THE FLUTE: THE MECHANICAL IMPROVEMENTS
ON THE BODY OF THE ORCHESTRAL
INSTRUMENT SINCE 1847

THESIS

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

For the Degree of

MASTER OF ARTS

By

Carolyn Nussbaum, B.A.
Denton, Texas
August, 1994
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This thesis uniquely explains the mechanical improvements which have occurred to the flute over the last 147 years. Theobald Boehm revolutionized the flute by changing many of its components culminating with the 1847 model flute. Since that time other improvements have been made which enhance the flute's capabilities in terms of pitch, tone, timbre, and simplification of fingering passages. Among those improvements which are discussed in the following pages are the Dorus G-sharp key, the gizmo key, the Cooper scale, and The Brögger Mekanik as well as the makers behind the various improvements including Vincent Dorus, George Barrère, and Albert Cooper.
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TERMINOLOGY

In this document the following diagrams are referred to without repeated notation.

Notes and keys are referred to in capital letters; however, when references are made to specific octaves, they are denoted by the following:

\[
\begin{align*}
&b \\
c^1 - b^1 \\
c^2 - b^2 \\
c^3 - b^3 \\
c^4 - d^4
\end{align*}
\]

The following fingering abbreviations are used:

\begin{itemize}
\item \textit{Th}--Left hand thumb
\item \textit{L1}--Left index finger
\item \textit{L2}--Left middle finger
\item \textit{L3}--Left ring finger
\item \textit{L4}--Left pinky finger
\item \textit{R1}--Right index finger
\item \textit{R2}--Right middle finger
\item \textit{R3}--Right ring finger
\item \textit{R4}--Right pinky finger
\end{itemize}
The following diagrams refer to specific keys and holes:

INTRODUCTION

The flute has a very descriptive past which is marked by specific stages of evolution. For centuries, composers, performers, and inventors have documented the flute’s metamorphosis; historians have gathered and analyzed information about the musical changes which have occurred with the advancement of the flute. Through the work of many, this instrument has been mechanically transformed to a highly sophisticated level.

The flute, which was a single bored piece of wood with carved tone holes in the medieval and renaissance periods, was enhanced by the addition of keys during the baroque and classical eras. The addition of keys extended the musical scale of the instrument and provided a wider range of notes; however, its sound was not clear and the intonation was inconsistent. Ludwig van Beethoven responded to a letter requesting flute music from a Scottish publisher, George Thompson;

Je ne peux pas me décider à travailler pour la flûte, parce que cet instrument est trop limité et imparfait.

1 November 1809

[I cannot make up my mind to write for the flute because this instrument is too limited and imperfect].

The nineteenth century marked a major change in the flute’s intonation and tonal quality. Theobald Boehm, a flutist and
goldsmith, is celebrated for his contributions to the flute’s development. Using the laws of physics and his knowledge of metals, Boehm produced the most advanced flute of its time. He replaced the conical shaped wooden flute with a cylindrical shaped metal flute. This physical alteration of the flute vastly changed the character of its sound.

Though alterations have been made since its creation in 1847, the basis of the Boehm flute remains the standard today. Many have worked to enhance the flute’s pitch, tone, and timbre to simplify fingering passages. Among those who are attributed to the modernization of the flute are Vincent Dorus, Giulio Briccialdi, John Coltman, and Albert Cooper. These attributes are thoroughly discussed in the following pages. Though many styles of flutes have been and are still being developed, this document is limited to the evolution of the flute common in modern orchestras.

The Boehm Flute

Theobald Boehm (1794-1881), who was a goldsmith and flutist, eventually combined these two skills and began building flutes for himself and others in 1812. Over the next thirty-five years, Boehm designed many flutes. His final model of 1847 featured the modern fingering system for the first time.² Boehm indicated his design innovations with a geometrical diagram known as the Schema (Figure 1).³
The Schema explains how the position of the holes were obtained using calculations based on a simple law of acoustics. The diagram shows the exact measures by the divisions of the air column based on the number of vibrations in the equally tempered scale. They are represented by the intersections of horizontal and vertical lines with diagonal lines to indicate the geometrical progression.
Boehm studied with physicist Carl von Schafhautl at the University of Munich in order to understand the bore of the flute. From this study, Boehm concluded that a cylindrical tube is more conducive to the harmonic tone quality of the flute. Boehm's flute of 1847 became well-known in the flute world almost immediately after its invention. In 1851, the Boehm flute took first prize in the Industrial Exhibition of All Nations. In 1855, it took the gold medal at the Paris Exhibition and first prize at the General German Industrial Exhibition in Munich.5

