THE DEVELOPMENT OF WOODWIND FINGERING SYSTEMS:
A LECTURE RECITAL, TOGETHER WITH THREE
RECITALS OF SELECTED SOLO AND
ENSEMBLE WORKS FOR BASSOON

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF MUSICAL ARTS

By

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Denton, Texas
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The lecture-recital, The Development of Woodwind Fingering Systems, traces the evolution of devices for controlling the pitch produced by woodwind instruments from prehistoric times to the present. The addition of keys, and the evolution of collections of individual keys into coordinated systems is particularly stressed, as are the various physical, physiological, and cultural forces which determined the directions of development of these systems.

The similarities between the fingerings of various woodwind instruments are explained, a system of numbers is introduced in order to clarify these similarities, and a projection of some possibilities for future development of woodwind fingering systems is offered.
Tape recordings of all performances submitted as dissertation requirements are on deposit in the North Texas State University Library.
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INTRODUCTION

This dissertation consists of four recitals: one lecture-recital, two recitals for solo bassoon, and one chamber music recital. The repertoire for these programs was selected to include most of the better-known solo works for bassoon, particularly the concertos of W. A. Mozart and C. M. von Weber, as well as several little-known works.

The lecture-recital, The Development of Woodwind Fingering Systems, traces the evolution of devices for controlling the pitch produced by woodwind instruments from prehistoric times to the present. The addition of keys, and the evolution of collections of individual keys into coordinated systems is particularly stressed, as are the various physical, physiological, and cultural forces which determined the directions of development of these systems.

The similarities between the fingerings of various woodwind instruments are explained, a system of numbers is introduced in order to clarify these similarities, and a projection of some possibilities for future development of woodwind fingering systems is offered.
NORTH TEXAS STATE UNIVERSITY
SCHOOL OF MUSIC

presents

JERRY VOORHEES

in a

GRADUATE BASSOON RECITAL

assisted by

SISTER NATALIA DA ROZA, Pianist

Tuesday, May 5, 1970 8:15 p.m.  Choir Room

Johann Christian Bach ......................Concerto in B-flat Major
   Allegro
   Adagio
   Presto

René Duclos ......................................Trois Nocturnes
   I Minh
   II Apak
   III Nieves

INTERMISSION

Louis Spohr ........................................Adagio

Carl Maria Von Weber .............................Concerto in F Major
   Allegro ma non troppo
   Adagio
   Rondo (allegro)

Presented in partial fulfillment of the requirements for the degree
Doctor of Musical Arts
NORTH TEXAS STATE UNIVERSITY
SCHOOL OF MUSIC

Presents

JERRY VOORHEES

in a

GRADUATE BASSOON RECITAL

assisted by

NATALIA DA ROZA, Pianist

Wednesday, September 30, 1970 8:15 p.m. Recital Hall

Antonio Vivaldi ................................................ Concerto in D Minor
  Allegro
  Larghetto
  Allegro molto

W. A. Mozart ......................... Concerto in B-flat Major, K.V. 191
  Allegro
  Andante ma adagio
  Rondo (Tempo di Minuetto)

INTERMISSION

Georg Philipp Telemann ...................... Sonata in E-flat Major
  Cantabile
  Allegro
  Grave
  Vivace giocoso

Gabriel Pierné .............................. Solo de Concert, Op. 35.

Presented in partial fulfillment of the requirements
for the degree Doctor of Musical Arts
NORTH TEXAS STATE UNIVERSITY
SCHOOL OF MUSIC

presents

Jerry Voorhees, Bassoonist

in a

LECTURE RECITAL

assisted by

NATALIA DA ROZA, Piano and Harpsichord
MARILYN RIEZ, Viola da Gamba

THE DEVELOPMENT OF
WOODWIND FINGERING SYSTEMS

Wednesday, February 17, 1971

8:15 p.m.

Choral Room 165

George Frederick Handel ................. Sonata in C Major, Op. 1, 7
for Recorder and Basso Continuo

Larghetto
Allegro
Larghetto
A Tempo di Gavotti
Allegro

Paul Hindemith ......................... Sonata for Bassoon and Piano

Leicht bewegt
Langsam
March
Beschluss, Pastorale-Ruhig

*Presented in partial fulfillment of the requirements for the degree
Doctor of Musical Arts*
NORTH TEXAS STATE UNIVERSITY
SCHOOL OF MUSIC
presents

JERRY VOORHEES, Bassoonist

in a

Graduate Chamber Music Recital

assisted by

Natalia da Roza, piano and harpsichord
Carole Farrar, flute
Carol Mizell, oboe
Jesse Youngblood, clarinet
Rule Beasley, bassoon
Janet Parmelee, bassoon
Kelbert Taylor, bassoon
Maurice Rhynard, horn

Carol Farrar, flute
Carol Mizell, oboe
Jesse Youngblood, clarinet
Kelbert Taylor, bassoon
Maurice Rhynard, horn

Monday, April 26, 1971 6:30 p.m. Music Hall 100

Ludwig van Beethoven ................. Duo I for clarinet and bassoon
Allegro commodo
Larghetto sostenuto
Rondo

Ludwig van Beethoven ............... Trio for flute, bassoon, and piano
Allegro
Adagio
Thema andante con variazioni

INTERMISSION

Michel Corette ... Quartet (Le Phenix) for four bassoons and harpsichord
Allegro
Adagio
Allegro

Paul Taffanel ...................... Quintette pour instruments à vent
Allegro con moto
Andante
Vivace

*Faculty, N.T.S.U. School of Music

Presented in partial fulfillment of the requirements
for the degree Doctor of Musical Arts
THE DEVELOPMENT OF WOODWIND FINGERING SYSTEMS

Two characteristics are present in all modern instruments now considered to be woodwinds: first, in all woodwinds, the sound is generated either by means of a reed, or by splitting an air column whistle-fashion; and second, the tubes of all woodwinds are pierced with lateral holes which may be opened or closed by the fingers or by mechanism in order to regulate the pitch produced by the instrument.

