

AN EXPERIMENTAL STUDY OF INTONATION FACTORS  
OF THE CORNET AND TRUMPET

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Many musicians have theorized that intonation would be improved if all players in a band or orchestral section used instruments of identical dimensions and material. This study consists of a test taken under experimental conditions comparing the Conn 38A cornets used in the North Texas State University Concert Band with a random selection of trumpets, using the same performers for both sets of instruments.

Each note of the practical range of the instrument and common alternate fingering was tested. The players and instruments were tested both with and without an intonation guide. The results of these tests were computed to show the averaged results of the total performance of the player and also to show the average variation of each pitch as played by all the performers.

In addition, the study includes consideration of the component parts of the trumpet and cornet and the construction of these instruments in relation to their effect on intonation. Variation in temperature and volume are discussed as factors of intonation. Also included is a

discussion of temperament and tuning standards.

Similarity of performance results indicate that there are no intonation differences between players using a matched set of instruments and the same players using a random selection of instruments. It is suggested that in future research, advantages in using a matched set of instruments can probably be found in the area of similar tone quality.

AN EXPERIMENTAL STUDY OF INTONATION FACTORS  
OF THE CORNET AND TRUMPET

THESIS

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## CHAPTER I

### INTRODUCTION

Many musicians have theorized that intonation would be improved if all players in a band or orchestral section used instruments of identical dimensions and material. This study consists of a test taken under experimental conditions comparing the Conn 38A cornets used in the North Texas State University Concert Band with a random selection of trumpets. The personnel participating in this study were the six members of the cornet section of the North Texas State University Concert Band.

It is not the intention of this paper to point out any deficiency in, or to recommend the use of, any specific brand or model of trumpet or cornet. It is not the objective of this paper to advocate the use of trumpets rather than cornets or cornets rather than trumpets.

The Conn 38A cornets used by the subjects participating in this study were the property of North Texas State University. The trumpets used in this study were the personal property of the participants. No attempt was made to predetermine the selection of trumpets for this study.

The existence of a matched cornet section at North Texas State University implies an advantage in the use of identical

(matched) sections. Instrument manufacturers advocate the use of a section of like instruments; they claim more favorable performance results when an entire section is equipped with instruments of identical make and measurement. The problem of this paper is to determine if one of these favorable factors is in the area of intonation. Tonal blend or ease of playing may be elements which are results of, or related to, intonation tendencies. However, this paper is confined to the specific area of relative intonation measurement. Every practical consideration was made to minimize the weight of playing factors other than physical variation of instruments.

#### Consideration of Tuning Standards

There is sufficient evidence to support the theory that players using the trumpet or cornet do not follow a set scale in actual performance. The equal-tempered scale, simply stated, is a man-made scale based on an arithmetical process used in the tuning of modern keyboard instruments.<sup>1</sup>

Just intonation, also known as the Chord of Nature, follows the overtone principle, and its resulting out-of-tuneness with equal-tempered tuning has plagued

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<sup>1</sup>Llewln S. Lloyd, "A Note on Just Intonation," Journal of the Acoustical Society of America, II (April, 1940), 445.

instrumentalists, acousticians, theorists and instrument manufacturers.<sup>2</sup> In his study of intonation James F. Nickerson has summed up the controversy concerning which temperament modern musicians actually use:

There is considerable confusion and speculation concerning the intonation employed by modern musicians in performance upon a relatively pitch-free medium such as a violin or "cello. Some feel that the conditioning influence of better than a century and a half of equi-tempered tuning as employed upon modern keyboard instruments has brought man to think, hear and perform in a manner approaching the equi-tempered intonation regardless of his medium of performance. Others feel that the harmonic tradition arising essentially through and following the period of the Renaissance has inevitably forced man to "hear" his intervals as just intervals (i.e., with simplest ratios) above a point as the root or in relation to other simultaneously sounding notes. Some would oversimplify the position to say that modern man would tend to perform in the just or natural scale. Still others have proposed or submitted experimental evidence that man tends to perform in a manner approaching Pythagorean intonation when playing melodically (i.e., without other melodic voices or harmonic accompaniment). Another theoretical position postulates that there is perceptual conflict arising between melodic demands calling for just interval ratios.<sup>3</sup>

Mr. Nickerson's findings indicate that Pythagorean tuning is most typical of the performance of unaccompanied melodies and of string quartet performance.

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<sup>2</sup>Mark H. Hindsley, "Valve Brass Intonation," unpublished paper, University of Illinois, p. 1.

<sup>3</sup>James F. Nickerson, "Intonation of Solo and Ensemble Performance of the Same Melody," Journal of the Acoustical Society of America, XXI (November, 1949), 593.

Earle Kent states that cup-mouthpiece instruments do not follow any fixed temperament:

It has been generally accepted among musicians and the makers of wind instruments that cup-mouthpiece instruments must follow the Just Scale or the Chord of Nature, and that they cannot be in tune with the Equally-Tempered Scale. However, accurate measurements, scientifically made, reveal that cup-mouthpiece instruments do not follow the Just Scale as a general rule. So it is false to believe that they are compelled to follow either the Just Scale or the Equally-Tempered Scale very closely if the bore is properly calibrated throughout the instrument.<sup>4</sup>

This discussion of temperament shows that an "out-of-tune" note is more accurately described as the pitch of a tone which is sharp or flat in relation to a given temperament. In this study, equal temperament was used as the standard for measurement rather than designated as the "correct" temperament.

The chromatic stroboscope was found to be the most practical device for measuring the deviation from this standard.

This instrument is especially adapted to musical use by having twelve disks rotating at speed corresponding to the frequencies of notes in a chromatic octave of the equally-tempered scale . . . deviation from standard tuning may be read with precision, following the simple manipulation of a single knob.<sup>5</sup>

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<sup>4</sup>Earle L. Kent, The Inside Story of Brass Instruments (Elkhart, 1956), pp. 2-3.

<sup>5</sup>Robert W. Young and Allen Loomis, "Theory of the Chromatic Stroboscope," Journal of the Acoustical Society of America, XXX (October, 1938), 112.

The object of having the player attempt to match the frequencies designated by the chromatic stroboscope was to determine if the instruments could be played in tune at the whim of the performer. The use of the stroboscope eliminated the variable of the accuracy of the player's ear.

### Physical Characteristics

All the instruments of the brass family act as acoustic transformers which are sounded by buzzing the lips as they are pressed against the mouthpiece.<sup>6</sup> The various components of these acoustic transformers contribute to intonation. Classified as lip-reed instruments,<sup>7</sup> the cornet and trumpet consist, first of all, of a cup-shaped mouthpiece. The mouthpiece itself has several sections which vary in their dimensions. Dale Olson lists these as the rim, bite, cup, throat shoulder, throat and backbore.<sup>8</sup> Both he and Vincent Bach<sup>9</sup> agree that the size of the throat of the mouthpiece is the largest single factor in mouthpiece construction which effects intonation.

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<sup>6</sup>T. H. Long, "The Performance of Cup-Mouthpiece Instruments," Journal of the Acoustical Society of America, XLIX (September, 1947), 893.

