8	B	C
		9	A	A
		10	G	G
		11	C	C
		12	G	F
		13	D	D
		14	A	A
		15	E	E

The two tape recordings were made to be used in a testing procedure. It was hoped that this test would serve as a preliminary study in the selection of judges who could perceive a difference when listening to tone qualities resulting from mouthpieces having the same tone chamber

measurements, and mouthpieces having different tone chamber measurements. The purpose of the testing procedure was to select judges who could detect differences in the musical excerpts heard and could score correctly at a significant level. These selected judges would then be used in a more critical testing program.

The tape recordings were made with a metronome, producing a flashing beat at a steady tempo, and the same tempo was maintained for all of the recordings. The tempo is indicated with the musical excerpt on page 73. A five-second interval was allowed between the musical excerpts in each pair, and a ten-second interval was placed between pairs.

The tape recordings were played for fifty judges, the group being made up of advanced clarinetists and perceptive music students. The ages of the judges varied from nineteen to thirty-nine years. The judges were instructed to listen to each pair of recordings carefully and, if the pair sounded alike, to place a circle around the letter S on the printed test paper which was provided for each person. If the pair of recordings sounded different, they were instructed to place a circle around either the number 1 or 2. Their choice was dependent upon which of the two recordings they preferred if they found them to be different. However, a circle placed around either number 1 or 2 would indicate that they had perceived a difference in the recordings, the difference being caused by changes introduced into the tone chamber.

A binomial expansion $(p + q)^n$ was used to determine if the scores made by the judges were significant at the .01 or .05 level of confidence. Twenty-two of the judges made scores which reached at least the .05 level. The tape recording of the changes made in the tone chamber taper size was

called tape number one, and the recording of the changes made in tone chamber depth size was named tape number two. Table 19 contains the significant scores made by the judges when listening to tape recordings numbers one and two.

TABLE 19
TEST SCORES MADE WITH TAPE RECORDINGS OF
TONE CHAMBER TAPER AND DEPTH CHANGES

Judge	Tape Number	Score	p.
A	1	12	.01
	2	15	.00003
B	1	15	.00003
	2	15	.00003
C	1	10	.09
	2	15	.00003
D	1	13	.003
	2	9	.19
E	1	12	.01
	2	10	.09
F	1	10	.09
	2	12	.01
G	1	13	.003
	2	14	.0005
H	1	14	.0005
	2	9	.19
I	1	11	.04
	2	12	.01
J	1	9	.19
	2	13	.003

TABLE 19 (continued)

K	1	12	.01
	2	10	.09
L	1	11	.04
	2	12	.01
M	1	9	.19
	2	12	.01
N	1	12	.01
	2	9	.19
O	1	11	.04
	2	11	.04
P	1	9	.19
	2	11	.04
Q	1	10	.09
	2	11	.04
R	1	11	.04
	2	9	.19
S	1	10	.09
	2	11	.04
T	1	11	.04
	2	9	.19
U	1	9	.19
	2	11	.04
V	1	9	.19
	2	12	.01

As can be seen from the table presented above, each judge made a significant score at the .01 or .05 level of confidence on at least one of the tape recordings. These twenty-two judges were selected, because of their scores, to participate in a second testing procedure of a slightly different nature. The significance of the scores indicate that

these judges were able to perceive subtle differences in tone quality.

The second group of recordings were made of pairs of performances of the musical excerpt by an expert clarinetist using a different mouthpiece dimension for each recording. The mouthpiece was the same as was used when the first group of recordings were made but, in the second group of recordings, each mouthpiece taper size and depth size was compared with the mean size of its particular group. For example, mouthpiece D was selected as the mean size for both the taper measurement and the depth size measurement recordings. This mouthpiece was paired with mouthpieces A, B, C, E, F, G, and H. This method made a comparison of all of the tone chamber taper size changes possible. The recording made with tone chamber taper size changes was called recording number three.

On tape recording number four the same procedure was followed in testing the various tone qualities as affected by tone chamber depth size changes. However, on the latter recording, mouthpiece tone chamber depth size D was compared with A, B, C, E, F, and G, as there were just six different depth sizes.

Each pair was repeated in reverse order somewhere in the test recording and all of the pairs were performed twice. The judges were given a printed test paper with the pair numbers listed along with the numbers one and two. The judges were instructed to listen carefully to each pair of recordings and to select the one which they preferred. When they had made their selection they were instructed to place a circle around either the number one or two. Enough time was allowed for the judges as a five-second time interval was placed between each excerpt, and a ten-second interval was allowed between each pair. The

dimensions used when the tone chamber taper size and tone chamber depth size were changed are included in Tables 17 and 18. The following tables show the order in which the pairs of recordings were placed:

TABLE 20
TAPE RECORDING OF TONE CHAMBER TAPER CHANGES WITH
MOUTHPIECE D SERVING AS THE MEAN SIZE

Recording Pair Number	Mouthpiece Order	
1	D	A
2	B	D
3	A	D
4	D	C
5	D	H
6	E	D
7	C	D
8	D	B
9	H	D
10	G	D
11	D	G
12	F	D
13	D	F
14	D	E

