The History of the Murray Flute

by Trudy Jo Wintizer

The Murray flute is the result of much consideration and experimentation by Alex Murray who is presently Professor of Flute at the University Of Illinois. After many successful years of performing on the most common, basically Boehm, flute Mr. Murray began to consider improvements that could be made on Boehm's "98% perfect creation". To date Mr. Murray has presented more than fifteen different models of the Murray flute, each one incorporating another step towards 100% perfection.

Each of Mr. Murray's early modifications may be classified under one or both of the following categories: facility and venting. The earliest changes are listed below in chronological order.

Open G#	facility and venting
Open D#	facility and venting
F# lever	venting
Split A key	venting
C# tone hole, D vent, and thumb keys	facility and venting
Linkage of lower trill key to D for B3	facility

Mr. Murray first had these alterations made on his own Boehm flute, a Hammig. Over ten years of evolution passed (1948-59) before the last "Early Period" change.

Open g#

In 1948 Mr. Murray, then solo flutist of England's Royal Air Force Band, became dissatisfied with the closed G# arrangement of the present-day Boehm flute (fig.1).

As he has stated: "I read Boehm's account of his instrument with Dayton Miller's commentary and decided that the open G# (Fig. 2) was a more rational system for at least four reasons.

i) The duplicate G# hole is unnecessary.
ii) The spring of an open key is lighter than one required to hold the key closed.
iii) Top E is greatly improved when correctly vented with the A hole alone and not with both the A and G# holes.
iv) One finger – one key (pad) on G."

Murray thus asked a flute repairer to alter his Hammig flute to the open g# and found himself, after a few weeks practice, amply rewarded–and justly so, according to Philip Bate in his article on the Murray flute:

After much experiment with authentic Boehm and other well-designed flutes the late Dayton C. Miller concluded that the open G# is no more difficult to master than the closed version, and that it has certain advantages in some parts of the scale.

Bate mentions that "Boehm is said to have refused to make instruments with a closed G#, but it is known that he did construct at least one such instrument to accomodate a favoured customer."

Lawrence Taylor also tells of Boehm's preference for the open g# in his article "Special Flute Keys":

Yet, Theobald Boehm, who developed the modern system flute which we play today, himself preferred the open G#, considering it from the standpoint of mechanics and acoustics more logical and more nearly perfect than the closed G#. (This statement refers to both the Dorus key of the nineteenth century and the duplicate g# key of today.) On the open G# flute the two keys operated by the third and fourth (little) fingers of the left hand are mechanically independent in this wise: the third finger down, added to thumb, first and second fingers, sounds G#; to sound G natural, the little finger must be added to those already down.

In a word, on the open G# flute, the notes G# and G natural are fingered exactly opposite to the way they are fingered on the closed G# flute. Thus there is no need, on the open G# flute, for having a hole on the underside of the flute at the G# level of the tube.

Walfrid Kujala, in his article "The Murray Flurry," presents statements by Boehm showing that he endorsed the open g# for reasons of spring action:

Boehm said: "I chose the open keys, as giving the greatest possible ease in playing, since they easily follow the movement of the fingers, and only weak springs are required to raise them quickly. On the contrary, closed keys require strong springs in order that large holes may be stopped airtight, and their motions are contrary to those of the fingers."

In other words, with an open-standing key such as the open g#, when the finger goes down, a key (pad) goes down and closes a hole. With a closed key, however, when the finger goes down, a lever goes down and the attached key (pad) goes up, opening a hole, and creating contrary motion between the finger and the true key. Kujala also adds that "Roger Mather has measured the average spring tension of an open key at 22 gr. (the weight required to move the key) and a closed key at 40 gr., which is almost double."

In addition, the open g# is a more logical arrangement because with it, as one moves from g# to g natural, he adds a finger, thus continuing to move down the scale by adding one finger at a time and moving down the tube. On a closed g# flute, this downward, and the corresponding upward, pattern is broken.

Conceding the logic of the foregoing statements, one might wonder why the open g# arrangement went out of use to such a great extent. Lawrence Taylor offers one explanation:

Probably the main reason for its having gone out of favor was the fact that the little finger of the left hand not only had to put its key down for G natural, but also had to be down for all the notes below it, i.e. F# thru D natural. This would be extremely confusing for doublers on sax and clarinet, where the action and use of the G# little finger key is exactly as we have it on our closed G# flute.

Also, Nancy Toff notes in her book, 'The Development of the Modern Flute', that:

Boehm's original design called for the open type; he claimed that it was acoustically superior, more logical in fingering, and produced a clearer e3. Players accustomed to the closed G# of the old system demanded a return to that variety, but the Dorus key of the nineteenth century has been replaced by a first order lever with a duplicate G# hole on the near side of the flute for venting.

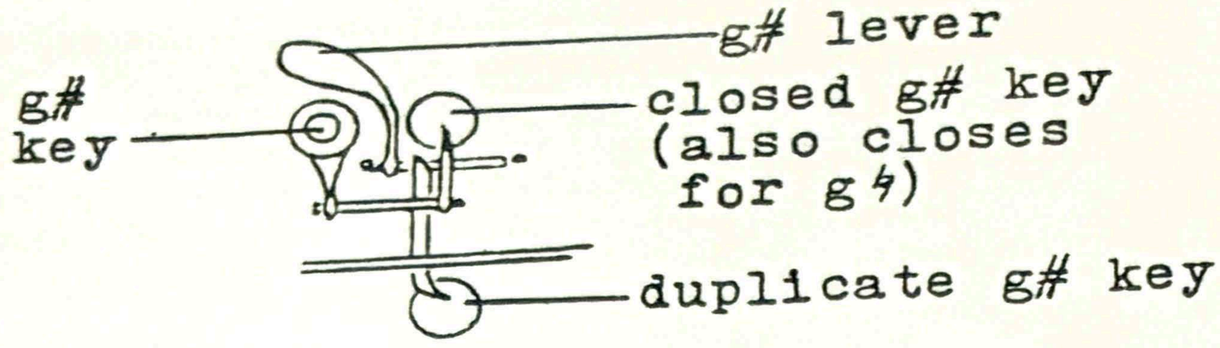


Figure 1. Present-day duplicate g# key (Diagram by Jerry L. Voorhees)

