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A Conductor’s Guide to Wind Instrument Deficiencies: A Practical Addendum to the Undergraduate Conducting Text

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The University of Southern Mississippi

A CONDUCTOR'S GUIDE TO WIND INSTRUMENT DEFICIENCIES:

A PRACTICAL ADDENDUM TO THE UNDERGRADUATE CONDUCTING TEXT

by

Donald Bradley Snow

Abstract of a Dissertation
Submitted to the Graduate Studies Office
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
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ABSTRACT

A CONDUCTOR'S GUIDE TO WIND INSTRUMENT DEFICIENCIES: A PRACTICAL ADDENDUM TO THE UNDERGRADUATE CONDUCTING TEXT

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The purpose of this dissertation is the construction of a supplement to the most commonly used undergraduate conducting texts that teach the correction of wind intonation deficiencies. Research has indicated that conductors must be aware of and be trained to recognize and correct intonation deficiencies of wind instruments. Music teachers must understand acoustical differences among just, Pythagorean, and tempered tuning systems. Nonetheless, existing pedagogical materials for undergraduate conductors in training are of little or no help. The supplemental text addresses intonation deficiencies and provides musical examples and exercises to help the young conductor gain an understanding of the factors that adversely effect the intonation of wind instruments.

The body of literature on the subject of intonation contributed by music educators has been utilized in the various chapters of this dissertation. The inherent problems of musical instruments and harmonic intervals as they relate to acoustics have also been examined. These resources have been essential in the development of individual tuning charts to reinforce musicians' awareness of the general pitch tendencies of their instruments and the systemization of intonation deficiencies found in the above mentioned research has been valuable in creating a system to aid performers in the awareness of the tendencies of their own instruments.

This study is a valuable resource for conductors struggling with wind intonation and serves as a time-saving reference source for instructors with limited rehearsal time. Without extremely clear and comprehensible answers to the questions “tune how?” and “listen to what?” student musicians face an impossibly vague challenge. This study will provide band directors with the resources to answer these questions.

ACKNOWLEDGEMENTS

The writer would like to thank the dissertation committee director Dr. Thomas Fraschillo and other committee members, Dr. Joe Brumbeloe, Dr. Jay Dean, Dr. Gregory Fuller, and Dr. Chris Goertzen, for their advice and support throughout the duration of this project. I would especially like to thank Dr. Thomas Fraschillo for his amazing support, patience, and constant prodding. Appreciation must also be expressed to Dr. Gary Adam. Without his passion for this topic and our many discussions, I would surely have been lost.

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CHAPTER I

COMMON INTONATION CHALLENGES ENCOUNTERED BY THE WIND BAND CONDUCTOR

Although excellent texts exist for the preparation of the young conductor in music education curricula of universities in the United States, no single text contains sufficient discussion of the topic of wind instrument deficiencies. Specifically designed for the conducting student, Elizabeth Green's *The Modern Conductor* (1997) contains conducting illustrations, musical examples, and exercises to reinforce those topics covered in the text, but places minimal emphasis on establishing knowledge of wind instrument deficiencies.[1] Like Green's text, Joseph Labuta's *Basic Conducting Techniques* (2000) stresses score study; however, no mention is made of intonation deficiencies of wind instruments.[2] The same can be said for Donald Hunsberger and Roy Ernst's *The Art of Conducting* (1992) and other popular conducting texts.[3]

Nonetheless, poor intonation is the most universal problem affecting school ensembles and is one of the dimensions of performance to which listeners most respond.[4] Nelson Hovey stated that "nothing detracts more from a satisfying performance than out-of-tune playing, and yet no problem in instrumental music education is more complex than that of achieving the highest standard in intonation."[5]

Research indicates that the way in which school bands approach tuning and

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[1] Elizabeth Green, The Modern Conductor, 6th ed. (Upper Saddle River, NJ: Prentice-Hall, 1997).

[2] Joseph Labuta, Basic Conducting Techniques, 4th ed. (Upper Saddle River, NJ: Prentice-Hall, 2000).

[3] Donald Hunsberger and Roy Ernst, The Art of Conducting, 2nd ed. (new York: McGraw-Hill, 1992).

[4] John Graschel, "Intonation Awareness," The School Musician 53 (1982): 12.

[5] Nelson Hovey, Efficient Rehearsal Procedures for School Bands (Elkhart, IN: The Selmer Company, 1976).

intonation varies. Some directors choose to aurally reinforce tuning and intonation by vocalizing and listening, while others use an electronic tuner. There are also those directors that leave this aspect of instruction to the student's ear, giving only a few simple directions by indicating movement of the tuning slide.

The purpose of this dissertation is the construction of a supplement to the most commonly used undergraduate conducting texts that teach the correction of wind intonation deficiencies. Research has indicated that conductors must be aware of and be trained to recognize and correct intonation deficiencies of wind instruments.[6] Music teachers must understand acoustical differences among just, Pythagorean, and tempered tuning systems.[7] Nonetheless, existing pedagogical materials for undergraduate conductors in training are of little or no help. The supplemental text addresses intonation deficiencies and provides musical examples and exercises to help the young conductor gain an understanding of the three factors that adversely effect the intonation of wind instruments:

1) The chord of nature - the overtone series and its relation to tuning systems.
2) Instrument deficiencies[8] - manufacturer compensations and the "six-percent rule."[9]
3) Physical and environmental factors - embouchure problems, effects of temperature and humidity, and instrument quality.

The body of literature on the subject of intonation contributed by music educators

6 O.H. Jorgensen, Tuning (East Lancing, MI: Michigan State University Press, 1991).

7 Charles Colnot, "Intonation Fundamentals," Symposium conducted at the Midwest Band and Orchestra Clinic, Chicago, IL, 29 December, 2001.

8 Notes produced by an instrument that are not in tune with the equal-tempered scale.

9 The "six-percent rule" refers to the scientific principle stating that a brass instrument's tubing must be increased in length by approximately six-percent in order to lower the pitch one half-step.

has been utilized in the various chapters of this dissertation. The inherent problems of musical instruments and harmonic intervals as they relate to acoustics have been examined by Al Fabrizio, Ralph Pottle, Milt Stevens, and Per-Gunnar Alldahl. Others, including James Geringer, Donald Sogin, and Matthew Ely have studied psychoacoustics and the perception of and preference for various tuning systems. Ralph Pottle provided findings on the effect of temperature on the intonation of wind instruments.[10] This research, accompanied by tuning recommendations of Mark Hindsley, has been widely adopted by band directors.[11] These resources have been essential to this dissertation in the development of individual tuning charts that reinforce musicians' awareness of the general pitch tendencies of their instruments as well as individual intonation problems.

Larry Cephus's research suggests that improving intonation requires the following: a) knowledge of the acoustical differences between the tempered and just scale, b) application of these acoustical differences within the musical score, c) knowledge of the deficient pitches on wind instruments as they relate to the tempered and just scale, and d) visual and aural methods for reinforcing standards of intonation.[12] Per-Gunnar Alldahl's research categorizes the problems of intonation for the school band into groups: a) those that are connected to the instrument, i.e., acoustics of wind instruments, tone, volume, and temperature, and b) those that are connected to the tuning systems - equal temperament, just, and Pythagorean.[13] The systemization of intonation deficiencies found in the above mentioned research has been valuable in creating a system to aid

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[10] Ralph Pottle, Tuning the School Band, 3rd ed. (Hammond, LA: Ralph Pottle, 1970).
[11] Mark Hindsley, "Intonation for the Band Conductor," The Instrumentalist 26 (1971): 59-62.
[12] Larry Cephus, "Intonation can be Improved," The School Musician 51 (1980): 17.
[13] Per-Gunnar Alldahl, Choral Intonation (Helsinki, Finland: Gehrmans, 1990), 8.

performers in the awareness of the tendencies of their own instruments.[14]

Paula Crider believes music educators are generally competent at teaching technique, but lack an organized approach to teaching how to play in tune.[15] This study is a valuable resource for conductors struggling with wind intonation and serves as a time-saving reference source for instructors with limited rehearsal time. Without extremely clear and comprehensible answers to the questions "tune how?" and "listen to what?" student musicians face an impossibly vague challenge. This study will provide band directors with the resources to answer these questions. Included in the Appendix is a sample syllabus for a course in undergraduate conducting for which this dissertation is designed. The contents of this dissertation may be easily incorporated into weeks five through seven.

[14] William Bailey, Aural Skills for Conductors (Mountain View, CA: Mayfield, 1992).
[15] Paula Crider, "Teaching Intonation to Beginners," The Instrumentalist 45 (1990): 64-65.

CHAPTER II

MUSICAL ACOUSTICS

The problems of intonation in wind instruments are both musical and scientific; therefore, understanding both arrays of these problems is the first step toward a solution. One must not underestimate the necessity for the study of acoustics of musical instruments. Sadly, most band directors complete their academic work with minimal to no study of the science of sound. Clifford Madsen suggests that approaching the study of acoustics from a purely mathematical perspective, as opposed to a more musical perspective, often quells student curiosity on the subject.[16] The first step in this process of understanding is to define intonation, requiring an awareness of some of the rudimentary principles of the physics of sound.

Basic Acoustical Principles

A sound is perceived when a vibration in a medium causes an auditory sensation in the ear. The vibration causes waves, which may be described as quickly alternating amounts of compression and rarefaction of the air.[17] (see Figure 1).

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[16] Clifford Madsen, "Sharpness and Flatness in Scalar Solo Vocal Performance," Sciences de l'Art-Scientific Aesthetics 9 (1974): 91.

[17] John Pierce, The Science of Musical Sound (New York: W.H. Freeman, 1992), 11.

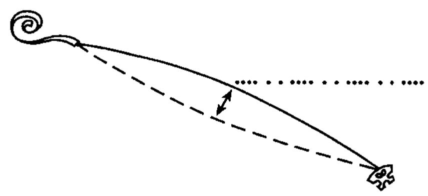

Figure 1. When plucked, a string at rest vibrates, producing a reaction in the air medium. It pushes against the air and packs the molecules tighter than normal atmospheric pressure. It then recoils, creating a condition called rarefaction. The wave which results is transmitted to our ears as sound.

A musical instrument being played produces sound waves, and most musical instruments produce a coherent sound called a pitch. The pitch of a tone is determined by the number of cycles (complete vibrations) per second at which a sound source is vibrating. The exact number of cycles per second, is referred to as frequency and is measured in Hertz. The aural sensation that a frequency causes is called pitch. The greater the frequency, the higher the perceived pitch.[18] Given that frequency is measurable, the present day standard of concert pitch in the United States is A = 440, meaning that the frequency of the pitch of A in the first octave above Middle C is 440 Hertz. For this reason, the fundamental pitch of A has been chosen as a reference pitch for all examples.

The other acoustical principle to be discussed is amplitude, which is related to the loudness of a sound. When a string of a fixed length vibrates, it remains at essentially the same pitch, no matter how loud or soft it is played. If the string is making a soft sound, it was played with little force and is moving over a fairly small area rather slowly. If it is making a louder sound, it was played harder and is moving over a larger area at a faster rate. Therefore, the wave of the soft sound would look small when compared to the wave of the loud sound, and so the soft sound has a smaller amplitude than the loud sound. In a string of fixed length, the frequency will remain the same even if its amplitude is altered.[19]

Figure 2. Illustration of two waves of the same frequency, but of different amplitudes. (frequency = pitch; amplitude = loudness)

Harmonic Series

Musical instruments produce composite sounds that consist of a main sound (the fundamental) and additional pure sounds called overtones.[20] Overtones are frequencies above the fundamental frequency which are the result of the complex vibration of the sound source. In other words, the overall audible vibration is a composite of multiple vibrations - the fundamental pitch, or main sound, and those of its harmonics.[21]

The terms partials and harmonics are used in the description of this composite sound - the fundamental along with the additional pure overtones. This harmonic series is a set pattern of notes created by nearly all musical instruments and is the basic principle of all brass instruments. All woodwind, brass and string instruments can produce these harmonics, due to the physical properties of the instruments.[22] Because it is the basis for true intonation of intervals and many chords, the memorization of this series is essential.

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[18] W.T. Bartholomew, Acoustics of Music (New York: Prentice-Hall, 1942), 7-8.
[19] Ibid., 12.
[20] Alldahl, 13.
[21] John R. Pierce, The Science of Musical Sound (New York: W.H. Freeman, 1992), 27.
[22] William Swor, "Absolute Intonation and the Fusion of Wind Instrument Sounds," Journal of Band Research 17 (1982), 21-23.

The overtones of the composite sound are a near match to the possible notes that an instrument may sound. Because of this, the term harmonic series designates the notes that can be performed by any given length of tubing. Each of these tones can be represented by a whole number multiple of the fundamental frequency. With an understanding of these basic acoustical principles, intonation, which is the relationship of the vibrations of two or more pitches together, can be better discussed .

Why do some notes sound good together while other notes seem to clash with each other? The answer to this question has to do with the harmonic series. The harmonic series occurs naturally in a variety of physical situations, but the most accessible example is that of a stretched string.[23] When a string vibrates, the main pitch heard is from the vibration of the whole string back and forth. That is the fundamental, or first harmonic; but the string also vibrates in halves, in thirds, fourths, and so on. Each of these fractions also produces a harmonic. The string vibrating in halves produces the second harmonic; vibrating in thirds produces the third harmonic, and so on. The technique of sounding a harmonic is to touch the string lightly at a harmonic node and pluck or bow the string near the far end. To hear the second harmonic, the node is at half the length of the string; the third harmonic has a node at one-third the string length; the fourth at one-fourth, etc. A column of air vibrating inside an open tube is different from a vibrating string, but the column of air can also vibrate in halves, thirds, fourths, and so on, of the fundamental, so the harmonic series will be the same.[24]

Because a harmonic series can have any note as its fundamental, there are many different harmonic series, however, the relationship between the frequencies of a harmonic series is always the same. The second harmonic always has exactly half the wavelength (and twice the frequency) of the fundamental; the third harmonic always has exactly a third of the wavelength (and so three times the frequency) of the fundamental, and so on.[25] The harmonic series gives a frame of reference in the understanding of intonation, and is the key to understanding harmonics and the basic functioning of many musical instruments.[26] There are many combinations of notes that share some harmonics and make a pleasant sound together. They are considered consonant. Other combinations share fewer or no harmonics and are considered dissonant. The scales and chords of most of music are based on these physical facts.[27]

The prime harmonics are the most important ones to know, because the subsequent overtones are simply the integer multiples of each prime harmonic. This method of naming and numbering harmonics is the most straightforward and least confusing. Other ways of naming and numbering harmonics can cause confusion. When the fundamental is included in calculations, it is called the first partial, and the rest of the harmonics are the second, third, fourth partials and so on. Also, some musicians use the term overtones as a synonym for harmonics.[28]

The first harmonic is the fundamental, which is the sound of the open string. This is the reference tone, the root of the harmonic series. When referring to any harmonic as

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[23] Robert Garofalo, Improving Intonation in Band and Orchestra Performance (Ft. Lauderdale, FL: Meredith Music, 1996), 32.

[24] Pierce, 30.

[25] Bartholomew, 12.

[26] James M. Burns, "Some Acoustical Principles Affecting the Intonation of Band Instruments," (EDD diss., Farleigh Dickinson University, 1984), 54.

[27] Brant Karrick, "An Examination of the Intonation Tendencies of Wind Instrumentalists Based on their Performance of Selected Harmonic Musical Intervals," Journal of Research in Music Education 46 (1998), 113.

[28] Mark Hindsley, "Intonation for the Band Conductor, Part III," The Instrumentalist 26 (January, 1972): 59.

an interval, the fundamental is implied as the other tone of the interval.

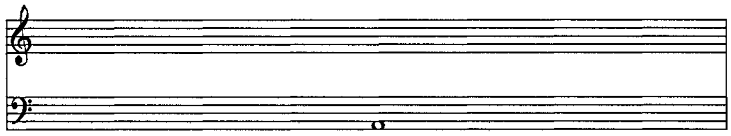

Figure 3. Diagram of fundamental.

A mathematical representation that two notes are an octave apart is expressed by the ratio of their frequencies as two to one (2:1). Although the notes themselves can be any frequency, the 2:1 ratio is the same for all octaves. All other intervals can also be described as being particular ratios of frequencies.[29]

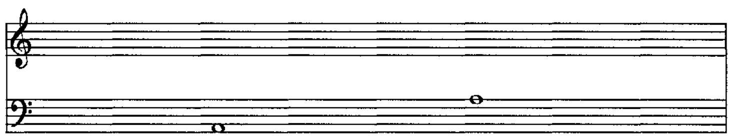

Figure 4. Diagram of fundamental through second partial.

The third harmonic, 3:1 relative to the fundamental, represents a new harmonic entity. This new interval, the perfect fifth, is represented by the ratio of 3:2.

Figure 5. Diagram of fundamental through third partial. The symbol above the final note indicates the deviation from the equal tempered scale.

[29] Bartholomew, 17.

The fourth harmonic is just the double of the second harmonic, and is effectively a repetition of the fundamental.

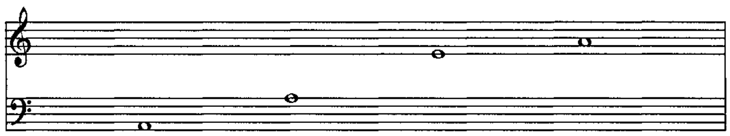

Figure 6. Diagram of fundamental through fourth partial.

The fifth harmonic is a prime harmonic, a major third above the second double of the fundamental and represented by the ratio of 5:4.

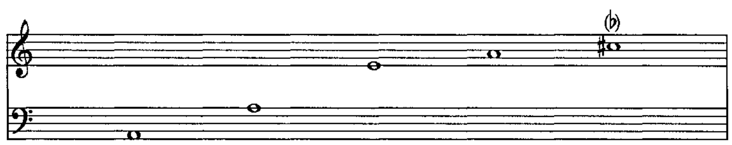

Figure 7. Diagram of fundamental through fifth partial. The symbol above the final note indicates the deviation from the equal tempered scale.