At first, all such pitch control was produced directly by fingers covering holes. It is quite possible that in primitive times the holes were bored in the instrument at places dictated not by musical pitch, but by the normal span of a man's fingers. From prehistoric times to the middle ages, the placement and size of the holes were slowly modified so that not only did they comfortably fit the span of a man's hand, but they could also produce an acceptable diatonic scale of some type.

As long as the whole scope of music was contained within a diatonic scale, woodwind builders had a relatively easy task. The diatonic scale had seven notes, and the woodwind player had six fingers to govern the holes, leaving the little fingers and thumbs free to support the instrument. The six finger holes made seven sequential finger positions available, starting with all six holes closed, and lifting one finger at a time from the bottom of the instrument up, in sequence, until all the holes opened.
During the middle ages, however, the composers' catalog of resources was extended to include pitches which were not to be found in the original diatonic scale. These were the first chromatic notes, and they presented the woodwind player with the task of producing more notes than he had fingers. He solved this problem by means of cross fingering or forked fingering.\(^1\) To cross finger, he temporarily abandoned his custom of lifting and lowering fingers in strict sequence, and closed a hole or two below an open hole. This flatted the pitch which would normally emerge from that open hole, though it also frequently made the tone a bit stuffy. In this way, the early woodwind player could make his six-holed pipe sound many more or less acceptable chromatic notes.

By skillful use of cross fingering, the Renaissance, Baroque, and even early Classical woodwind players were able to draw a complete chromatic scale from instruments which had no more lateral holes than the performer had fingers. A good example of such an instrument is the recorder. It has eight holes instead of six, but can be played over a range of more than two chromatic octaves, using no keys at all—only sequential and cross fingerings.

Plate I contains a segment of a fingering chart for the recorder. Several important matters are illustrated by this plate. First, letter names have not been used to designate pitch. Instead, for purposes of this paper, a system of numbers has been substituted. This has been done in order to make the comparisons of fingerings on different instruments more obvious. The basic sequence of finger movements is

\(^1\)These two terms are synonymous.
generally the same for all woodwinds, but the names of pitches produced by identical fingerings vary for different instruments. The system of numbers works in this manner: the note produced by covering all six finger holes, and the thumb hole, if there is one, as well as the key or holes which lowers the six-finger note a full step, is considered to be the key-note of the instrument, and is called "1." On flutes, oboes, Saxophones, the clarion register of clarinets, and recorders in C, this note is "C." On bassoons, the chalumeau register of clarinets, and recorders in F, it is "F." Lifting the fingers so as to produce the major scale of which 1 is the keynote makes the notes 2, 3, 4, 5, 6, 7, and high 1 or 8. On instruments on which 1 is "C," the note 4, for example, is "F," while on instruments on which 1 is "F," 4 is "Bb," because it is the fourth degree of the F scale. Chromatics in this system are referred to as "1 sharp" or "7 flat," while notes which are merely out-of-tune are called "sharp 4" or "flat 7," and in the Plates are indicated by a plus sign if sharp, or a minus if flat. If the letter-name system were used, it would not tell us, for example, that the notes f and c on clarinets are actually fingered identically, except for the register key. The number system, however, calls both of these notes 1, and the similarity of their fingerings is thus clearly indicated. The number system, then, is designed to simplify discussing and understanding the concepts which are being considered in this paper.

Second, it may be seen that it is necessary to cross finger even some of the notes of the recorder's basic scale. Fingering that scale sequentially would produce a sharp 4 and a sharp 8, because the holes normally giving those notes have been enlarged in order to tune certain
cross fingerings. Since more notes must be produced than there are holes on the instrument, some holes must serve double duty, and the use of one sequential note may be sacrificed in order to improve the tone quality and pitch of one or two fork-fingered notes. In the case of the recorder, the sequential fingering for 4 has been sacrificed, so both 4 and 4# are produced by fork fingering; 8 is also fork-fingered. Finding adequate fingerings for these same notes, and others close to them, presents a problem on every woodwind instrument, for reasons which will be considered later.

Third, the recorder's thumb hole acts as a register vent on notes 3' and above. Notes in that octave are fingered substantially the same as those in the first octave, except that for the upper-octave notes the thumb hole is slightly opened, the opening being made smaller as the notes ascend.

Twentieth-century woodwind players have become so used to the complex mechanisms on their instruments that they may tend to consider a keyless woodwind incomplete—perhaps a toy. To the Baroque woodwind player, however, such instruments were not only complete, but perfect—the tools of his trade which had been developed and honed over centuries of use, and which were quite adequate to the music of the time.

Many recorders and other woodwind instruments from as early as the Renaissance period had keys. The first keys added to woodwind instruments were designed to increase the instruments' compass downward. These keys were of the open type, as illustrated in Plate II, A. That is, they were held open by their springs and closed by the pressure of
the finger on a touch piece which was linked to the pad cup as a pair of interlocked see-saws. Pushing the touch piece downward caused the pad to move downward also. These keys were normally controlled by the little fingers or thumbs, and the levers, pad cups, and pads were generally covered by a perforated sleeve called a fontanelle—either to "tame" the sound of the low notes, or more likely, because at that time the sight of mechanism on a woodwind instrument was aesthetically displeasing.