<sup>7</sup>Clyde E. Noble, The Psychology of Cornet and Trumpet Playing (Missoula, 1964), p. 45.

<sup>8</sup>Dale Olson, "Brass Mouthpiece Function," The Brass World, III (Winter, 1967), 210.

<sup>9</sup>Vincent Bach, Embouchure and Mouthpiece Manual (Elkhart, 1956), p. 16.

In this study each player used a mouthpiece which differed in dimensions from the mouthpiece used by every other player. This was a necessary variable in the test as each player was using the trumpet and cornet mouthpiece which he had found to be the most suitable for his desired tone quality and playing style. Statements by Vincent Bach indicate that a section of players using identical mouthpieces would not necessarily be an ideal situation:

If a half dozen trumpet players were to try one instrument with the same mouthpiece, each one would produce a different timbre of tone - some a more brilliant tone, some a darker color. This depends upon the texture of the player's lips, the manner in which he holds his lips when in playing position, his schooling, the size of his mouth cavity, and his way of breathing.<sup>10</sup>

Another component of the trumpet and cornet is a folded cylindro-conical tube. Kent states that this element contributes to intonation tendencies in the following manner:

The frequencies at which the instrument resonates are dependent upon the physical length of the air column (the distance the sound has to travel in the instrument); the speed at which the sound travels through the instrument; and the shape, or calibration, of the bore of the instrument.<sup>11</sup>

Kent also states that the unpredictability of the resonance in cup-mouthpiece instruments is due to the fact that all sounds do not travel at the same speed in all parts

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<sup>10</sup>Vincent Bach, Embouchure and Mouthpiece Manual, p. 17.

<sup>11</sup>Kent, Inside Story of Brass Instruments, p. 2.

of the instrument at a given temperature:

. . . in the portions of the instrument that have a flaring bore, neither conical nor cylindrical, the low frequency tones travel at a higher speed than do the higher frequency tones and make the instrument act as though it were shorter at the low end of the scale than at the high end. This difference between high tones and low tones depends upon the calibration of the cross-section, or bore, of the inside of the instrument from one end to the other.<sup>12</sup>

Dale Olson states that there are a number of complex tapers, curves and cylindrical sections which constitute the make up of a brass instrument. The "bore size" refers to the size of the valve bore, the only perfectly cylindrical section of the instrument. The tapered sections exert more influence on the performance characteristics of the instrument than does the slight variation in the valve bore. The norm of bore size throughout the tubing of the instrument includes a variety of diameters.<sup>13</sup> It is difficult, therefore, to determine the actual diameters of the tubing as they differ among manufacturers as well as varying in different models of instruments by the same manufacturer.

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<sup>12</sup>Kent, Inside Story of Brass Instruments, p. 2.

<sup>13</sup>Dale Olson, "The Bore of Brass Instruments," The Instrumentalist (January, 1963), 60.

Vincent Bach maintains that it is not possible to produce any kind of musical instrument with perfect intonation.<sup>14</sup> Another instrument manufacturer states that improvements in the intonation of certain harmonics can be made by building constrictions or enlargements in the tubing. This, however, leads to the danger of tampering with the pitch of harmonics other than the one which the experimenter was trying to raise or lower.<sup>15</sup>

Renold Schilke maintains that a majority of the problems of intonation can be attributed directly to the leader pipe of the instrument and the manner in which the mouthpiece fits into the leader pipe.<sup>16</sup>

Tuning slides also effect intonation in the bore of the instrument:

Then the distance is lengthened by pulling the tuning slide or by placing longer tubing in the instrument by use of valves, the resonance points are moved lower in the frequency scale. We then say that it is flat compared to the previous tuning.<sup>17</sup>

<sup>14</sup>Vincent Bach, The Problem of Tuning Correctly (Elkhart), Form No. 6012.

<sup>15</sup>C. G. Conn, Practical Problems in Building Wind Instruments (Elkhart, 1942), p. 5.

<sup>16</sup>Renold O. Schilke, "Leader Pipe and its Function," The Instrumentalist (May, 1958), 26.

<sup>17</sup>Kent, Inside Story of Brass Instruments, p. 2.

It is obvious then, that instruments may vary not only in bore dimensions but also in the way the instruments are constructed: the placement of the various folds, curves and tapers.

The categories of instruments in this study are instruments of identical material and dimensions as compared to instruments of differing materials and dimensions. The separation by cornet and trumpet was coincidental as the players in the study group owned trumpets and would have used them to perform in the North Texas State University Concert Band had they not been supplied with the cornets.

Kent defines the difference between cornet and trumpet as one of calibration of the bore of the instrument which causes the strengthening of certain harmonics in tones. This effects tone quality rather than intonation.<sup>18</sup> This paper assumes that the same results would have occurred had the categories of like and unlike instruments consisted of all trumpets or of all cornets.

The third component of the trumpet and cornet is the system of valves. These are necessary in order to play all the notes of the chromatic scale. The depression of one or more of the valves lengthens the tubing and lowers the pitch. Intonation problems arise with the use of valves. "If the

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<sup>18</sup>Kent, Inside Story of Brass Instruments, p. 11.

valve slide lengths are correct to produce the proper resonant frequency when the valves are used individually, they consistently produce a total length which is too short when the valves are used in combination."<sup>19</sup>

Solutions to this problem of valve length discrepancy are many. Instrument manufacturers can compromise on the length of the valve slides to produce the best average intonation.<sup>20</sup> Also, intonation compensating devices in the form of moveable valve slides on the first and third valve slides operated by means of a trigger or ring are standard equipment on most first line instruments. Pottle recommends the use of a trigger mechanism attached to the main tuning slide of the instrument.<sup>21</sup>

Alternate fingerings on some notes may bring about the desired pitch. Also, the performing skill of the player greatly influences this problem. "The existing deficiencies make it necessary for each player to humor certain pitches with his embouchure."<sup>22</sup> Kent states that

it must be remembered that the musician has some control of the intonation; he can play the instrument sharp or flat even though the optimum

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<sup>19</sup>Ibid., p. 3.

<sup>20</sup>Ibid., pp. 3-4.

<sup>21</sup>Ralph R. Pottle, Tuning the School Band and Orchestra (Hammond, 1962), p. 13.

<sup>22</sup>Vincent Bach, "Problems in Intonation of Brass Instruments," Symphony (September, 1950), 9.

design indicates that it should be in tune. Tests have shown that some musicians tend to play some notes flat or sharp on any instrument, either through habits of training or personal preference.<sup>23</sup>

This manipulation of the pitch by the embouchure is commonly referred to as "lipping" and is generally used among all brass players.

These compensating devices may be used singly or in combination. Their effectiveness depends upon the skill and training of the individual player.

The final component of the cornet and trumpet to be considered is the bell. "The calibration of the bore of the bell reacts with the rest of the instrument to yield the magnitudes and locations of the resonance peaks and also determines the efficiency of the bell as a radiator, or projector, of sound and its directional characteristics."<sup>24</sup> Generally, when the diameter of the bell is increased it becomes a more efficient radiator of sounds, particularly at low frequencies.<sup>25</sup>

Instrument dealers produce instruments which differ even among their own models as to bell size. Also, the materials the instruments are constructed of differ,

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<sup>23</sup>Kent, Inside Story of Brass Instruments, p. 4.