The sixth harmonic is simply the double of the third harmonic, and creates a minor third above the fifth harmonic. It is represented by the ratio of 6:5.

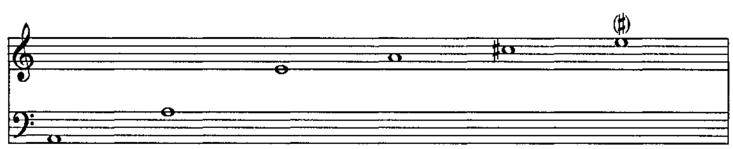

Figure 8. Diagram of fundamental through sixth partial. The symbol above the final note indicates the deviation from the equal tempered scale.

The seventh harmonic is another prime harmonic. It is flat seventh above the second double of the fundamental and is represented by the ratio of 7:6.

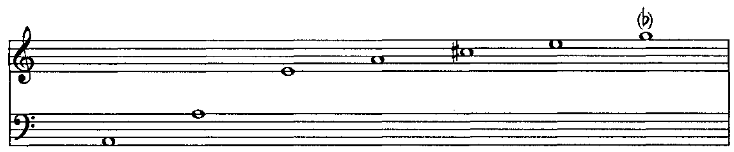

Figure 9. Diagram of fundamental through seventh partial. The symbol above the final note indicates the deviation from the equal tempered scale.

Notice that harmonics 4, 5, 6, and 7 form a just dominant seventh chord, but the dominant seventh chord of equal temperament does not convey the same sound. The tempered approximation of the seventh is 31 cents sharper.[30]

Figure 10. Diagram of dominant seventh chord.

The eighth harmonic is the third double of the fundamental.

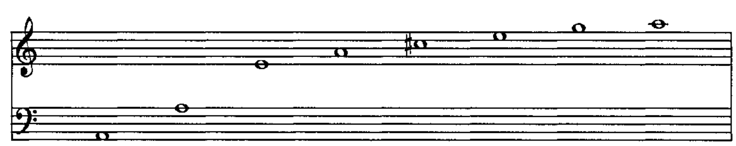

Figure 11. Diagram of fundamental through eighth partial.

The ninth harmonic is a major second above the third double of the fundamental and is represented by the ratio of 9:8.

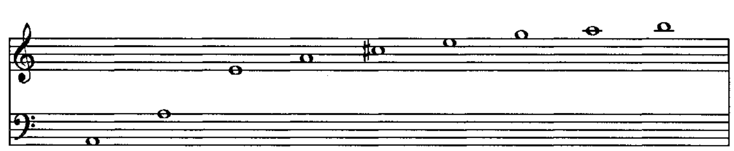

Figure 12. Diagram of fundamental through ninth partial. The symbol above the final note indicates the deviation from the equal tempered scale.

30 A cent is 1/100 of an equal-temperament semitone. Given that there are 1200 cents in an octave, 100 cents equals one semitone or half-step.

The tenth harmonic is simply the double of the fifth harmonic.

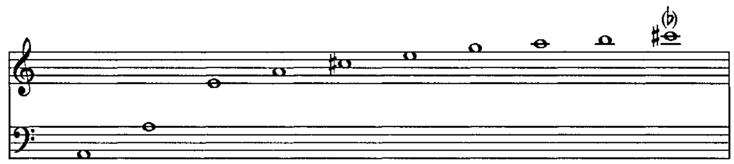

Figure 13. Diagram of fundamental through tenth partial. The symbol above the final note indicates the deviation from the equal tempered scale.

Another prime harmonic, the eleventh harmonic is a fourth above the third double of the fundamental and appears a quarter-tone sharp in relation to equal temperament.

Figure 14. Diagram of fundamental through eleventh partial. The symbol above the final note indicates the deviation from the equal tempered scale.

The twelfth harmonic is simply the second double of the third harmonic.

Figure 15. Diagram of fundamental through twelfth partial. The symbol above the final note indicates the deviation from the equal tempered scale.

The thirteenth harmonic is another prime harmonic occurring a sixth above the third double of the fundamental.

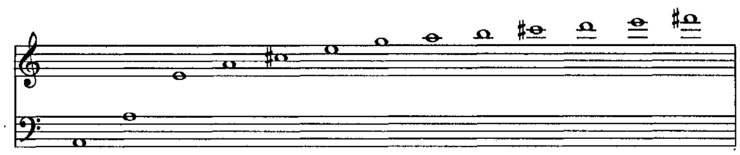

Figure 16. Diagram of fundamental through thirteenth partial.

The fourteenth harmonic is the double of the seventh harmonic.

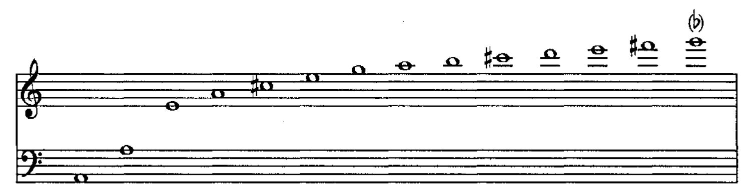

Figure 17. Diagram of fundamental through fourteenth partial. The symbol above the final note indicates the deviation from the equal tempered scale.

The fifteenth harmonic is a major seventh above the third double of the fundamental.

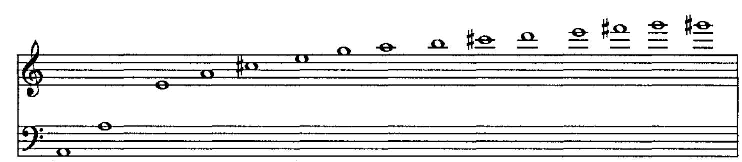

Figure 18. Diagram of fundamental through fifteenth partial.

The sixteenth harmonic is the fourth double of the fundamental.

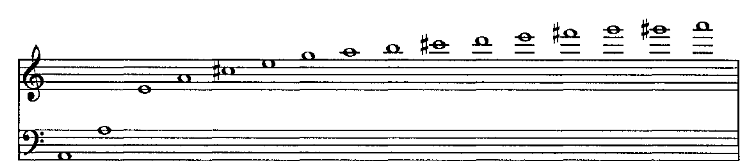

Figure 19. Diagram of fundamental through sixteenth partial.

With the exception of octaves, none of the overtones is exactly in tune with tones of any modern tuning system.[31]

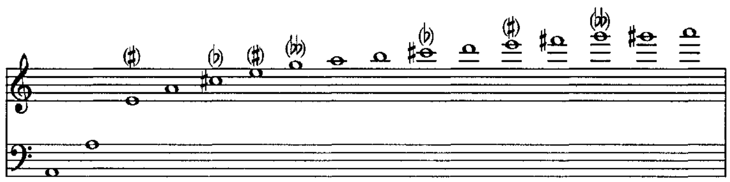

Figure 20. Diagram of harmonic series through sixteenth partial in relation to even-tempered scale. The symbols above notes indicates their deviation from the equal tempered scale.

Tuning Systems

The pitches of the tones in our modern scale of twelve tones in one octave, or the way the scales are "tempered," furnish the main, if not the full criteria, for what we call intonation.[32] Several methods have been developed for dividing the octave into intervals for the purpose of harmonic and melodic treatment. Usually the purpose of doing this is to reduce the number of tones in the scale, by going from frequencies based on exact ratios to those which produce equal intervals.[33] From these derived methods have come many theoretical and practiced standards of intonation in the performance of Western Music. The scales of equal-temperament, Pythagorean, and just intonation are three of the different and well-established intonation standards and are the intended target of this study.

Equal Temperament

The equal-tempered scale is a synthetic scale, dividing the octave into twelve equal intervals. The result is a distortion of every interval except that of the octave. The

[31] Ibid., 31.
[32] Pierce, 32.
[33] William F. Swor, "Absolute Intonation and the Fusion of Wind Instrument Sounds," Journal of Band Research 17, no.2 (1982): 15.

perfect fifth is two cents smaller than the Just and Pythagorean perfect fifths.[34] The byproduct is the elimination of unequal enharmonics (C# has the same pitch as Db). This scale became a technical necessity for keyboard and mallet instruments, to make multi-key, modulatory, and innovative harmonic performance possible and practical.[35] This scale makes it possible to play equally in tune or mildly out of tune in all keys. It functions as a compromise temperament, both melodically and harmonically.

Pythagorean intonation

The Pythagorean system of intonation is based on the principal of the acoustic perfect fifth. A synthetic scale featuring perfect fourths and fifths, diatonically and chromatically, is created using the ratios of 2:3 or 3:2, downward or upward intervals, of the perfect fifth respectively.[36]

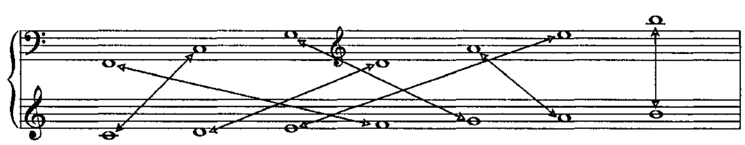

Figure 21. Illustration of a series of pure perfect fifths with notes rearranged to be in the same octave to produce a given scale.

Using a series of perfect fifths, one can eventually fill in an entire chromatic scale. The series would continue F sharp, C sharp, and so on. Although these notes produce a pure interval, the intervals of major and minor thirds and sixths are not consonant from the ideal, simple ratio standpoint.[37] Another disadvantage is that no matter how many fifths (3:2 intervals) one takes, either above or below a given note, one never arrives at an

[34] Mark Hindsley, "Intonation for the Band Conductor," The Instrumentalist 26 (September, 1971): 66.
[35] John Barcelona, "Woodwind Intonation," Flute Talk 5 (1982): 18-19.
[36] Hindsley, 67.
[37] Bartholomew, 19.

octave multiple of that note.[38]

Another feature of the Pythagorean scale is its placement of the chromatic tones; the sharped tones are placed off-center toward the next higher tone on the way up, and the flatted tones are placed equally off-center toward the next lower tone on the way down. The Pythagorean chromatics function gravitationally in their natural directions; and the natural half-step diatonic intervals E-F and B-C are closer than in the other scales, making the E and B function quite naturally as leading tones to F and C.[39] In contrast to those of the just scale, the equalities of the diatonic intervals foretell the evenness of the Pythagorean temperament melodically. All the tones may move adjacently either way, up or down, with equal gravitation. The Pythagorean scale, then, may be considered as valuable, consistent, and reliable melodically, but not one on which we can rely or can approve harmonically.[40]

Just Intonation

Just intonation is a pure system based on the previously discussed naturally occurring harmonic pattern of the open tube. It is the system of tuning that is used, often unconsciously, by musicians when they make small tuning adjustments quickly. It is a system of tuning based on naturally occurring ratios of intervals.[41] The creation of a scale in just intonation involves the usage of frequency ratios based on integer proportions as found in the harmonic series rather than a division of the octave into exactly equal parts as in the case of equal temperament. Every interval used in just intonation can be found

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[38] Hindsley, 69.

[39] Mark Hindsley, "Intonation for the Band Conductor, Conclusion of Part II," The Instrumentalist 26 (November, 1971): 61.

[40] Ibid., 63.

[41] Douglas Keislar, "Psychoacoustic Factors in Musical Intonation: Beats Interval Tuning, and Inharmonicity," (Ph. D. diss., Stanford University, 1991), 37.

somewhere in the harmonic series.[42] By definition, the harmonic series is a sequence of frequencies that are all whole-number multiples of any particular fundamental frequency. Thus, since any just interval is expressible as a frequency ratio of two whole numbers, that interval is also the interval between those same two harmonics. Unlike the Pythagorean system, intervals are derived not only from the perfect fifth, but also from the pure third. This system of tuning makes use of all perfect intervals of the harmonic series. From the just scale and its primary ratios are derived the so-called consonant intervals of the perfect fifth and fourth and the major and minor third and sixth.[43] The natural harmonics of a pipe or string fit more closely to a scale of just intonation than to the Pythagorean.

Within this scale, some of these intervals do not have the primary ratios cited; therefore, the scale cannot be completely depended upon for consistent consonance. More specifically, within the diatonic form of the just major scale (two whole steps and a half step, three whole steps and a half step) C-G, E-B, F-C, G-D, and A-E are perfect and consonant, but D-A is an imperfect, contracted, and non-consonant fifth. All of the major thirds in this scale - C-E, F-A, and G-B are equal and consonant. The minor thirds E-G, A-C, and B-D are equal and consonant as well, but D-F is contracted and non-consonant.[44] The inverted fifths and thirds become fourths and sixths and have the same consonant or non-consonant properties.

Although the two minor seconds E-F and B-C and their inverted major sevenths are equal, the major seconds and minor sevenths appear in two sizes: C-D, F-G, A-B are

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[42] Jon Nichols, "Methods of Teaching Intonation Discrimination Skills to Wind Instrumentalists" Dialogues in Instrumental Music Education 11, no.2 (1987): 64.
[43] Alldahl, 14.
[44] Hindsley, 64.

larger than D-E and G-A, with the reverse situation in the inverted sevenths. Studies of the chromatic and enharmonic tones show more inequalities and inconsistencies. The just-tempered scale, then, may be considered as most valuable, though somewhat unreliable harmonically, and quite erratic melodically.[45]

An important byproduct of just intonation is the presence of resultant tones. Charles Colnot defines a resultant tone as a third tone produced by any two notes played simultaneously by two instruments. For example, if the two tones are 1500 Hz and 2000 Hz, the difference tone will be 500 Hz.

Comparative Analysis

Table 1 shows the comparative frequency ratios in Hertz and cents of the notes in the scale as they occur in the Pythagorean, just, and equal-temperament systems of tuning.[46] Except for the unison and the octave, none of the ratios for equal temperament are exactly the same as for the pure interval. However, many of them are reasonably close. In particular, perfect fourths and fifths and major thirds are not too far from the pure intervals. The intervals that are the furthest from the pure intervals are the major seventh, minor seventh, and minor second. Because equal temperament is now so widely accepted as standard tuning, musicians do not usually speak of intervals in terms of ratios. Instead, tuning itself is now defined in terms of equal temperament, with tunings and intervals measured in cents.

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[45] Mark Hindsley, "Intonation for the Band Conductor," The Instrumentalist 26 (January, 1972): 60.

[46] C.A. Taylor The Physics of Musical Sounds (London: Oxford University Press, 1965), 128-9.

Note	Pythagorean Frequency	Pythagorean Cents	Just Intonation Frequency	Just Intonation Cents	Equal Temperament Frequency	Equal Temperament Cents
C	1	0	1	0	1	0
C♯	$\frac{2187}{2048}$	114	$\frac{25}{24}$	71	$2^{1/12}$	100
D♭	$\frac{256}{243}$	89	$\frac{16}{15}$	112		
D	$\frac{9}{8}$	204	$\frac{9}{8}$	204	$2^{1/6}$	200
D♯	$\frac{19683}{16384}$	317	$\frac{75}{64}$	275	$2^{1/4}$	300
E♭	$\frac{32}{27}$	294	$\frac{6}{5}$	316		
E	$\frac{81}{64}$	409	$\frac{5}{4}$	386	$2^{1/3}$	400
E♯	$\frac{177147}{131072}$	522	$\frac{125}{96}$	457		
F♭	$\frac{8192}{6561}$	385	$\frac{32}{25}$	427		
F	$\frac{4}{3}$	498	$\frac{4}{3}$	498	$2^{5/12}$	500
F♯	$\frac{729}{512}$	612	$\frac{45}{32}$	590	$2^{1/2}$	600
G♭	$\frac{1024}{729}$	588	$\frac{36}{25}$	631		
G	$\frac{3}{2}$	702	$\frac{3}{2}$	702	$2^{7/12}$	700
G♯	$\frac{6561}{4096}$	816	$\frac{25}{16}$	773	$2^{2/3}$	800
A♭	$\frac{128}{81}$	792	$\frac{8}{5}$	814		
A	$\frac{27}{16}$	906	$\frac{5}{3}$	884	$2^{3/4}$	900
A♯	$\frac{59049}{32768}$	1019	$\frac{225}{128}$	977	$2^{5/6}$	1000
B♭	$\frac{16}{9}$	996	$\frac{9}{5}$	1018		
B	$\frac{243}{128}$	1109	$\frac{15}{8}$	1088	$2^{11/12}$	1100
B♯	$\frac{531441}{262144}$	1228	$\frac{125}{64}$	1159		
C♭	$\frac{4096}{2187}$	1086	$\frac{48}{25}$	1129		
C	2	1200	2	1200	2	1200

Table 1. Comparative frequency ratios in Hertz and cents of the notes in the scale as they occur in the Pythagorean, just, and equal-temperament systems of tuning.

Tempered Scales and the Wind Band

Wind players have a tendency to revert to true harmonics when they are able to do so. For example, a wind ensemble, may find themselves playing perfect fourths and fifths, "contracted" major thirds and "expanded" minor thirds. From the descriptions of these three differently tempered scales, a broad statement may be made that the Pythagorean scale should be used melodically, and that the consonant, simple ratio portion of the just scale should be used harmonically.[47] Theoretically it is possible for trombone players to do just that. However, this combination is impossible for keyboard and mallet players; it is also a practical impossibility for players of wind instruments other than the trombone, because it involves adjusting the pitch of each tone in the diatonic major and minor scales over a range of 33 1/3 “cents” (one-third of a half-step or semitone), and in the chromatic scales over a range of 74.3 cents (almost three-fourths of a half-step). These extreme variations cannot be made in many or most wind instruments without considerable loss of tone quality and/or control.[48]

Since bands do not adhere strictly to the use of equal temperament, a combination of tuning possibilities is needed to eliminate intonation problems within chords and to temper individual notes of the scale. Mark Hindsley suggests that bands play in the combination of the just and Pythagorean temperaments with wind instruments tuned to equal temperament in manufacture and adjustment.[49] He further states that “we should prefer the Pythagorean scale for melodic lines, but at worst we may have to accept the equal scale. We should prefer the consonant, simple ratio relationships of the just scale harmonically, but at worst we may have to accept the harmonic relationships of the equal

[47] Hindsley, 61.
[48] Ibid., 62.

scale."[50]

Steps for Better Band Intonation

When taking a chord apart in order to tune it, tune the most consonant intervals first and then go on to the more complex ones later. For instance, in a major seventh chord tune the roots first (this includes all octave doublings of the root pitch), then the fifths, then the thirds, and finally the sevenths. If the fifths are not in tune, then the thirds cannot possibly be. For atonal music equal temperament is the preferred tuning method.[51] Just tuning is usually better in relatively diatonic, consonant music. In consonant music that is modulating in a chromatic manner, often the bass line will move in a relatively tempered manner and the treble lines will then tune to that using just tuning. What mainly is heard is the relationships between the intervals, and if this is well in tune, the less precise tempered movement of the bass line will not be apparent. Going back and forth between different tuning methods is an intuitive act that is part of good musicianship. The end result will be that which sounds the best.