Although the new flute was becoming increasingly popular, it was banned from many orchestras in countries such as Germany, Italy, and Russia, because of its timbre and because many professional players did not want to change over to the new fingering system. This continued for many years; in 1914, Macaulay Fitzgibbon observed that the Boehm flute was still not used in German orchestras.6 However, older players were soon faced with competition from younger players who knew only the superior new system. The number of professional players decreased temporarily because of this.7 The new group of professionals brought the Boehm flute into the orchestras and concert work. The extended range of Boehm's flute encouraged composers to write for it. For example, in 1878, Brahms, Symphony No. 2, second movement includes a $b^3$, and his Symphony No. 4 is scored with $c^4$s in the first movement. Richard Strauss wrote $c^#4$s in Til Eulenspiegel (1895), and a $d^4$ appears in his Also sprach Zarathustra (1899).
Tchaikovsky wrote a $b$ in the second flute part of the third movement of his Sixth Symphony (1893). Boehm’s 1847 system flute soon became the preferred instrument for performers and listeners alike. The Boehm flute has undergone minor modifications over the years, yet the original design of the flute is unchanged.

**G-Sharp Key**

There are four styles of G-sharp keys: one is an open key, in which the tone hole is open unless closed by pressing a key, and three which are closed and opened by pressing a key (Figure 2).

The first style with an open G-sharp key was by Boehm. Boehm believed that this style is theoretically and tonally better than a closed G-sharp because there is only one hole drilled in the tube to produce this frequency. A weaker spring is used for simpler key operation and the G-sharp hole can be closed independently, allowing the $e_3$ to be purer and fuller in sound. With Boehm’s open G-sharp, $L4$ remains down for notes using the lower end of the flute, which is very different than the pre-Boehm system.

The second example is the "Dorus G-sharp key," which was developed by Vincent Dorus, the flute professor at the Paris Conservatory, in 1838. This closed G-sharp operates by $L3$ lowering the A key, which simultaneously covers the G-sharp and produces a G-natural. Dorus based his development of the closed G-sharp on the pre-Boehm fingering system. Many flutists objected
to the open G-sharp mainly because players had not developed the technical skill to use the L4 as much as the system required. Flute makers were unsuccessful in reclosing the G-sharp. When they tried, intonation problems resulted because the Schema required the open G-sharp for many other tones. Dorus designed this "new" closed key by adding a ring key to the A hole and attaching it to the open
G-sharp key with a divided sleeve and clutch. The main problem with this device was that the opposing springs’ strengths were unequal. The stronger key over the A hole made the spatula key difficult to press.

Boehm did not use the Dorus G-sharp key and believed it to be inferior. As seen in this excerpt, from a letter by Boehm quoted by Carte (1845), Boehm discussed the unjust criticism from the French flutists and noted that German flutists employed the open G-sharp.

The Boehm flute as I play it myself, with the G-sharp key open, is perhaps the best among a dozen of other systems of fingering, all well considered, and some executed and tried by myself. Playing for months upon that which I found adapted best to all possible combinations of notes, and consequently of passages of all descriptions. After what I have seen and known in mechanics, and done myself in my youth in that line, I may be believed if I say that I did not want to wait for the French artists to construct a key for G-sharp, but that I might have made half-a-dozen plans very soon for that purpose, perhaps better than that made by M. Dorus. But I cannot see why my simple and most rational system should be sacrificed to prejudice and unwillingness to overcome an old habit, which by anyone is conquered in less than four weeks, and rewards sufficiently the small trouble in the beginning. Nobody found fault with all the other notes but the G-sharp, only because all others have such a different fingering that the idea of changing must be given over at once, only this little poor G-sharp key found objection because it remains more on the old system, though every one, after the least consideration, must assert that it gives not in the least more trouble or action to the finger to shut my G-sharp key than it gives to open one. If it was possible to make a key for this note without complication, I would not say a word against it, but as this cannot be, and as there is for a beginner not the least difference, and for an old player but a practice of a short time you will be thanked for persevering in this, as I am sure the French players will never arrive at the same perfection.
in their way, as has long been attained by German players, particularly by M. Stettmayer at Hechingen, who shows off the Flute in a splendid way.