<sup>24</sup>Ibid., p. 7.

<sup>25</sup>Ibid.

particularly the bell. Benge features an alloy which is defined as "Resno-tempered" for better tone quality and tuning.<sup>26</sup> The Olds Company features a metallic combination it has termed "Re-O-Loy."<sup>27</sup> The Conn Company has bells constructed of an "Electro-D" alloy and some of its models have brass or "Coprion" bells which the manufacturer claims will achieve a desired quality.<sup>28</sup> Jody Hall states that the material used in the instrument is of much less importance than the calibration of the bore.<sup>29</sup>

In the light of these physical differences in the construction of the cornet and trumpet, it is reasonable to propose that instruments of identical measurements and materials would minimize intonation problems. It is the concern of this paper to determine if the use of identical instruments does, in fact, reduce "out-of-tune" playing.

#### Other Physical Considerations

Internal and external temperature effect intonation. External temperature is that of the atmosphere outside the instrument. Internal temperature is that of the air inside

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<sup>26</sup>Benge Trumpet Catalog, 1967.

<sup>27</sup>F. E. Olds & Son Band Instruments Catalog, 1966.

<sup>28</sup>C. G. Conn Illustrated Price List, 1967. Elkhart, Indiana.

<sup>29</sup>Jody C. Hall, "Questions and Answers," Connchord (November, 1958), 18.

the instrument. Temperature changes the speed of sound.<sup>30</sup>

Any tuning standard that is adopted must be defined in terms of a definite temperature. This is true in wind instruments because the speed of sound in air changes with temperature. Wind instruments become sharper if the speed of sound is faster, and they become flatter if it is slower. Since the speed of sound increases with higher temperatures, the sound then goes through the instrument faster, and the instrument is sharper, because, effectively, it is shorter.<sup>31</sup>

Pottle states that instruments are designed and tuned to perform in a normal 72°F. external temperature, but that temperatures vary greatly in actual rehearsal and performance. He states that a 10° rise in temperature will cause a Bb cornet to become sharper to the previous tuning by 6.8 cents. Pottle also states that the internal air column warmed by the player's breath (normal 98.6°F.) will soon be raised to a level of 90°F. whatever the external temperature. Pottle's recommendations to overcome these handicaps include a thorough "warm-up" of the instrument, frequent re-tuning to the standard and the blowing of warm air through the instrument during rests.<sup>32</sup>

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<sup>30</sup>Robert W. Young, "Dependence of Tuning of Wind Instruments on Temperature," Journal of the Acoustical Society of America, XVII (January, 1946), 187.

<sup>31</sup>Jody C. Hall and Earle L. Kent, The Effect of Temperature on the Tuning Standards of Wind Instruments (Elkhart, 1959), p. 3.

<sup>32</sup>Pottle, Tuning the School Band and Orchestra, pp. 28-35.

The tests were taken over a period of three non-consecutive days. The total temperature variance in the room used for the experiment was 22 degrees. The players were instructed to be thoroughly warmed up before testing and were directed to blow air through the instrument during rests. Also, each player tuned and re-tuned his instrument at short intervals throughout each test. He tuned each instrument to concert Bb as dictated by the chromatic stroboscope. He adjusted his instrument if necessary. This was done so that temperature variation would not be a variable factor in this study.

Variation in loudness is another factor in the problem of intonation. Pottle states:

A condition which causes wind instruments to digress from their normal frequency is a variation in loudness with which they are played. When played gradually from pianissimo to fortissimo, as in executing a crescendo, tones go sharp on some wind instruments and flat on others. The opposite phenomenon occurs when observing a decrescendo.<sup>33</sup>

To guard against the degree of loudness being a variable factor in this study, a Conn Dynalevel was used. This device is described as follows:

The dynamic level indicator demonstrates visually the intensity of a tone by means of colored lights. As the intensity of the tone increases, the lights go on higher and higher in a column showing the musician the changes of dynamics as he plays, and enabling him to achieve a uniform volume.<sup>34</sup>

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<sup>33</sup>Ibid., p. 26.

<sup>34</sup>Emily K. Yoder, "Science Opens the Door for Art," Connchord (May, 1956), 14.

One disadvantage to using this dynamic level indicator is that a specific dynamic level is a relative term. Also, the dynamic level indicator reading varies when the distance of the microphone from the bell of the instrument is varied. In order to stabilize the reading of this device the bell of each instrument was kept the same distance from the microphone in all tests. An approximate dynamic level of mezzo forte was judged by the experimenter to be correct at that distance.

## CHAPTER II

### PROCEDURE

The following are the specific conditions and procedures which were used in this study.

The performers of the study group comprise the cornet section of the North Texas State University Concert Band, Spring, 1969. Membership in this organization depends principally upon audition and assumes outstanding playing ability. All performers in this section are music majors with trumpet concentration at North Texas State University. Breakdown by classification includes 1 graduate student, 2 seniors, 1 junior, and 2 freshmen.

Five of the six have had trumpet teaching experience, two of these at the college level. Five of the six have been awarded scholarships to various institutions on the basis of their playing ability. All of the group have held membership in valid musical organizations other than the North Texas State University Concert Band.

This study was undertaken the Spring semester, 1969. Five of the members played together as a section for two semesters. The sixth member played with the section for one semester.

Two of the players professed a preference for the trumpet, two preferred the cornet, and the remaining two stated that they performed an equal amount of time on both the trumpet and the cornet.

All six players testified that listening carefully was one of the most important elements in playing well in tune. Other items listed as important considerations included awareness of notes which are consistently out of tune on one's instrument and compensating for this beforehand; knowledge of the playing characteristics of each trumpet or cornet player in the section. Also, knowledge of and skill in using intonation compensating devices are other factors which these players considered important for playing in tune as a section. None of the players felt that there was any difference in the Conn 38A Constellation cornet which he was using and those of the other players in the section.<sup>1</sup>

The instruments used in this study:

Cornets: Conn 38A Constellation cornets (6) equipped with "Tune as You Play" mechanism attached to the tuning slide, nickel silver finish all over.<sup>2</sup> In Conn's Illustrated Price List<sup>3</sup> this instrument is described as "The world's highest degree of brasswind refinement

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<sup>1</sup>See Appendix for communications to band members.

<sup>2</sup>Description from order for these cornets from the North Texas State University School of Music.

<sup>3</sup>Conn Illustrated Price List; Conn Corporation, Elkhart, June 15, 1968.