In 1619, Michael Praetorius wrote a trilogy called Syntagma Musicum, and the second book of this work, De Organographia, contains woodcuts of virtually every musical instrument known at the time. These plates show that the open keys for extending range downward had been applied to recorders, cromornes, shawms, sourdines, bassoons, bassanelli, schryari, and cornetti.²

At that time, and for perhaps a hundred years thereafter, there was no convention dictating which hand should be placed above the other on the body of a woodwind instrument. Consequently, keys intended to be played by the little finger were designed with double-touch pieces so that they could be controlled by either little finger no matter which hand was placed below. Keys with these double-touch pieces were called butterfly or swallowtail keys, and they were symmetrical and aesthetically pleasing. The results of their aesthetic virtues will be discussed later.

²Michael Praetorius, De Organographia, Book II of Syntagma Musicum, Wolfenbüttel, 1619, facsimile by Erenreiter (Kassel, 1955), Plates VI, VIII, IX, X, XI, XII, XIII.
In his woodcuts, Praetorius shows us three instruments called "schryari."\(^3\) These are historical oddities which have not been discussed or illustrated by any other early writer, although they may be found in contemporary lists of instruments.\(^4\) For us, however, their interest lies in the fact that the woodcut places on them what may be the first closed key, and the first key designed to extend a woodwind's compass upward. A closed key is illustrated on Plate II, B. It works as a simple, spring-loaded seesaw. The spring holds the key closed until it is opened by pressure on the touch piece. Closed keys must be sprung more strongly than open keys in order to prevent air leaks around the pad, and therefore pad wear on them is greater. They do have one striking merit, however. When not disturbed, they do not change the pitch of any note, and may therefore be ignored until they are needed. Open keys, on the other hand, always leave a hole somewhere in the bore until they are deliberately closed. Attached to the bottom of an instrument for purposes of extending the range, they work well. Placed in the middle of an instrument's tube, they present technical problems which have been solved only relatively recently.

The fingering systems on woodwinds of the Baroque and early Classical periods did not vary much from those used in Praetorius' time, except for that of the clarinet, which was invented around 1700.\(^5\) Its characteristic of overblowing a twelfth instead of an octave made

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\(^3\)Ibid., Plate XII.


necessary the use of both closed keys at the top of the instrument and open keys at the bottom to bridge the gap between registers.

Classical clarinets had holes similar to those of recorders which yielded, in the chalumeau register, the written notes f, g, a, bb+, c, d, e, f#, and g, and chromatics by means of cross fingerings. They also had a closed key for a, and one which doubled as a register key and a key for bb. On the bottom of the tube was an open key which gave b' in conjunction with the register key, and completed the bridging of the gap between the chalumeau and clarion registers.

During the harque period, woodwinds were fully chromatic in the middle of their ranges, and diatonic in the extensions. Bassoons, for example, could descend a perfect fifth below their note "1" by means of thumb holes and open keys. This was only a diatonic extension, however, which included the notes Bb, C, D, and E. B, C#, and Eb were not available. This harque bassoon extension mechanism is illustrated on Plate V, B, 3. Oboes likewise made their note 1 or c' by means of an open little finger key—but there was no c#. Early flutes did not have a note 1. Their compass began on note 2; that is, d', with six finger holes closed.

During the Classical period, the extra notes provided by the traditional extensions came to be accepted as a part of the instruments' normal ranges, and steps were taken to render these extensions fully chromatic. Probably the first key added for this purpose was a closed key on the bottom of the flute which, when pressed, produced a good 2#. Because it was generated so near the bottom of the instrument, there had previously been no good was to play this note. Fork-fingering it was
either impossible or unsatisfactory, so first the flute, and then the other woodwinds adopted a closed key for this note. On oboes, this key was added below the swallowtail touch for 1, and in early instruments was duplicated so that there was a 2# key on either side of the swallowtail. As the placement of the left hand over the right became standardized for woodwind players, the extra 2# key was deleted.

Other keys designed to fill gaps in the chromatic scale were added to woodwind extensions, particularly on the bassoon and clarinet. For the most part, these were closed keys—ignored until the particular semitone for which they were designed was required.

And that was the way matters stood at the end of the eighteenth century—each woodwind instrument had at least one key, and some had several, but all these keys were designed to extend the range of the instrument either upward or downward, or to provide chromatics for the previously diatonic extensions. In the middle of each instrument there were no keys. The most important part of the compass of every woodwind instrument was still governed by six to eight finger holes.

The next stage in the development of woodwind fingering systems was brought about by the dissatisfaction of woodwind players with the pitch and tone quality of notes which they could already produce. The roots of this dissatisfaction lay in the stuffiness and out-of-tuneness inherent in many of the forked fingerings. Up to the middle of the Classical period, these weaknesses had been taken for granted as basic parts of the character of these instruments, and as a challenge to the skillful player. Toward the end of the Classical period, however,
certain developments in orchestral music shook the woodwind players' complacency about the state of their instruments.

First, orchestras were getting bigger, and woodwind players found that they needed greater volume and penetration in order to be heard. In order to achieve this greater projection, as well as a more unique tone color, reed instrument players began to use reeds which were less flexible and more sensitive to the variations in the tube with which they were coupled. It was then found that many of the cross fingerings which had previously been controllable could not be coaxed to respond to the new reeds, that the timbre of the instruments became painfully uneven.

Second, musicians were becoming more aware of the musical possibilities of contrasting tone colors. The duties of woodwind players changed from those of reinforcing the strings on their various parts to those of providing contrasting tone colors in the orchestral spectrum. Therefore, they played less often, and when they did play, the passages were generally very exposed and soloistic. Under these circumstances, the tone color they produced was much more audible and much more important, and the cross-fingered notes became obviously inadequate.

Third, composers were becoming bolder in their use of key signatures with many sharps or flats. Before this time, the cross-fingered notes generally were found in unstable positions in the music; that is, on notes which classical theorists would have considered dissonances or imperfect consonances in relation to the tonic note. The note $\text{ab}$, for example, acts as a dissonance in relation to the note $\text{g}$, and as an imperfect consonance with the notes $\text{f}$ or $\text{c}$. Because it does not function as a perfect consonance, its tone quality need not be particularly smooth.
or pleasing. In the key of Ab, however, it becomes the tonic, and must have a good quality and a stable pitch. As key signatures became more complex, cross-fingered notes were more frequently required to function as tonic or dominant notes, and in these critical positions, their shortcomings became more evident.