Theobald Boehm ("Munich, March 7, 1843")

In response to the demands for a closed G-sharp, Boehm invented his own style of closed G-sharp key. In his, the two keys remained independent with a strong spring which required greater force from $L4$ to open it. To solve the main problem with Boehm's closed G-sharp, which was the intonation of the A when following his Schema, Boehm repositioned the A tone hole 1.2 millimeters above its Schema position. He did not, however, advertise this key option and encouraged the open G-sharp. According to his workshop ledger, from 1847 to 1859, Boehm made only 2 flutes with closed G-sharp, Nos. 2 and 22. The other 128 were with open G-sharp.

The Dorus G-sharp key was soon replaced by a duplicate hole placed on the inner side of the flute tube. The change reverted back to the pre-Boehm system using $L4$ to produce G-sharp. In this flute, the A and G-sharp keys are operated by $L3$ and cannot be separated; therefore, the duplicate key is necessary to produce G-sharp. This is the most common key system in operation today.

Today, the controversy continues between open and closed G-sharp. In many areas the open G-sharp is used, such as in the former Soviet Union, Israel, Germany, and Australia. Many flutists in America use the open G-sharp as well, such as Clement
Barone, Hubert Laws, Victor Just, and Fernando Morrone. In England such renowned performers as Geoffrey Gilbert, William Bennett, Alexander Murray, Gareth Morris, and Simon Hunt use the open G-sharp. Albert Cooper, an eminent flute maker, described the ideal situation regarding the open versus closed G-sharp when he referred to William Bennett who "plays both systems equally well." There are some disadvantages when playing the open G-sharp, including availability, resale value, and access to another instrument in emergency situations. According to Geoffrey Gilbert, some passages are easier with the open and some with the closed. Even though he played on an open G-sharp, Gilbert did not begin students on, or recommend switching to, the open G-sharp. Gilbert also stated that if he were to begin again he would start on a closed G-sharp.

Oliver R. Minzloff, a flute teacher from Berlin, now residing in Basle, Switzerland, experimented with eight beginning students who were approximately 10½ years of age, four on closed and four on open G-sharp flutes. (The four open G-sharp flutes used were flutes ordered with a split-E mechanism which he converted to open G-sharp.) The results of the experiment showed that the open G-sharp players could play melodies in all keys in approximately six months, whereas the others still had difficulty with the left little finger after eighteen months. "The third octave seems to be equal though I found some passages, like the scale in the beginning of Ravel's Daphnis & Chloe solo again favoring to open G# flute! Soundwise the open G#
has its advantages in the third octave undoubtedly: The top E is much better in tune, speaks easier and there is no problem to slur from or into the E from any other note."\textsuperscript{21}

\textbf{B-Flat Fingering}

The only mechanical alteration to the Boehm system flute affecting the fingering system has been the B-flat thumb key added by Giulio Briccialdi in 1849. The 1847 Boehm flute system used \textit{Th} to operate the B key using \textit{RI} to produce B-flat.\textsuperscript{22} Briccialdi, an Italian flutist living in London, found that adding a lever over the B key, in order to close the B-flat, facilitated technique in the flat keys. B-flat can be fingered simply by using \textit{Th} and \textit{LI}, the original fingering, only when B and B-flat occur chromatically. The Rudall and Rose Flute Company of London added the first Briccialdi lever at his request on a cocuswood flute built by Clair Godfroy.\textsuperscript{23} Boehm, after seeing Briccialdi's invention, designed his own B-flat thumb key, which he considered superior because the B-flat key was placed lower than the B key in order to follow the succession of the chromatic scale on the flute (Figure 3).\textsuperscript{24} The thumb moved down to play the B-flat.\textsuperscript{25} Despite Boehm's logic, the Briccialdi key prevailed.\textsuperscript{26}