TABLE I  
TRUMPETS USED BY THE STUDY GROUP

Trumpets			
Manufacturer	Model	Bore Size	Compensating Devices
Benge	3x	.460	1st and 3rd valve slide saddles
Bach	Stradivarius	.459	1st and 3rd valve slide saddles
Reynolds	Contempora	.462	3rd valve slide ring and tuning slide trigger
Benge	5x	.460	3rd valve slide ring and tuning slide trigger
Bach	Stradivarius	.462	1st and 3rd valve slide rings
Getzen	Severinsen	.460	1st valve slide trigger and 3rd valve slide ring

in a short model cornet. Favorite of professionals and serious students for its free blowing and large bore feel. Electro-D mouthpiece and bell. Third valve slide throw ring. Micro-finish mouthpiece. Length 17 1/8". Bell 4 13/16".

The trumpets used in the study are shown in Table I.

The mouthpieces used by the study group are as follows:

TABLE II  
MOUTHPIECES USED BY THE STUDY GROUP

Mouthpieces	
Trumpet	Cornet
Bach 7B	Bach 7B
Bach 9B	Bach 9C
Bach 1	Bach 1 1/4 C
Bach 1 1/2 C	Bach 1 1/2 C
Bach 7C	Bach 7C
Bach 5B	Bach 7B

The players were individually tested three different times. Each of these tests consisted of playing the harmonic series (ascending) on each valve combination plus some commonly used alternate fingerings of certain notes. The specific music is illustrated in the Appendix. The performer played each of his instruments first with no intonation guide and was instructed to play the "centered" pitch of the

instrument on each note, not using any intonation compensating devices. The second time the player was allowed to watch the chromatic stroboscope and was instructed to attempt to tune to it. Therefore, the player tested both cornet and trumpet, tuned and untuned. Each series of tests was administered three times.

Each instrument was initially tuned to concert Bb. Each was retuned to this pitch after every valve series in order that room temperature and internal temperature of the air column would not change the pitch of the instrument and count as a variable in this test.

Other equipment and its function used in this study are as follows:

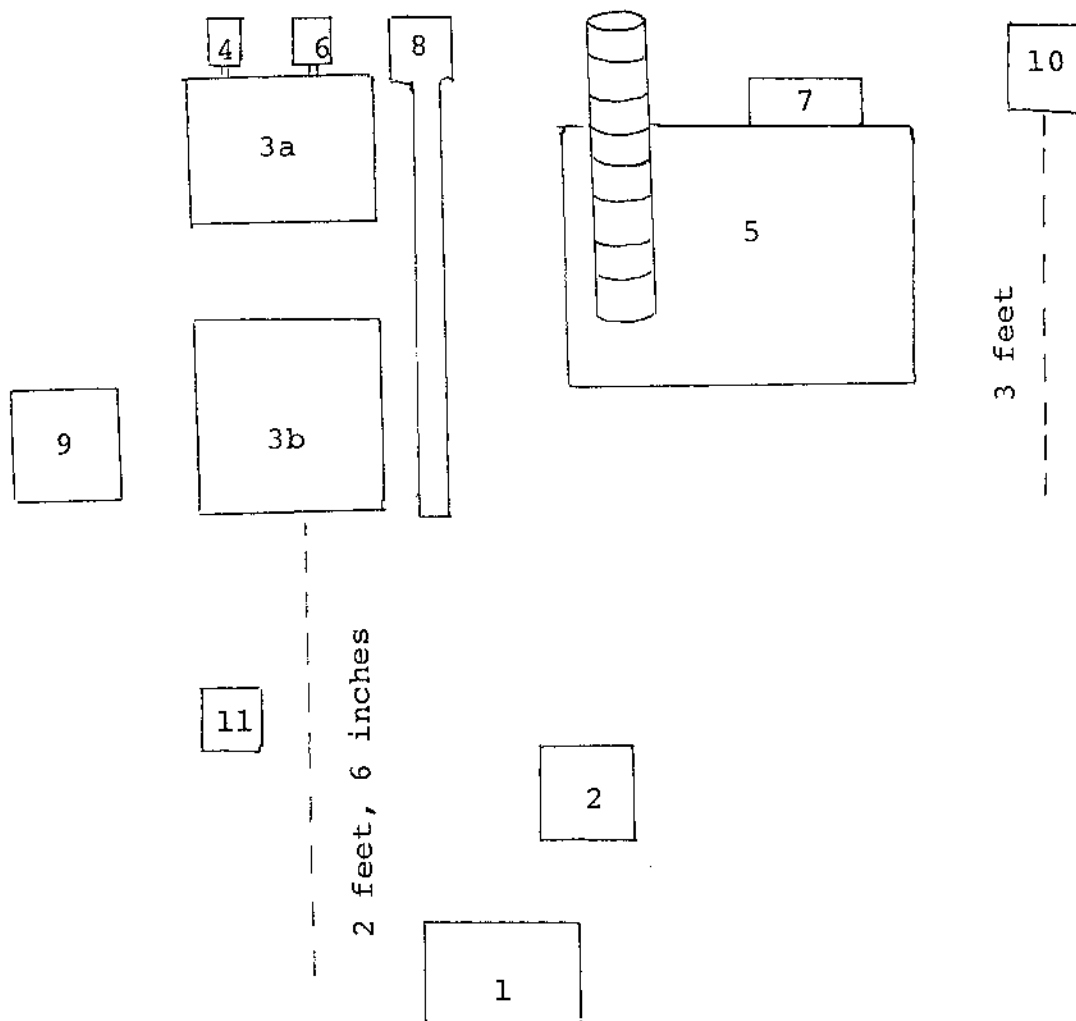
Chromatic Stroboscope: used in this study to tune instruments to a consistent pitch (third space "C" on the trumpet and cornet); to be used as a visual aid for the players to tune to in the "tuned" segment of this study; and to serve as a standard for computing the results.

Recording Equipment: Ampex AG-40 tape recorder. (1) Telefunken-Neumann Km-84 microphone. Scotch 203 Dynarange tape. Used to record the performance of the players and playback to compute the results.

Conn Dynamics Level Indicator (Dynalevel): used in this study to insure consistency of dynamics, so that the dynamic level at which the player performed would remain constant so that this would not be a variable factor in this study. The dynalevel was set at "3". The microphone of the dynalevel was level with the bell of the player and at a distance of five feet. The estimated dynamics level was a mezzo forte. This standard was kept for every player. He was instructed to maintain this level as closely as possible in all registers.

Metronome: An electric metronome was set at 60. The players were instructed to play at four second intervals, the duration of the tones to be four seconds also. This was used to insure that the length of time the tone was played was sufficient time to record the pitch of the tone when analyzing the results.

The tests took place in Room 171 of the School of Music at North Texas State University. This is the band rehearsal room and the players are accustomed to performing in this room. Figure 1 depicts the placement of the above articles at the time of testing. These were kept constant for each player and each test.