Major third	14 cents flat
Minor third	16 cents sharp
Perfect fifth	Two cents sharp
Minor seventh	29 cents flat
Major seventh	12 cents flat
Major ninth	4 cents sharp

Table 2. Deviation in cents of the just intervals from equal temperament.

[49] Ibid., 61.
[50] Ibid., 62.
[51] George Papich and Edward Rainbow, "A Pilot Study of Performance Practices of Twentieth-century Musicians," Journal of Research in Music Education 22 (1974): 31.

Finally, a conductor must know the pitch tendencies of instruments. A good player will compensate to minimize these tendencies. However, if a problem persists when playing with one of these instruments, a conductor will have some idea how to work to adjust specific tuning issues of the given chords. These tendencies are discussed in greater detail later in this study.

CHAPTER III

INSTRUMENT DEFICIENCIES

Striving for superior intonation is a universal challenge for all instrumentalists. Musicians are bombarded by an array of difficulties when addressing intonation: instrument construction, temperature, tendency of partials, and melodic and harmonic tuning.[52] Given these factors, there are several inherent problems regarding the intonation of wind instruments. Initially, a competent performer needs to be aware of the natural intonation tendencies of the harmonic series. Next one needs to understand design of brass instruments and the function of the valve mechanism. Finally, the use of this knowledge in practice in order to make intonation adjustments in performance defines one's mastering these concepts.

The "Six-Percent" Rule

Brass instruments operate under the principles of physics; therefore, a brass instrument should be constructed so that the harmonic series is as close to in tune as possible. The instrument must be able to achieve semitones (half-steps) between the partials. The fact remains, however, that all brass instruments are constructed inherently out-of-tune, with the exception of the trombone. The physical and mathematical relationships simply create too complex a system for an instrument to sound perfectly in tune with any system using all valve combinations.[53]

A basic brass instrument has three valves which are tuned approximately a semi-tone apart. There are seven different combinations that produce different notes. The

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[52] Norman Hunt and Dan Bachelder, Guide to Teaching Brass (Dubuque, IA: W.C. Brown, 1991), 4.

[53] Donald Stauffer, Intonation Deficiencies of Wind Instruments (Birmingham, AL: Stauffer Press, 1989), 5.

trombone, however, utilizes a slide that is constructed so that each position of the slide represents a half-step; therefore, the seven positions on the trombone slide each correspond to a valve combination. Valves are numbered consecutively, beginning with the one closest to the lead pipe. Valve combinations are named according to the numbers of the valves that are pressed in the down position. The term "open" refers to the situation where all of the valves are in the resting position.

In theory, the second, first, and third valves should lower the pitch of the open tube by one, two and three semitones respectively.[54]

Valves	Trombone Slide Position	Effect
0	1 (slide fully in)	None
2	2	1 half-step lower
1	3	2 half-steps lower
3 (1+2)	4	3 half-steps lower
2+3	5	4 half-steps lower
1+3	6	5 half-steps lower
1+2+3	7	6 half-steps lower

Table 3. The above chart shows the theoretical effect on the pitch produced by the open tone for all possible valve combinations and chromatic adjustments downward.

The use of single valve combinations presents no problem in the function of brass instruments that were manufactured so that the first, second, and third valves produced three successive semitones. A problem arises, however, when the valves are combined to provide a length of tubing. The length is slightly shorter than the length required for perfect intonation. If all three valves were manufactured to produce correctly tuned single valve tones, then the tone produced by using all three valves in combination would be

[54] Hunt and Bachelder, 5.

sharp by more than a quarter-step.[55]

To clarify this problem, consider the trombone that requires approximately 110 inches of tubing to produce the B-flat harmonic series. In order to produce the harmonic series beginning on the next lower semitone, (in this case the A harmonic series) the tubing must be lengthened by 5.95%. Therefore, 116 10/16 inches of tubing is the desired length. For each successive lower semitone the percentage of increase remains the same, and as a result, there is a progressive increase between slide positions in order to produce all seven semitones.[56]

The second valve that lowered the open tube by one semitone simply is not long enough to lower the length of tubing of the open tube as well as the additional tubing added by the pressing of the first valve another semitone. The result is a sharp combination of valves. In order to solve this problem, manufacturers produce valves that produce a flatter pitch when pressed. So that the combinations will not be as sharp, the second valve is manufactured to produce a tone that is five cents flat. The first valve is also manufactured to produce a tone that is five cents flat, and the third valve is manufactured to produce a tone that is twenty-one cents flat.[57]

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[55] Stauffer, 7.
[56] Hunt and Bachelder, 5.
[57] Ibid., 5.

Valve Combination	With Adjustments	Without Adjustments
0	In tune	In tune
2	5 cents flat	In tune
1	5 cents flat	In tune
3	21 cents flat	In tune
1 + 2	1 cent sharp	11 cents sharp
2 + 3	8 cents flat	18 cents sharp
1 + 3	7 cents sharp	23 cents sharp

Table 4. The above chart illustrates the difference in intonation with and without adjustments of tuning slides.[58]

Even with adjusted valve lengths, there are still sizeable intonation problems in the last three valve combinations. Manufacturers have designed a number of different schemes to compensate for these inherent tuning imperfections. On smaller instruments, mechanisms are provided that allow the player to move one or more tuning slides while playing. Various rings, levers and brackets are fitted to the instrument that permit the first and third valve slides to be moved with the player's left hand. Larger instruments are sometimes designed with overall tuning slides that can be operated with the player's free hand.[59]

A much more common solution is to add one or more extra valves. The fourth valve (equivalent to a 1+3 valve combination) has become nearly standard on the euphonium and tuba. This valve compensates for the most common out-of-tune notes and also provides additional low-end range. Some tubas are designed with as many as five or

[58] Published by C.A. Conn Band Instrument Co. from a pamphlet entitled "The Inside Story of Brass".

[59] Stauffer, 8.

six valves. Pottle lists three advantages of compensating valves: 1) they provide accurately tuned single valve tones, 2) closer tuning on all valve combinations, 3) superior tone quality because of reduced lipping.[60] However, in order to improve intonation, the player must attain the flexibility to lip tones that are slightly sharp or flat.

The ability of a player to use his lips to correct the pitch of a faulty note varies greatly between the higher and the lower brasses. This difficulty rises from forcing a column of air to vibrate at a frequency other than the one that should be produced naturally by the length of the tube (i.e. to sound certain upper partials) becomes progressively more difficult as the vibrating columns become longer. In this sense, a trumpet is much more under the control of the player's lips than any other brass instrument. Trombone players can deal with the problem by adjusting their slide, while horn players can approach the issue by varying their right hand position in the bell. Tuba and euphonium players, on the other hand, have no such means of overcoming the difficulty. This implies, at the very least, that whereas a trigger or ring mechanism fitted to a trumpet may be considered almost a luxury, the use of a fourth valve on the tuba or euphonium is essential.[61]

Knowing the pitch tendencies of instruments allows a conductor to make an educated guess as to which direction and to what degree certain pitches will vary from ideal intonation. The remainder of this chapter contains detailed information to help improve knowledge of characteristic intonation problems and their possible solutions. Fabrizio acknowledges that knowing these tendencies is not a cure for the ills of acoustics, nor is it a help when dealing with below average instruments and insufficient

[60] Pottle, 12.
[61] Stauffer, 17.

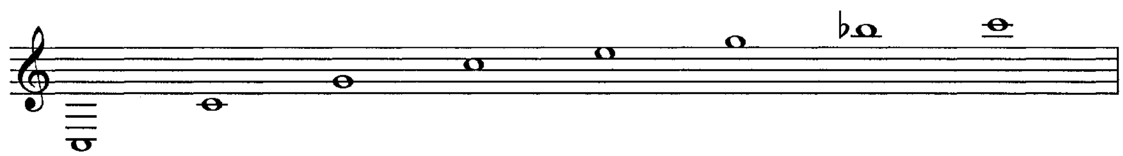
practice habits, but merely a guide to the understanding and solving of problems that exist on most instruments.[62]

The Brasses

Tuning a brass instrument is much more involved than pulling or pushing a few slides. Assuming that the player is doing his part to play in tune, he will improve only to the limits of the instrument. By far, the most common difficulty stems from the student's tendency to allow the physical nature of their instrument to determine intonation rather than attempting to correct intonation themselves. The majority of notes require subtle adjustments of embouchure, air pressure, tongue, and jaw movement. Certain notes, however, require correction by some mechanical means, such as extension of a valve slide or an alternate fingering.

The harmonic series for the open tube of each of the brass instruments, through the eighth harmonic, follows:

Trumpet



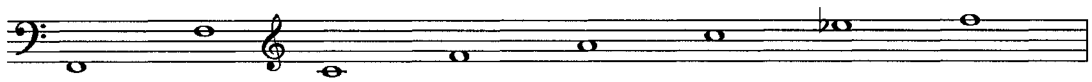
1 2 3 4 5 6 7 8

F Horn

1 2 3 4 5 6 7 8

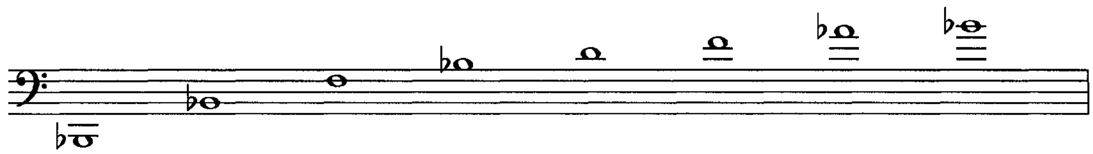
[62] Al Fabrizio, A Guide to the Understanding and Correction of Instrument Deficiencies (Ft.

B-flat Horn



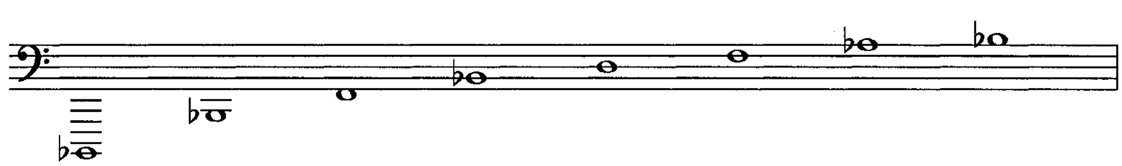
1 2 3 4 5 6 7 8

Trombone / Euphonium



1 2 3 4 5 6 7 8

Tuba

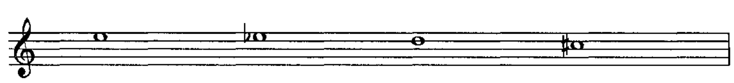


1 2 3 4 5 6 7 8

The second, fourth, and eighth partials (all concert b-flats) correspond exactly to the tempered scale. Of the others, the third partial is slightly sharp, the fifth is flat, the sixth is sharp, and the seventh is extremely flat. These tendencies apply not only to the open notes shown, but all other notes in each particular partial of the harmonic series. For practical purposes, those notes would include the open note, continuing down to, but not including, the next open note.

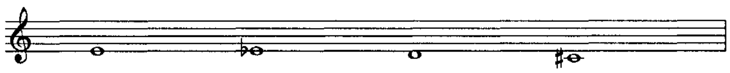
The following, then, would be the fifth partial notes:

Trumpet

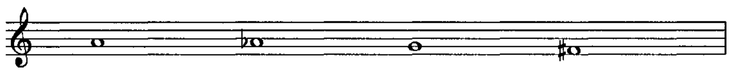


Lauderdale, FL: Meredith Music, 1996), 3.

F Horn



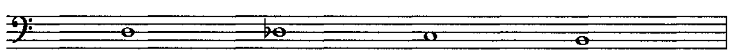
B-flat Horn



*The fifth partial is not ordinarily used on the B-flat side of the double horn

Trombone / Euphonium

Tuba



All of the above notes will be flat for the valved-brass instruments. The possible exception is the fourth note that utilizes the sharp valve combination of first and second. The sharp fingering will partially compensate for the flatness of the fifth partial.

Trumpet

Trumpet players need to learn to adjust intonation using the first and third valve slides. All trumpet players should have a third valve tuning ring or kick trigger. This is an area that is grossly neglected by music educators, especially those who teach beginning students.[63] It is essential that student-line beginning instruments have this third valve tuning adjustment and this tuning accessory should be a requirement for all trumpet players. The third valve slide should move freely. If this does not, the slide may need to be cleaned. For step-up or professional-model instruments, not only should there be a

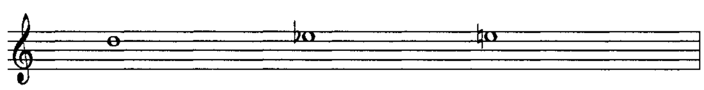
[63] Crider, 64.

third valve slide adjustment, but also a first-valve tuning adjustment.

Technical demands limit the number of notes that can be altered by lengthening the first and third valve slides. There are, however, certain notes that require this type of correction to bring them into tune:

The low F# and G tend to vary in pitch from player to player. Some must use the third valve slide, while others can play these notes in tune with minimal or no adjustment:

A more complex problem involves the D, Eb, and E:



These notes are rarely up to pitch and require an adjustment of both embouchure and air stream. Alternate fingerings may also improve the intonation of these notes, but their use often brings on technical fingering complications.

As a simple rule, the longer the valve combination, the sharper an instrument becomes. This principle along with the intonation characteristics of the harmonic series can drastically affect a brass instrument's intonation.[64] For example, a sharp fingering used on a normally flat partial may make the desired pitch close to being in-tune, but a sharp valve combination on a normally sharp partial will make the pitch excruciatingly sharp.

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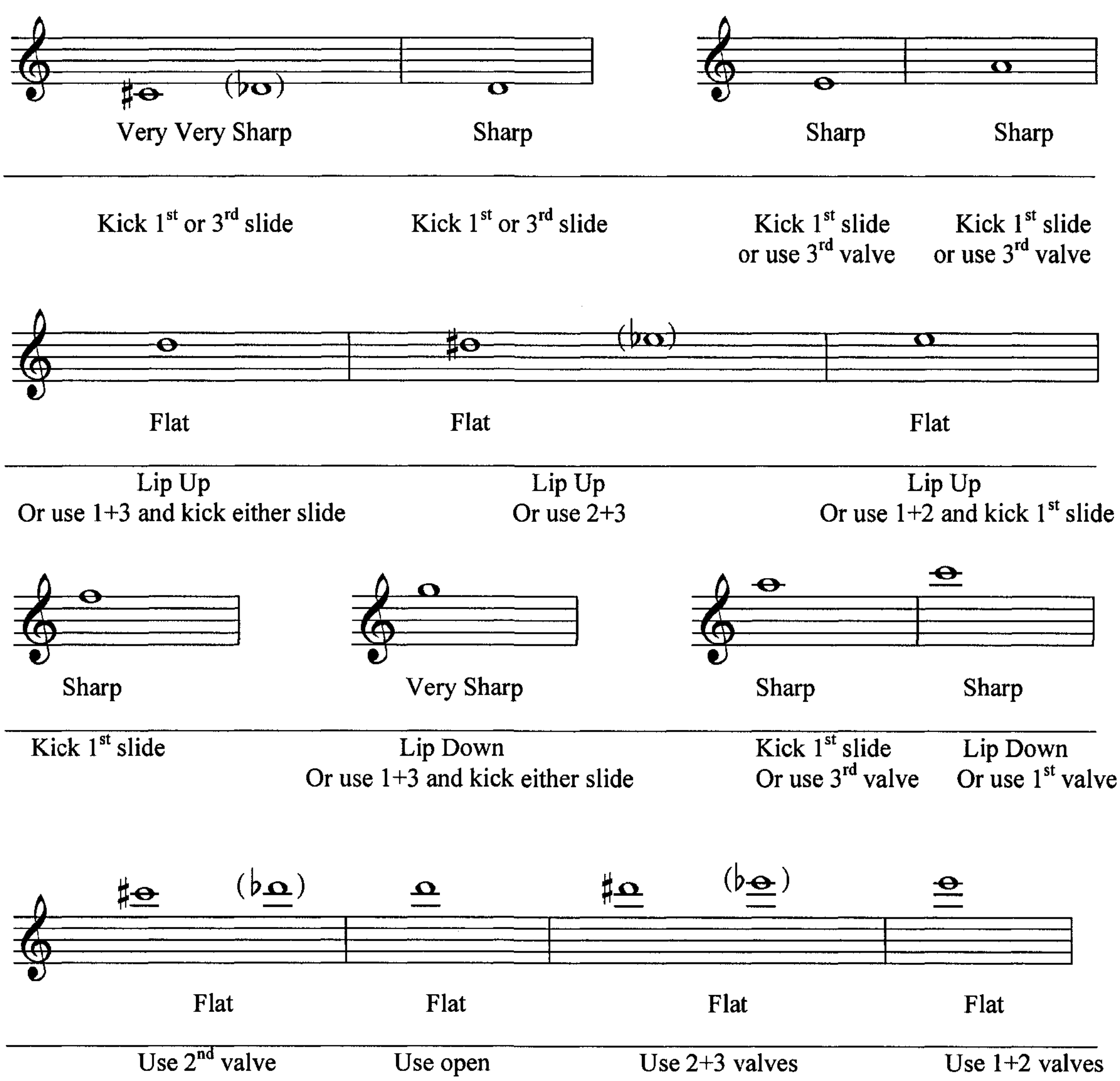
[64] Hunt and Bachelder, 7-8.