The thumb key options are linked to an \textit{RI} trill lever, also known as the B-flat side key. This lever helps facilitate passages which include B and B-flat chromatically, as well as fast sections such as G, A-sharp, B, A-sharp due to the technical impossibility of using
the F key or the B-flat thumb key throughout these sections. This lever also simplifies the G-sharp and A-sharp trills.\textsuperscript{27}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{bflatthumblevers.png}
\caption{Examples of Briccialdi and Boehm B-Flat Thumb Levers.}
\end{figure}

\textbf{C-Sharp Trill Key}

The C-sharp trill key is an optional key and was first used as early as 1863 by the French firm, Louis Lot. It was patented much later in France in 1909 by Mme. Cornelie Villedieu Laubé.\textsuperscript{28} This
additional C-sharp key is located between the small D/D-sharp trill keys and the thumb keys. It is controlled by a "side" lever for R1 (Figure 4).  

![Diagram of a flute with labels and a lift key indicating C-sharp trill functionality.](image)

Figure 4. Laubé patent. French Patent No. 409,922 (1909). Supplementary C# hole (a) controlled by side lever (d). Trill lever (f) closes C/D trill key (b); trill lever (g) closes C#/D# trill key (h).

This simplifies the C-sharp trill and also improves three additional trills: b\(^1\)/c#\(^2\), b\(^2\)/c#\(^3\) trill, b#\(^1\)/c#\(^2\), b#\(^2\)/c#\(^3\) trill, and f#\(^3\)/g#\(^3\) trill. This also provides a new trill fingering for g\(^3\)/a\(^3\) trill by combining it with the C/D trill lever.  

The g#\(^3\) can be split by using this key to greatly improve the pitch. As with any additional mechanism, problems can occur, however. The added weight of the C-sharp key and the extra tone hole are thought to have a negative effect on overall tone quality. The additional cost can also be a factor in the decision to include this key.
Note Facilitators

Four alterations are available on the flute to help with intonation. Three are associated with the top octave of the flute, $e^3$, $f#^3$, $c^4$, and one with the footjoint. These mechanisms are referred to as the split-E, the split-F-sharp, the high C facilitator, and footjoint lever.

The split-E mechanism allows the A and G-sharp keys to work independently. The $e^3$ has been a problem in pitch and sound since the closed G-sharp key was reinstated. The intonation is sharp and the texture is weak and unclear. The idea of a split-E first started with Boehm, when he built his closed G-sharp key. He never explored it, however, because $e^3$ was not a problem on the open G-sharp flute, which he preferred. In 1895, the split-E for the closed G-sharp flute was invented by Djalma Julliot with the assistance of Paul Taffanel. When playing a closed G-sharp flute, the venting of the G-sharp hole is operated solely by the A hole; therefore, when playing $e^3$, the G-sharp hole must be kept open. The ideal situation is to have the G-sharp hole closed and the A hole open. The necessity is to duplicate the action of the open G-sharp on a closed G-sharp flute. The split-E mechanism is connected with $R2$ which covers the G-sharp hole so that the A and G-sharp keys move separately. This allows the G-sharp plate to be closed by $R2$ and $L3$, thus maintaining the Boehm fingering (see flute diagram). Flutes without the split-E option can be improved by adding bushes or
doughnuts (rubber pieces) to the G-sharp hole. This should only be done to an in-line G-sharp key with perforated keys in order to avoid dulling the sound of $a^1$ and $a^2$ (Figure 5).

![Figure 5. Example of Flute with Doughnut.](image)

The $f#^3$ on the perforated key model tends to be extremely sharp and unstable. Many attempts have been made to correct $f#^3$. In 1923, Charles B. Gage advertised the "Gage Articulated B, F-sharp Device." New fingerings were necessary even though the advertisement claimed otherwise. In 1926, Lambros Callimahos designed a key that was operated by an additional trill key attached to a new key on the under side of the tube. Others continued to try to find a solution, but none prevailed, until Albert Cooper proposed a
logical solution. Because the F-sharp is high in pitch due to the extra venting over the B hole, it does not seem to be as high on a plateau model flute. In order to lower the pitch, the B perforated hole needs to be covered without covering the B hole itself. To help correct for instability and intonation of F-sharp, Cooper made the B-flat trill key into a high F-sharp key (Figure 6). From Figure 6, one can see the felt insertion filling the B-flat hole. This gives equal intonation and balance between $f^\#_3$ and its surrounding notes of $f^3$ and $g^3$. The disadvantages of this design include the loss of the B-flat trill key and the necessity of learning a new fingering for $f^\#_3$. In order to improve the intonation, a new fingering is inevitable.