The most obvious solution to improving the tone quality of chromatic notes was to add more holes to the body of the instrument. These holes were placed in acoustically correct positions to sound the individual chromatics without cross fingering, and they were controlled by means of closed keys. Plate III, B, shows how such keys might be added to a tube without disturbing the original holes. Although each instrument added these chromatic keys in a different order, within a remarkably short time nearly every chromatic note on every instrument was given a closed key which sounded the note with better tone quality and pitch than the cross fingering had provided.

Since all the keys added to the middle of the instruments were closed keys, a performer who was not familiar with their use could ignore them and cross-finger the instrument as of old. In fact, even with the new keys, cross fingerings were still necessary, because in many instances the six major fingers were committed to covering holes, and could not be spared to open a closed key. For instance, an oboist given the passage 2 to 4 slurred—that is, d' to f —cannot use his 4 key because it is designed to be opened by his right ring finger, and this ring finger must cover a hole in order to produce the note 2. From there, it cannot move smoothly to the 4 key. Therefore, the oboist reverts to the old fork fingering for 4 in this passage.
The new keys did improve the tone quality of notes, but only two of these keys could be used consistently—those for 2# and 5#. They were designed to be operated by the little fingers of the right and left hands respectively, and these fingers had previously either had no duties, or their duties were limited to operating the extensions. The other keys, however, were designed for fingers which were already quite busy with existing finger holes, and they could not be used in certain patterns of notes. Therefore, the closed keys for notes 4, 4#, 7b, and 8 proved inadequate, and new ways of controlling these notes were sought.

The developments which followed were of a truly revolutionary nature. Woodwind mechanisms were brought to the state in which we find them today by means of the application of new mechanical and acoustical ideas which were developed during the first half of the nineteenth century.

Of the new mechanical developments, the one which provides the stable base for all the others is the rod-and-post system of key mounting used in conjunction with the needle spring. Such a mount is illustrated on Plate II, C. This type of mounting was first used around 1806 by Laurent of Paris, a flute maker. In modern practice there are three variations on this mounting: pivot screw, in which the rod is solid and pivots on two conical screws supported by posts; rod and tube, illustrated on Plate II, E, in which one or more tubes are fitted over a solid rod and pivot on it; and compound, in which a solid rod supporting tubes is itself rotated on pivot screws, as may be seen on Plate III, C, 2.

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The principal advantage of rod-and-post mountings is that they are quite free from sidewise motion, and return the pads to their holes with remarkable consistency of position; but rod-and-tube mounts are susceptible to binding due to corrosion, dirt, or bending of either the rod or tube. Compound mounts are even more fragile, and are always difficult to repair.

The rod-and-post mounting quickly became standardized as the best way of mounting woodwind keys, and all the subsequent mechanical developments were based on this method of mounting.

One of the earliest and most significant mechanical developments of the nineteenth century was the ring key, which was designed to control a chromatic hole in the body of an instrument without using a closed key. The first crude ring key was invented by Frederick Nolan and patented in 1808, but the first practical application of the ring key to a musical instrument was devised around 1832 by Theobald Boehm, a Munich jeweler and flutist, and a man of great mechanical inventiveness. Boehm's ring keys are illustrated on Plate II, D, and on Plate III, C. In this system, four holes, placed in their acoustically correct positions, are used instead of three, but only three fingers control the system. Notes 3 and 4 are produced by sequential fingering, but in order to play 4# the index finger is released, allowing the 4# hole to open, while the ring finger returns to hole 3, and keeps 5 from opening. Note that this is a cross fingering. The hole 3 is closed by this action, and for best venting, it should be left open. However, since both holes 4 and 4# are

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7Ibid., p. 52.  
8Paines, op. cit., p. 321.
open above it, its capacity to flatten note 4# is minimal. Moreover, since the 4# tone hole is now freed from the double acoustical function it performed on old flutes without the 5 hole, it may now be slightly enlarged to compensate for the flattening effect of the closed 3.

All other ring mechanisms operate in a similar manner, controlling the action of chromatic keys without requiring that fingers be moved from their accustomed positions. Thus both the timbre and intonation of cross-fingered notes are improved, and that improves the technical possibilities of the instrument.

The clutch is another indispensable element in the mechanical development of the systems now being considered. It is designed to transfer motion selectively. An early application of this principle is found on Boehm's flutes even before 1832. Plate II, E, shows two keys connected by a clutch in such a way that closing X always closes Y, but closing Y does not affect X. An application of the clutch mechanism may be seen on the Boehm-system clarinet devised by Henri Klose and Auguste Buffet in 1844, and illustrated on Plate III, C, 1. This clutch is designed to allow the ring around the 7b hole to be released while the key over the 7 hole is held closed by a finger on any of the rings for 3, 4, or 4#, thus allowing the note 7b to be sounded. Closing the 7b ring, however, does not affect the lower rings because of the selective effect of the clutch.

A final important mechanical development, and one which can be attributed to a somewhat later period, perhaps around 1850, is the

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9Rendall, op. cit., p. 102.
opposing spring action. In this mechanism, keys are connected to each other by clutches which are loaded with springs of different strengths. Perhaps the first important example of this type of mechanism may be found on the French oboe of around 1850.\textsuperscript{10} It is illustrated on Plate II, F.