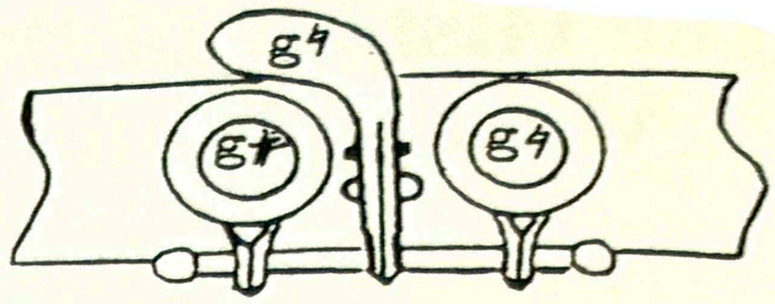


Figure 2. Murray's open g# (Diagram by Philip Bate)

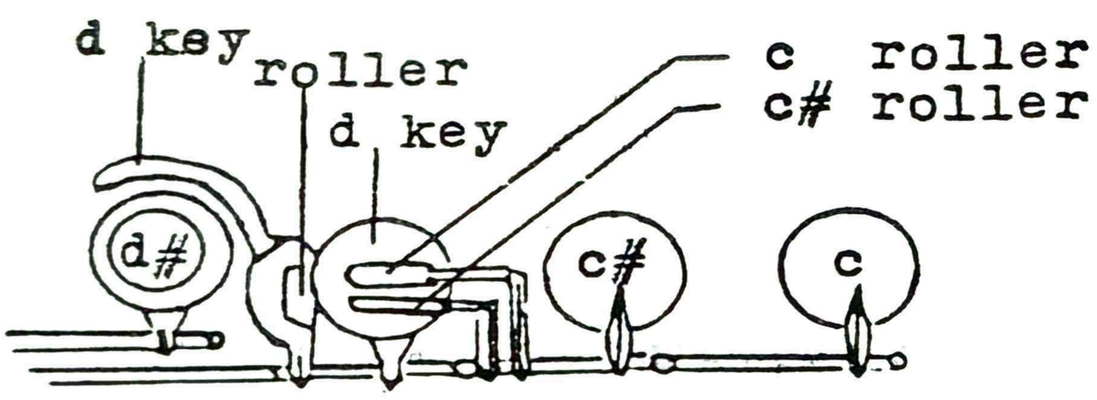


Figure 3. Murray's open d# mechanism, first arrangement (Diagram by Philip Bate)

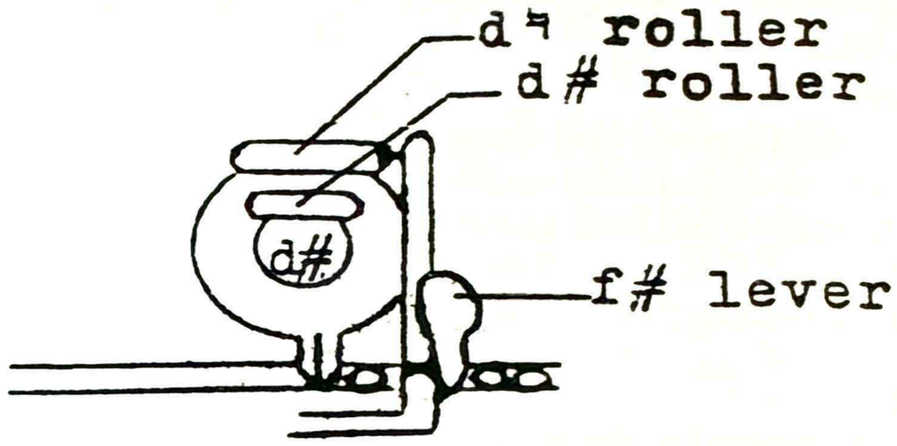


Figure 4. Murray's open d# mechanism, second arrangement

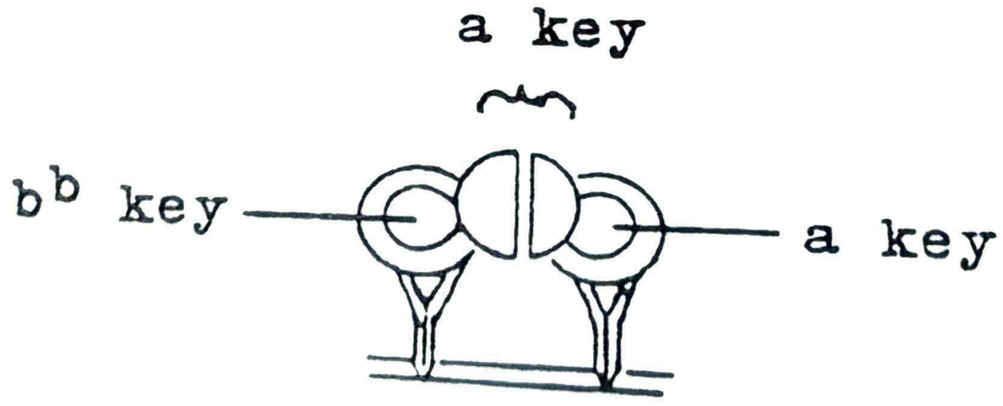


Figure 5. Split a key

Perhaps preference for an established system was an important reason for using the closed g# years ago, and perhaps the open g# does prove awkward for doublers today, but Murray has shown that the open g# is certainly advantageous for the modern flute player who does not double and who prefers the more logical and better-vented arrangement.

Open d#

The next change Mr. Murray incorporated also involved an inconsistency in Boehm's open-hole concept–the d# key (or lever) for the little finger, right hand. As Murray explains:

The asymmetrical use of the little fingers, in particular the necessity for maintaining the right little finger down much of the time struck me as undesirable and I experimented with an open d# by turning the foot-joint until the d# hole was within reach of my little finger. I unhooked the spring and maintained the key open with an elastic band. The flute became a little unstable to balance but I solved this by sticking a wedge of cork on the body above the right thumb. (I no longer require this crutch, having learned to balance the instrument without it.) I felt that the action of the key was an improvement on the closed d#.

In his article, "The Murray Flute: an Improvement," Mr. Murray presents various advantages that this new arrangement presents:

. . . the springing is lighter, the chromatic fingering D, D#, E is simpler, there is not contrary motion of the fingers in playing D-E and Eb-F. The flute cannot be gripped between the little finger and thumb (a bad habit which to my knowledge has nearly ruined certain players. . . .