- |    |   |    |  |
|----|---|----|--|
| 1  | Player's chair                              | 6  | Dynalevel microphone                       |
| 2  | Music stand                                 | 7  | Metronome                                  |
| 3a | Chromatic Stroboscope<br>Visual Aid         | 8  | Tape recorder microphone                   |
| 3b | Chromatic Stroboscope<br>Frequency Adjustor | 9  | Examiner's chair                           |
| 4  | Stroboscope microphone                      | 10 | Height of bell of<br>instrument            |
| 5  | Dynalevel                                   | 11 | Length from player's chair<br>to equipment |

Fig. 1--Placement of testing devices

## CHAPTER III

### RESULTS AND CONCLUSIONS

The results of the three tests given to the performers were averaged so that one final test score is shown. The portion of the test where the performer was allowed to watch the chromatic stroboscope as a guide to intonation is referred to as the "tuned" test. The performance when the player had no clue to "correct" intonation is referred to as the "untuned" test. The results are stated in terms of cents sharp or flat to the standard of equal temperament as shown by the chromatic stroboscope. In all observations, positive numbers (un-signed) indicate cents relatively sharp to the standard. Negative numbers ( - ) indicate cents relatively flat to the standard.

Table III represents the mean deviation from equal temperament by each of the controlled and experimental groups as determined by the chromatic stroboscope. The order of the notes is derived from their occurrence in the ascending harmonic series. The numbers beside the notes identify the valve or valve combination used. Table III illustrates the "untuned" test results.

TABLE III  
MEAN--UNTUNED AVERAGE RESULTS

Player 1				Player 2				Player 3			
Note	Deviation			Note	Deviation			Note	Deviation		
	E*	C**			E	C			E	C	
C	0	0	7 cents	C	0	4	5 cents	C	0	-2	3
G	0	1	4	G	0	1	5	G	0	-4	0
C	0	-1	0	C	0	0	3	C	0	-2	-2
E	0	-22	-7	E	0	-6	5	E	0	-9	7
E	12	0	2	E	12	15	10	E	12	9	21
G	0	4	4	G	0	15	12	G	0	-1	18
C	0	2	9	C	0	7	15	C	0	10	23
B	2	8	18	B	2	1	2	B	2	-4	0
F#	2	6	16	F#	2	-1	4	F#	2	-10	11
B	2	3	9	B	2	-1	3	B	2	5	7
D#	2	-20	-1	D#	2	-13	-1	D#	2	-10	8
F#	2	-4	7	F#	2	5	11	F#	2	-1	31
B	2	0	6	B	2	5	13	B	2	15	25
Bb	1	2	11	Bb	1	-3	-3	Bb	1	-7	7
F	1	7	13	F	1	7	4	F	1	0	10
Bb	1	9	8	Bb	1	4	-2	Bb	1	5	-4
D	1	18	-7	D	1	-9	-2	D	1	-8	-4
D	13	20	16	D	13	11	10	D	13	22	25
F	1	5	11	F	1	9	13	F	1	7	22
Bb	1	-1	-4	Bb	3	10	13	Bb	1	24	20
A	12	-5	22	A	12	-7	-7	A	1	-3	-2
E	12	13	22	E	12	10	11	E	12	3	17
A	12	15	8	A	12	6	-2	A	12	9	-1
C#	12	-6	-9	C#	12	-8	-7	C#	12	-4	0
A	12	14	10	A	12	15	9	A	12	17	14
Ab	23	-10	-2	Ab	23	-31	-29	Ab	23	-23	0
Eb	23	13	12	Eb	23	-1	-1	Eb	23	4	14
Ab	23	7	0	Ab	23	-3	-9	Ab	23	-3	0
Ab	23	3	-1	Ab	23	11	3	Ab	23	10	6
G	13	6	-3	G	13	-14	-31	G	13	-7	-8
D	13	38	38	D	13	5	5	D	13	20	24
F#	123	25	8	F#	123	-10	-13	F#	123	0	2
C#	123	48	48	C#	123	29	25	C#	123	39	44
E	3	11	9	E	3	6	-7	E	3	-12	8
A	3	-3	-12	A	3	5	-4	A	3	3	-4

\* "E" equals the experimental group; i.e., trumpets

\*\* "C" equals the controlled group; i.e., cornets

TABLE III--Continued

Player 4				Player 5				Player 6			
Note	Deviation			Note	Deviation			Note	Deviation		
	E	C			E	C			E	C	
C	0	-3	1	C	0	-7	13	C	0	-1	0
G	0	0	-4	G	0	-1	6	G	0	1	6
C	0	0	0	C	0	0	2	C	0	2	6
E	0	-2	-4	E	0	-2	31	E	0	1	12
E	12	6	0	E	12	12	24	E	12	10	19
G	0	11	8	G	0	7	31	G	0	14	9
C	0	10	4	C	0	0	18	C	0	10	14
B	2	3	7	B	2	-8	-1	B	2	3	3
F#	2	0	2	F#	2	7	8	F#	2	3	8
B	2	6	3	B	2	2	6	B	2	12	3
D#	2	-3	2	D#	2	-1	13	D#	2	-2	1
F#	2	7	7	F#	2	17	19	F#	2	10	9
B	2	9	7	B	2	5	19	B	2	11	16
Bb	1	0	14	Bb	1	-3	-10	Bb	1	-2	2
F	1	5	3	F	1	6	7	F	1	8	8
Bb	1	0	1	Bb	1	13	9	Bb	1	18	2
D	1	-5	-1	D	1	8	7	D	1	4	1
D	13	3	2	D	13	15	20	D	13	16	8
F	1	10	5	F	1	19	24	F	1	22	14
Bb	1	14	2	Bb	1	31	20	Bb	1	21	3
A	12	2	3	A	12	3	-3	A	12	2	6
E	12	6	6	E	12	16	12	E	12	22	16
A	12	9	1	A	12	13	14	A	12	21	7
C#	12	0	-1	C#	12	8	-1	C#	12	10	-4
A	12	22	9	A	12	20	19	A	12	11	7
Ab	23	-9	3	Ab	23	-10	-12	Ab	23	0	-3
Eb	23	-6	2	Eb	23	13	13	Eb	23	14	16
Ab	23	-6	3	Ab	23	14	8	Ab	23	22	9
Ab	23	6	4	Ab	23	19	11	Ab	23	23	5
G	13	0	4	G	13	5	5	G	13	8	2
D	13	12	13	D	13	16	21	D	13	26	1
F#	123	12	14	F#	123	28	13	F#	123	8	5
C#	123	23	20	C#	123	36	37	C#	123	20	11
E	3	-11	-5	E	3	-3	-1	E	3	0	-4
A	3	-2	-4	A	3	9	2	A	3	-1	-16

Table IV represents the average results of the tests where the player attempted to tune to the stroboscope.