![Figure 6. Split F-sharp.](image)

When the low B footjoint is used, there tends to be a delay in response when playing the $c^4$. The best way to correct this is to be able to close the low B while the C and C-sharp stay open. In the late
1930s, the high C facilitator was invented by George Barrère and eventually was implemented by Verne Q. Powell. This addition, better known as the "gizmo" key was never patented and is available by almost all manufacturers (Figure 7). By 1976, Powell began manufacturing a gizmo key with no additional charge and made it a standard addition to the low B footjoint.  

![Figure 7. Flute with and without the gizmo key.](image)

In 1902 the trend toward supplementary keys began. This was the addition of keys to help facilitate difficult passages. The additional lever for the low C key was developed by J. Thibouville-Lamy and Cie. This lever was connected by a rod which was placed in
front of the right hand keys and was attached to the low C on the footjoint, thus facilitating the $c^1/c^1\#$ trill. With the low C-sharp key closed by its normal finger, $R4$, the low C key can be manipulated by $L4$. This lever can be connected to the low B key in order to operate passages with $b$, and to act as an alternate high C facilitator (Figure 8).  

![Figure 8. Thibouville-Lamy patent. French Patent No. 326,145 (1902). Supplementary key (e) for left pinky closes low C key (a). Side key (m) controls C thumb key (l). New trill key (j) closes B hole (k).](image)

**Plateau and Perforated Keys**

Two different types of key structures are available on the flute; plateau and perforated. Plateau keys (closed or American style) have a solid surface, whereas the perforated (open or French style) have five keys with open centers for $L2$, $L3$, $R1$, $R2$, and $R3$ (Figure 9).
The two styles are not interchangeable because of the adjustments made to allow for the extra venting of the perforated keys while keeping larger spaces between the keys and the tone holes on the plateau model.\textsuperscript{45} Until the mid-1920s, the perforated model was not popular in the United States. Thus, the name American model became synonymous with the plateau model. By 1922, Haynes began advertising its advantages, which were also advocated by the Paris Conservatory (hence the name French model), including intonation benefits through the ability to vent keys, which allowed flat notes to be brought up in pitch.\textsuperscript{46} In the music of the avant-garde, the difference between the plateau model and the perforated model becomes more apparent. Bruno Bartolozzi, an avant-garde flutist, provided a fingering chart based on the quarter-tone scale from $d^1$ to
This chart is complete except for three quarter tones which cannot be played due to the coupling of hole covers. Bartolozzi claims all of these notes can be played on a plateau model flute. However, Thomas Howell, also an avant-garde musician, stated that these notes are impossible to produce clearly without the perforated keys. Howell’s quarter-tone scale for the perforated keys ranges from \( b \) to \( f^\# \), omitting eight quarter-tone pitches which he states cannot be played on the flute. Another avant-garde flutist, Robert Dick, provided full quarter-tone scales for both the plateau and perforated models. The perforated model is also required when playing avant-garde music which includes other techniques such as multiphonics and glissandos.

The plateau style is easier for a beginner or a person with smaller hands because the fingers do not need to cover the holes. Yet the perforated keys help to enforce proper finger placement and hand position, which results in better technique. Professional doublers find the plateau keys more convenient when switching instruments due to the various finger positions among the different woodwinds.

**The Cooper Scale**

Among the many individuals who have tried to improve the intonation problems of the Boehm scale, is Londoner Albert Cooper. Cooper began as a flute repairman and eventually began building his own flutes. He worked as a repairman for Rudall Carte and Company
from 1938 to 1958. In 1958, he opened his own repair shop, but eventually changed courses and became a flute maker. He was aware of the many complaints about various flutes over the years and decided to address as many as possible. Cooper designed his scale in 1973. Cooper, like Boehm, used a mathematically calculated scale. However, his was different from Boehm’s, mainly because the standard pitch is different now; older flutes were tuned to $A = 435$. Today’s orchestra pitch has moved up to $A = 440$, or even $A = 442$. The first thing Cooper established in designing his scale was the octave length and the A hole within this octave. The A is placed in perfect relation to the interval between $c^2$ and $a^1$, and between $a^1$ and $c^1$. Cooper established that each semi-tone must be divided by 17.835, like Boehm’s Schema, which is based on the division of string lengths. Cooper’s scale is built on unequal size holes which improves intonation because each hole is adjusted to the note it produces, unlike the equal sized holes which establish a general pitch from note to note. Most flute makers today use at least three or four different hole diameters. Many companies now sell Cooper Scale flutes, including Powell and Brannen.