Because tuning issues vary with each individual instrument, the following chart represents the most common discrepancies inherent in the three-valve system:

Pitch Tendencies and Adjustments
Trumpet and T.C. Euphonium



Horn

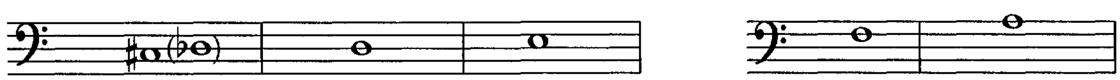
The tube lengths of the horn are controlled in the same manner as the trumpet. The double horn in F and B-flat has two sets of valve shanks and a thumb valve to change from one set to another. By depressing the thumb trigger on the double horn, one eliminates approximately four feet of tubing, and the harmonic series of the open horn is raised a perfect fourth from F to B-flat.[65]

The horn shares the intonation problems experienced by other valved brass instruments. The performer can adjust the pitch by gently cupping the right hand in the bell to flatten a note or opening the hand to sharpen one.

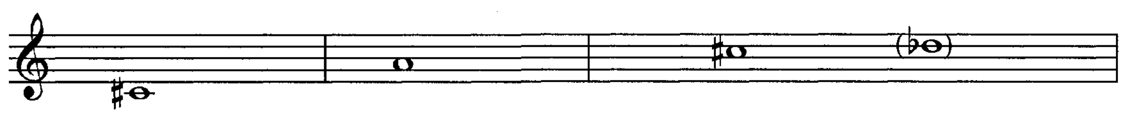
[65] Hunt and Bachelder, 69.

Because tuning issues vary with each individual instrument, the following chart represents the most common discrepancies inherent in the three-valve system for the double horn:

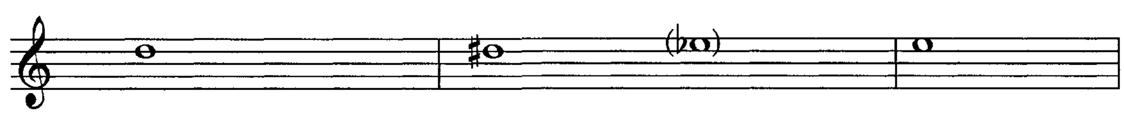
Pitch Tendencies and Adjustments
Horn



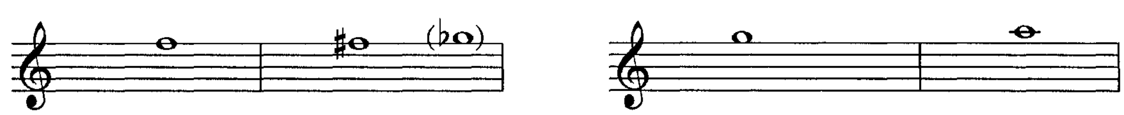
Very Sharp	Sharp	Sharp	Flat	Sharp
Use B-flat side 2+3 valves	Use B-flat side 1+2 valves or 3rd valve	Use B-flat side 2nd valve	Use B-flat side play open	Use F side 3rd valve



Sharp	Sharp	Sharp
Use F side 3rd valve	Use F side 3rd valve	Use B-flat side 2+3 valves



Flat	Sharp	Flat	Flat
F side play open	B-flat side Use 3rd valve	Use B-flat side 1st valve	Use B-flat side 2nd Valve

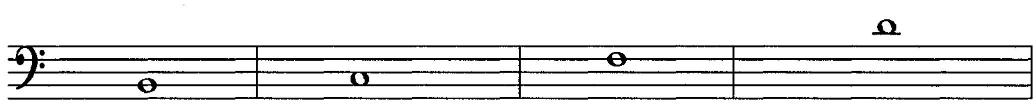


Flat	Flat	Flat	Flat	Flat	Very Flat	Sharp
F side 1+3 valves	B-flat side open	F side 2+3 valves	B-flat side Use 2nd valve	F side 1+3 valves	B-flat side open	B-flat side Use 3rd valve

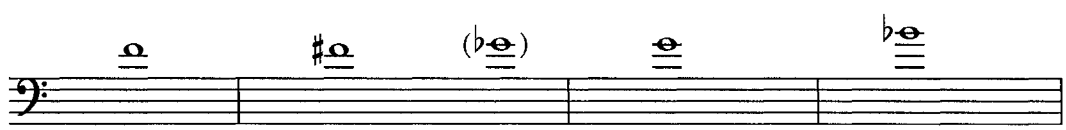
Trombone

The trombone is the only wind instrument with the inherent capacity to play perfectly in tune. The one limiting factor, in this regard, is the player. For example, in the case of the flat fifth partial, the notes D-flat, C, and B require only that the player adjust by raising the slide very slightly. This is not possible for the first position D, which would need to be lipped up or played in fourth position.[66]

Pitch Tendencies and Adjustments
Trombone



Sharp	Sharp	Sharp	Flat
Use trigger and lower 2nd position	Use trigger and lower 1st position (may still be very sharp if trigger is not properly tuned)	Lower 1st position	Use 4th position



Very Sharp	Very Flat	Very Flat	Sharp
Lower 1st position	Raise 3rd position	Raise 2nd position	Lower 1st position

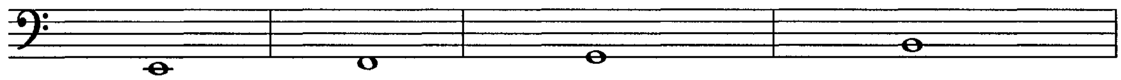
[66] Hunt and Bachelder, 87.

Euphonium / Tuba

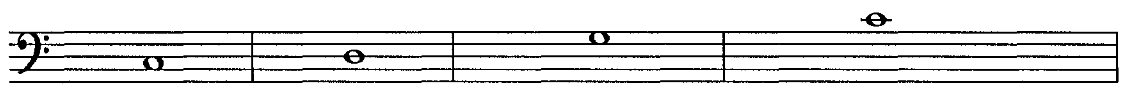
In addition to extending the range downward a perfect fourth, the fourth valve on the euphonium and tuba provides an important aid in overcoming intonation problems caused by valves used in combination. It is used in place of the sharp first and third valve combination for low C and in combination with the second valve for low B. This combination of second and fourth valves will still be slightly sharp, but not nearly as sharp as the combination of first, second, and third valves. Many euphoniums and tubas utilize an automatic compensating system in which valve slides are equipped with extra ports that open automatically to lengthen the tubing when they are used in combination with other valves. Such instruments have an additional means of dealing with the problems of the sharp sixth partial. A satisfactory solution to combat the sharpness of these notes (F, E, and E-flat) is the addition of the fourth valve to the regular fingering.[67]

[67] Stauffer, 23.

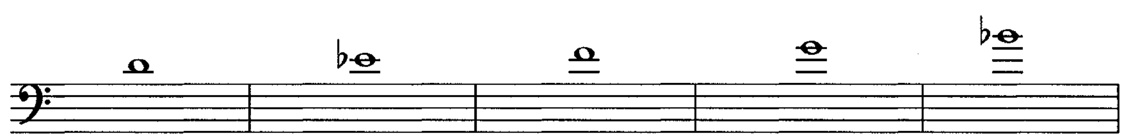
Pitch Tendencies and Adjustments
Euphonium



Very Very Sharp	Very Sharp	Sharp	Very Very Sharp
Use 2+4 and drop jaw	Use 4th valve	Use 3rd valve or pull 1st slide	Use 2+4 valves and drop jaw



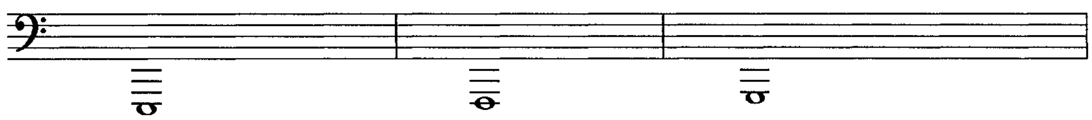
Very Sharp	Sharp	Sharp	Flat
Use 4th valve	Use 3rd valve or pull 1st slide	Use 3rd valve or pull 1st slide	Use 1+3 valves and pull 1st slide or use 4th valve



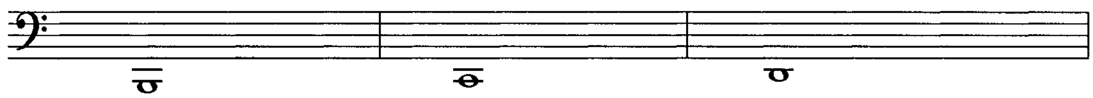
Flat	Sharp	Very Sharp	Very Sharp	Sharp
Use 1+2 valves or 3rd valve	Pull 1st valve slide	Use 4th valve or 1+3 valves and pull 1st slide	Use 3rd valve or pull 1st slide	Use 1st valve

The intonation problems of the euphonium and tuba are the same as for the trumpet. These deficiencies, however, are compounded by their larger size.

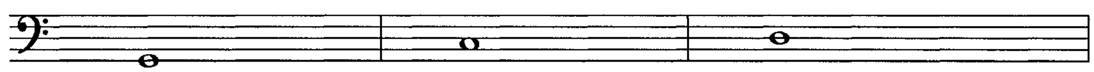
Pitch Tendencies and Adjustments
Tuba



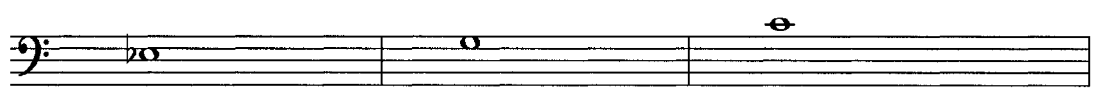
Very Very Sharp	Very Sharp	Sharp
Use 2+4 valves and drop jaw	Use 4th valve	Use 3rd valve or pull 1st valve slide



Very Very Sharp	Very Sharp	Sharp
Use 2+4 valves and drop jaw	Use 4th valve	Use 3rd valve or pull 1st valve slide



Sharp	Flat	Flat
Use 3rd valve or pull 1st slide	Use 1+3 valves or 4th valve	Use 1+2 valves



Sharp	Very Sharp	Flat
Pull 1st slide	Use 3rd valve	Play open

The preceding charts were constructed after a number of instruments were examined and their pitch tendencies recorded.[68] Fabrizio notes that these are just a guide and should not be misconstrued as absolute. Therefore, the use of as many similar brands as possible in each section of instruments within an ensemble will bring the pitch tendencies into greater focus.[69] Additionally, the need for alternate fingerings and how successful they might be, is dependent upon the instrument and the player. They should be treated as a last resort and used only if the regular fingering proves incapable of producing the desired pitch or if the amount of lipping necessary to produce proper intonation results in an unacceptable tone quality. Longer harmonic fingerings often cause a less secure response and increase the possibility of poor entrances.

Mutes

Another important factor affecting all brass instruments are the use of mutes. The most frequent result is for the straight and Harmon mutes to raise pitch and the cup mute to lower pitch.[70] The tuning slide should be adjusted accordingly for muted sections.

The Woodwinds

Intonation of a woodwind instrument involves much more than the simple adjustment of slides. Even though there are those instruments that are of finer quality than others, there are certain factors that will affect all woodwind instruments, regardless of brand or level. When keys are too close to tone holes, the sound of the instruments will be stuffy and the pitch will be flat. When the keys are too high, the overall pitch of the instrument is usually sharp, and the tone of the instrument will be very bright, making it

[68] Adapted from charts published by Al Fabrizio in A Guide to Understanding and Correction of Intonation Problems (Ft. Lauderdale, FL: Meredith Music, 1996), 9-22.

[69] Ibid., p.23

[70] Hunt and Bachelder, 123.

hard to blend with the rest of the group. When one key is noticeably higher or lower, it can affect that particular note as well as the adjacent notes, making the tuning of the instrument more difficult to control.[71]

Flute

More than any other factor, air direction affects intonation. A raised air stream will raise pitch, and a lowered air stream will lower pitch. The contact point of the flute to the lip should not be disturbed, nor should the hands be encumbered with unnecessary movement.[72]

The length of the flute's tubing can be changed in two ways; the first of which is the changing of the position of the cork that is attached inside the crown of the top end of the headjoint. The headjoint cork has a silver plate at each end and should be pre-set to a permanent spot, i.e., 17.3 millimeters from the center of the embouchure hole. Checking proper cork positioning can be done by using the marker on most cleaning rods by inserting the marked end of the rod and checking to see if the tick-mark is visible exactly in the center of the embouchure hole.[73]

The second way of lengthening or shortening the flute involves the pulling out of the headjoint from the flute's middle section. This is something done in order to fine-tune the tube's length. The flute maker's standard is that the headjoint should at all times be pulled out anywhere from three millimeters to as much as fifteen millimeters. The number of millimeters depends on the flutist's individual embouchure, and the design of their particular brand of flute. The further the headjoint is drawn out, the longer the flute's

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[71] Frederick Westphal, Guide to Teaching Woodwinds (Boston: W.C. Brown, 1990), 285.

[72] Ibid., 28.

[73] Ray Edward Church, "Intonation Tendencies of Selected University Flute, Oboe, and Clarinet Players," (EDD diss., University of North Carolina at Greensboro, 1990), 33.

tube becomes, resulting in a flatter pitch. The further the headjoint is pushed in, the shorter the tube becomes, resulting in a sharper pitch.

The basic tuning problems of the flute are as follows:

1) Playing loudly causes the flute to go sharp.

2) Playing softly, with slow air, causes the flute to go flat.

3) Playing at a high angle (bottom lip aiming the air more upward) causes increased sharpness.

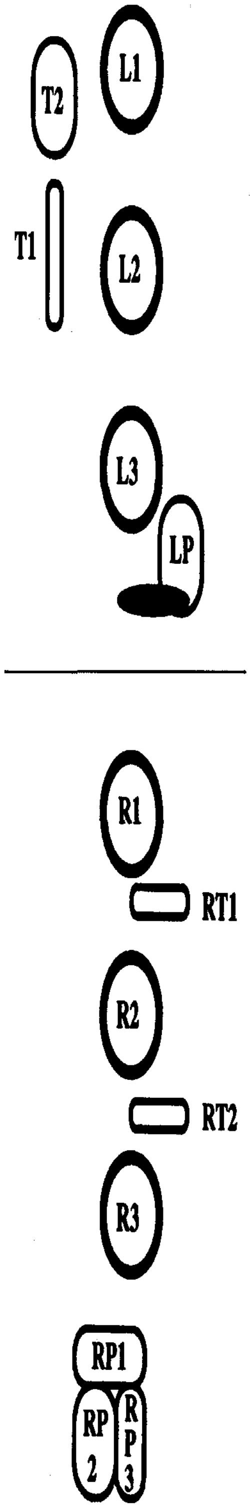
4) Playing at a low angle (top lip aiming the air more downward) causes increased flatness.

5) Uncovering the opening in the head joint (placing the lower lip at less than 1/4 coverage) causes sharpness.

6) Covering the opening in the head joint (lower lip covers more than 1/3) causes flatness.[74]

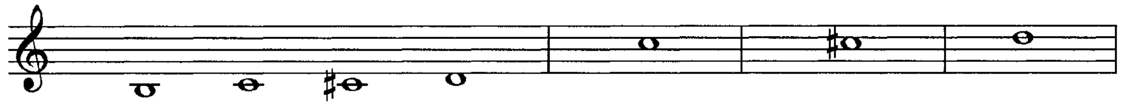
Each note on any given brand name of flute can have a tendency to be sharp or flat depending on how the distances between the holes have been calculated by the manufacturer. The following chart represents the most common deficiencies.

[74] Church, 40.

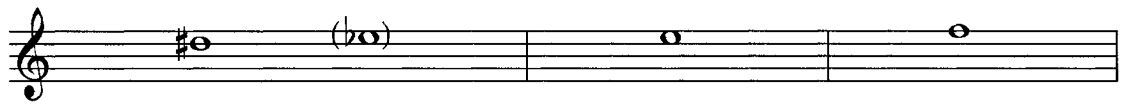


Flute fingering chart

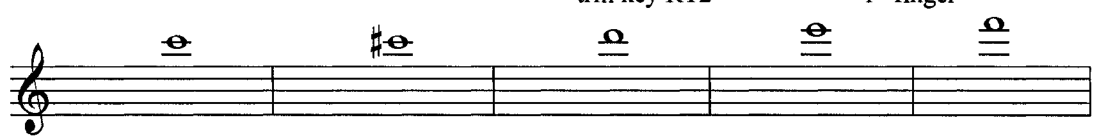
Pitch Tendencies and Adjustments
Flute



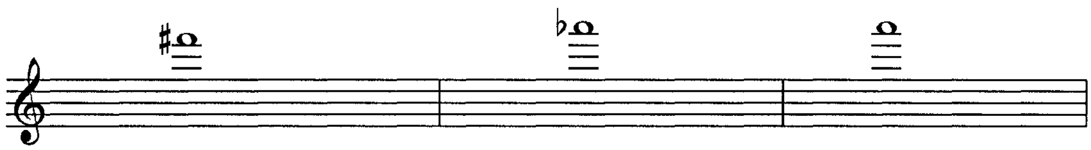
Flat	Sharp	Very Sharp	Flat
Direct air flow upward	Add 3rd finger of left hand and direct air down	Add all 3 fingers of right hand or use low C# fingering, Direct air down	Add top right hand trill key 1/2 open RT1



Flat	Flat	Flat
_ hole 3rd finger of right hand	Add lower right hand trill key RT2	1/2 hole right hand 1st finger

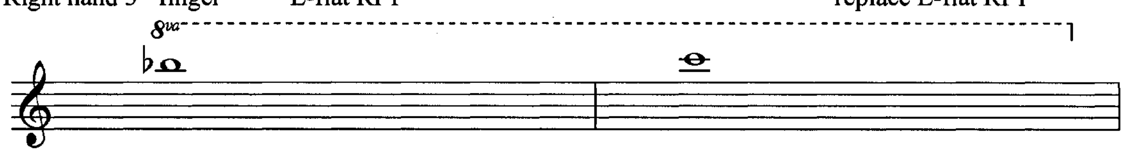


Sharp	Very Sharp	Flat	Sharp	Flat
Add 3rd finger of left hand, direct air down	Add all 3 fingers of right hand, direct air down	1/2 hole left hand 3rd finger	Do not use E-flat key RP1	Use low C# RP2 in place of E-flat RP1



Sharp or Flat depending on the instrument	Sharp	Flat

Use right hand 2nd finger to replace Right hand 3rd finger	Use low C# RP2 in place of E-flat RP1	Add 2nd and 3rd fingers of right hand	Add right hand 3rd finger and use low C# RP2 to replace E-flat RP1



Sharp	Sharp or Flat depending on the instrument
Use thumb, L1 and L3 of left hand, RT1, RT2 and RP1 of right hand. Many possible alternates exist.	Use all 4 fingers of left hand, 1st and 1/2 hole 2nd of right hand / Use all of left, 1,3, and C key of right hand (No thumb for either)

Oboe

As is the case with the flute, the oboe is also inclined to flatness in the lower register and sharpness in the upper. The flatness generally extends from low B-flat through D-flat. The sharpness in the upper register is usually most noticeable from C-sharp above the staff, extending upward. The intonation of some of these notes may be improved by the use of alternate fingerings.