TABLE IV  
MEAN--TUNED AVERAGE RESULTS

Player 1			Player 2			Player 3		
Note	Deviation		Note	Deviation		Note	Deviation	
	E	C		E	C		E	C
C	0	2	C	3	0	C	5	7
G	3	1	G	4	0	G	-3	7
C	3	2	C	3	0	C	0	4
E	-6	9	E	-3	-2	E	0	14
E	12	4	E	12	6	E	12	12
G	5	4	G	12	8	G	0	7
C	5	8	C	13	12	C	0	13
B	0	6	B	-4	-3	B	2	3
F#	0	6	F#	2	-7	F#	2	6
B	0	1	B	1	-4	B	2	2
D	-7	0	D	-6	-1	D	2	3
F#	-1	2	F#	8	1	F#	2	10
B	-2	4	B	5	10	B	2	15
Bb	3	10	Bb	1	-3	Bb	1	4
F	0	10	F	1	0	F	1	11
Bb	0	1	Bb	1	7	Bb	1	1
D	-6	-2	D	1	-5	D	1	1
D	13	1	D	13	10	D	13	12
F	3	2	F	1	19	F	1	16
Bb	0	3	Bb	1	12	Bb	1	13
A	12	4	A	12	3	A	1	0
E	4	13	E	12	11	E	12	10
A	3	4	A	12	9	A	12	8
C#	-6	1	C#	12	-1	C#	12	-1
A	3	7	A	12	22	A	12	14
Ab	23	2	Ab	23	-20	Ab	23	0
Eb	1	9	Eb	23	1	Eb	23	3
Ab	23	0	Ab	23	1	Ab	23	2
Ab	23	-3	Ab	23	17	Ab	23	6
G	13	9	G	13	-33	G	13	0
D	13	8	D	13	11	D	13	1
F#	123	7	F#	123	-19	F#	123	6
C#	123	2	C#	123	13	C#	123	6
E	3	3	E	3	-2	E	3	7
A	3	0	A	3	5	A	3	6

TABLE IV--Continued

Player 4				Player 5				Player 6			
Note	Deviation			Note	Deviation			Note	Deviation		
	E	C			E	C			E	C	
C	0	-3	1	C	0	0	0	C	0	0	0
G	0	0	2	G	0	0	0	G	0	0	0
C	0	-1	0	C	0	0	0	C	0	0	0
E	0	2	2	E	0	0	1	E	0	0	2
E	12	0	2	E	12	7	1	E	12	3	5
G	0	4	2	G	0	5	2	G	0	2	1
C	0	-2	1	C	0	5	8	C	0	4	9
B	2	0	0	B	2	2	0	B	2	0	0
F#	2	-2	-1	F#	2	6	2	F#	2	0	0
B	2	3	0	B	2	0	0	B	2	0	0
D#	2	0	-4	D#	2	0	-2	D#	2	0	2
F#	2	6	8	F#	2	2	4	F#	2	0	5
B	2	3	4	B	3	2	0	B	2	-2	5
Bb	1	0	0	Bb	1	-1	0	Bb	1	0	0
F	1	7	-3	F	1	3	1	F	1	3	0
Bb	1	2	0	Bb	1	2	1	Bb	1	0	-1
D	1	2	-1	D	1	0	1	D	1	0	-4
D	13	0	2	D	13	0	3	D	13	11	0
F	1	1	5	F	1	8	7	F	1	6	0
Bb	1	10	2	Bb	1	6	3	Bb	1	3	-1
A	12	-1	0	A	12	0	2	A	12	0	0
E	12	0	3	E	12	1	5	E	12	3	0
A	12	0	-1	A	12	7	-1	A	12	6	-1
C#	12	-3	-1	C#	12	0	-2	C#	12	0	0
A	12	5	3	A	12	8	0	A	12	6	0
Ab	23	-6	0	Ab	23	2	-2	Ab	23	-4	-1
Eb	23	-4	0	Eb	23	3	2	Eb	23	6	2
Ab	23	-6	0	Ab	23	2	0	Ab	23	5	0
Ab	23	2	6	Ab	23	1	0	Ab	23	4	-3
G	13	0	4	G	13	0	0	G	13	3	-3
D	13	-1	3	D	13	0	0	D	13	7	-1
F#	123	3	12	F#	123	-1	0	F#	123	4	3
C#	123	0	5	C#	123	2	-1	C#	123	9	4
E	3	-3	0	E	3	-3	2	E	3	-1	0
A	3	1	0	A	3	-1	0	A	3	-5	-4

The test results were analyzed in two ways. In the first, the total performance by the player on the controlled and experimental groups of instruments was computed.

Table V illustrates the average deviation from the norm of all the notes played by the individual performer as he played on both the tuned and untuned tests.

TABLE V  
ANALYSIS BY PLAYER

Player	untuned		tuned	
	Mean		Mean	
	E	C	E	C
1	7.20	5.88	4.00	1.41
2	2.88	3.22	-3.14	3.57
3	9.08	2.93	6.74	2.25
4	3.74	3.68	1.60	.54
5	11.57	8.77	1.05	1.94
6	5.77	9.91	.54	2.08

Since 3 "cents" is the least pitch variation distinguishable by the average human ear<sup>1</sup> none of the players was shown to play radically out of tune. It may be pointed out that this analysis of the total performance by the player

<sup>1</sup>Robert W. Lundin, An Objective Psychology of Music (New York, 1953), p. 22.

is not a true indication of the intonation tendencies as there are several notes on the instrument which are "out-of-tune" due to the construction of the instrument and this analysis does not take into account these discrepancies. Therefore, the results of the tests were also computed comparing the intonation of individual notes as played by all of the performers.

In the analysis by note, the players theoretically performed together. Table VI illustrates the analysis by note when the players were given no guide to intonation. The results are shown in the average deviation from the standard of tempered tuning and also in the average amount of frequency variation which the players differed from each other.

Table IV shows that the players performed equally well in tune on both categories of instruments. The average deviation from tempered tuning was slightly closer to 0 with the "C" group. However, it is important to remember that there was no guide to "correct" intonation given to the players at the time of the test. The average difference of deviation was approximately the same for both groups of instruments. This means that both groups of instruments were played equally close to the same frequency, that is, both groups or categories of instruments were equally well in tune with each other.

TABLE VI  
ANALYSIS BY NOTE--UNTUNED

Note		Mean		Standard Deviation	
		E	C	E	C
C	0	4.83	-1.50	4.33	3.30
G	0	2.83	-0.33	3.67	1.79
C	0	1.50	-0.16	2.56	1.21
E	0	7.33	-6.66	12.39	7.56
E	12	12.66	8.66	9.30	4.74
G	0	13.66	8.33	8.84	5.64
C	0	13.83	6.50	6.09	4.07
E	2	6.33	.83	6.16	5.23
F#	2	8.16	.83	4.56	5.64
B	2	2.83	4.50	4.91	4.03
D#	2	3.66	-8.16	5.15	6.86
F#	2	12.33	5.66	5.61	6.92
B	2	14.33	7.50	6.62	4.82
Bb	1	3.50	-2.16	8.22	2.79
F	1	7.50	5.50	3.40	2.63
Bb	1	2.33	8.16	4.78	5.98
D	1	-1.00	1.33	4.35	9.69
D	13	13.50	14.50	7.69	6.23
F	1	15.00	12.00	6.70	6.27
Bb	1	9.00	16.50	9.23	10.34
A	12	-0.16	-1.33	4.29	3.85
B	12	14.00	11.66	5.06	6.28
A	12	4.50	12.16	5.67	4.91
C#	12	-3.66	0	3.35	6.83
A	12	11.33	16.50	4.02	3.68
Ab	23	-7.16	-13.83	10.79	10.18
Eb	23	9.33	6.16	6.42	7.73
Ab	23	1.83	5.16	5.98	10.18
Ab	23	4.66	12.00	3.59	6.97
G	13	-5.16	-0.33	12.37	7.84
D	13	17.00	19.50	12.39	10.51
F#	123	11.16	17.00	7.47	10.98
C#	123	30.83	32.50	13.23	9.60
E	3	0	.30	6.27	6.92
A	3	-6.33	1.83	5.93	4.25
Average difference of deviation from the expected norm		3.90	3.81	2.10	2.09
Average deviation		6.75	5.74	---	---

Some note may be taken of the standard deviation as there is a wide deviation on some pitches. Although different pitches were played with a broader deviation, both groups of instruments averaged the same deviation.