TABLE 21

TAPE RECORDING OF TONE CHAMBER DEPTH CHANGES WITH
MOUTHPIECE D SERVING AS THE MEAN SIZE

Recording Pair Number	Mouthpiece Order	
1	D	A
2	A	D
3	D	B
4	D	C
5	C	D
6	B	D
7	D	E
8	D	G
9	F	D
10	E	D
11	D	F
12	G	D

The theory tested with the latter two tape recordings was that the mean size tone chamber dimension would be selected by the judges more often than the more extreme sizes. For example, mouthpiece D would be preferred significantly more often than mouthpiece G or A; there would be less difference in the choices made between mouthpieces D and B, or D and F; still less difference between mouthpieces D and C, or D and E. Therefore, the hypothesis that the choices made by the judges

would be equally divided on each comparison was chosen. As each pair of recordings was duplicated somewhere on the completed tape recording, there was a possibility of forty-four responses. The expected results then would be that there would be twenty-two choices made for each mouthpiece heard on the recordings. To determine if the choices of the judges were significant at the .01 or .05 level of confidence, the chi square test was used. These two tape recordings were played and the test administered to the twenty-two selected judges and Tables 22 and 23 contain the results of the tests.

TABLE 22

CHOICES BY SELECTED JUDGES WHEN COMPARING THE TONE QUALITY WITH
A MEAN SIZE TONE CHAMBER TAPER WITH THE TONE QUALITY
PRODUCED WITH SEVEN OTHER SIZES OF TAPER

Mouthpiece Choice	Total Score	p.
D	38	< .001
A	6	
D	32	< .01
B	12	
D	24	> .50
C	20	
D	16	> .05
E	28	
D	32	< .01
F	12	
D	32	< .01
G	12	
D	34	< .001
H	10	

TABLE 23

CHOICES BY SELECTED JUDGES WHEN COMPARING THE TONE QUALITY WITH
A MEAN SIZE TONE CHAMBER TAPER WITH THE TONE QUALITY
PRODUCED WITH SIX OTHER SIZES OF DEPTH

Mouthpiece Choice	Total Score	p.
D	32	< .01
A	12	
D	27	> .10
B	17	
D	28	> .05
C	16	
D	23	> .70
E	21	
D	40	< .001
F	4	
D	41	< .001
G	3	

As can be seen from the above tables, a real difference was found by the judges between mouthpiece tone chamber taper and depth size D and others used in the recording. In the case of the recording using the various tone chamber taper sizes, a significant difference was found between mouthpieces D and A, D and B, D and F, and D and E. In addition, mouthpiece taper size D was selected over all the other mouthpiece taper sizes heard on the tape recording except mouthpiece taper size E and, in this case, the difference was not significant.

The results of testing with tape recording number four, which contained the performances with mouthpiece tone chamber depth size changes, showed that the judges found a real difference to exist between mouthpieces D and A, D and F, and D and G. Mouthpiece D was selected in preference to all of the others included in the test recording. The hypothesis that the choices of the judges would be equally divided would be accepted in the comparisons made between mouthpieces D and C, D and B, and D and E. No real difference can be considered to exist between these three combinations.

In general, the selected judges chose mouthpiece taper and depth size D at a significant level when a difference was perceived between the two sizes tested. This would indicate that the tone quality produced when using a mouthpiece with a mean size tone chamber taper and depth size is more satisfactory than that produced when using the more extreme sizes.

Evaluation of Student Clarinetist's Performances

The purpose of this portion of the study was to see if a difference could be perceived by music educators when hearing pairs of tape recordings made by advanced clarinetists using both their own mouthpieces and corrected ones which were supplied by the writer. Fifteen clarinetists from the public schools and colleges were selected who were having tone quality and/or intonation difficulties. The students were recommended by their teachers and their ages were between twelve and nineteen.

In the first recording made, the student used his own original mouthpiece. The musical excerpt used in the recordings is included in Figure 2. After the first performance was completed, an evaluation of the student's mouthpiece was made by actual testing by an expert clarinetist, and the inner portion of the mouthpiece was measured with telescopic gauges and a micrometer. The students' mouthpieces were found to be faulty in light of the information uncovered during this study. Many of the mouthpieces were difficult to play in tune because of an oversize bore measurement in relation to the clarinet used by the student. In addition, a few of the mouthpieces contained a cylindrical bore which also caused difficulties in intonation. Some of the students' mouthpieces were extreme in the dimensions found in tone chamber taper and depth sizes.

After an evaluation was made of the student's mouthpiece, the clarinet was measured to determine the size of the bore. A mouthpiece was selected which was identical in bore measurements to the clarinet he was using. In addition, the corrected mouthpiece had a bore length of 2 1/8 inches, bore taper between 0.030 inch and 0.050 inch. The tone chamber dimensions were maintained between 0.060 inch and 0.090 inch in taper size, and between 0.515 inch and 0.535 inch in depth size.