The tube on which key 8 and ring 7 are mounted is sprung to open, but it is held closed by the clutch connection to the tube on which the 7\textsuperscript{b} key is mounted. This tube is sprung closed with a spring stronger than the one which opens 7 and 8; the strong spring overrides the weaker spring and thus closes 7 and 8. If the note 7\textsuperscript{b} is wanted, the key is pressed, and the 7\textsuperscript{b} hole is opened, as pressure of the hand overcomes the strong spring; 7 and 8 would then open under the influence of their weak spring were they not held down by the finger on the 7 ring. When the note 7 is wanted, the key is released, and the heavily-spring clutch rises to prevent the opening of key 8, even though the finger over hole 7 has been lifted. For note 8, only the key is pressed; 7\textsuperscript{b} is opened by the key, and 8 is opened by its own weak spring, freed at last to do its job.

These, then, are the principal mechanical elements from which modern woodwind mechanisms are assembled. There are also several subordinate mechanical devices which are used to convey movement from one part of the instrument to another in the most expeditious way. These are illustrated on Plate II, G, and consist of the following parts:

\textsuperscript{10}Philip Tate, The Oboe (London, 1956), pp. 62-63.
(1) The bridge, which is a solid metal bar connecting two segments of rotating tubing. It carried movement around intervening mechanism hinged to the same rod.

(2) The rocker, which is a bar hinged in the middle, with a clutch at each end. It not only carries motion for the length of its bar, but also reverses the direction, so that an opening motion is changed to a closing one, and vice versa.

(3) The connecting rod, found mostly on bassoons, contrabassoons, and low-pitched clarinets, which carries motion from the front of an instrument to the back or vice versa. It is not hinged to the body of the instrument, but may be connected to the keys it activates.

All of these mechanical devices are presently used in woodwind fingering systems. Their advantages are obvious; used in proper combinations, they allow the development of fingering systems in which chromatic holes may be controlled without distorting the hand position. Such mechanical improvements are not bought without cost, however. Perhaps the least important price paid by the modern woodwind player is the doubling or tripling of the weight of his instrument. More significant is the fact that the addition of these mechanical features raises the possibility of mechanical failure, faulty adjustments, and misalignments which render the instrument unplayable. Very little could go wrong with a classical instrument, but the myriad mechanical devices on modern woodwinds present myriad possibilities of failure. As the nursery rhyme puts it: When they are good, they are very, very good, but when they are bad, they are horrid!
Nineteenth-century instrument makers soon divided into two schools of thought on the ways in which these new mechanical devices should be employed. One school believed that the best approach was to ignore the classical fingering systems, and to start afresh by drilling a hole for every semitone in its acoustically correct position, and then to devise a fingering system to control these new holes. Against this philosophy stood that which wanted to preserve the classical fingerings of notes, and to improve and add to them.

The greatest spokesman for the first approach was Theobald Boehm. He was well aware of the inadequacies of the eighteenth-century flute, for it was on such an instrument that he learned to play.\textsuperscript{11} The instrument's tone was weak, its intonation was unsure, and the technical requirements for playing it in remote keys were virtually insurmountable.

Once, on a visit to London, Boehm heard the eminent English flutist, Nicholson, and immediately was struck by the great power and resonance of his tone. He learned that the flute Nicholson used had very large finger holes, which made the powerful sound possible. Nicholson also had unusually large hands and fingers, and few other people were physically able to cover those large holes.\textsuperscript{12} Boehm then built a mechanism which would allow people of normal physical endowment to use a flute with large holes. The acoustical and physical criteria for the flutes he designed were as follows: First, the bore should be cylindrical instead

\textsuperscript{11}Theobald Boehm, The Flute and Flute-Playing, translated by Dayton C. Miller (Cleveland, 1922), Fig. 2.

\textsuperscript{12}Baines, op. cit., pp. 320-321.
of inversely conical, and the body might be made of either wood or metal. Second, there should be a tone hole for every half step, and these holes should be placed in their acoustically correct positions. Third, the holes should be as large as practical. Fourth, all holes below the hole sounding a note should stand open, except in cross fingerings, where the lower closed hole must be separated by at least two open holes from the upper closed hole. Taken together, the third and fourth items constitute the principle of full venting.\textsuperscript{13}

Around 1847, Boehm produced the first metal cylindrical flute employing the principles of full venting.\textsuperscript{14} This instrument used a modification of the fingering system he devised in 1832. The mechanism for the notes 3 through 5 was the one previously examined as an illustration of the ring mechanism, with one exception. Instead of open rings, Boehm substituted large, padded finger plates, and connected them by a series of clutches so that the end result of their action was almost exactly the same as if rings had been used. This mechanism is illustrated on Plate III, C, 2. The padded plates were substituted at the expense of a more complex mechanism because the holes they closed were now much too large to be covered by fingers alone, in order to conform to the principle of full venting. With the clutch mechanism previously studied, Boehm used key 4\# to close key 7 so that 7\textsuperscript{b} is produced. The definitive mechanical features of all "Boehm system"

\textsuperscript{13}A detailed discussion of these criteria and their fulfillment may be found in \textit{Boehm, op. cit.}, Chapters II and IV.

\textsuperscript{14}\textit{Ibid.}, p. 12.
instruments, then, are the producing of note 4 by means of the right hand index finger, the elimination of the 4 key and cross fingering, the producing of 4# by means of a well-vented cross fingering, and the ability to lower note 7 to 7♭ with the right hand index finger.

Boehm's improvement of the flute did not escape the study of other instrument makers. In 1844, Henri Klose and Auguste Buffet of Paris brought out a clarinet which used the definitive Boehm fingerings, and was thus called a "Boehm system" clarinet, even though Boehm had no direct hand in its design. Not all the principles of full venting were employed on this instrument, however. The finger holes were kept fairly small, so the more primitive and less fragile ring system was used. This system may be seen on Plate III, C, 1.