Many people, however, agree with Philip Bate's statement that Boehm "seems to have regarded the closed D# key as unavoidable though it remained a glaring inconsistency in the 'open hole' concept." Also, Robert Baasch, in his article "The Murray Flute an Improvement?" states that:

. . . Boehm left the D# key closed for one logical reason: in requiring the player to hold the key open with the little finger of the right hand he gained the advantage of greater stability in holding the flute and at the same time established his complete open-holed system. It should be noted that Baasch considers the "open-holed system" and the "open-keyed system" to be two separate entities. This does not seem to be true of certain other noted authorities, including Kujala, Bate, and Murray.)

After careful consideration, one realizes that neither Bate's nor Baasch's statement is true. Murray has apparently overcome the "unavoidable" closed d# key, and Walfrid Kujala presents a direct response to Baasch's stability theory:

. . . This was not Boehm's reason, for he said: "I have retained the three foot keys for C#, D, D# for the little finger of the right hand in the form already well established." Furthermore, Boehm relied mainly on the left hand crutch for achieving stability: "The crutch should be inserted so that the weight of the flute rests between the thumb and index finger of the left hand, then the movements of the fingers will be much freer than when the thumb is used for holding the flute." In any case, it is by now well known that the right hand little finger is not necessary for balancing the flute.

If the closed d# key is not actually needed for balancing the flute, which is particularly true of new Murray flutes, then the ony rationale that remains for keeping the closed d# key is Boehm's–adhering to a pre-established form. On the one-keyed flute the little finger is relatively inactive, utilised for D# and F# in the lower octave. Contrary motion occurs between E & F# and not D & E as on the Boehm flute. The D# key does not remain open for most notes above D#. If this is done, however, the remaining 2% perfection of the flute will never be achieved.

In light of the foregoing evidence, Murray's second, and perhaps the most controversial, change seems to be quite rational and very profitable. As Murray points out, however, one inherent problem of the open d# needed to be solved:

The problem remained, how to trill c-d or c#-d. When the little finger was removed from c or c#, d# was the note that sounded. In order to circumvent this, a crescent-shaped key [Fig. 3] was built from the d key around the front of the ring-finger key. (I still use this mechanism on the piccolo). This finger could then close both keys simultaneously when required, giving d#.

Later it was found better to have two parallel rollers [Fig. 4] so that the ring finger could move easily from d to d#, in the same way as the little finger moves from c to c# on a flute with two rollers on the foot-joint.

f# Lever and Split a Key

After Mr. Murray had freed the little finger of the right hand of some of its usual duties, he began adding new ways it could be used for advantages never before possible (such as the c-d, c#-d trill key). Because the little finger now would not be in use between d and d1, he constructed a little finger lever for f# (Fig. 4), based on the same principle as the Carte, Julliot, Brossa, and Rockstro f# keys, which, according to Murray, has several advantages:

When f# is fingered in this way, all holes below the f# hole are open. A good trill for e-f# is provided with no change of fingering (for f#) and by splitting the a key [Fig. 5] (so that the b hole can remain open when the b flat hole is closed) and connecting the lower key to the f# lever, the correct venting for top f# is made practicable (comparable to top e on the open g#).

Murray also mentions that "the right hand has the normal F# fingerings available although these are only used when F# is preceded or followed by C1, C#1, and for F3-F#3 trill."

C# Tone Hole, d Vent, and Thumb Keys

Next, Murray's interest turned to the c#2 hole compromise of the common Boehm flute. He writes about this compromise and his solution in his article, "The Murray Flute":

The ~~other~~ notes which needed improvement were those using the small c# hole. The multiple function of this hole are:

i) a tone-hole for c#2, 3, and 4
ii) a vent-hole for d2, 3, 4, d[#] g#3, a3, b flat 3.

As Boehm pointed out, some compromise in its size and position is inevitable.

On many flutes the interval c#-d#2 requires careful blowing to produce a whole-tone acceptable to the ear (c#2 has to be flattened and d#2 sharpened, an unhappy juxtaposition of compensations). After several experiments a relatively simple mechanism was devised to divide the functions between two holes – a large c# tone hole [Fig. 6] and a small d vent [Fig. 7]. This entailed no change in fingering apart from a reversal of the Briccialdi thumb keys [Fig. 8] and a return to the more rational order originally used by Boehm (b1# [natural] nearer the headjoint) [in order to avoid a complicated trill mechanism] [Fig. 9]

Murray's arrangement (Fig. 10) differs from Boehm's, however, in that both thumb keys are merely touches that control keys located on the top of the flute and are both placed on the same axle. Although Murray does not fully explain in his article, "The Murray Flute," why the Boehm key order is more rational (and logical), Philip Bate, in his article on the Murray Flute, explains it rather succinctly:

On the original model of the cylinder flute of 1847 Boehm provided no Bb thumb lever. About 1849, however, Briccialdi, a distinguished Italian flautist then living in London, invented a thumb mechanism which is almost universal today, and in that year he had it constructed for him by Rudall and Rose. Soon after Briccialdi's invention Boehm himself designed a Bb thumb lever on a somewhat different

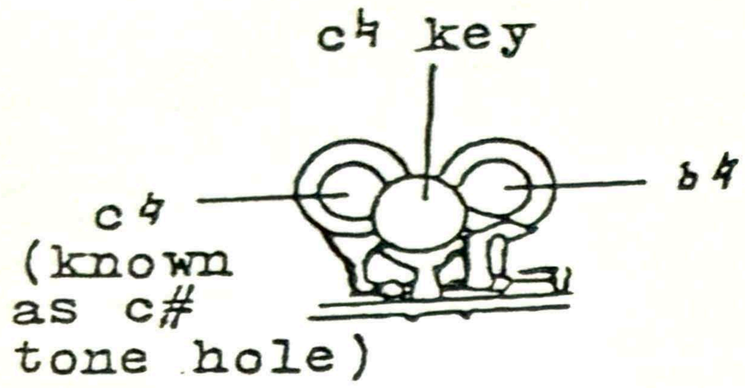


Figure 6. Large c# tone hole (top view of flute)

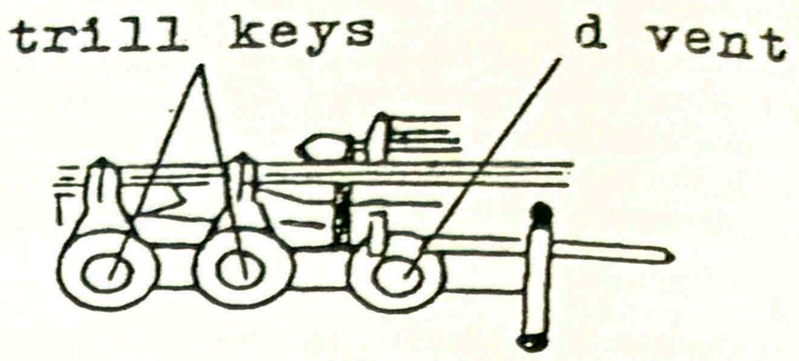


Figure 7. Small d vent (side view of flute)