The student was given the corrected mouthpiece to perform on for a few minutes and, after he was accustomed to it, a new recording of the musical excerpt was made. After fifteen pairs of recordings were made, the tape recording was played for a group of music educators. Because the judges would be asked to select the tone quality and/or the intonation which they considered the better of the two, the order in which the recording was made was varied so that a logical pattern would not

exist. Table 24 demonstrates the order in which the recording was presented. Mouthpiece number one was the original mouthpiece, and number two, the corrected mouthpiece.

TABLE 24

TAPE RECORDING OF STUDENT CLARINETIS'S PERFORMANCES

Subject	Recording Pair Number	Mouthpiece Order	
A	1	1	2
B	2	2	1
C	3	2	1
D	4	2	1
E	5	1	2
F	6	1	2
G	7	2	1
H	8	1	2
I	9	1	2
J	10	2	1
K	11	1	2
L	12	2	1
M	13	1	2
N	14	1	2
O	15	1	2

The hypothesis tested with this tape recording was that a corrected mouthpiece would make a real difference in the performance of student clarinetists and that the difference could be perceived by the judges. The judges were given a printed test paper with the pair numbers listed followed by the letters A and B. They were instructed to listen to each pair of recordings carefully and to select the one they preferred and circle either the letter A or the letter B. This would indicate that they preferred either the first or second recording heard.

The judges selected for the testing had varying amounts of teaching experience. Some of the judges were beginning teachers and others had been teaching for almost twenty years. All were instrumental music educators and the ages varied from twenty-two to thirty-eight.

A binomial expansion $(p + q)^n$ was used to determine if the choices of the judges were significant at the .01 or .05 level of confidence. It was hoped that the judges would perceive a difference between the original mouthpiece and the corrected mouthpiece when heard on the recordings. If the corrected mouthpieces were selected enough times to place the scores in the .01 or .05 level, a real difference would seem to exist. Table 25 shows the results of this testing procedure.

TABLE 25

CHOICES BY JUDGES WHEN COMPARING STUDENT PERFORMANCES
WITH ORIGINAL AND CORRECTED MOUTHPIECES

Judge	Number of Times the Corrected Mouthpiece was Chosen	p.
A	12	.01
B	12	.01
C	15	.00003
D	14	.0005
E	13	.003
F	11	.04
G	11	.04
H	11	.04
I	14	.0005
J	13	.003
K	12	.01
L	12	.01
M	12	.01
N	12	.01
O	11	.04

All of the judges used in this testing procedure preferred the corrected mouthpiece to the original student mouthpiece a significant number of times. All of the scores were significant at the .04 level

or higher. The results of this test would indicate that the music educator can perceive a difference when a corrected mouthpiece is fitted to the student's clarinet to eliminate tone quality and/or intonation difficulties. Also, the results of this test would indicate that the perceptive teacher could evaluate the student's mouthpiece and replace it, if necessary, with a mouthpiece having correct specifications.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

When attempting to determine what factors are important in the production of good tone quality and accurate intonation on the clarinet, many variables are found. The mouthpiece has been considered to be of major importance in affecting tone quality. The amount of air pressure generated against the reed, the embouchure of the performer, the facing of the mouthpiece, and the training of the clarinetist have all been considered. Many writers and clarinetists have mentioned the importance of the internal dimensions of clarinet mouthpieces, but precisely what effect various bore and taper sizes may have on intonation and tone quality has not been clearly defined. Some writers have considered the facing as receiving too much importance in the production of good tone quality and accurate intonation. One writer stated that the internal section of the mouthpiece should be properly proportioned, but did not mention in what way this should or could be carried out.

Clarinetists and clarinet teachers accept the fact that all clarinet mouthpieces will vary in some way. Usually the variance is detected in an actual performance on the mouthpiece, after which a subjective evaluation is made. When selecting a group of mouthpieces at random, it was found that all differed when measured internally with telescopic gauges and micrometer. When measuring mouthpieces made specifically for a particular clarinet, it was found that the bore size of the

mouthpiece and the bore size of the clarinet differed. In addition, when selecting a group of mouthpieces made by the same manufacturer to one set of specifications, the mouthpieces all varied as to bore taper and tone chamber taper and depth sizes.

The clarinetist and clarinet teacher are usually able to select mouthpieces for students subjectively. Because of the training involved, the clarinetist develops a high degree of perception in regard to clarinet tone quality. He is usually satisfied with an actual performance on the selected mouthpiece and evaluates it by its responsiveness.

The music educator, who is usually not an expert clarinetist, cannot evaluate mouthpieces in the same manner. However, he is confronted with many teaching problems regarding the clarinetists in his music organizations and classes. When the selection of a mouthpiece is made for the students, can the mouthpiece be evaluated objectively, to some extent, by the teacher who is not a clarinetist? Because the mouthpieces available to the music educator vary a great deal, how can he select one which will satisfy his demands?