**C-Sharp Key**

The C-sharp key, known as the Coltman C-sharp, was invented by physicist John Coltman in 1976. The Coltman C-sharp is intended to improve the intonation of $c#^2$ and $c#^3$. A new hole is placed
between the regular C-sharp vent hole and the C thumb hole. This hole is used in combination with the vent hole to produce $c\#^2$ and $c\#^3$. The hole is not used for any of the other notes, which the regular hole facilitates (Figure 10).

Figure 10. Coltman C-sharp.

The existing intonation problem of the C-sharp is caused by the small C-sharp hole which is also used as the vent for six other notes. Boehm moved this hole up the tube and decreased its size in order to facilitate all eight notes effected, $c\#^2$, $c\#^3$, $d^2$, $eb^2$, $d^3$, $g\#^3$, $a^3$, and $bb^3$. He understood the complications of the C-sharp tone hole, but was unwilling to make his key system more complicated; he placed the hole considerably higher than its true position and then reduced the size in order to compensate for the move. The Coltman C-sharp improved the intonation of the C-sharp, allowing performers the flexibility to color and shape the pitch as desired. The fingering is unchanged through the mechanical linkage.
The closing of the vent key overlays the new C-sharp key allowing \( L1 \) to operate it. When the vent is open a bridge and clutch from the B key closes the Coltman C-sharp key, allowing the standard Boehm fingering to apply. The mechanism is designed to retain the ordinary feel of the instrument, and the short bridge from the B key provides a reliable mechanism.\(^{58}\) An additional benefit of this key is better intonation of the C-sharp trills.\(^{59}\)

**The Brögger Mekanik**

The Brögger Mekanik was first introduced in 1986 and is patented in Denmark and the United States. It is used to facilitate difficulties within the pins and rods which connect the keys of the flute. This mechanism overcomes many of the problems of the Boehm mechanism, such as the keys coming out of alignment.

The **Boehm mechanism** pins the keys to the axle in order to operate a minimum of sixteen tone holes with nine fingers. Most of the fingers operate at least two keys at a time, one of which is being manipulated through the rotation of the axle. The springs are set at a higher tension in order to counteract the friction inside the rods, which occurs during each rotation (Figure 11). The Brögger mechanism transfers the motion needed to operate multiple keys through bridge rods and reduces the majority of the friction. The mechanism is smoother and the springs are more evenly balanced
through the entire flute (Figure 12). The Brögger mechanism allows for adjustments between keys to be made with full-sized back connectors, making them more stable and less apt to change. This mechanism is available in the United States through Brannen Brothers Flutemakers.\textsuperscript{61}

**Summary**

Over the last 147 years, the flute has improved through the hands of such inventors as Theobald Boehm, Vincent Dorus, Giulio Briccialdi, John Coltman, and Albert Cooper. In 1847, Theobald Boehm developed a new model flute with a new fingering system. In the following years improvements and minor changes were made to
the instrument and new keys were added to improve the intonation and flexibility while keeping the fingering system virtually the same. The options which are now available on the flute allow performers more choices and simpler solutions when playing difficult passages.

The Briccialdi B-flat thumb key helps many difficult passages which include A, B♭, C, B♭, while the John Coltman C-sharp key improves the intonation problems caused by the reduction of the C-sharp hole. Added note facilitators amend the problems of $e^3$, $f#^3$, and $c^4$.

Over the centuries the flute has had many dramatic changes affecting the quality and appearance of the instrument as well as musical compositions. Thanks to Boehm, the flute has advanced in
the musical world and, since 1847, only minor changes have been made. To quote Albert Cooper: "Boehm’s actual key work mechanism remains virtually unchanged to the day and for this we owe him a great deal."\textsuperscript{63}

Through trial and error, the pitch, tone, and texture of the flute have been improved, and will continue to improve with the help of performers and builders working together. By viewing the evolution of the flute, it is evident that it can no longer be considered a too limited or imperfect instrument.
TIMELINE

1838--Dorus G-sharp key. Vincent Dorus, a flute professor at the Paris Conservatory, developed a closed G-sharp key for Boehm's open system G-sharp. This key is based on the pre-Boehm fingering system.