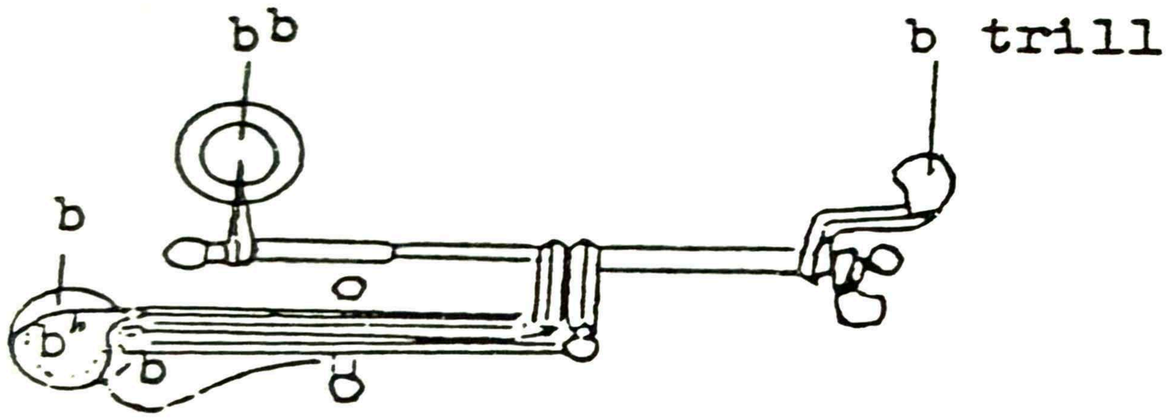


Figure 8. Briccialdi b^b thumb lever arrangement (Diagram by Dayton C. Miller)

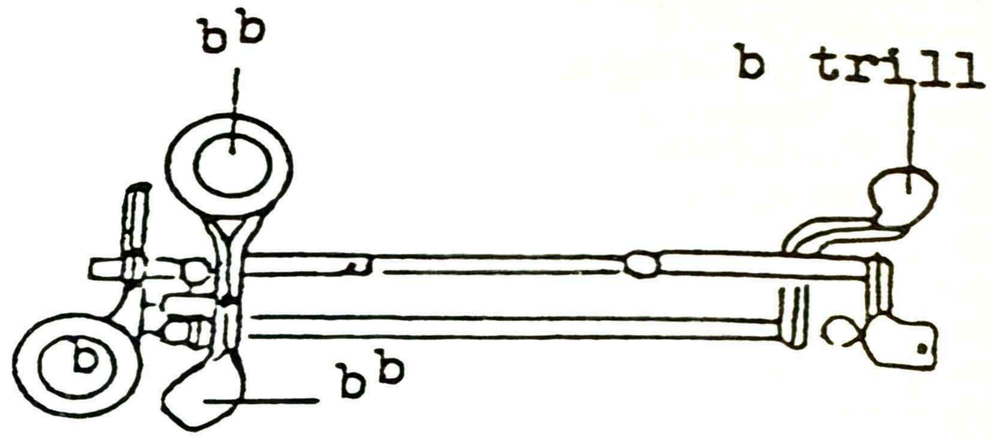


Figure 9. Boehm b^b thumb key arrangement (Diagram by Dayton C. Miller)

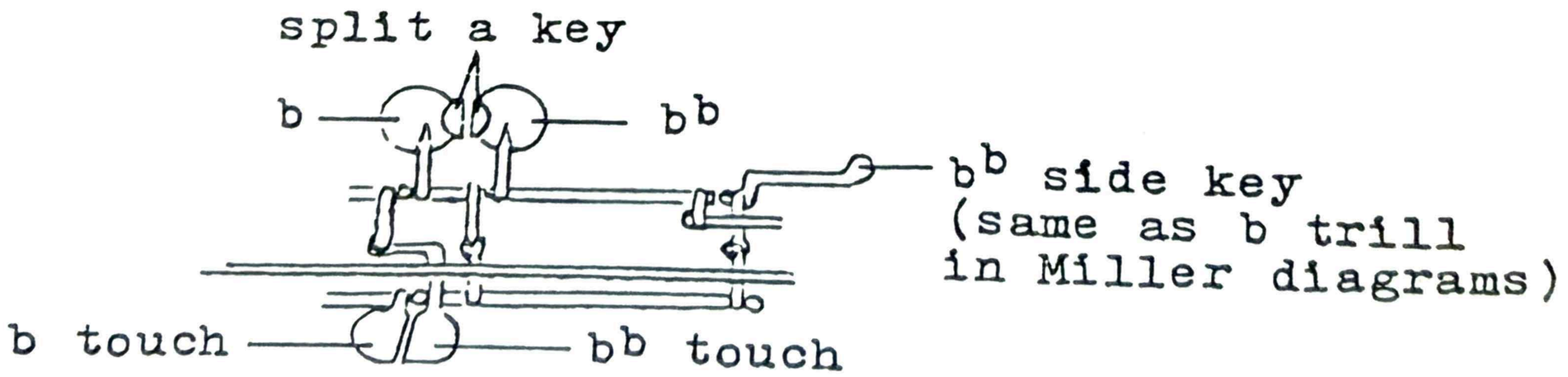


Figure 10. Murray b^b thumb key arrangement (Diagram by Jerry L. Voorhees)

principle, and employing, as he claimed, a more rational movement of the digit in that in passing from B to Bb the thumb moved down the instrument not up as with the Briccialdi. Both arrangements included a B-C trill lever for the right forefinger, though Boehm seems to have regarded this as an accessory rather than as a regular part of his system.

There seems to be no apparent reason why the Briccialdi arrangement (coming from the old flute in which Bb is fingered by a movement of the thumb in the head-joint direction) became "almost universal" and has remained that way despite Boehm's more logical arrangement where the thumb moves down the instrument to produce the lower-sounding b flat, except for, once again, the preference to adhere to a pre-established form. However, it is evident that by avoiding the common c# tone hole/d vent compromise Murray has improved the intonation and tone quality of both notes and has, in the process, incorporated more logic into the art of flute playing.