This study was an attempt to supply the music educator and clarinet teacher with information concerning the effects of various internal dimensions on tone quality and intonation. Because the internal dimensions are usually ignored when a selection of mouthpieces is made, this study attempted to analyse the internal portion of the clarinet mouthpiece and endeavored to answer the following questions:

1. What effect do various taper sizes, bore sizes, and bore lengths have upon intonation when the tone chamber and facing remain unchanged?
2. What effect do various tone chamber sizes have upon tone quality and intonation when the bore taper, bore size, bore length, and facing remain unchanged?
3. Will the changes in tone quality produced with various tone chamber sizes be perceptible to expert clarinetists?

Summary of Procedures

When making the analyses of the effects of various mouthpiece bore tapers on intonation, two mouthpieces were used having the medium "French" facing. The bore measurement of these mouthpieces was identical with each of the clarinets used in the study, 0.591 inch and 0.585 inch. Brass shim stock was used in the bore to form the various tapers and rubber cement was used to make the cone airtight. Tapers tested varied from 0.000 inch to 0.100 inch. The tones from each register of the clarinet were played and the deviations in pitch from equi-tempered tuning were recorded in cents. Each of the registers of the clarinet: chalumeau, throat, clarion, and acute were tested separately. The deviations were totaled for each register and the average from each was reported tabularly.

To determine the effect of various bore sizes on intonation, a mouthpiece was selected having a bore measurement of 0.581 inch. This bore size was gradually increased by filing, and as each change was made the mouthpiece was tested with the two clarinets used in the study. The bore size was finally increased to an oversize of 0.595 inch. A Strobocomm was used which indicated the deviations in cents from equi-tempered tuning.

To analyse the effects of various bore lengths on intonation, an ebonite mouthpiece was cut lengthwise, the bore reamed out to an oversize measurement of $2 \frac{3}{8}$ inches. The bore length was then varied with the use of red dental wax and reduced in size gradually until a measurement of $1 \frac{3}{4}$ inches was reached. Notes from each register of the clarinet were played by an expert clarinetist and the total deviations for each register were averaged. This procedure was followed using the two clarinets and two mouthpieces having identical bore size measurements.

To analyse the tone chamber taper, a mouthpiece was used having an undersize taper of 0.030 inch. This measurement was gradually increased by filing until an oversize dimension of 0.135 inch was reached. The effects of these changes were indicated when the wave forms were analysed with a harmonic wave analyser, and the deviations in pitch from equi-tempered tuning were obtained with a Stroboscopes. The tape loops were made while using an Ampex tape recorder, Model No. 600, and a Shure Unidyne Unidirectional microphone, Model No. 556S. An expert clarinet player made the tape loops while standing approximately ten feet from the microphone. The same volume setting was used for all tape loops. The tones recorded were concert pitch f, f', f'', and c'''.

This procedure was continued with the tone chamber depth analyses. The depth sizes were varied from 0.495 inch to 0.555 inch and the increase in size was accomplished by filing. The tools used to make the measurements were two telescopic gauges and a micrometer, which measures in thousandths of an inch.

The tape recordings made when using mouthpieces with changes introduced in tone chamber taper and depth were played for selected

judges. An attempt was made to determine if the judges could perceive a difference when hearing the same musical excerpt played with mouthpieces having different tone chamber specifications.

Finally, the information gathered during the study was used in an attempt to improve the student clarinetist's performance, especially when the student was recommended by his teacher as having difficulty in achieving good intonation and/or tone quality. Fifteen students were selected to make the recordings using their original mouthpiece and the corrected mouthpiece. The corrected mouthpiece was selected for each student after an examination was made of his original mouthpiece and the clarinet which he was using. These recordings were then played for selected music educators to determine if a difference was perceived between the two performances.

Findings

The Internal Dimensions and Intonation

When an analysis was made on the effect of various bore taper sizes on intonation, it was found that as the taper was increased in size the intonation was gradually raised. Although the intonation in the chalumeau register was quite satisfactory when using bore taper sizes of less than 0.030 inch, the upper registers were quite flat. With bore taper sizes larger than 0.060 inch, the intonation was quite sharp especially in the chalumeau and the acute registers. The selection of mouthpieces with bore taper sizes between 0.030 inch and 0.050 inch would appear to be best for overall intonation accuracy.

In the analyses made of the effect of the mouthpiece bore size on intonation, it was found that the best intonation resulted when the

mouthpiece bore size was identical with the clarinet used. If the bore was oversize in relation to the clarinet bore size, the tendency was for the pitch to rise slightly. When the bore size of the mouthpiece was undersize to the clarinet used, the tendency was for the intonation to lower slightly. However, mouthpieces having a bore size larger than the clarinet with which they are used have a greater negative effect on intonation than do those whose bore sizes are smaller.

Although the bore length size does not affect the intonation as greatly as does taper or bore size, it was found that with a bore length of less than $2 \frac{1}{8}$ inches, the intonation was slightly sharp. When a mouthpiece bore length of greater than $2 \frac{1}{8}$ inches was used, the intonation was slightly flat. The bore length of $2 \frac{1}{8}$ inches appeared to be best for both clarinets used in the study.