Table VII illustrates the analysis by note when the players were given a guide to intonation. Predictably, the results show that the players performed much closer to zero on the standard of tempered tuning when they were given a visual guide to intonation. Again, both groups performed equally close to tempered tuning. Also, there was no significant differences in their performance as a section. That is, they played equally close to the same frequency as shown by the average difference of deviation. In fact, the slight differences shown in all averaged results is indistinguishable by the human ear. The standard deviation illustrates a more consistent inability to play certain pitches in tune on both categories of instruments. It is, however, a problem of the pitches themselves rather than an idiosyncrasy of either category of instrument. Both categories of instruments averaged the same deviation.

#### Implications of Results

Performance results are so similar as to indicate that there are no intonation differences between players using a matched set of instruments and these same players using

TABLE VII  
ANALYSIS BY NOTE--TUNED

Note		Mean		Standard Deviation	
		E	C	E	C
C	0	1.66	.83	2.49	2.54
G	0	1.66	.66	2.49	2.28
C	0	1.00	.83	1.52	1.57
E	0	4.33	-1.16	5.43	2.60
E	12	5.00	5.00	3.55	5.35
G	0	4.00	4.33	2.64	4.19
C	0	8.50	4.66	3.86	4.42
B	2	1.00	-0.33	2.82	1.79
F#	2	1.00	.50	4.47	2.93
B	2	-0.16	.83	1.86	1.06
D#	2	-0.33	-2.16	2.35	3.07
F#	2	5.00	2.50	3.16	3.35
B	2	6.33	2.33	4.85	3.59
Bb	1	1.83	0	4.18	2.23
F	1	3.16	3.83	5.33	3.62
Bb	1	-0.16	1.50	1.46	2.81
D	1	-2.16	-1.50	3.13	2.93
D	13	2.33	5.00	4.85	6.53
F	1	6.00	7.00	5.06	5.80
Bb	1	3.50	7.00	4.46	4.39
A	12	.66	0	1.88	1.52
E	12	6.00	3.33	4.32	3.68
A	12	1.50	4.16	3.40	3.43
C#	12	-0.50	-0.83	3.86	3.33
A	12	4.16	10.00	5.01	6.75
Ab	23	-6.16	-6.00	13.39	7.11
Eb	23	1.16	1.00	5.33	3.10
Ab	23	-2.33	.33	6.15	3.30
Ab	23	.33	5.83	4.19	5.87
G	13	-5.66	-4.16	17.55	13.33
D	13	2.83	4.66	3.23	5.18
F#	123	-0.16	1.33	13.40	10.17
C#	123	5.50	6.83	5.62	4.67
E	3	1.83	-1.50	2.87	2.63
A	3	.33	.66	2.92	3.30
Average difference of deviation from the expected norm		1.82	1.48	.96	1.64
Average deviation		1.79	1.92	---	---

instruments of different manufacture. There are too many factors not within the control of the experimentalist to prove even this conclusively, however. Such factors as mouthpiece differences and the individual's playing habits cause many variables which are not within the control of the researcher. A mechanical device simulating the breath and embouchure of the brass player and affixed to a standard mouthpiece on each of the categories of instruments in this study would probably produce different and more consistent results.

The results of this test would be beneficial to the players of this particular section as it can be readily seen which notes these performers play consistently out of tune with each other and with the standard of tempered tuning. Awareness of these factors would undoubtedly improve intonation within this section.

The players performed predictably better in tune with equal temperament when a visual guide to intonation was given them. There was no indication that the instrumentalists played in a particular temperament when no guide was given to them. Also, in these untuned portions, the player had nothing to relate his pitch to except the preceding note. He had no way of knowing whether or not this was a "correct" pitch. Had the player been performing with another instrumentalist or with the section, the results might have been

different. This, however, would have created an insurmountable problem of measurement to the experimentalist. Therefore, this approach was judged to be the most practical, even with its aforementioned defect.

The raw results of the test were averaged to show one result for each player. (Tables III and IV). The players and the notes which they played with the greatest frequency variation from tempered tuning varied greatly in pitch. However, when the individual's total performance was averaged, (Table V) the players were found to play within a few cents of each other when total performance was measured. Since this is obviously not a satisfactory indication of true intonation tendencies, the results were analyzed by average deviation of individual notes. (Tables VI and VII). This is a better analysis as it can be seen which notes are generally played out of tune with tempered tuning by the performers, and to what degree of variation these notes are played. The averaged results of these figures show that neither category of instruments was played better in tune with tempered tuning nor was one group of instruments played better in tune with the other members of the section.

If the test is to be taken at face value, the results show that there is no advantage in using a matched cornet section for reasons of better intonation. The benefits of

an identical section might well be found in the area of matched tone quality.

#### Suggestions for Future Research

Advantages in using a matched set of instruments can most probably be found in the area of similar tone quality. The relative strength of various harmonics in a tone would influence intonation as well as quality of sound.

More conclusive results may be obtained by using a smaller range of notes rather than all notes and alternate fingerings. A selected musical excerpt representative of the practical range of the instrument would be a more efficient method and perhaps provide more decisive results, although these results would not be as thorough as testing the entire range and fingerings of the instrument.

Also, it is recommended that a larger group of players be tested. A larger sampling of players would naturally produce more conclusive results.

A more truthful indication of the player's intonation and tonal quality would be given if the experimentalist was able to measure the performance of the individual player as he played with the section using his ear to compensate for intonation faults and to match his sound with those other players, rather than tuning to a visual guide such as the Conn stroboscope used in this study. This would produce more realistic results.

APPENDIX

The following is a copy of the letter which was sent to the members of the North Texas State University Concert Band cornet section as an introduction to this study:

March 10, 1969

Dear Band Members:

One of our graduate trumpet students, Ann McMahon, is conducting a study for her thesis comparing an unmatched trumpet section to a matched cornet section and would like to use the NTSU Concert Band cornet section as her study group. I would like to ask that you cooperate with her on this project.

You will be asked to make a tape recording using both the Conn 38A Constellation cornets and your own trumpets. You will be individually tested three times and each test should take about twenty minutes of your time. The tests will be arranged at times of mutual convenience. This testing should be helpful to you as a section as well as an individual player in solving problems of intonation.

If you can not or do not wish to participate in this study, please notify me immediately.