Linkage of Lower Trill Key to d for b3

One additional change remains in the "Early Period" of the development of the Murray flute, and that is the linking of the lower (d) trill key to b3. Philip Bate also explains this small, facilitative change very clearly:

Finally, the closed D trill key, which, together with the D# trill, has remained virtually unaltered since Boehm inherited it from Capeller, has been slightly modified. By linking it to the right hand D key the D# hole is automatically closed for the normal fingering of top B, thus again leaving the right little finger free.

CHAPTER II

THE MIDDLE PERIOD

The Middle Period of development of the Murray flute was mainly a time of trial and error experimentation. Mr. Murray preented more than ten models of the Murray flute within a fifteen year period, all having various alteration. These alterations ranged from the addition of various keys, which resulted in some fairly complicated mechanical designs, to changes in various key shapes, some of which were basically cosmetic. Nancy Toff, in her book, The Development of the Modern Flute, does an excellent job of presenting these changes and the rationale behind each of them. The tables which are included are comprised mainly of information extracted from her book. Thus, her book may serve as a reference if any additional information is desired.

In summation, it should be noted that all of the alterations from the Early Period were maintained in the Middle Period. Many of the alterations that were made during the Middle Period were changes of key shapes, such as the rectangular finger plates of the 1960 First Cooper Prototype and the various shapes used for the thumb keys, such as on the 1960 Armstrong prototype I and the 1972 Armstrong Prototype II. Key shape alterations were often attempts to facilitate finger movement, but were sometimes cosmetic as well. New keys and levers were also tested, such as the Dorus-like wishbone key and the e trill key of the 1976 M.O. Model. The late Period of development presents the most experimentally altered flute of the collection, and also shows which changes from the first two periods proved to be of lasting value.

Chapter III

THE LATE PERIOD

The Late Period of development of the Murray flute begins with the 1978 Final M.O. Model, which may justly be referred to as the acme of Murray's experimentation. A reconstructed early Armstrong model, the Final M.O. Model is still in the hands of Pat North for rebuilding. When asked to describe the Final M.O. Model, Mr. Murray writes:

The Final M.O. has two long keys for the right thumb which open holes opposite the b flat and f# keys to provide perforations. The g# is covered directly and is a perforated key [Fig. 11].

The thumb hole is perforated and fingered directly–the only key without a perforation is d#. (letter from Alexander Murray, April 9, 1982)

Perforated g#–covered by the little finger of the left hand. Fig. 11. Perforated g# key.

These additions were actually results from Murray's meetings with Robert Dick. Dick was interested in some of the earlier changes that Murray had made beause of the additional multiphonic options they presented. To increase the number of options for Robert Dick, Murray added the extra keys and perforations. Robert Dick had written and recorded a piece for the Final M.O. Model flute, the title of which is "Or," that is dedicated to Murray. "He wanted to write something that he couldn't do on anything else," mentions Murray.

There are, however, some inherent problems with the Final M.O. Model. Murray states:

[The new perforations] are very difficult to cover for small hands. The little finger of the right hand is overworked as d# is independent and must be closed simultaneously to play c#, c, and b (b is also independent) . . . . Is it worth it?

Perhaps the Final M.O. Model is worth the additional trouble for an avant-garde enthusiast looking for new sounds and colors, but it is certainly not a flute to be used in more traditional daily practice sessions. After the Final M.O. Model, however, Murray's interest seems to have turned mainly to simplifying and streamlining his flutes. The next flute Murray presented, an altered 1965 Cooper (Figs. 12 and 13. See also Table XV), is much less complicated than the Final M.O. Model.

Murray's next flute, the 1979 Murray-Coltman-Moore (Figs. 14 and 15. See also Table XVI), is even simpler in design than the Cooper with Alterations.

Murray's 1981 White Gold Model (Figs. 16 and 17. See also Table XVII), made by Jack Moore, looks slightly more complicated than the Murray-Coltman-Moore, but actually incorporates a very beneficial mechanism–the Coltman c#.

John Coltman, in collaboration with Jack Moore, has developed a new c# mechanism (Fig. 16) which Murray first used in 1981 on his new White Gold Model. The mechanism, which replaces Murray's c# tone hole/d vent arrangement, is described in Mr. Coltman's article, "A New C# for the Boehm Flute":

A new hole is added between the C# vent hole and the C (thumb) hole. In contrast to some other approaches to the problem, this hole is not used alone, but rather in combination with the vent to produce C#5 and C#6, while the vent is used alone for the notes D5, Eb5, D6, G#6, A6 and Bb6. This separation of functions makes it possible to adjust the size and position of the vent to get the vented notes (especially G#6) in tune, and then to depend on the added hole to produce C#'s that are in tune and have tone colors consistent with the other notes of the flute.