The analyses of clarinet mouthpiece intonation indicate that the mouthpiece can be proportioned to assure the least deviations from standard pitch. Every effort should be made to obtain a mouthpiece with identical bore measurements in relation to the clarinet used by the performer. However, if an oversize or undersize mouthpiece bore size is used, the intonation can be improved by changing the taper of the mouthpiece bore. Thus, if an oversize mouthpiece bore size is used and the intonation is slightly sharp, this could be compensated for by using a bore taper measurement of less than 0.030 inch.

In the case of bore length, which does not affect the intonation as greatly as taper size or bore size, adjustments may be made which

will contribute to the accuracy of the overall intonation. Thus, if the bore size of the mouthpiece is oversize in relation to the clarinet, which would have a tendency to make the intonation slightly sharp, a bore length of more than 2 1/8 inches may be used.

When the taper size of the tone shamber was changed, the deviations remained relatively constant until an extreme measurement of 0.120 inch was reached. At this point the deviations from standard pitch became greater and the intonation became flat. All of the taper sizes in the tone chamber from 0.030 inch to 0.105 inch appear to be satisfactory in regard to intonation accuracy. Thus, it would appear that the tone chamber taper size is not as critical as bore size and bore taper size unless an extreme taper size is used. If so, a compensation would have to be made within the bore to cancel out the resulting deviations from standard pitch.

The changes made in depth size within the tone chamber showed that the intonation was affected somewhat as the depth was increased. The greater the depth, the sharper the intonation became. The best depth measurement for the two clarinets used in the study, in regard to intonation accuracy, was found to be between 0.495 inch and 0.505 inch. Again, if an extreme size is used in the tone chamber depth, the bore size, or bore taper could be altered to compensate for the higher intonation which would occur.

The Internal Dimensions and Tone Quality

When the wave forms were measured with a harmonic wave analyser, all tones which were used in the study showed a similarity in their patterns of partial strength. However, the analyses made when the tone chamber taper size was changed showed that the partials present in the upper registers were stronger when using a mouthpiece with a taper measurement in the tone chamber of from 0.045 inch to 0.105 inch. The taper measurement in the tone chamber of 0.030 inch and over 0.120 inch show a weaker strength level when measured in millivolts. In addition, the tenth partial was present within this range and absent when the extreme sizes were used.

Because of the greater strength of the partials in the higher registers when using tone chamber taper sizes between 0.045 inch and 0.105 inch, the selection of a mouthpiece with a tone chamber taper size within this range would appear to be desirable. As the tones produced with these mouthpieces were very similar in the lower registers, the strength of the partials produced in the higher registers should be considered.

Changes made in tone chamber depth sizes did not greatly affect the wave forms when measured with a harmonic wave analyser. In the case of c^{'''}, the partial strength was slightly greater when using the tone chamber depth sizes of 0.495 inch and 0.505 inch. In general, the effects resulting from the introduction of changes in the mouthpiece tone chamber seem to be very subtle.

Concerning the perception of effects produced when changes were introduced in the tone chamber of the mouthpiece, tape recordings were made and a perception test administered. The first testing procedure was concerned only with the selection of expert judges who could perceive a difference in clarinet tone qualities at a significantly high level. When the selection was made, the second testing procedure was instigated and completed.

The choices made by the judges of the mean size tone chamber taper size, which was 0.075 inch, showed that a significant difference was perceived between the mean size and the extreme sizes. Also, the judges could perceive no significant difference between the mean size and the sizes next to it, which were 0.060 inch and 0.090 inch. The analyses made of the wave forms showed the upper partials of the extreme sizes to be slightly weaker in millivolt strength.

The judges also found a significant difference existing between the mean size tone chamber depth size, which was 0.525 inch, and the more extreme sizes. Although the upper partials of tones produced with mouthpieces having sizes of 0.495 inch and 0.505 inch were slightly stronger in the acute register of the clarinet range, this slight difference evidently did not produce a significantly perceptible difference when heard on a tape recording.

When a difference was perceived in the tone qualities produced when changes were introduced in the tone chamber, the judges selected the mean size a significant number of times. This would indicate that the tone quality produced when using clarinet mouthpieces with tone

chamber taper and depth sizes, which are not extreme, would be more satisfactory to a qualified listener.

When the recording was played for selected music educators with students performing a musical excerpt using their original mouthpieces and the corrected mouthpieces, the judges selected the performances produced with the corrected mouthpieces a significant number of times. When students, who were having tone quality and/or intonation difficulties, were supplied with a mouthpiece which was fitted to their clarinet, an improvement was noted in their performances.

Conclusions

With the completion of the study regarding the effects of various tone chamber taper and depth sizes, and bore taper, size, and length, on tone quality and intonation, the questions stated as the problem of the study may be answered. In regard to question number one, concerning the effect of various bore sizes, taper sizes, and bore lengths on intonation when the tone chamber and facing remain unchanged, the following conclusions were reached:

1. As the bore taper sizes are increased, the intonation is gradually raised. When using a bore taper size of less than 0.030 inch, the upper registers of the clarinet will be quite flat. With a bore taper sizes of more than 0.060 inch, the intonation is quite sharp in the chalumeau and acute registers.
2. Concerning the effect of bore size on intonation, if the bore is oversize in relation to the clarinet, the instrument will be sharp. If the bore size of the mouthpiece is undersize to the clarinet with which it is used, the intonation will be flat. Oversize mouthpiece bores have a greater effect on intonation than do undersize bores.