Boehm himself drew up a fingering system for oboe, and several experimental Boehm-system oboes were built. These were rather consistently unsuccessful because the tone they produced had a certain broad, unfocused quality somewhat reminiscent of an indifferently played Saxophone. Similarly, later in the nineteenth century, a few Boehm-system bassoons were built by the Triébert firm in Paris. The mechanism mounted on these instruments was extremely complicated, yet very well constructed. They apparently suffered from the same tonal afflictions which plagued the Boehm-system oboe, however, an inadequately veiled, somewhat Saxophone-like quality. According to the

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15Rendall, op. cit., p. 102.
16Bate, op. cit., pp. 71-74.
well-known bassoon historian, Lyndesay Langwill, only four Boehm-system bassoons were ever built, and most of these are now in museums.¹⁷

While a considerable amount of thought and energy was being expended in attempts to adapt the Boehm system to oboes and bassoons, inventors of the second school, who believed in retaining the classical fingerings, had been at work on these instruments. The results they produced were tonally acceptable to the musical market and their instruments were quickly adopted, the Boehm-system experiments finally being abandoned.

Why did these Boehm-system experiments not come up to expectations? How could a system so successfully applied to flutes and clarinets prove so inadequate on double-reed instruments? In the opinion of this writer, the problem was an acoustical and not a mechanical one. The difficulty lay in Boehm’s own requirement for full venting. Full venting works very well on flutes, but flutes are quite unique acoustically. Oboes, clarinets, and bassoons are reed instruments, and do not accept the principle of full venting as gracefully as do flutes. Moreover, the tone quality which has been associated historically with them was largely a product of the small finger holes they carried. Since the holes were small, much of the acoustical energy traversed the entire length of the tube and passed out through the bell. As a result, the tones were dark, centered, and mellow. Increasing the size of the lateral holes in these instruments brightens and broadens the tone into an uncharacteristic sound.

The Boehm-system clarinet was successful precisely because Boehm was not directly involved in its development. Klosé and Buffet adopted Boehm's mechanism without using the full venting upon which Boehm would have insisted. Oboes and bassoons with Boehm mechanisms could sound almost exactly the same as standard instruments, provided that the lateral holes were kept small.

In fact, modern oboes and bassoons were developed along different lines. Their makers strove to improve the sound of the classical fingerings instead of completely revising the fingering patterns and position of tone holes. The most important, consistent, and obvious manifestation of adherence to the old pattern is the existence of a functionally important 4 key on the instrument. This key may be seen on the systems illustrated on Plate III, D and E. Oboes, French bassoons, and German clarinets also use the old forked 4 as an alternative to this key. German bassoons, in order to achieve better venting on certain notes, have given up this forked 4.

Perhaps the most sophisticated non-Boehm fingering system in use on American woodwinds today is that on the conservatory oboe. On this instrument the forked 4 has been maintained, though at the cost of formidable difficulty. The development of this system is attributable to the Triébert company in Paris.18

The first rings on the oboe were arranged as shown on Plate III, D, 1. On this mechanism, the note 4 was played either by opening the 4 key (with the 5 and 4+ holes closed), or by closing 3 and 5, leaving

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18 Bate, op. cit., pp. 60-71.
4+ open. This hole is tuned sharp, to compensate for the flating effect of the closed hole 3. In each case, 4# is closed. Releasing 3 and 4+ also releases 4# and allows that note to sound.

This system did not prove altogether satisfactory because the forked 4 still proved occasionally unruly, and today oboes carry a great deal of mechanism which is designed to control the action of the forked "F" resonance key; a key specifically placed and sized to improve the quality and pitch of the forked f' and f". This mechanism is illustrated on Plate III, D, 2. The action is designed to open the resonance key when hole 3 is closed and 4+ is opened, and to keep it closed at all other times. Although the resonance key usually does improve the forked "F," the note remains perverse enough so that many professional oboes also mount a long "F" key actuated by the little finger of the left hand, which opens the "F" key and thus effectively skirts the forked fingering. The manufacturers have thus built a mechanism involving a rod and tube mounting, an opposing spring, three clutches, a bridge, a rocker, and an extra lateral hole, and the improvement still does not guarantee a consistently good forked "F."

While the Boehm-system clarinet was gaining in popularity west of the Rhine river, German clarinet makers were devising mechanical improvements in non-Boehm directions. These German clarinets all had a 4 key and an alternate forked 4—almost exactly the same system as that used on the French oboe. The most famous non-Boehm system for clarinet was that devised by the Albert family in Brussels. This system was improved by Oehler, and the fingering system of the modern German
The clarinet is called "Oehler system." The Oehler-system clarinet also has a forked 4 resonance key, mounted somewhat more simply than that on the conservatory oboe, due to the clarinet's ring system, and to the absence of a need to close the resonance hole on notes above 4#.

Heckel bassoons have been able to dispense with the forked 4 only because the manner of holding the bassoon frees the right thumb to press the 4 key, as may be seen on Plate III, E. This fingering is never rendered impossible because the remaining duties of that thumb may be assumed by other fingers, unlike the obligation of the right hand ring finger to close hole 3 on oboes and clarinets.

With the problems presented by the notes 4 and 4# solved along either Boehm or non-Boehm lines, the makers' attention shifted to the notes 7b, 7, and 8. Here one is in less consistent territory, for the fingerings of classical instruments differed for these notes, depending upon whether or not the instrument had a thumb hole. Flutes, oboes, and bassoons had no thumb hole, while clarinets and recorders did. Concerning contemporary instruments, it may be stated that the left index finger alone always gives 7 (with any thumb holes closed) and that on Boehm-system instruments the addition of the right index finger produces 7b. The note 8 is produced in several different ways. Boehm added a left thumb hole to the flute while rebuilding it, and opening that hole while leaving the left index finger down produces 8. Clarinets and bassoons produce 8 by lifting the left index finger, and Saxophones produce 8 by

19Baines, op. cit., pp. 140-142.
means of the classical forked fingering, using the left middle finger alone. The unusual way in which the conservatory oboe makes the notes $7^b$ and 8 is noteworthy. The player of a Boehm-system instrument first attempting a scale on a conservatory oboe soon finds that though the left index finger does not lower the 7 to $7^b$, it raises it to 8!