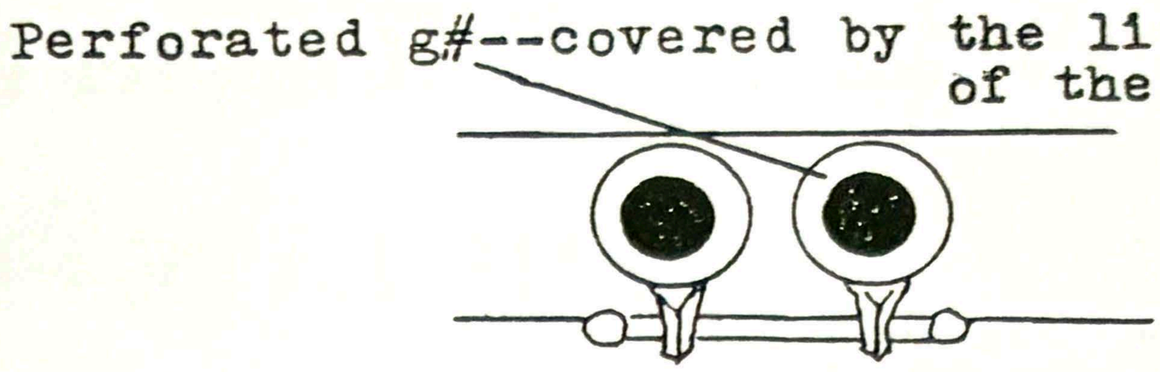


Fig. 11. Perforated g# key

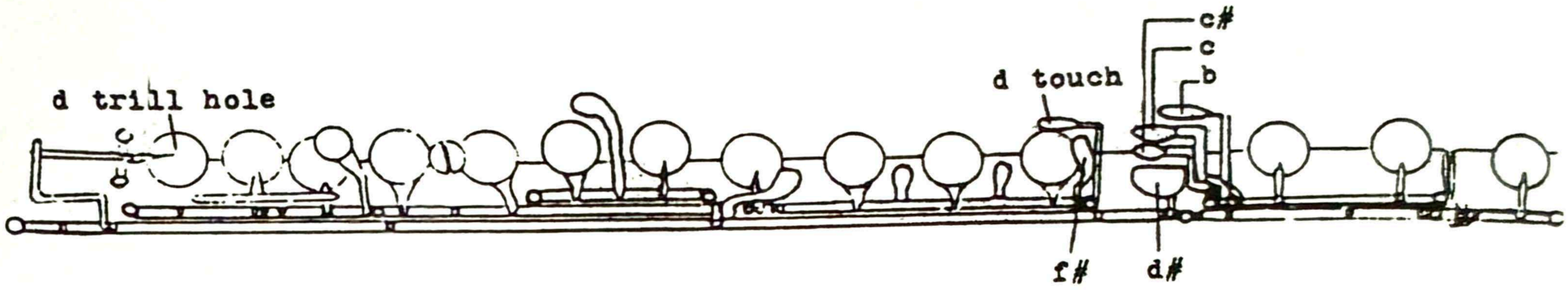


Fig. 12. 1965 Cooper with Alterations (top view)

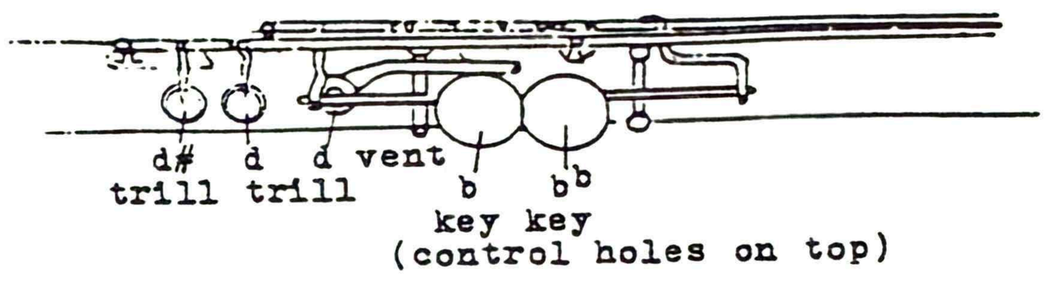


Fig. 13. 1965 Cooper with Alterations (side view)

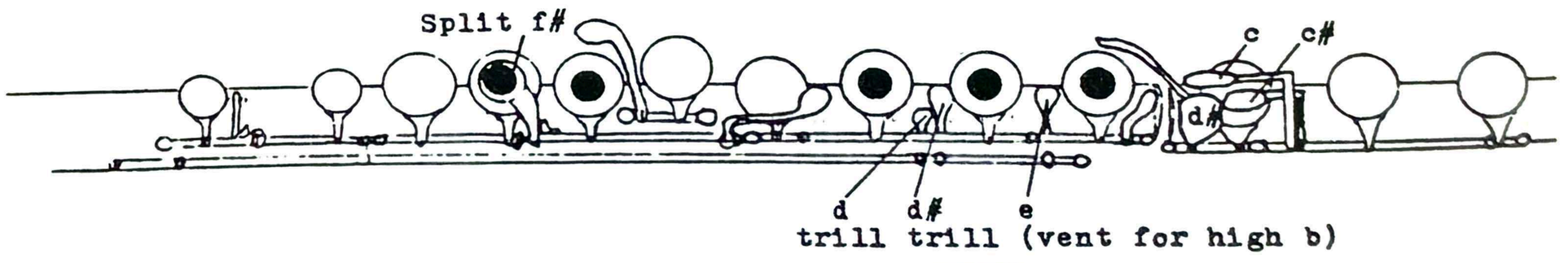


Fig. 14. 1979 Murray-Coltman-Moore (top view)

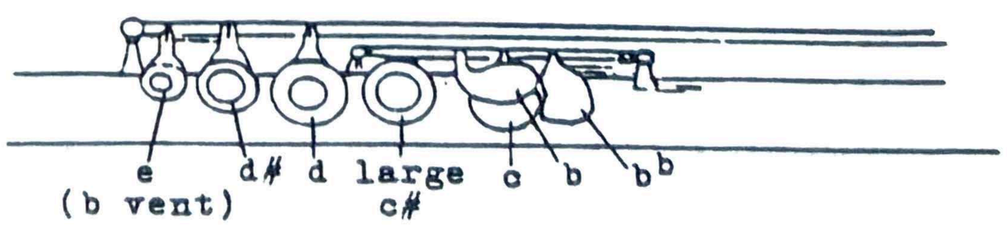


Fig. 15. 1979 Murray-Coltman-Moore (side view)

The vent key is operated as usual by a touch for the first finger. This touch overlays the key of the new hole, so that it holds this key down also. When the first finger is up, the new key is closed by a bridge and clutch from the key on the B hole. This key is down for all the notes which employ a C# vent, so that the vent hole operates alone on these notes.

The vent hole and the new C# hole are not very large, and their keywork and springs are made light so that the feel of the ordinary C# touch is retained. The bridge from the B key is short and is rigidly supported on the C# key axle, so that this mechanism is positive and reliable. Because the new key is held down by the first finger for all notes except those employing the C# vent, the presence of the bridge introduces no change in the feel of the flute mechanism.

Murray's newest flute, made in 1982 by David Wimberly of Elkhart, Indiana, is supposedly his last. "Simplicity is now the keynote," states Murray. As one looks at a list of specifications for the Wimberly flute, one sees that Murray is true to his word:

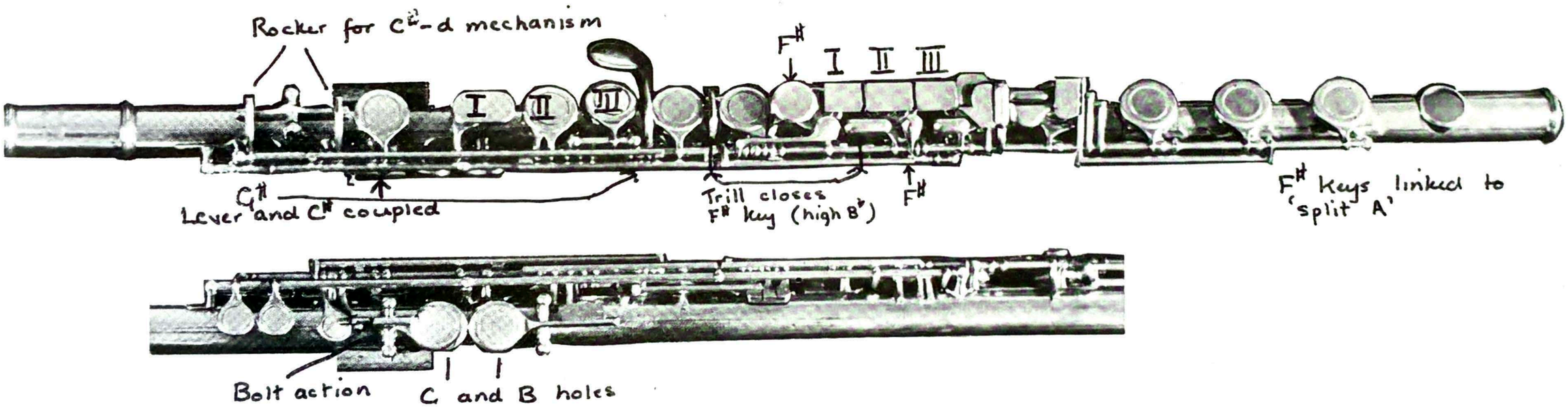
1. Coltman c#
2. Murray/Brossa f#
3. Reversed thumb keys (Boehm arrangement)
4. Two trills (large d and d#–d# vents high b and b flat)
5. Open g#
6. Open d#
7. No split a key
8. Open holes
9. Offset g-a
10. c foot
11. Silver body, head, and foot with nickel key work

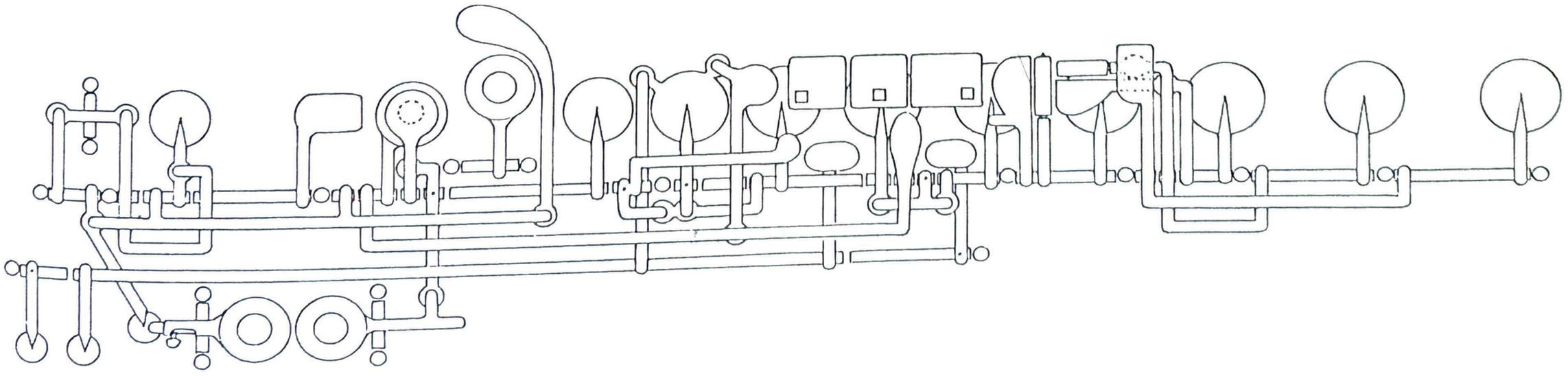
It should be noted that each of the first six items listed is actually either a change that was made in the Early Period or an improved variation of an Early Period alteration. The Murray/Brossa f#, open g#, and open d# are reproductions of Early Period alterations. The Coltman c# replaces the c# tone hole/d vent arrangement, but the Boehm thumb key arrangement is still retained. Also, the venting of high b is still accomplished with the two trill keys available on the new model. The only Early Perid alteration that is not accommodated on the Wimberly model is the split a arrangement, which has apparently been sacrificed for simplicity. The remaining specifications are those common to many flutes produced today.

Although many of Murray's alterations proved to be too complicated or inefficient for practical use, one should remember that it has been his continued interest in experimentation and willingness to revise his designs that have allowed him to create the balance between mechanical innovaion and simplicity of mechanism and execution that he presents to us today.

Murray Flute by A·K· Cooper, London.

No. I - large tone holes throughout. (1961)





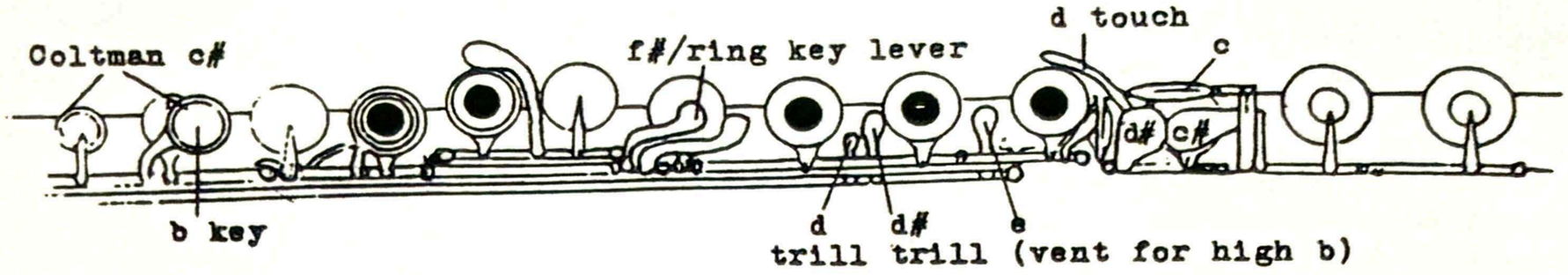


Fig. 16. 1981 White Gold Jack Moore Model (top view)