3. When using a bore length of less than 2 1/8 inches in combination with clarinets having bores of 0.591 inch and 0.585 inch, the intonation is slightly sharp. A bore length of more than 2 1/8 inches has a tendency to lower the pitch throughout the range of the clarinet.

In regard to question number two, concerned with the effect of various tone chamber sizes upon tone quality and intonation when the bore taper, bore size, bore length, and facing remain unchanged, the following conclusions were reached:

1. The tone chamber taper size does not affect the intonation to a great degree. Taper sizes from 0.030 inch to 0.105 inch appear to be satisfactory in regard to intonation.
2. As the tone chamber depth size is increased, the intonation is raised. The smaller sizes, 0.495 inch and 0.505 inch, were found to be best in regard to intonation accuracy.
3. In regard to tone quality, the tone chamber taper sizes between 0.045 inch and 0.105 inch produce a greater harmonic strength than do the more extreme taper sizes.
4. Changes made in tone chamber depth did not affect the strength of the partials to a great degree. However, the depth sizes of 0.495 inch and 0.505 inch produce a slightly greater partial strength in the acute register.

Question number three, which was concerned with changes in tone quality produced with various tone chamber sizes and the perceptibility to expert listeners of these changes, is answered in the following conclusions:

1. The mean size tone chamber taper was selected by the judges as being better than the more extreme sizes used in the study. Although the judges found no difference to exist in tone chamber taper measurements between 0.060 inch and 0.090 inch, they did perceive a difference between taper sizes below and above these measurements when compared with the middle range sizes.
2. A difference was perceived in the tone quality produced with different tone chamber depth sizes. The selected judges chose the mean size, 0.525 inch, as producing the superior tone.

3. A difference was perceived by expert listeners when the judges preferred the performances of students with corrected mouthpieces significantly more often than their performances with uncorrected mouthpieces. Therefore, the changes introduced into the mouthpiece tone chamber are perceptible to expert listeners.

Recommendations

The provision of a correct mouthpiece with each clarinet may be the responsibility of the manufacturer; however, because each mouthpiece varies to a great extent when leaving the manufacturer, the clarinet teacher and music educator should check the measurements of each mouthpiece in relation to the clarinet used by the student to determine if intonation and tone quality difficulties are attributable to the mouthpiece. The actual measurements can be taken with telescopic gauges and a micrometer. An evaluation of each mouthpiece in the clarinet section would be especially valuable in attempting to maintain overall accurate intonation in a large group of performers. An evaluation would contribute to better understanding between teacher and student, and the student could perform more accurately if, through the evaluation, a corrected mouthpiece were substituted.

The information gathered and reported in the preceding chapters can be used as a guide for the clarinet teacher and music educator to indicate what intonation and tone quality difficulties can be expected from each mouthpiece considered for the student's use. For example, after the measurements are made of the mouthpiece bore size, and the bore size of the clarinet, if the mouthpiece bore size is found to be larger than the bore size of the clarinet, the intonation can be expected

to be sharp. If the mouthpiece bore size is found to be smaller than that of the clarinet, the intonation can be expected to be flat.

In addition, an understanding can be gained from the information included in this study as to what proportioning must be necessary for accurate intonation when the selection of a mouthpiece is made. For example, an undersize mouthpiece bore measurement can be compensated for by having a taper size in the mouthpiece bore of greater than 0.060 inch. The larger bore taper size would raise the pitch somewhat whereas the undersize bore measurement would lower the pitch.

Certain dimensions used in the internal portion of the clarinet mouthpiece appear to be better than others for intonation accuracy. Also, there appears to be some extreme sizes which should be avoided when the production of good tone quality is expected. The following list of recommendations indicate the desirable internal dimensions for the clarinet mouthpiece when used with each of the clarinets used in the study:

1. Every effort should be made to obtain a mouthpiece with an identical bore size to that of the clarinet with which it is used.
2. The best mouthpiece bore length for both clarinets used in the study is 2 1/8 inches.
3. A mouthpiece should be selected having a bore taper size between 0.030 inch and 0.050 inch.
4. The most desirable tone chamber taper sizes are between 0.045 inch and 0.105 inch. The best tone quality, as selected by the judges, resulted from the mouthpiece with a tone chamber taper size of 0.075 inch.

5. The most desirable tone chamber depth size in regard to intonation was found to be within 0.495 inch and 0.505 inch. Concerning tone quality, as affected by tone chamber depth, the judges selected the mouthpiece tone chamber depth size of 0.525 inch as best.

The music educator and clarinet teacher should consider the mean sizes of the tone chamber taper (0.060 to 0.090 inch), and tone chamber depth (0.515 to 0.535 inch), as being the better potential in regard to the achievement of good tone quality by the student clarinetist. That the selected judges chose the mean sizes of the tone chamber taper and depth sizes would indicate that the tone quality produced with mouthpieces using these tone chamber sizes are more satisfactory. If an extreme size is found when measuring the tone chamber taper (below 0.060 inch or above 0.090 inch), or the depth of the tone chamber (below 0.515 inch or above 0.535 inch), it should be considered as being less likely to produce a satisfactory tone quality.