This peculiar mechanism is a direct descendant of the one previously examined as an example of opposing springs. In that example, small keys for the notes $7^b$ and 8 were lightly sprung to open, but were held closed by a stronger spring, which was overcome by hand pressure on the key when these notes were wanted. This design was adopted because it allowed the vents for $7^b$ and 8 to stand closed unless they were deliberately opened. The Triéberts felt that this was desirable because they rejected Boehm's theories of full venting for the oboe, and strove to maintain the old classical venting, in which there were only three open holes in the instrument's upper joint. In the course of development of this mechanism, the touch for overcoming the strong spring was moved from a key for the side of the right index finger, as seen on Plate III, D, 1, to a plate for the left thumb, and finally back to the regular ring or plate for the right index finger, as seen on Plate III, D, 2. This mechanism is almost unique to conservatory oboes, and is their most distinctive characteristic.\textsuperscript{20}

One more set of mechanisms deserves consideration: those which operate the downward extensions of modern woodwinds. Just as all woodwinds share the basic difficulties inherent in producing the notes, 4,

\textsuperscript{20} Bate, op. cit., pp. 66-71.
4#, 7♭, and 8, so they also share the common difficulty of controlling the notes 2# downward through low 7 or low 7♭ by the use of only the left and right little fingers (or, in the case of the bassoon, the right little finger and right thumb.)

As might be expected, the solutions which were presented for this common problem were diverse—even more diverse than those devised for notes 4, 4#, 7♭, and 8. Instead of standardizing on one or even two basic fingering mechanisms, at least give were adopted—a different one for each important modern woodwind!

The problem itself is more difficult than it might at first appear. Not only is it necessary to arrange a touch piece for every extension note, and to devise a mechanism to activate the pad cups, but provisions must be made also for passing smoothly and quickly between every possible combination of extension notes. In order to achieve this smooth passage, builders developed two mechanical approaches: alternative keys, and rollers.

Two touches may be provided for each of the notes, so that either little finger may be used to play any note, and any passage may be played smoothly, by alternating the little fingers on the duplicate touches.

The Boehm clarinet uses such a system, which is illustrated on Plate IV, B. The advantages of the alternative system are the ease with which any conceivable combination of notes may be accommodated on it, and its rugged simplicity. The disadvantages of the system are its weight, which is considerable since every touch is duplicated, and the mental exercises necessary to remember the positions and functions of so many keys, and to "translate" each passage into a workable fingering sequence.
On the other hand, the builder may not provide any alternative touches, but may place rollers on the principal touches so that the little fingers may slide smoothly from one to the other. The Saxophone uses such a system, as does the Oehler clarinet, shown on Plate IV, A. The advantages of the roller system are that it is somewhat lighter than an alternative system would be, and that each note is always activated by the same key, eliminating the need for fingering pattern calculations. The disadvantages are that the sliding motion required is not a natural or easy one to master, and that involved passages can make the performer very uncomfortable. Poorly spaced or adjusted keys may defeat all attempts at achieving smoothness in certain passages.

The extension on the flute is of the roller type, but is controlled entirely by the right little finger. The system has severe limitations, perhaps the most important one being the difficulty of passing smoothly between $f$ and $e^b$. Nevertheless, this extension is probably a good one for the flute, considering the infrequency with which the lowest two or three notes are used, and the discomfort which would be caused by the weight of a more complete and complex mechanism multiplied by the long lever arm which the flute becomes in its playing position.

The extensions on bassoons are characteristically much longer than are those of other woodwinds. For the notes 2# through low 7, the bassoon mechanisms show many similarities with those of other woodwinds, except that the right little finger shares duties with the right thumb, instead of the left little finger. French bassoons employ the roller system principally, while Heckel bassoons use a combination of rollers and alternatives for these notes.
In order to play the notes below low 7, the French bassoonist employs only his left thumb, while the bassoonist using the Heckel alternates between the left thumb and little finger. These sub-extension mechanisms are shown on Plate V, B, 2 and 3. Although they are fully chromatic, not all combinations and trills are playable on them.

A consideration of the extension mechanism of the conservatory oboe has been saved for last, because it illustrates the results of extending one particular school of thought to and perhaps a bit beyond the limits of rationality. The basic doctrine which permeates the development of this system is that while it is permissible to add new features to the fingering mechanism, no old feature shall be discarded, and no rebuilding of the system is permitted which requires the experienced oboist to change his ways. Consequently, the extension on the oboe adheres to neither the alternative nor roller concept, for there are no rollers on the oboe, yet there is only one bona-fide alternative key--2# for the left little finger. An illustration of the oboe's extension mechanism may be found on Plate IV, C.

Originally, this extension mechanism harbored many technical limitations, but as each difficulty became obvious, it inspired a special mechanical device designed to overcome the specific limitation. Consequently, the oboe's extension mechanism is extremely complex. There is not a great deal that cannot be performed on it if the player fully understands the capability of the mechanism, and if it is all working properly. A few of the specific devices require the use of new touch pieces; for example, the "banana key" 1. This key solves a fingering
problem generated by another part of the extension, by providing the means to trill between 1 and 1#; however, it is so awkward to reach that it cannot be considered a true alternative, but merely a contingency key, useful only in specific emergency situations. The present extension mechanism of the conservatory oboe, along with its compensating devices, requires the use of fourteen clutches, at least two opposing springs, and a complex tube mounting. By comparison, a Boehm clarinet mechanism, which accomplishes the same tasks more smoothly, requires only six clutches, and no opposing springs or complex tube mountings; and the extension mechanism from the Oehler-system clarinet uses only two clutches.