The most important factor influencing the pitch of an oboe is the reed. The way in which it is cut, the type of cane used, and how well it fits the player's embouchure all have major effects on pitch. A reed that is too soft will play flat over the range of the instrument, and a reed that is too hard will play generally sharp over the range of the instrument. Old reeds make intonation difficult to control.[75]

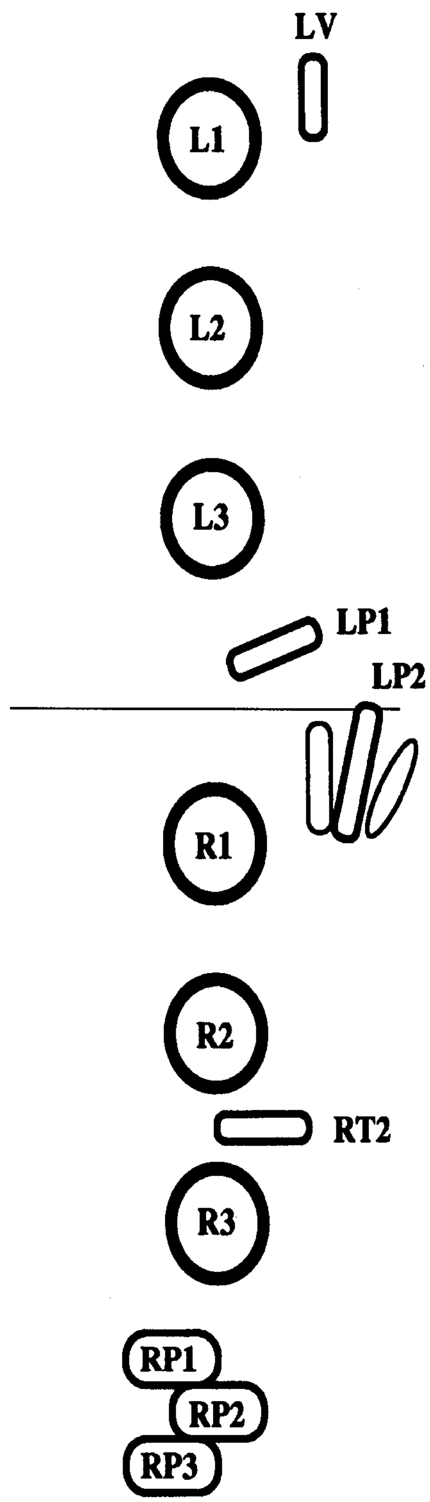
The combination of embouchure and reed is a primary factor in intonation. To raise the pitch of a note, the embouchure must contract around the reed to increase pressure. To lower the pitch of a note, the embouchure must relax to reduce pressure. The amount of reed taken into the mouth also has considerable influence on pitch and intonation. If too much reed is in the mouth, the overall pitch tends to be sharp. Conversely, if too little reed is in the mouth, the overall pitch tends to be flat. In both instances, the natural tendencies toward sharpness or flatness of certain notes on the oboe will be emphasized.[76]

Other factors influencing oboe pitch are volume and playing position. An increase in volume will lower the pitch and a decrease will raise it. Playing angles of greater than forty degrees in relation to the body will cause an overall flattening effect. If the

[75] Westphal, 259.
[76] Church, 45.

instrument is held to closely to the body, the overall pitch will be sharp.[77]

[77] Westphal, 47.



Oboe fingering chart

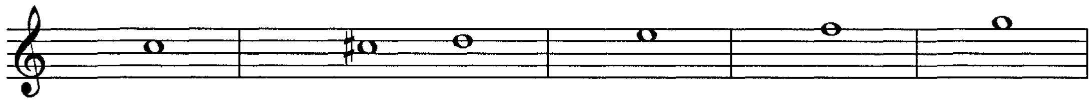
Pitch Tendencies and Adjustments
Oboe

Flat | Very Flat | Flat

Use RP3, more reed in mouth | More reed and air
Firm embouchure | More reed and air
Firm embouchure

Sharp | Flat or Sharp | Sharp | Sharp

Add low R3 key | Regular fingering | R1/R3/RP3 | Less reed
add R3 or RP1 | Add R3 and RP1

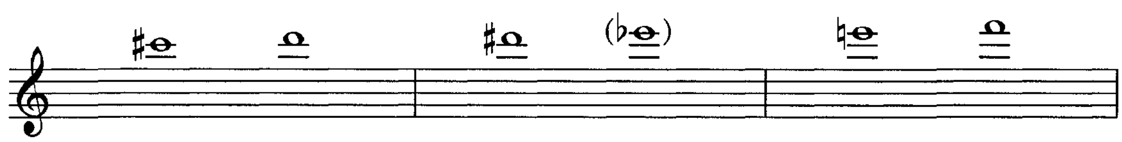


Very Sharp | Sharp | Sharp | Flat or Sharp | Sharp

Use less reed
Add RP1 or R1,
R2 and R3 | Use less reed | Add LP2 or
low B-flat key
if available | Add RP3 | Use R1
and R3
only | Add LP2

Flat | Flat | Very Flat

Use more reed,
add adjusting key
such as LP1 (experiment) | Use more reed, add adjusting key
(experiment) | Use more reed,
add adjusting key
(experiment)



Very Sharp | Flat | Sharp

Add LP2 | Multiple fingerings are available, depending on instrument
(experiment)

Bassoon

Due to the nature of its construction and playing condition, any bassoon can have many intonation problems. Because of a combination of acoustical and mechanical factors, it tends to have more out of tune notes than any other woodwind instrument. Sharpness is the most common problem; however, from middle C up to the F immediately above has a tendency to be flat.[78]

Some of the basic causes of bassoon sharpness and possible solutions are:

1. Poor embouchure formations. One should emphasize lowering the jaw, relaxing the lips and throat muscles (form the vowel "oh"), and lower the back of the tongue as if having your throat examined.

2. The reed is too hard. One should soften the reed or try another one. Hard reeds are often the cause of embouchure problems.

3. The bocal is too short. One should use a longer one (larger number). Pulling out the bocal or slightly pulling at the tenon joints will help lower the instrument. It is not possible to pull them out far enough to make a difference in the pitch. Bocals range from zero to four in length with zero being the shortest and four being the longest. Two is the standard length bocal.

4. Tension in the face and head muscles or shoulders, and twisting the body to the side will cause the pitch to go sharp even if the embouchure is correct. One should face straight ahead and work on relaxing the tense muscles.[79]

Some of the basic causes of bassoon flatness and possible solutions are:

1. Poor embouchure formations. One should emphasize lowering the jaw, relaxing

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[78] Westphal, 219.
[79] Ibid., 259.

the lips and throat muscles (form the vowel "oh"), and lower the back of the tongue as if having your throat examined. Emphasize keeping the lower lip parallel to the teeth and directly under the reed while keeping air out of the cheeks and lips. Shaping the vowel "ay" or "ee" in the throat can also raise the pitch.

2. One should strengthen the air stream.

3. The reed is too soft. One should harden the reed or try another one.

4. The bocal is too long. One should use a shorter one (smaller number).[80]

The bocal is an important component of bassoon intonation. It can also provide the bassoonist with a quick fix for overall flatness or sharpness. Bassoon bocals are made in different lengths to give the bassoonist a means to raise or lower the overall intonation of the instrument without having to alter their reed. The standard length, a number two bocal, is intended to play at A=440.

The reed contributes very much to the overall and relative intonation of the instrument. A good reed can do much to compensate for a poor instrument, but a good instrument cannot do much to overcome a poor reed.

Even when a bassoon is played with a well-tuned reed and the proper bocal has been selected, intonation problems on individual notes still exist.[81] The bassoon player must be aware of the pitch tendencies of each of the notes and registers of the bassoon. The reed must be flexible enough to allow embouchure adjustment of the pitch for the full range of the instrument, especially so that the player may accommodate certain sharping or flatting tendencies of the other instruments in the ensemble.

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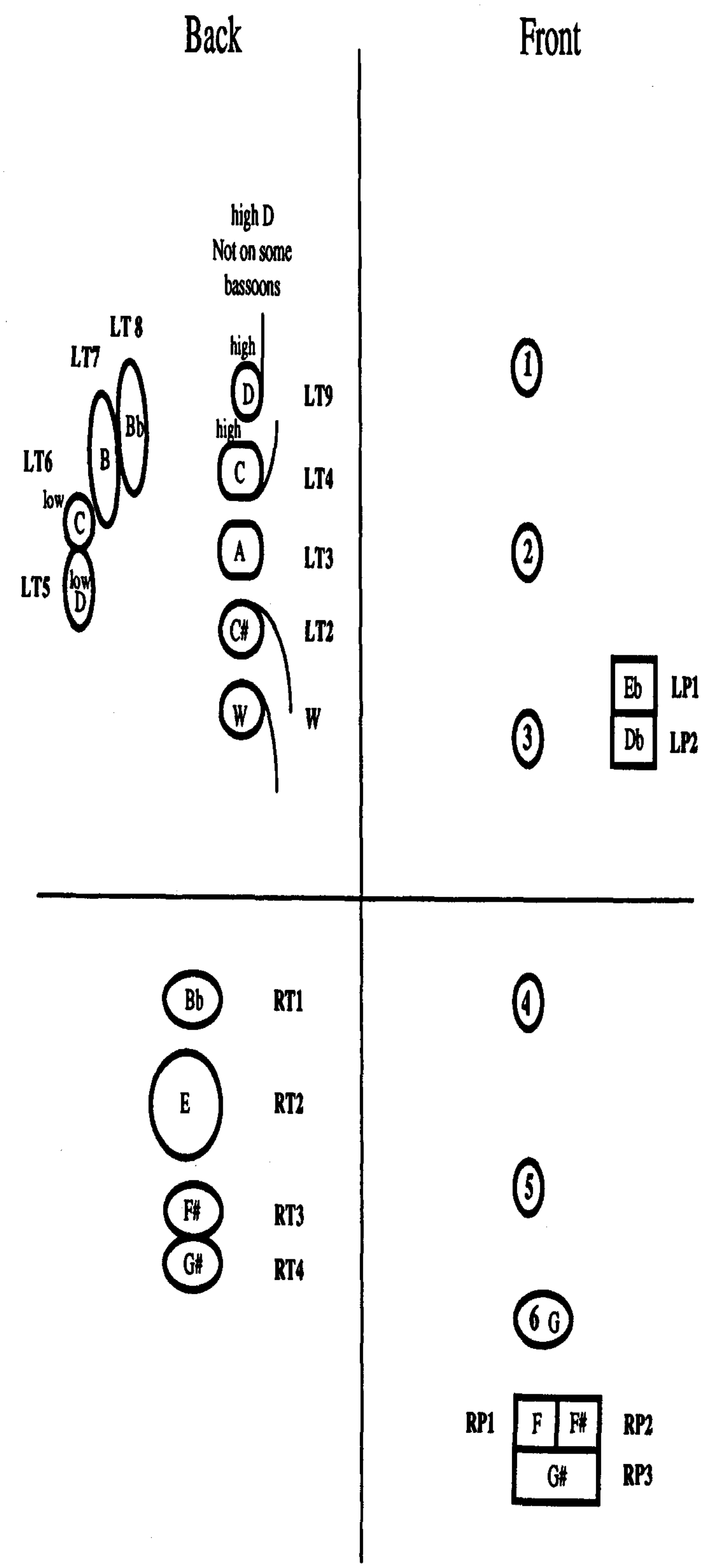
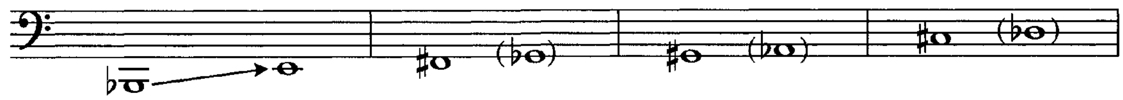
[80] Westphal, 237.
[81] Satuffer, 27.

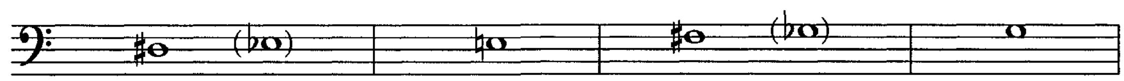


Bassoon fingering chart.
Trill keys not needed for basic fingerings are not included.

Pitch Tendencies and Adjustments
Bassoon

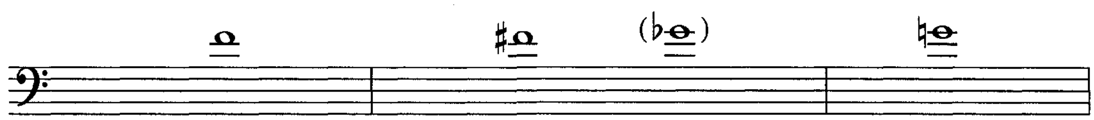


Sharp	Flat or Sharp	Flat or Sharp	Flat or Sharp
No alternate exists Drop jaw, open throat Check on adding tuning ring if extremely sharp	Could be either Use RT3 RP2 - alternate	Could be either Use RP3 RT4 - alternate	Could be either Stuffy and unstable Use W, LT2, LT5

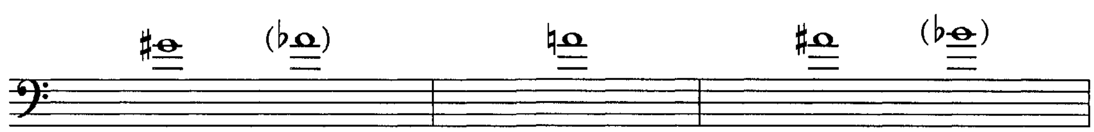


Flat	Flat	Very Sharp	Sharp
Unstable - Add 4, RT1 to W,1,3	Add 6 to W, 1 If still flat or unstable, reed is too soft or closed	Use RT3, W, 1/2 hole 1, 2,3,4,5,6, LP1. May need more open 1/2 hole to speak better	Use W, 1/2 hole1, 2,3,4,5,6, LP1

Sharp	Flat or Sharp	Flat	Flat
Use RP3, W, 1/2 hole 1,2,3,4,5,6	Could be either Unstable Add 5,6, RP1 to 1,2,3, LT2	Use 1,2,4,5,6	Use 1,3,4,5,6 and either LP1 or LP2



Flat	Flat or Sharp	Sharp
Use 1,3,4,5, plus either LP1 or LP2	Best: 2, LP1,4,5,RP1 Sharper: 2,3,4,5,RT1,LP1 or LP2 Flatter: 1/2 hole 1,2,3,4	Use W, 1/2hole 1,2,3,4, RP1



Sharp	Flat	Sharp
Use 1,2,3,6	Add LP1 or LP2 to LT2,LT3,1,2,3,6	Use LT2,LT3,1,2,3,4,5,RP1

Clarinet

The clarinet is a unique woodwind instrument in that the acoustical response of the instrument makes it impossible to produce the even-numbered partials of the harmonic series. Adding the register key to a fingering on the clarinet produces a note that is a twelfth above the lower note. The significance of this has to do with the tuning of notes in the even-tempered scale, because the harmonic series does not produce pitches of exactly the required frequency, other than the octave. Since the twelfths of the even-tempered scale are out of tune with natural harmonics, a clarinetist has greater inherent intonation problems than other woodwind instruments.[82]

Embouchure formation, the reed, the mouthpiece, the barrel, and breath support are all component influences on clarinet intonation. Frequently, the problems are caused by more than one of these factors.

An overall flatness of pitch may be caused by one or more of these factors:

1) A reed that is too soft.
2) Too much mouthpiece in the mouth.
3) The angle of the clarinet to the body is too great.
4) The embouchure is too loose.
5) Poor breath support.
6) Failure to compensate with the embouchure at loud dynamic levels.
7) The barrel is too long.[83]

An overall sharpness of pitch may be caused by one or more of these factors:

1) A reed that is too hard.

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[82] Westphal, 73.
[83] Church, 50.

2) The angle of the clarinet to the body is too small.

3) Failure to compensate with the embouchure at soft dynamic levels.

4) The embouchure is too tight.

5) Too little mouthpiece in the mouth.

6) The barrel is too short.[84]

Given that all of these factors are properly adhered to, intonation problems on individual notes still exist. The clarinet player must be aware of the pitch tendencies of each of the notes and registers of their instrument. There are basic principles used in making intonation adjustments.