A significant difference can be made in the clarinet student's performance by substituting a correct mouthpiece in relation to the student's instrument. Therefore, the internal dimensions should be considered, along with the facing, in the selection of a mouthpiece. This should be done when attempting to improve intonation and tone quality for the individual clarinetist, in the selection of a mouthpiece for the beginning clarinet student, and for the improvement of intonation and tone quality for the clarinet section in a musical organization.

During the course of this study, a number of factors appeared which possibly could have an effect on clarinet tone quality and intonation and, perhaps, should be considered for further study.

1. A number of barrels found on various clarinets have a cylindrical bore whereas others are conical. The barrels recommended by the leading clarinet manufacturers are made in the form of an inverted cone. This is the type used in this study. However, what would be the effect produced when combining the various internal measurements of clarinet mouthpieces with a cylindrically bored barrel?
2. Clarinet reeds vary in the manner in which the profile is placed on the reed. Although only one style of reed was used for all of the tests in this study, what is the effect produced when using a number of styles in combination with various sizes of mouthpieces?

It is hoped that this study will provide information which will be helpful in instigating further study so that eventually clarinet mouthpieces can be evaluated in a more objective manner.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

- Baines, Anthony. Woodwind Instruments and their History. Faber and Faber Limited, London, 1957.
- Culver, Charles A. Musical Acoustics. McGraw-Hill Book Company, Inc., New York, 1956.
- Edwards, A. L. Experimental Design in Psychological Research. Rinehart and Company, Inc., New York, 1950.
- Forsyth, Cecil. Orchestration. The Macmillan Company, New York, 1947.
- Geiringer, Karl. Musical Instruments. Oxford University Press, New York, 1943.
- Grout, Donald Jay. A History of Western Music. W. W. Norton and Co., Inc., New York, 1960.
- Klose, H. Method for the Clarinet. Meissonnier, 1843. English edition, Hawkes, London, 1906.
- Lloyd, L. S. Music and Sound. Oxford University Press, New York, 1951.
- Miller, D. C. The Science of Musical Sounds. The Macmillan Company, New York, 1926.
- Rendall, F. G. The Clarinet. Ernest Benn Limited, London, 1954.
- Richardson, E. G. The Acoustics of Orchestral Instruments and of the Organ. Oxford University Press, New York, 1929.
- Sachs, Curt. The History of Musical Instruments. W. W. Norton and Co., New York, 1940.
- Stein, Keith. The Art of Clarinet Playing. Summy-Birchard Publishing Co., Evanston, Ill., 1958.
- Willaman, Robert. The Clarinet and Clarinet Playing. Carl Fischer, Inc., New York, 1949.

Periodicals

- Arey, Rufus M. "Tone and Tune." The Clarinet, 1 (Spring, 1950), Symphony, New York.

- Bonade, Daniel. "Playing in Tune." The Clarinet, 17 (Winter, 1954-55), Symphony, New York.
- Bonade, Daniel. "Tone Production." The Clarinet, 15 (Summer, 1954), Symphony, New York.
- Brymer, Jack. "Henry Lazarus." The Clarinet, 2 (Summer, 1950), Symphony, New York.
- Das, P. "Theory of the Clarinet." Indian Journal of Physics, Volume 6, Part I (1931).
- Galper, Abe. "The Clarinet Air Column." The Clarinet, 3 (Fall, 1950), Symphony, New York.
- Gee, Harry R. "Clarinet Mouthpieces." The Instrumentalist, Volume XI, Number 8 (April, 1947), Evanston, Ill.
- Ghosh, R. N. "The Theory of the Clarinet." The Journal of the Acoustical Society of America, Volume 9 (1938).
- Gigliotti, Anthony. "Playing Legato." The Clarinet, 17 (Winter, 1954-55), Symphony, New York.
- "Instruments Boys Like." The Instrumentalist, Volume V, Number 4 (January-February, 1951), Evanston, Ill.
- Link, Otto. "Refacing Mouthpieces." The Clarinet, 2 (Summer, 1950), Symphony, New York.
- Low, Floyd E. "Keep that pitch up." The Instrumentalist, Volume IV, Number 2 (November-December, 1949), Evanston, Ill.
- McGinnis, C. S., and Gallagher, C. "The Mode of Vibration of a Clarinet Reed." The Journal of the Acoustical Society of America, Volume 12 (1941).
- McGinnis, C. S., Gallagher, C., and Sher, N. "An Experimental Study of the Tone Quality of the Boehm Clarinet." The Journal of the Acoustical Society of America, Volume 14 (1943).
- McGinnis, C. S., and Pepper, R. "The Intonation of the Boehm Clarinet." The Journal of the Acoustical Society of America, Volume 16 (1945).
- McLane, Ralph. "Single or Double Lip." The Clarinet, Symphony Supplement, Symphony, New York.
- O'Brien, Harry E. "On Clarinet Mouthpieces." The Clarinet, Symphony Supplement, Symphony, New York.