Sincerely,

John J. Haynie  
(Professor of Trumpet)

The following is a copy of the letter sent to the members of the North Texas State University Concert Band cornet section which includes the players' instructions at the time of testing:

Dear Band Members:

You have been asked to take part in a study to determine if intonation is effected by your use of matched cornets in the NTSU Concert Band as opposed to a random selection of instruments which you would probably be using were you not assigned the Conn 38A Constellation cornets.

The purpose of this study is to test the instruments rather than the player. There will be no judgement passed on an individual's ability to play in tune. Also, please do not attempt to prejudice the test by favoring one of the instruments over the other.

At the time of each test it is preferable that your lip be in good playing condition, that is, not already worn out by a full day's playing. Please be warmed up at the time of the test. Your usual warm-up method and length of time is preferred. Also, you will be asked to continue blowing warm air through the instrument to keep the temperature of the instrument as constant as possible.

The test itself consists of tape recording each note of the harmonic series twice each on both instruments. The first time you will be asked to play the pitch without favoring it in any way. The second time you will play the note attempting to tune it using any compensating devices you wish and watching the chromatic stroboscope.

The exact pitches will be written out for you. They will each be played approximately four seconds each at four second intervals. You will be aided in this by a flashing metronome. Please try to adhere as closely as possible to this. There should be no talking and as little room noise as possible during the entire test.

You are also asked to maintain a constant mezzo forte. A Conn Dynalevel will help you to determine this dynamic level at the time of testing.

If you cannot arrange to meet at the time signed for, please tell me as much in advance as possible and I shall be happy to arrange a more convenient time.

I appreciate the help that you are giving to me in this project.

Sincerely,

Ann E. McMahon

The following is a copy of the questionnaire which was answered by each member of the study group.

Name: \_\_\_\_\_ Permanent address \_\_\_\_\_

Number of years you have played cornet and/or trumpet \_\_\_\_\_

Please list any musical organizations which you have belonged to, soloed with etc.: \_\_\_\_\_

Please list any awards or scholarships which you have received. Also include teaching experience. \_\_\_\_\_

What is your status at NTSU? \_\_\_\_\_ Other colleges attended: \_\_\_\_\_

What make trumpet will you use in this study? \_\_\_\_\_ Model? \_\_\_\_\_  
Bore size? \_\_\_\_\_ State any work you have had done to it. \_\_\_\_\_

Age of instrument: \_\_\_\_\_ Condition of instrument: \_\_\_\_\_

What intonation compensating devices are on your trumpet? \_\_\_\_\_

Is there any factor that you know of which makes the physical construction of your cornet different from the cornets the other members of your section play? \_\_\_\_\_

What trumpet mouthpiece do you use? \_\_\_\_\_ (Make and size)

What cornet mouthpiece do you use? \_\_\_\_\_

Have you had any work done to either of these? \_\_\_\_\_

What compensating devices for intonation do you consistently use?

1st valve slide trigger or ring \_\_\_\_\_

3rd valve slide trigger or ring \_\_\_\_\_

Lipping \_\_\_\_\_

Alternate fingerings \_\_\_\_\_ - On which notes?

Tuning slide saddle \_\_\_\_\_

Other \_\_\_\_\_

What do you personally feel are the most important elements for playing well "in tune" as a section? \_\_\_\_\_

With which instrument, cornet or trumpet, do you spend the greater amount of playing time? \_\_\_\_\_

The following is a checklist which was kept at the time of each individual test of the band players:

Name: \_\_\_\_\_ Date and Time: \_\_\_\_\_  
 Test Number: \_\_\_\_\_

Instrument: \_\_\_\_\_ Make and Model: \_\_\_\_\_  
 Bore size: \_\_\_\_\_

Mouthpiece: \_\_\_\_\_

Lip Condition: \_\_\_\_\_ Warm up time: \_\_\_\_\_  
 Adequate?: \_\_\_\_\_

Room temperature Start \_\_\_\_\_ Instrument temperature: \_\_\_\_\_  
 End \_\_\_\_\_

Dynalevel Setting: \_\_\_\_\_ Deviation: \_\_\_\_\_

Height of microphones: \_\_\_\_\_ Deviation in placement: \_\_\_\_\_

Deviation in physical setting: \_\_\_\_\_

Deviation in any other conditions that might influence  
 performance?: \_\_\_\_\_

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Metronome setting: \_\_\_\_\_

Tape setting: \_\_\_\_\_

The following is the music used for all tests.

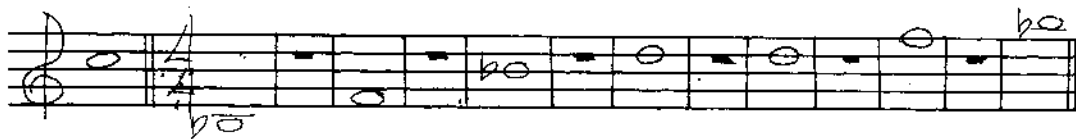
**Tune**



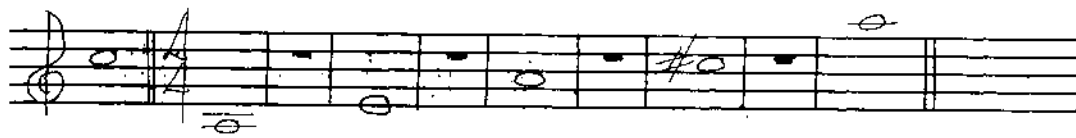
**Re-Tune**



**Re-Tune**



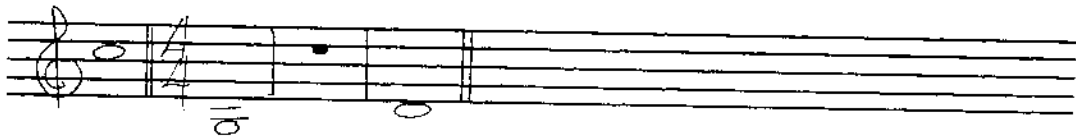
**Re-Tune**



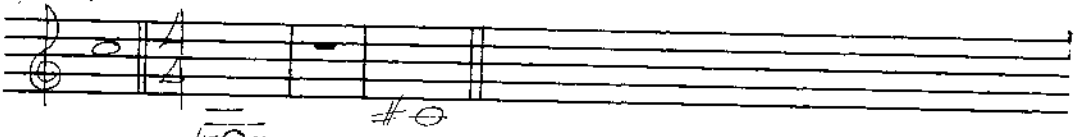
**Re-Tune**



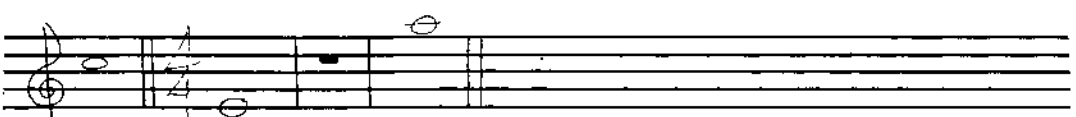
**Re-Tune**



**Re-Tune**



**Re-Tune**



**Fig. 2: Music Used for Tests**

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