1. In general, opening tone holes will raise the pitch and closing them will lower the pitch.

2. At least one tone hole below the last closed hole involved in the fingering must remain open.

3. The closer to the last tone hole that additional holes are opened or closed, the greater the effect on the pitch. Conversely, the further from this tone hole, the less effect on pitch.

4. More than one finger may be added to the basic fingering to correct pitch.[85]

The most frequent intonation problems occur in the "throat" tones (G through B-flat on the staff) of the clarinet. Alternate fingerings are normally not used in technical passages, but only in cases where the note is of sufficient duration that pitch and quality become high priorities.[86]

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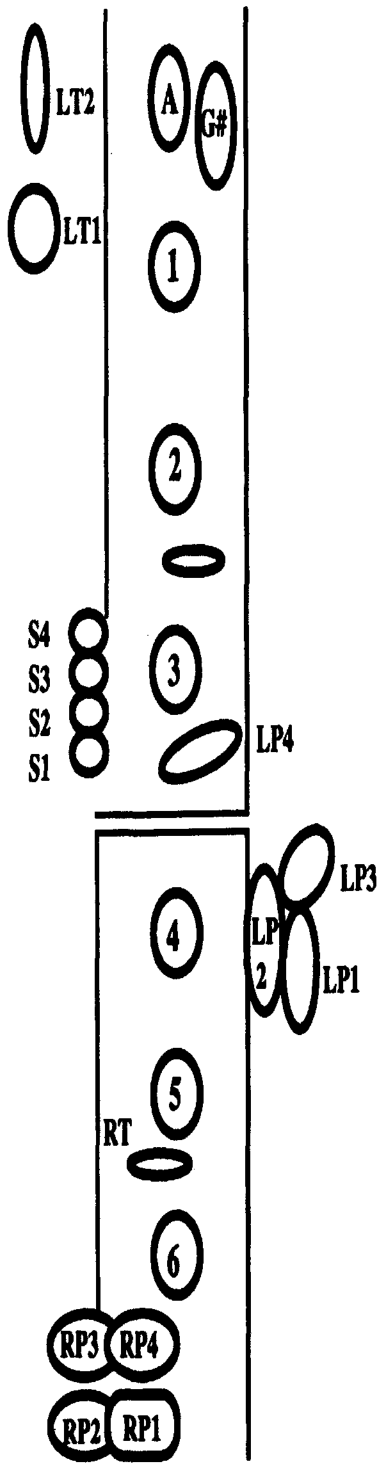
[84] Westphal, 73.
[85] Church, 50.
[86] Ibid., 48.

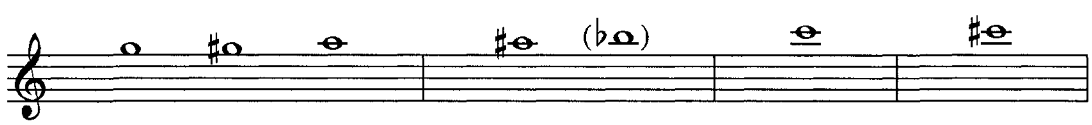


Clarinet fingering chart

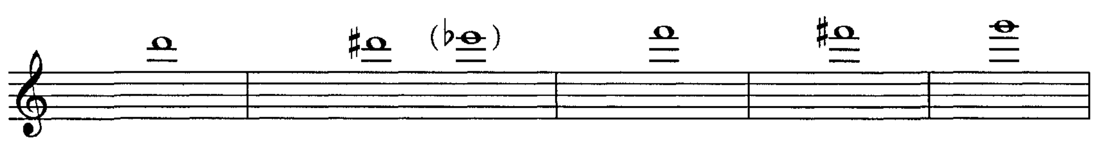
Pitch Tendencies and Adjustments
Clarinet

Flat	Flat	Flat	Flat
No fingering adjustment	1,2,3,4 and RT	Use 1 and 4	None

Flat	Sharp	Sharp	Very Sharp
LT1 and S1	Add 4,5,6	Use 3,4,5,6 and RP1	Use A and S4 or 3,4 and RP1



Sharp	Sharp	Sharp	Sharp
None	Use A and S4 or 1 and 4	None Possible shading of left hand	Half hole 1



Sharp	Sharp	Very Flat	Very Flat	Flat
Half hole 1	LT1, 1/2 hole 1,2,3 5 and RP4	LT1, 1,2,3, LP4 4,5,6	LT1, 1,2,4, 5,6, RP4	LT1, 2,4,5,RP4 or LT1, 1,4,RP4 or LT1, RP4

Saxophone

Acoustically, the normal range of the saxophone uses only pitches that are of the first harmonic. Since the octave harmonic is double the frequency rate of the fundamental in both the even-tempered and natural harmonic scale, every note on the saxophone should theoretically be in tune. However, the saxophone tends to flatness in the lower register and sharpness in the upper. The flatness of the lower register is most noticeable from C through E-flat. The upper register sharpness is apparent from C-sharp through F above the staff.[87]

Slight pitch adjustments on the normal playing range can be made by opening or closing one or more tone holes in addition to those involved in the standard fingering. The following basic principles apply:

1. In general, opening tone holes will raise the pitch and closing them will lower the pitch.
2. At least one tone hole, preferably two, below the last closed hole involved in the fingering must remain open.
3. The closer to the last tone hole that additional holes are open or closed, the greater the effect on the pitch will be. Conversely, the further from this tone hole, the less effect on pitch.
4. One or more finger may be added to the basic fingering to correct pitch.

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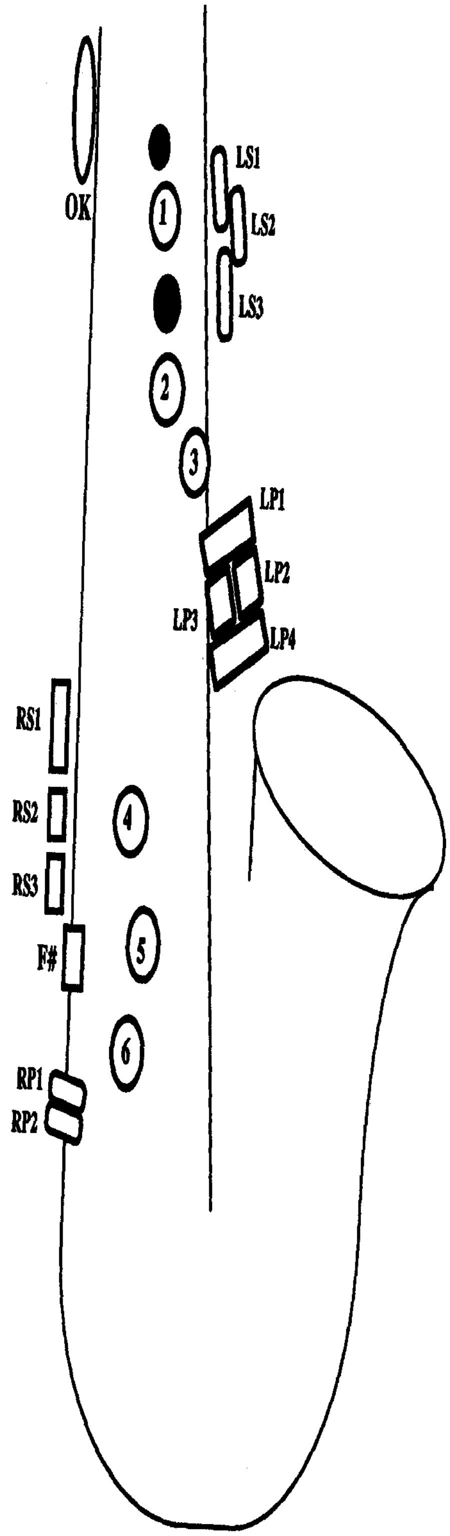
[87] Westphal, 139.



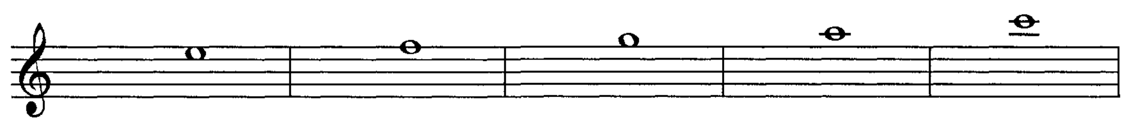
Saxophone fingering chart

Finger adjustments will tend to cause changes in timbre.

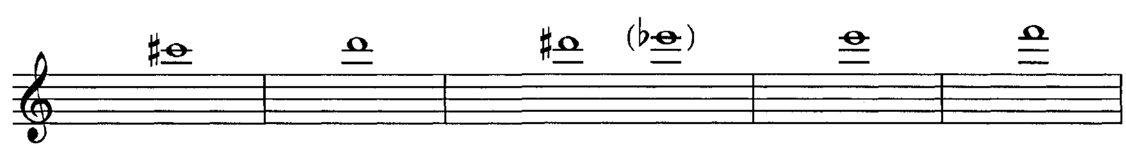
Pitch Tendencies and Adjustments
Alto Saxophone

Flat	Flat	Very Flat	Flat
None	Add LP2	Add LP2	Add LP3 or LP4

Flat	Very Flat	Sharp	Sharp
Add F-sharp key	Add RS2 or OK and 3	Add LP3	Add LP3



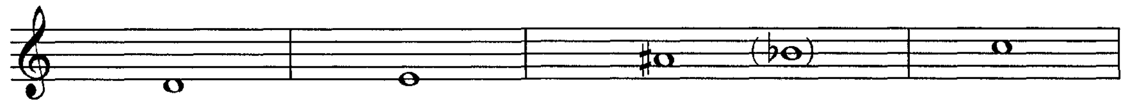
Very Sharp	Sharp	Sharp	Sharp	Sharp
Add LP4	Add RP2	Add RP2	Add 6	Add 4,5,6



Very Very Sharp	Very Sharp	Very Sharp	Very Very Sharp	Very Sharp
Use 4 and 6	Add 4,5,6	Close LS2	Close LS2 or use RP1	Close LS1

Finger adjustments will tend to cause changes in timbre.

Pitch Tendencies and Adjustments
Tenor Saxophone

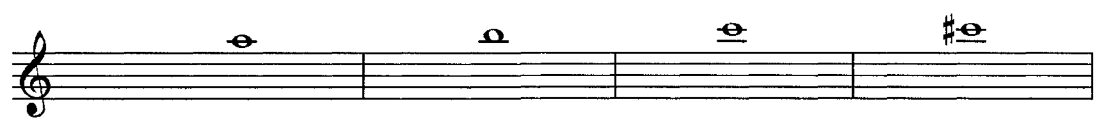


Flat Flat Flat Sharp

None Add RP1 Use LP1 Use 4,5,6

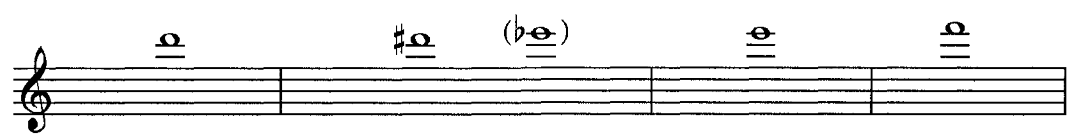
Sharp Very Sharp Sharp Very Sharp Sharp

Use 4,5,6 Use LP4 Use RP2 Use RP2 Use RP2 and LP4



Sharp Sharp Very Very Sharp Very Very Sharp

Use 6 None Use 4,5,6 Use 4 and 6



Very Sharp Very Sharp Very Very Sharp Very Sharp

Use 4,5,6 Close LS2 Close LS2 or use RP1 Close LS1

The woodwind fingering alterations given in the previous charts represent the most common ones. Many others are possible. Generally, the closing of a vent somewhere below the lowest open tone hole will lower the pitch of a given note, and opening a vent below the lowest open tone hole will raise it. Such alterations should only be used after every measure has been taken to ensure that the problem is not a result of poor tone production or mechanical adjustment.

CHAPTER IV

THE EFFECTS OF TEMPERATURE

Temperature has an important influence on pitch, so much so that Stauffer cautioned that it is the greatest variable in coping with band intonation.[88] Manufacturers specify a room temperature of 72° Fahrenheit (22°Celsius) as ideal for both tuning and performance. Unfortunately, such temperature conditions are not always possible in performance. Even so, the intonation problems associated with variations in air temperature represent a powerful reason why bands should warm-up and tune onstage and not be entirely dependent on back-stage warm-ups and tuning. Pottle found that room temperature usually rises above 72° at public concerts due to the multiple effects of warmth of 98.6° Fahrenheit radiating from the audience and the performing ensemble, and additional heat generated by auditorium and stage lights.[89]

Pottle conducted an experiment in which 2640 frequency measurements of tones on wind instruments were taken under various temperatures ranging from 60°F to 100°F. Measurements were made at ten degree temperature intervals and taken only after the instruments had been warmed up. It was found that a ten degree rise in temperature affects the tuning of several wind instruments by varying amounts, generally based on the size of the instrument. Pottle was able to determine that an increase in room temperature sharpens large wind instruments much more than small instruments. The results of Pottle's experiment are represented in the following chart.

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[88] Stauffer, 179.
[89] Hindsley, 28.

Instrument	60° to 70°	70° to 80°	80° to 90°	90° to 100°
Flute	+6.7	+6.2	+9.9	+10.0
Bb Clarinet	+4.3	+4.3	+4.1	+5.4
Bb Trumpet	+5.8	+6.2	+6.6	+7.3
Bb Bass Clarinet	+7.5	+8.5	+10.0	----
Eb Alto Saxophone	+7.5	+7.1	+6.5	+6.7
Bb Trombone	+7.2	+6.9	+7.8	+8.8
Horn in F	+7.3	+7.8	+9.5	+11.9
Bb Euphonium	+8.4	+9.1	----	----
Bbb Tuba	+14.2	+14.2	+14.2	+15.1
Vibraphone	----	-3.0	-1.8	-1.7
Xylophone	----	-6.0	-5.8	-4.3
Marimba	----	-5.8	-5.8	-4.0

Table 5. Mean intonation changes of various musical instruments due to increase in room temperature of ten degrees Fahrenheit. A plus sign (+) indicates amount sharp in cents. A minus sign (-) indicates amount flat in cents.[90]

In addition to the evidence of wind instruments going sharp as the temperature rises, Pottle's study also found that pitches produced by mallet instruments flattened slightly as temperature increased. As a result of this study Pottle concluded that the most desirable procedure is to make correction as the concert or rehearsal progresses by adjusting the tuning of the brass and other large wind instruments downward. This affords retention of the A-440 level, which is strongly advocated in normal situations. Pottle lists three salutary effects upon performance: 1) it permits and encourages the use

[90] Pottle, 30.

of the piano and organ when needed and of various mallet played and electronic instruments. 2) it permits the players of smaller instruments to employ a comfortable embouchure, thus enhancing tone quality and insuring optimum blend. 3) it permits these players to retain the normal "pull" on their instruments, resulting in markedly improved intonation in these instruments and throughout the ensemble.[91]

The Warm-Up

The evidence supports that the tuning frequency of wind instruments is affected by the temperature of the atmosphere in which they are played. A cold instrument will tend to play flat, while one exposed to higher temperatures will tend to play sharp. The air temperature inside the bore, rather than the instrument itself, is the critical factor since cold air is more dense than warm air. The cold air molecules provide greater resistance to the sound vibrations and thus lower the pitch. Metal instruments warm up and cool down faster than those made of wood. Those with large bores and longer tubing take even longer to change temperature. This is the reason why the intonation of the tuba section in particular will be most effected during rehearsal and performance. Tuning cold instruments cannot be very efficient, particularly because the pitch of different wind instruments rises by different amounts and at different rates during the warm-up process, and larger instruments require a little more time than the smaller ones.

Since the tonal air column is influenced in temperature jointly by that of the surrounding atmosphere and the breath of the player, the consideration of this second factor and its effect upon tuning becomes necessary. Blaikley explains it in this manner. "Whatever the outside temperature, the air inside an instrument near the mouthpiece will soon be raised to about 90°F (since the player's breath is 98.6°F), so that if we assume

[91] Pottle p.31

the temperature outside the instrument is 70°, the mean temperature in the instrument is something between 90° at the mouthpiece and 70° at the bell. The exact amount of variation varies in different instruments. The smaller the instrument, the more highly it is warmed by the breath.[92]

The speed of sound in air depends upon the temperature, and as air warms up the sound wave will travel faster. The warmer the temperature, the faster the sound moves. As a sound wave travels faster in a wind instrument, the frequency will increase making the instrument go sharp. Using the equation $v = fL$, the velocity of sound (v) is equal to frequency (f) times wavelength (L). The wavelength is determined by the physical size of the instrument and therefore, is fixed for each instrument. So, if the velocity increases, and wavelength is fixed, frequency must increase to balance the equation. Therefore, the higher the frequency, the higher the pitch.[93]

In an effort to determine the impact of warming up on the pitch level of wind instruments, Pottle devised an additional test in which 758 measures were made of tones played by skilled musicians both before and after their warm-up.

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[92] Pottle, 32.

[93] D.J. Blaikley, Acoustics in Relation to Wind Instruments (London: Boosey and Company, 1980), 36-37.

Instrument	60° F	70° F	80° F	90° F	100° F
Flute	+31.5	+14.2	+7.8	+4.3	-.3
Clarinet	+14.0	+10.2	+5.6	+3.3	----
Bass Clarinet	+20.5	+11.1	+7.8	+3.8	----
Bassoon	+20.0	+14.0	+13.0	----	----
Alto Saxophone	+10.8	+9.0	+6.6	----	----
Baritone Saxophone	+20.3	+12.3	+5.0	----	----
Trumpet	+20.2	+16.4	+7.6	+3.4	-.3
Horn in F	+13.6	+12.4	+5.0	+1.1	-2.3
Trombone	+20.6	+6.3	+4.2	----	----
Euphonium	+12.3	----	+4.0	----	----
Bbb Tuba	+10.3	+7.8	+1.0	+1.5	-2.3

Table 6. Mean frequency variations due to the "warm up" in tones played on wind instruments at five chosen temperatures. A plus sign (+) indicates amount sharp in cents. A minus sign (-) indicates amount flat in cents.