- O'Brien, Harry E. "Mouthpiece Bores & Tone Chambers." The Clarinet, 9 (Spring, 1952), Symphony, New York.
- O'Brien, Harry E. "The Mouthpiece Bore." The Clarinet, 13 (Winter, 1953-54), Symphony, New York.
- O'Brien, Harry E. "The Mouthpiece Bore." The Clarinet, 2 (Spring, 1950), Symphony, New York.
- Parker, Sam E. "Analyses of the Tones of Wooden and Metal Clarinets." The Journal of the Acoustical Society of America, Volume 19, Number 3 (May, 1947).
- Portnoy, Bernard. "The Embouchure and Tone Color." The Clarinet, 23 (Summer, 1956), Symphony, New York.
- Redfield, J. "Air Column Behavior in Orchestral Wind Instruments." The Journal of the Acoustical Society of America, Volume 6 (1934).
- Volpe, Gennaro. "Clarinetists and Mouthpieces." The Clarinet, 20 (Fall, 1955), Symphony, New York.
- Waln, George E. "Clarinet Mouthpieces and Tuning Problems." The Instrumentalist, Volume III, Number 4 (March-April, 1949), Evanston, Ill.

General Reference Works

- Apel, Willi. Harvard Dictionary of Music. Harvard University Press, Cambridge, Massachusetts, 1958.

Bulletins

- Richardson, Arlie. "The Clarinet Mouthpiece in Relation to Tone and Pitch." Leblanc Educational Series Publication, Leblanc Corp., Kenosha, Wisconsin.

Unpublished Material

- Zepp, Raymond. "Effects of Four Factors on Clarinet Tone Quality." Unpublished Doctoral Dissertation, Department of Music Education, University of Kansas, 1954.

APPENDIX A

Forms used in Tone Quality Perception Tests

TONE QUALITY PERCEPTION TEST

Name _____

Directions: Thirty pairs of tape recordings will be heard. After listening to both recordings in each pair, decide whether the pair are the same or different. If the pairs are the same, place a circle around the letter S. If the pairs are different, place a circle around either numbers one (1) or two (2), whichever of the two is the best.

Example: If after hearing pair number one you decide that recording two is better than one, place a circle around number two (2). The differences are very subtle so please listen carefully.

<u>Tape Number One</u>				<u>Tape Number Two</u>			
Pair 1	S	1	2	Pair 1	S	1	2
Pair 2	S	1	2	Pair 2	S	1	2
Pair 3	S	1	2	Pair 3	S	1	2
Pair 4	S	1	2	Pair 4	S	1	2
Pair 5	S	1	2	Pair 5	S	1	2
Pair 6	S	1	2	Pair 6	S	1	2
Pair 7	S	1	2	Pair 7	S	1	2
Pair 8	S	1	2	Pair 8	S	1	2
Pair 9	S	1	2	Pair 9	S	1	2
Pair 10	S	1	2	Pair 10	S	1	2
Pair 11	S	1	2	Pair 11	S	1	2
Pair 12	S	1	2	Pair 12	S	1	2
Pair 13	S	1	2	Pair 13	S	1	2
Pair 14	S	1	2	Pair 14	S	1	2
Pair 15	S	1	2	Pair 15	S	1	2

TONE QUALITY PERCEPTION TEST

Name _____

Directions: Twenty-six pairs of tape recordings will be played. The musical excerpt is the same throughout. However, a different mouthpiece was used for each recording. After hearing each pair, decide which of the recordings sounds best to you. This is a forced choice. Example: If after hearing pair number one you decide that the second recording heard sounded the best to you, place a circle around the number two (2) after pair number one. The differences are very subtle so please listen carefully.

TAPE NUMBER THREE

PAIR NUMBER

1.	1	2
2.	1	2
3.	1	2
4.	1	2
5.	1	2
6.	1	2
7.	1	2

PAIR NUMBER

8.	1	2
9.	1	2
10.	1	2
11.	1	2
12.	1	2
13.	1	2
14.	1	2

TAPE NUMBER FOUR

PAIR NUMBER

1.	1	2
2.	1	2
3.	1	2
4.	1	2
5.	1	2
6.	1	2

PAIR NUMBER

7.	1	2
8.	1	2
9.	1	2
10.	1	2
11.	1	2
12.	1	2

CLARINET TONE QUALITY PERCEPTION TEST

Directions: Fifteen pairs of recordings will be played. The same person made each pair, one with his own mouthpiece, and the other with a mouthpiece corrected for his clarinet. After hearing each pair select the one which sounds the best to you. Example: after hearing pair number one you decide that the first sample recording sounds best to you, place a circle around the letter A, etc.

Pair Number

1.	A	B
2.	A	B
3.	A	B
4.	A	B
5.	A	B
6.	A	B
7.	A	B
8.	A	B
9.	A	B
10.	A	B
11.	A	B
12.	A	B
13.	A	B
14.	A	B
15.	A	B

Name _____