1847--Boehm's flute of 1847. Boehm's final model was invented along with the Schema and new fingering system, which is used today. Between 1847 and 1859, Boehm made two flutes with his own closed G-sharp key.

1849--Briccialdi B-flat thumb key. Giulio Briccialdi, an Italian flutist living in London, made the only mechanical alteration to the Boehm fingering system by adding a B-flat thumb key.

1851--Boehm's flute took first prize in the Industrial Exhibition of All Nations.

1855--Boehm's flute took the good medal at the Paris Exhibitions. Boehm's flute took first prize at the General German Industrial Exhibition in Munich.

1860--In the 1860s the duplicate G-sharp appeared, inventor unknown.

1863--The first evidence of a C-sharp trill key which was used by the French firm of Louis Lot.
1895--The split-E mechanism. Djalma Julliot invented the split-E mechanism for the closed G-sharp flute, with the assistance of Paul Taffanel.

1902--The additional lever for the low C key was developed by J. Thibouville of Lamy and Cie., which allows L4 to manipulate c♭ in order to facilitate fast passages containing b, c♯, and c♯.  

1909--The C-sharp trill key was patented in France, by Mme. Cornelia Villedieu Laube.

1920--In the mid-1920s, the perforated model keys became popular in the United States.

1922--The Haynes Flute Company began advertising the advantages of the perforated model which were advocated by the Paris Conservatory, including intonation benefits through the ability to vent keys.

1923--"Gage Articulated B, F-sharp Device." Charles B. Gage attempted to invent a device to improve the intonation of f♯.  

1926--Lambros Callimahos added a new key on the under side of the flute tube in an effort to improve the intonation of f♯. 

1930--The "gizmo" key. In the late 1930s, George Barrère invented the high C facilitator, which was added to the low B roller in order to make c⁴ respond more quickly. This key was implemented first by Verne Q. Powell.
1967—Bruno Bartolozzi, author of *New Sounds for Woodwind*,
published a fingering chart based on the quarter-tone scale from
\( d^1 \) to \( e^3 \#^\wedge \).

1973--The Cooper Scale. Albert Cooper designed the Cooper Scale
based on a reevaluation of Boehm's work.

1974--Thomas Howell, author of *The Avant-Garde Flute: A
Handbook for Composers and Flutists*, stated that it is
impossible to play the quarter-tone scale on the plateau model
flute and published a quarter-tone fingering chart for the
perforated flute.

1975--Robert Dick published a quarter-tone fingering chart for the
perforated and plateau model flutes in his book, *The Other
Flute*.

1976--The Gizmo key. Powell began manufacturing the gizmo key
without an extra charge and made it a standard addition to the
low B footjoint.

1990--In the early 1990s, Albert Cooper proposed a logical solution to
the \( f^\#^3 \) intonation problem by changing the B-flat trill key into a
high F-sharp key.
NOTES


3. Ibid., 41, 45.


6. Ibid.


11. Ibid., 361-362.


13. Ibid.

15. Research does not reveal who invented this duplicate key.


21. Ibid., 21.


23. Toff, The Development, 73.


25. Ibid.

26. Research does not explain why the Briccialdi B-flat prevailed.


28. Ibid., 162.


30. Ibid.


32. Berdahl, "The First Hundred Years," 162.
33. Ibid., 170.

34. Toff, The Development, 132.

35. Ibid.


37. Picture taken by Carolyn Nussbaum.


40. Ibid., 8-9.


42. Picture taken by Carolyn Nussbaum.

43. Toff, The Development, 160-162.

44. Picture taken by Carolyn Nussbaum.


47. $c#^3$ is one quarter step higher than $c#^3$.


60. Sketches supplied by James J. Keefe, general manager of Brannen Brothers Flutemakers.

61. Information supplied by James J. Keefe, general manager of Brannen Brothers Flutemakers.

62. Ibid.

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