Though extension mechanisms developed through cumulative additions sometimes present us with illogical complexities, perhaps the most illogical of complexities to be found in woodwind fingering systems is the lack of standardized positions for the touches operating the extensions of the various woodwinds. An examination of Plate V, A, reveals that certain general statements may be made concerning the positions of these touches: First, every instrument has touches for 1 and 2# for the right little finger, and all but the Saxophone also have a 1# touch for that finger. Second, all but the flute have low 7 touches for the left little finger (or right thumb), and all but the bassoon have a 5# touch for that finger. These are the similarities which the various systems possess, but there are also important areas of disagreement, a few of which are listed here: First, should 1# or 2# or neither of them be duplicated? Second, should the right hand 2# be placed above or below the 1? Third, what relative positions should the right hand 1# and 2# take?
The apparently purposeless diversity in the placement of these keys may be attributed primarily to tradition, which generally maintains keys in the positions at which they first appeared.

A particularly clear example of this traditionalism may be seen by considering why the 2# key is placed above the 1 key on flutes, clarinets, and Saxophones, while it is placed below the 1 key on oboes and bassoons. Of all the Renaissance woodwind instruments which carried the swallowtail 1 key, only the oboe and bassoon survive today. Up until the nineteenth century, flutes could not produce the note 1, so the first key added to them was the 2# key. Early clarinets had a little finger hole for 1, instead of a key, so there also the 2# key preceded the 1 key. The Saxophone appeared, of course, at a much later date, and incorporated from the beginning the advances designed by Boehm, including the placement of 1 and 2# keys which he used on flutes. It would seem that the placement of the 2# key above the 1 is most logical, on the basis that higher notes are vented farther up the tube of a woodwind than lower notes; therefore, the key for the higher-pitched 2# should lie above the 1 key. Oboes and bassoons, however, have defied logic and clung to four hundred years of tradition. Even before Praetorius' time, they had fine, handsome swallow-tail keys for note 1. When the key for 2# was added, it was added below that handsome touch, so as not to interfere with it either mechanically or aesthetically. At the time, the possibility of redesigning the whole mechanism was probably never considered—and apparently such a re-design has never been thought useful, because the 1 and 2# keys on oboes and bassoons are just as backward today as they have always been.
The conclusion to which all this historical data seems to point is that there is more than one way to mechanize a woodwind instrument, and that making any decision concerning, for example, how the note 4 will be played frequently generates an entire system based upon that decision. It would also seem that there is a possibility that the various fingering systems which are used so exclusively in the United States may have been selected more because of the eminence of the performers who advocated them or because of the tonal qualities of the bore and lateral holes commonly associated with them than because of any intrinsic superiority which they possessed over competing systems. And finally, there is considerable room for improvement in most of these systems. It would seem advisable, for example, to make a serious attempt to determine what pattern of extension touches is really the most efficient, and then to standardize that pattern as much as possible among the various woodwinds.

Woodwind instruments will continue to change, as they have in the past, and one of the important duties of the professional woodwind player will be to consider the proposals for changes which the inventors present to him, and to select those which are truly improvements, rejecting the others. These improvements may lie along the mechanical lines we have been discussing, but it is more likely that they will be electronic in nature. The woodwind fingering systems of the nineteenth century used the mechanical technology of the time—levers, hinges, and slides not too far removed from those found in steam engines and typewriters.
Twentieth-century technology is much more interested in the transistor than in the lever, and experiments have already been made in which the lateral holes in a specially constructed bassoon are activated by solenoids operated by push-buttons and controlled by a simple computer.\(^{21}\)

Perhaps this is a forerunner of the woodwinds of the future. At present, however, we woodwind players must be satisfied with the instruments which the nineteenth-century inventors have left us. For the most part, we have made our peace with them, and regard their limitations with a certain affection born of familiarity.

Basic Units of Woodwind Mechanisms

A. Open Key
B. Closed Key
C. Rod and Post Mount with Pivot Screws and Needle Spring
D. Ring Keys as used on The Boehm-System Clarinet
E. X
F. Opposing Springs as applied to French oboes C. 1850
G. The Bridge

Plate II
DEVICES FOR PRODUCING 4, 4#
7b, 7, AND 8

Six Finger Holes
No Keys

Six Finger Holes
Closed Keys for Chromatics

Boehm System Action
1. 2. = with rings
2. = with covered plates

Non-Boehm Action
1. 2. = Early (1850)
2. = More Modern (including Forked F Resonance Key)

Simple Non-Boehm Mechanism
Stylized from Heckel Bassoon

Plate III
EXTENSION MECHANISMS

A

Oehler Clarinet (Based on Rollers)

B

Boehm Clarinet (Based on Alternation)

C

Conservatory Oboe

Plate IV

Legend:

= Low 7th Mechanism

= 1st Mechanism

= 1st Mechanism

= 2nd Mechanism
Placement of Touches for Extensions

<table>
<thead>
<tr>
<th>5#</th>
<th>5#</th>
<th>5#</th>
<th>Left Little Finger (except as noted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low 7</td>
<td>Low 7</td>
<td>Low 7</td>
<td></td>
</tr>
<tr>
<td>1#</td>
<td>1</td>
<td>2#</td>
<td></td>
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<td></td>
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</tbody>
</table>

Saxophone  | Boehm Clarinet | Boehm Flute | Heckel Bassoon | Conservatory Oboe

Sub-Extensions for Bassoons

1. **Berger Period** (Diatonic only)

2. Modern Heckel

3. Modern French

Plate V

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Articles