The above data supports the necessity of a thorough warm-up of wind instruments and indicates that wind players should warm up their instruments thoroughly prior to tuning while warm to A-440 before ensemble playing. The air column begins to cool immediately upon removal of contact with the player's breath. Therefore, it is necessary for wind instrumentalists to retain full warmth of their instrument during periods of rest in order to assure good intonation upon their reentry into the ensemble.

The effect of thorough warm-ups and tune-ups is certain to be immediate and positive. Hovey states, "If conductors expect nothing, that's what they'll get in return; if the aim is professional intonation, it may not be achieved, but results will be repaid in proportion to expectations."[94]

[94] Hovey, 7.

CHAPTER V

BAND INTONATION

It is crucial for conductors and performers to understand that tuning and intonation issues do not disappear after the warm-up and initial tuning process. They must understand that every instrument is different and that an instrument is never in tune with itself.[95] They must be aware of the notes on instruments that may be more out of tune than others, and that between any two instruments, the same notes are going to have different variances. The adjustment of instrument variances to the whole ensemble is a never-ending procedure. Ensemble conductors and performers must also understand that A=440 is only a reference point and that it cannot be a constant.[96] The pitch center will change as the ensemble continues to warm up and as embouchures fatigue.[97]

Tuning Guides

Mark Hindsley provides the following detailed tuning guides for all of the standard wind band instruments.[98]

Flute

This pitch should not be adjusted. The tone should be played straight and the headjoint should be adjusted until the pitch is in tune. In order to better assure that the

[95] Garofalo, 53.
[96] O.H. Jorgernsen, Tuning, (East Lancing, MI: Michigan State University Press, 1991), 22.
[97] James Jurrens, Tuning the Band and Raising Pitch Consciousness, (San Antonio, TX: RBC Publications, 1991), 15.
[98] Mark Hindsley, Hindsley on Bands, 7th ed. (Homewood, IL: Mark H. Hindsley, 1998), 99-101.

pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner:

The tones most affected by changes of pitch by the adjustment of the headjoint are those closest to it. All tones below the B-flat toward the foot joint are affected less and less by adjustments of the headjoint. After this tuning procedure has been completed, the tone-pitch production and general accuracy of the instrument should be checked as follows:

finger but make it sound

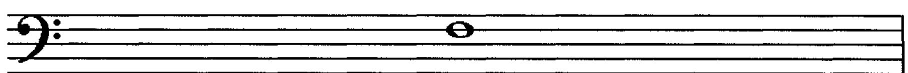
Repeat the B-flat with the normal fingering. The two pitches should be identical. The normal tendencies are flatness in the low register and sharpness in the upper register.[99]

Oboe

This pitch should not be adjusted. The tone should be played straight and the reed should be adjusted into or out of the instrument until it is in tune. This tone is near the top of the instrument and is one of the most sensitive to the adjustment of the reed. The following tones should be checked in order to make certain that they are exactly one-half step apart:

If the B and C are more than one-half step apart, and the B-flat and C are more than one step apart, this is an indication that there is too much reed in the mouth. This will result in a general sharpness in the high register and flatness in the low register. If they are less than one-half and one step apart, the reverse will be true.[100]

Bassoon



The pitch should not be adjusted. It should be played straight in order to determine if it is in tune with the established pitch. In order to better assure that the pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner:

For most bassoons this basic tuning must be accomplished by choosing the bocal of the correct length. It is imperative that the correct combination of reed and bocal be

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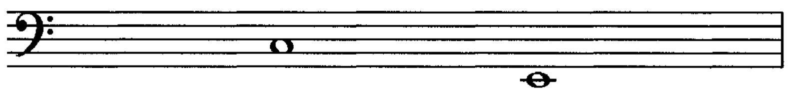
[99] Hindsley, 99.

determined. The bassoon should be tested on two other tones:

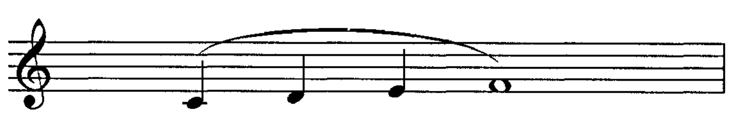


If the C is sharp, pull the tenor joint until it is in tune. If the E is sharp, pull the long joint until it is in tune.

For tones that are consistently out-of-tune when all mechanical adjustments have been made, alternate fingerings should be employed for use in sensitive situations.[101]

Clarinet

The pitch should not be adjusted. The tone should be played straight and adjustments made at the barrel until it is in tune. In order to better assure that the pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner:



The tuning note given is the highest fingering in the chalumeau register which is also normally used in the clarion register (producing high C). With the exception of the adjacent F-sharp through third-line B-flat, this fingering is the most sensitive to adjustment at the barrel. As more fingers are added, the tones become less sensitive to

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[100] Hindsley, 100.
[101] Hindsley, 101.

barrel tuning.

When the above procedure has been completed, the second-line G should be checked. If this tone is sharp, the middle of the instrument should be pulled until it is in tune. The third line B should then be checked and an outward adjustment of the bell should be made if this tone is sharp.[102]

Saxophone

The pitch should not be adjusted. The tone should be played straight and adjustments made at the mouthpiece or neck until it is in tune. In order to better assure that the pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner:

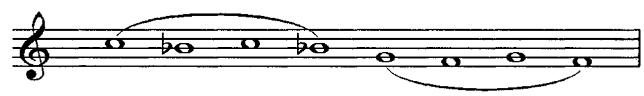
This note is chosen for tuning because it is almost at the top of the instrument, and therefore, one of the most sensitive to adjustment of tube length.[103]

Horn

The pitch should not be adjusted. The tone should be played straight and adjustments made at the tuning slide until it is in tune. The B-flat and F sides of the double horn should be tuned to the same tone (concert F). On both horns it is

[102] Hindsley, 102.
[103] Hindsley, 103.

recommended that the first and second valves be tuned exactly one step and one-half step respectively below the open tones. On the F side, the second and third valve combination should be tuned exactly two steps below the open tone. On the B-flat side, the third valve should be tuned alone to play exactly one and one-half steps below the open tone. The setting of the tuning slides may be tested in the following manner:



F Horn First Valve

F Horn Second Valve

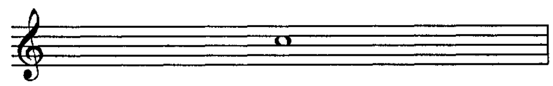
F Horn Second and Third Valves

B-flat Horn First Valve

B-flat Horn Second Valve

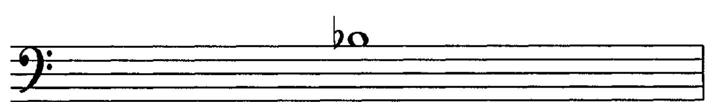
B-flat Horn Third Valve[104]

Trumpet

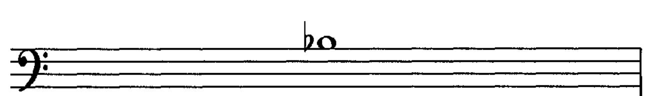


The pitch should not be adjusted. The tone should be played straight and adjustments made at the tuning slide until it is in tune. In order to better assure that the pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner[105]:

Trombone



The pitch should not be adjusted. The tone should be played straight and adjustments made at the tuning slide until it is in tune. In order to better assure that the pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner[106]:



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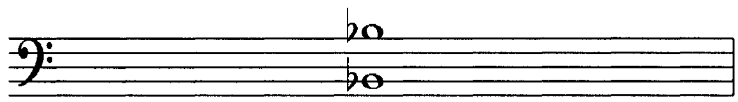
[104] Hindsley, 106.
[105] Hindsley, 104.
[106] Hindsley, 105.

Euphonium and Tuba



The pitch should not be adjusted. The tone should be played straight and adjustments made at the tuning slide until it is in tune. In order to better assure that the pitch is the same as it would be produced when performed with a band, it should be approached from below, in the following manner:

In order to tune the fourth valve, the third harmonic F should be played on the open tube. The fourth valve should then be engaged and the pitch should match. If the pitch produced is sharp or flat, adjustment should be made at the fourth-valve tuning slide.[107]

Tuning Charts

The use of a high quality tuner is a tremendous aid for a conductor seeking superior intonation. Conductors must realize, however, that a tuner reflects only the tempered scale.[108] Therefore, it cannot take into account such things as raised leading tones. A tuner's main ability is to show intonation deficiencies and to make comparisons. There is no substitute for conductors and individual players knowing which notes are characteristically sharp or flat, and to what degree. One way for individual players to

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[107] Hindsley, 108.
[108] Pottle, 77.

acquire this understanding is by completing a tuning chart. It requires that each player establish a pitch level at A=440. As one performer plays the chromatic scale, another utilizes a tuner to determine the number of cents that each pitch deviates from being in tune.[109] This data may be recorded on a chart similar to the following:

Acoustical Considerations

Superior ensemble intonation is largely due to the understanding and implementation of the fundamental principles of acoustics. The process of correcting faulty intonation in ensemble performance involves constant listening for the presence of acoustical beats and quick elimination of the pulsation by adjustment techniques. This acoustical phenomenon is a result of the interference of two sound waves with slightly

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[109] Stauffer, 35.

different frequencies. Once beats are heard, it must be determined if the pitch is sharp or flat in reference to other players. If unsure, slight adjustments should be made upward or downward using physical or mechanical techniques appropriate for each instrument. If the beats become faster, the adjustment has been made in the wrong direction and an adjustment should be made in the reverse direction.[110] The use of just intonation is utilized in order to achieve "beatless" triads. Therefore, acceptable intonation of each chord member should be adjusted in the following manner:

1) Roots should be tuned in accordance with equal temperament.

2) Major thirds should be adjusted 14 cents flat.

3) Minor thirds should be adjusted 16 cents sharp.

4) Perfect fifths should be adjusted two cents sharp.

5) Minor sevenths should be adjusted 29 cents flat.

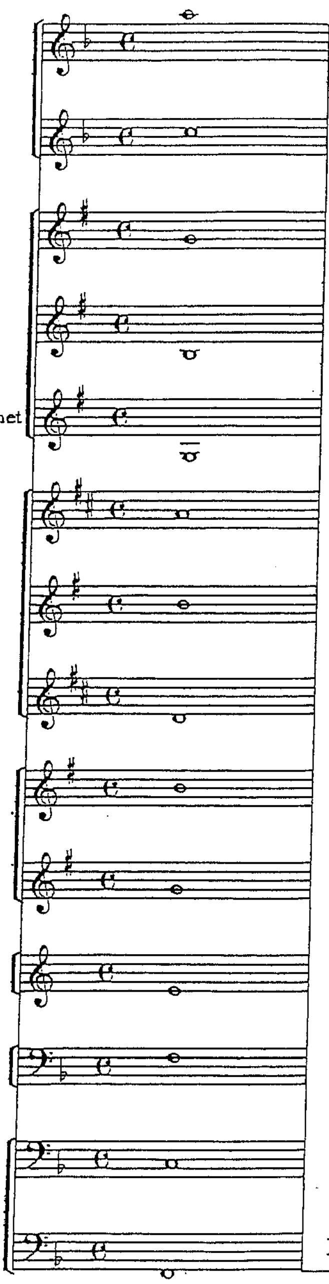
6) Major sevenths should be adjusted 12 cents flat.

7) Major ninths should be adjusted four cents sharp.

8) Compound multi-voice chords should be tuned as separate triads.[111]

The following examples illustrate common problems in wind band intonation and provide possible solutions. The chords in these examples are referenced according to their proper placement in just intonation. The pitch tendency of the corresponding instrument and physical adjustments are also notated.

[110] James Burns, "Some Acoustical Principles Affecting the Intonation of Band Instruments", (EDD diss., Farleigh Dickinson University, 1984), 37.
[111] Fabrizio, 23.



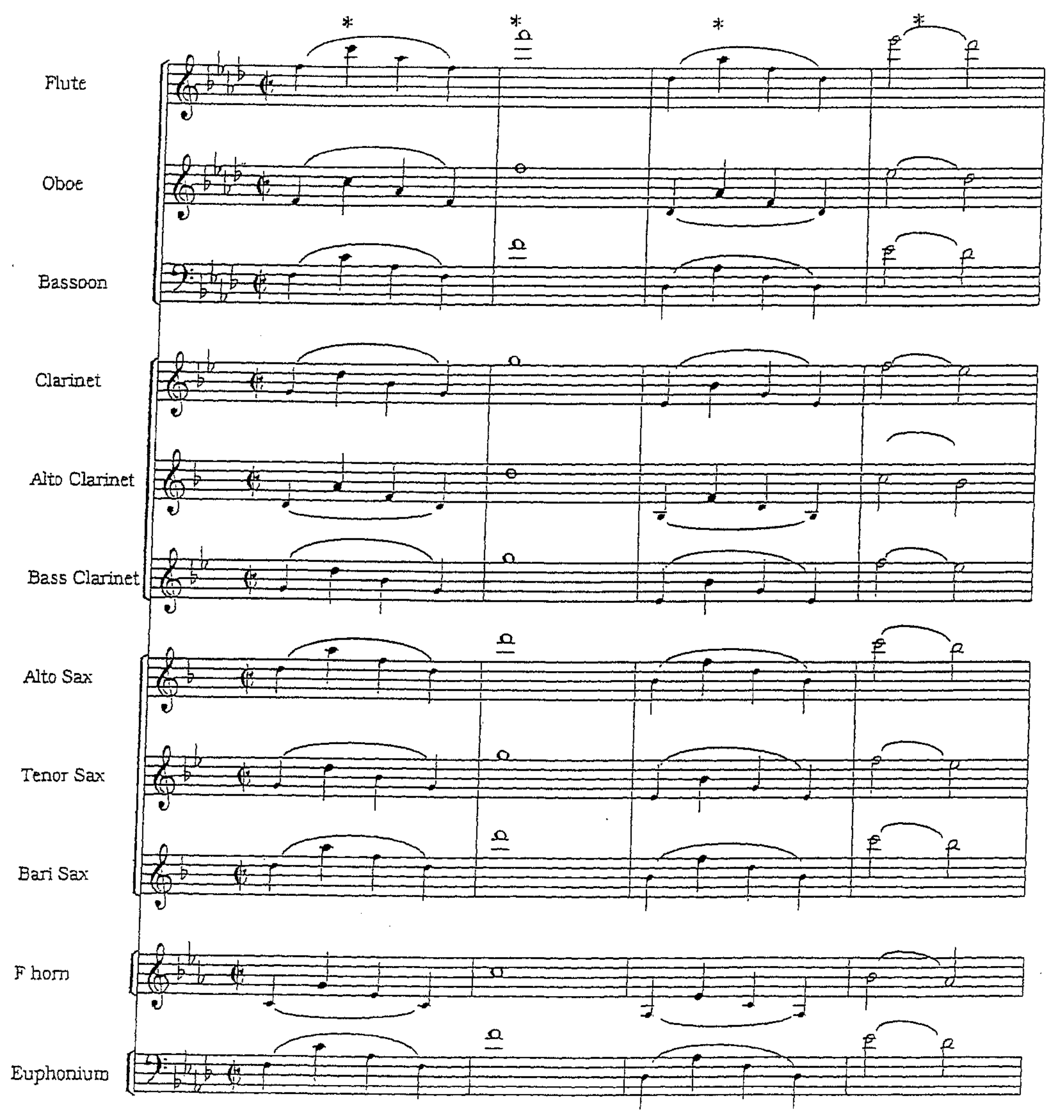
Instrument	Just Intonation	Pitch Tendency	Adjustment
Flute	3rd (-14)	sharp	Blow down into embouchure hole
Oboe	5th (+2)	sharp	Less reed in mouth or add C key or right hand
Clarinet 1	Root	sharp	Add right hand
Clarinet 2	3rd (-14)	ok	Use sliver key
Bass Clarinet	Root	flat	Lip up
Alto Sax	5th (+2)	sharp	Lip down
Tenor Sax	3rd (-14)	ok	Lip down
Bari Sax.	Root	flat	Lip up
Trumpet 1	3rd (-14)	sharp	Lip down
Trumpet 2	Root	flat	ok
F Horn	3rd (-14)	sharp	More hand in bell, Open throat
Trombone	Root	sharp	Lower slide
Euphonium Bassoon	5th (+2)	Euph. sharp Bsn. ok	Use 4th valve ok
Basses	Root	sharp	Drop jaw

Example 1. F major chord acoustical considerations.

	Just Intonation	Pitch Tendency	Adjustment
Flute	9th (+4)	flat	Half hole 3rd finger left hand
Oboe	9th (+4)	sharp	Less reed in mouth
Clarinet 1	5th (+2) 4th (-2)	both very sharp	Right hand down
Clarinet 2	E 9th (+4) C 7th (-29)	flat ok	Lip up E Lip down C, shade
Bass Clarinet	Root	ok	ok
Alto Sax	4th	sharp	Add low B key
Tenor Sax	5th (+2)	sharp	ok
Bari Sax	Root	sharp	Add 3rd finger of right hand
Trumpet 1	9th (+4)	flat	Use 1st & 2nd and pull 1st valve slide or use 3rd valve
Trumpet 2	7th (-29)	sharp	Drop jaw
F Horn	7th (-29)	sharp	Add hand, drop jaw
Trombone	5th (+2)	ok	ok
Euphonium Bassoon	Root	Euph. sharp Bsn. ok	Use 4th valve ok
Basses	Root	Top flat Bottom sharp	Use 1st & 3rd or 4th Use 4th valve

Example 2. Acoustical considerations (Dominant 7th and 9th).

Unison lines in multiple instruments present a problem due to varying degrees of pitch tendencies caused by tessitura and unrelated keyed instruments. It should first be determined what instrument or groups of instruments are the strongest influence on a particular note.