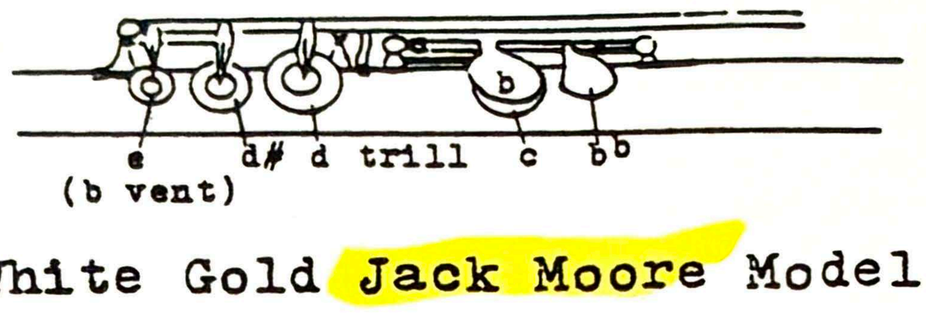


Fig. 17. 1981 White Gold Jack Moore Model (side view)

Table I

1960 – First Cooper Prototype

Characteristics	Explanation
1. Alterations applied to Murray's Hammig flute	(from early period)
2. Cooper experimental scale	(see Appendix B)
3. Third thumb key	(below b flat touch; closed c natural hole without closing c# to produce g3#)
4. Rectangular finger plates	
5. b natural footjoint	

Table II

1961-2–Murray "Mark I"

Characteristics	Explanation
1. Rectangular touches, right hand only	
2. Circular-shaped thumb keys	
3. No third thumb key	
4. Remaining thumb keys cover their holes directly	
5. Rockstro-like f# key	(for right hand ring finger)
6. Split f	(also connected to a right forefinger lever)
7. Uniformly large tone holes	(based on Rockstro's pattern)
8. Embouchure ae measures as close as possible to that of tone holes	(resulted from Murray's hearing Severino Gazzelloni play a flute with an unusually large embouchure)

Table III

1964–Cooper No. 129

Characteristics	Explanation
1. b flat hole on top of flute again	
2. c hole remains under upper thumb key on the near side	
3. Circular split a	
4. Two rollers (d and d#) superimposed on the d# key on footjoint	
5. Large rectangular d plate	(to the right of the d# key; provides the most direct fingering for d)
6. Flat plate for c	(to the right of the two rollers)

Table IV

1965–Cooper 131

Characteristics	Explanation
1. Thumb key pattern of first modification	(from Hammig)
2. d# roller removed from d# key on footjoint	
3. Roller to operate the optional b foot	

Table V

1971–Armstrong Prototype I

Characteristics	Explanation
1. By Jack Moore	
2. Changes in thumb key shapes	
3. d# roller reinstated	(over d# key on footjoint)
4. Circular d touch	(over d key on footjoint)
5. Alteration of positions of c natural and b rollers	(both stand vertically on the lower side of the d key)

Table VI

1972–Armstrong Prototype II

Characteristics	Explanation
1. Changes in thumb key shapes	(to trapezoidal and rectangular, respectively)
2. Split a plates form an oval	
3. c foot	
4. Form of Cooper No. 131 readopted for c natural	(vertical disposition of the c roller unnecessary)

Table VII

1972–Armstrong Production Model

Characteristics	Explanation
1. "School Model" flutes	(for use by students)
2. No d# roller	
3. Modified thumb key shapes	
4. Modified d plate shape	
5. Circular split a	
6. Two pieces	(no separate footjoint)

Table VIII

1973–Armstrong Heritage Flute No. H–3002

Characteristics	Explanation
1. Large d trill	(on top of flute; no room for it on the side)
2. d# roller appears again	
3. c#, c natural, and b rollers are in a parallel, horizontal series	(above the d key–or d hole)
4. c natural roller is considerably longer than the others	(for better facility)
5. b foot	(with detachable b key)
6. First gizmo on a Murray flute	

Table IX

1974–White Gold Model

Characteristics	Explanation
1. c foot	(thus, no gizmo)
2. No d# roller	
3. Ring over hole cover of the key	(pressing hole cover alone closes only that key; pressing ring closes the b flat key, also)
4. Parallel lever for right index finger	(just below the b flat/e side key; for c#-d or g-a trill)

Table X

1976–French Model

Characteristics	Explanation
1. Open-hole	(an adaptation which met with the approaval of Robert Dick, the advant-garde flute specialist)

Table XI

1976–"M.O." Model (Multiple Option)

Characteristics	Explanation
1. Developed from 1976 French model	
2. All keys open independently	
3. Elimination of parallel bar in thumb key mechanism	(for simpler appearance)
4. Three trill keys	(large d and d#, and small e, the latter designed by Robert Dick for multiphonics; later removed)
5. Dorus-like wishbone key	(an expedient; applied to b flat lever and f# key; abandoned in favor of simplicity)
6. Left hand forefinger touch is an open ring	("merely a gimmick") [Toff, The Development of the Modern Flute, p. 154]

Table XII

1976–F Flute

Characteristics	Explanation
1. For Murray's young daughter	
2. No c# mechanism; only one vent for c#	(space limitation of smaller flute)
3. Left hand closely resembles Boehm's design	
4. Upper (b) thumb key covers c hole directly	
5. Lower (b flat) thumb key closes b natural holes on top	
6. d vent on top of tube	(space limitation)
7. c# key reverted to a crescentic touch curving around the d# key on footjoint	
8. Closed-hole	
9. Other minor key shape changes	
10. Body by Cooper and keywork by Moore	

Table XIII

1976–Moore Prototype

Characteristics	Explanation
1. d vent moved to top of tube	(because of success with design of f flute)
2. Open-hole	

Table XIV

1977–Jack Moore No. 33

Characteristics	Explanation
1. Open-hole	
2. f# is played with the a key	(split a was initially controlld by the right hand middle finger)
3. The three foot rollers	(b–largest, c#– smallest)
4. No gizmo	(not necessary–b roller can be reached without depressing c or c# roller)
5. Keywork by J.R. Kilpatrick	
6. Three trill keys	

Table XV

1978-1965 Cooper with Alterations

Characteristics	Explanation
1. d trill hole on top	(d vent on near side necessitates this placement)
2. d# key linked to trills	(for venting of high notes)
3. f# lever closes b flat hole automatically	
4. Adjustable foot	(sounds notes down to low a; retained from 1965)
5. Inoperative d trill	(blocked by addition of large d trill)

Table XVI

1979–Murray-Coltman-Moore

Characteristics	Explanation
1. e trill key	(vent for high b)
2. Replacement of split a key with split f ring	
3. Changes in shapes of right hand little finger levers	
4. Removal of complicated d trill hole mechanism	
5. Pounded Cooper headjoint	

Table XVII

1981–White Gold Jack Moore Model

Characteristics	Explanation
1. Coltman c#	
2. f#/ring lever	(for right hand index finger; closes f# and ring key)
3. e trill key	(vent for high b)