Example 3. Unison lines.

Measure one, second note: Adjust pitches by the use of alternate fingerings. Tune to the F Horn "G" and Clarinet "D".

Flute	C	Sharp
Oboe	C	Sharp
Bassoon	C	Flat
Clarinet	D	Ok
Alto Clarinet	D	Ok
Alto Saxophone	A	Very sharp
Tenor Saxophone	D	Sharp
Bari Saxophone	A	Very sharp
F Horn	G	Ok
Euphonium	C	Flat

Measure two. Adjust pitches by the use of alternate fingerings. Since there are no stable notes on any of the given instrument, it is necessary to secure a sustained concert F.

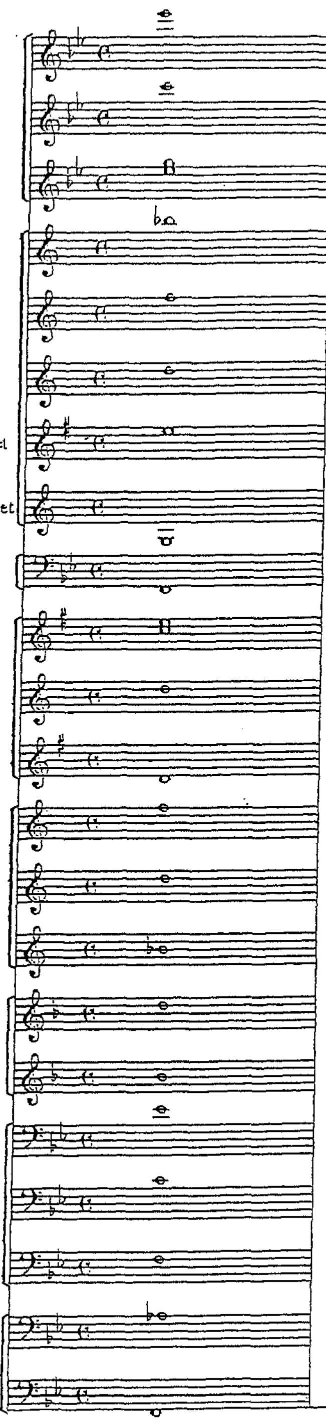
Flute	F	Flat
Oboe	F	Sharp
Bassoon	F	Flat
Clarinet	G	Sharp
Alto Clarinet	D	Very sharp
Bass Clarinet	G	Sharp
Alto Saxophone	D	Very sharp
Tenor Saxophone	G	Sharp
Bari Saxophone	D	Sharp
F Horn	C	Sharp
Euphonium	F	Very sharp

Measure 3, second note. Adjust pitches by the use of alternate fingerings. Tune to the F horn, euphonium, and tenor saxophone.

Flute	Ab	Ok
Oboe	Ab	Ok
Bassoon	Ab	Sharp
Clarinet	Bb	Very sharp
Alto Clarinet	F	Ok
Bass Clarinet	Bb	Very sharp
Alto Saxophone	F	Sharp
Tenor Saxophone	Bb	Sharp
Bari Saxophone	F	Sharp
F Horn	Eb	Ok
Euphonium	Ab	Slightly flat

Measure four. Adjust pitches by the use of alternate fingerings. Tune to the F Horn.

Flute	Eb	Ok	Db	Very sharp
Oboe	Eb	Sharp	Db	Sharp
Bassoon	Eb	Flat	Db	Flat or sharp
Clarinet	F	Ok	Eb	Ok
Alto Clarinet	C	Sharp	Bb	Very sharp
Bass Clarinet	F	Ok	Eb	Ok
Alto Saxophone	C	Sharp	Bb	Ok
Tenor Saxophone	F	Sharp	Eb	Sharp
Bari Saxophone	C	Flat	Bb	Flat
F Horn	Bb	Ok	Ab	Ok
Euphonium	Eb	Sharp	Db	Ok



Instrument	Just Intonation	Pitch Tendency	Adjustment
Piccolo	Dom 7th (-29)	sharp	Blow down & roll in
Flute	5th (+2)	very sharp	Add 3rd finger of left hand, blow down
Oboe	9th (+4) Dom 7th (-29)	sharp sharp	Should be close Less reed, drop jaw less air
Clarinet 1	Minor 3rd (+16)	sharp	Close, use sliver key
Clarinet 2	Dom 7th (-29)	ok	Lip down and shade right hand
Clarinet 3	5th (+2)	ok	Should be close
Alto Clarinet	9th (+4)	sharp	Lip down slightly
Bass Clarinet	Root	flat	Lip up
Bassoon	Root	ok	Should be close
Alto Sax	9th (+4) Dom 7th (-29)	very sharp flat	Lip down, add B key Lip down more
Tenor Sax	5th (+4)	sharp	Lip down, add B key
Bari Sax	Root	flat	Lip up
Trumpet 1	Dom 7th (-29)	sharp	Pull 1st valve slide
Trumpet 2	5th (+4)	flat	Use 1st & 3rd valve
Trumpet 3	Minor 3rd (+16)	flat	Lip up (May not be enough
F Horn 1	9th (+4)	sharp	3rd valve & hand
F Horn 2	Dom 7th (-29)	sharp	Use F horn & more hand
Trombone 1	Dom 7th (-29)	sharp	Lower 3rd
Trombone 2	5th (+2)	ok	Should be close
Trombone 3	Root	sharp	Lower 1st
Euphonium	Minor 3rd (+16)	flat	Lip up (May not be enough)
Tuba	Root	sharp	Lip down

Example 4. F minor nine chord.

CHAPTER VI

CONCLUSION: CLARITY THROUGH INTONATION

Attempting to achieve good intonation must be incorporated into the daily routine of any musical ensemble. In his book, *Rehearsing the Band,* John E. Williamson compiles thoughts and advice from eleven of the country's more successful wind band conductors. The bulk of the advice of these educators addresses tuning, intonation, and tone production; and that these elements should not be separated.[112] Conductors can do nothing physically to affect any changes to these elements; they are the player's responsibilities. While it is possible for a conductor to stop and make verbal corrections as they arise in rehearsal, it is impossible to do the same in the middle of a performance. Ideally, conductors must strive to train their ensembles to learn to identify problems and to make the proper adjustments on their own.

W. Francis McBeth argues that the one factor of intonation and pitch that looms above all others is that pitch is a direct result of balance. Simply described, his concept of balance requires that the lower the voice line, the louder the volume. His claim is acoustically grounded in that in any given composite sound the fundamental is perceived as the loudest element while the upper partials decrease in volume.[113] Using his concept of balance, each player tunes to a lower part with the exception of the instrument providing the bass voice. If the bass voice, or fundamental, is wrong, then it is impossible for upper partials to be correct. It should not be assumed, however, that the lowest voice sounding at any given time always produces the fundamental of the chord. McBeth's conception of listening downward should only be utilized as a starting point as younger

[112] John Williamson, Rehearsing the Band (Cloudcroft, NM: Heidig Services, 1998), 85.

players learn to whom and for what they are to listen.

Good wind band intonation can only result from constant listening by every member of the ensemble. The proper placement of each note performed is determined by harmonic (correct intervallic relationships with other chord tones) and melodic (correct intervallic relationship with the notes that precede and follow) considerations. Ensemble performers must constantly be alert to each of these considerations and adjust as necessary to resolve discrepancies as they occur.

This process should be approached at successively higher levels as the preparation of a particular piece of literature progresses. The isolation of unison or octave lines is a vital starting point of the preparation of any selection. Conductors must solve intonation problems of noticeably out-of-tune notes by checking individual notes with a tuner as they occur. Some performers may be required to employ alternate fingerings, to lip the pitch up or down, or to adjust the tuning slide. Once a consensus has been achieved, the line should be performed from the beginning of the phrase. Once the problem note is reached and properly adjusted, it should be sustained. This process should be repeated until all performers are consistently able to immediately pinpoint the proper pitch.

Intonation is a basic element of performance. Therefore, dealing with intonation problems should not be ignored at any level. This skill requires careful listening and the ability to adjust pitches quickly while playing. The ability to adjust pitches requires a knowledge of the techniques involved and an understanding of the intonation deficiencies and tendencies of instruments. Prior to the application of any of this knowledge in performance, instruments must be precisely tuned; and this requires an understanding and

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[113] McBeth, W. Francis, Effective Performance of Band Music: Solutions to Specific Problems in the Performance of 20th Century Band Music (San Antonio, TX: Southern Music Company, 1972),7-9.

knowledge of the tuning process for each family of instruments. Understanding factors that can cause poor intonation in ensemble performance and a knowledge of acoustics of musical instruments provides a conductor with a foundation for developing strategies to reinforce good intonation.

Although pitch varies with temperature, dynamic level, mechanical equipment, range, and scale temperament, general agreement can be reached as to what is approximately in tune. When an ensemble reaches this agreement, it produces a clear sound; without agreement it produces a muddy sound. Whereas tuning is the process of adjusting one's instrument to the correct length of tubing, intonation is the process of playing an instrument with a pitch that matches those of others.

Attaining superior wind band intonation is a direct result of the conductor's knowledge and his ability to convey this knowledge to the performers. The primary requisite to success in this area is the ability of a conductor to recognize pitch discrepancies. It must be accompanied by a knowledge of effective solutions for intonation problems and the ability to communicate solutions to the ensemble. Finally, a conductor must possess an unrelenting determination to accept nothing less than superior intonation.

APPENDIX A

COURSE SYLLABUS

Course: Undergraduate Conducting

Instructor: D. Bradley Snow

Course Description:

Development of techniques used in conducting instrumental ensembles. Course includes in-depth study and development of conducting skills, rehearsal techniques, the study of wind instrument deficiencies, and the study and preparation of scores.

Required Texts:

Green, Elizabeth A.H. *The Modern Conductor*. 6th edition. Upper Saddle River, NJ: Prentice-Hall, 1997.

Labuta, Joseph A. *Basic Conducting Techniques*. 4th edition. Upper Saddle River, NJ: Prentice-Hall, 2000.

Supplementary Materials:

Conducting Baton - 14" is preferred
May be obtained from:
Newland Custom Batons
2254 Seventh Street
Cuyahoga Falls, OH 44221
1-800-272-6561
www.newlandbatons.com

Video Tape

Optional Supplemental Readings:

Hunsberger D., Ernst Roy E. *The Art of Conducting*. 2nd edition. New York: McGraw-Hill, 1992.

Lisk, Edward S. *The Creative Director: Alternative Rehearsal Techniques*. 3rd edition. Ft. Lauderdale, FL: Meredith Music Publications, 1991.

McBeth, W. Francis. *Effective Performance of Band Music: Solutions to Specific Problems in the Performance of 20th Century Band Music*. San Antonio, TX: Southern Music Company, 1972.

Course Content:

Week One
- Introduction and Course Overview
- Holding the Baton
- Preparatory Position
- Standard Conducting Patterns (Labuta p.17)
- Musical Excerpts (Labuta pp.83-84)

Week Two
- Beat Patterns and Preparations
- Instrument Transpositions
- Musical Excerpts (Labuta pp.85-89)

Week Three
- Preparations and Releases on All Counts
- Musical Excerpts (Labuta pp. 100-111)

Week Four
- Fractional Beat Preparations
- Terminology (Green p.271)
- Musical Excerpts (Labuta pp. 112-118)
- First Video Tape Evaluation

Week Five
- Divided Meters
- Conducting Musical Style - Part 1
- Musical Excerpts (Labuta pp. 119-131)
- Instrument Deficiencies - Brass

Week Six
- Conducting Musical Style - Part 2
- Musical Excerpts (Labuta pp. 132-145)
- Instrument Deficiencies - Woodwinds

Week Seven
- Fermata
- Instrument Deficiencies - Percussion
- Mid-term Examination
  - Instrument Transpositions
  - Terminology
  - Standard Conducting Patterns

Week Eight

- Cueing - Part 1
- Left Hand - Part 1
- Tempo - Part 1
- Musical Excerpts (Labuta pp. 168-179)

Week Nine

- Cueing - Part 2
- Left Hand - Part 2
- Tempo - Part 2

Week Ten

- Second Video Tape Evaluation

Week Eleven

- Score Preparation and Analysis - Part 1
- Tuning

Week Twelve

- Score Preparation and Analysis - Part 2
- Marking the Score
- Rehearsal Outlines

Week Thirteen

- Rehearsal Techniques
- Tuners
- Metronomes

Week Fourteen

- Comprehensive Examination
- Third Video Tape Evaluation

Grading:

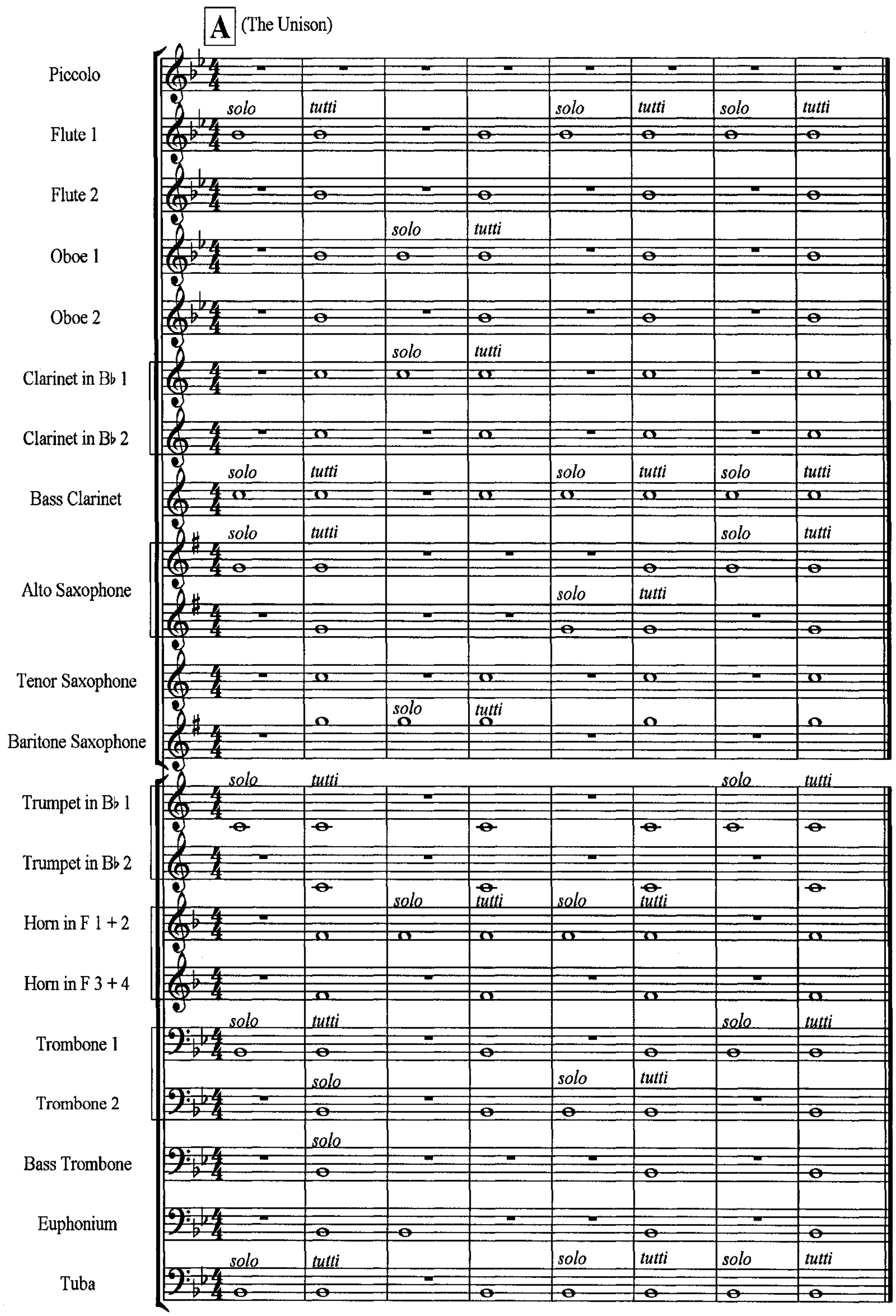
Daily Participation	25%
Mid-Term Examination	25%
Video Tape Evaluations	10%
Final Examination	40%

Attendance is expected and will be considered as part of the daily participation grade.

APPENDIX B

TUNING EXERCISES

Basic Tuning Exercises for Wind Band




B
(The Octave)
9
Picc.
Fl. 1
Fl. 2
Ob. 1
Ob. 2
Cl. 1
Cl. 2
B. Cl.
A. Sax.
T. Sax.
B. Sax.
Tpt.
Tpt.
Hn. 1 + 2
Hn. 3 + 4
Tbn. 1
Tbn. 2
B. Tbn.
Euph.
Tba.
solo
tutti


C (Fourths and Fifths)
17
Picc.
Fl. 1
Fl. 2
Ob. 1
Ob. 2
Cl. 1
Cl. 2
B. Cl.
A. Sax.
T. Sax.
B. Sax.
Tpt.
Tpt.
Hn. 1 + 2
Hn. 3 + 4
Tbn. 1
Tbn. 2
B. Tbn.
Euph.
Tba.


4
D (Major Third)
25
Picc.
Fl. 1
Fl. 2
Ob. 1
Ob. 2
Cl. 1
Cl. 2
B. Cl.
A. Sax.
T. Sax.
B. Sax.
Tpt.
Tpt.
Hn. 1 + 2
Hn. 3 + 4
Tbn. 1
Tbn. 2
B. Tbn.
Euph.
Tba.

E (Minor Third)
35
Picc.
Fl. 1
Fl. 2
Ob. 1
Ob. 2
Cl. 1
Cl. 2
B. Cl.
A. Sax.
T. Sax.
B. Sax.
Tpt.
Tpt.
Hn. 1 + 2
Hn. 3 + 4
Tbn. 1
Tbn. 2
B. Tbn.
Euph.
Tba.

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