Cooper's Scale Revisited

by Trevor Wye with William Bennett and Eldred Spell.

Albert Cooper's Scale revolutionized our flutes, serving us well for more than 30 years. It remains considerably better than the non-Cooper variety, but needed updating.

For those readers unfamiliar with flute scales there is much to absorb in this article. To make this easier, after an **Introduction**, it has been divided into six sections:

1. Why a Revision of Cooper's Scale is Necessary. The history behind the formation and calculation of the first Cooper Scales and concludes with how the **Revised Cooper Scale** was arrived at, together with notes on retuning flutes.

2. Intonation Control by Flutists which may help illuminate some of the problems of performers and their flutes.

3. Twelve Popular Misconceptions about Flutes and Intonation.

4. Is Your Flute in Tune? A simple process using a flute and a tuning machine, by which a player can find out whether their flute has a good scale. Includes advice on buying a flute.

5. A Plea to Teachers, Players and Makers.

6. The Revised Cooper Scale: the figures.

Introduction: To understand a flute scale, the tone-hole positions are best seen as related to the layout of the guitar fingerboard, an idea suggested by the brilliant Theobald Boehm and referred to as his "Schema.":

The placement of tone holes follows a simple mathematical layout, but with certain allowances added for tone hole size, open/closed keys, key height, and a few more subtle compromises. Until the 1960s, the traditional high-quality flutes, such as those by the two famous US makers, and many European instruments too, were built to between A=435hz and A= 438hz, the performer being expected to play them at A=440hz or higher. As the orchestral pitch rose in the 1930s, makers appear to have shortened the head joint, but also as time passed, made alterations to the scale by moving a few holes. Perhaps the reason why a complete revision of the scale was thought unnecessary was that the rise in pitch was too small, or perhaps the knowledge of how to achieve this was wanting. Makers ought to have calculated a new scale, but the method of calculation seems to have died with Boehm.

When the scale is poor, the player needs to develop special intonation control skills to overcome the faulty workmanship of the maker. Some have managed to do this with great dexterity in the same way that a fine violinist might still manage to play a badly tuned violin in tune. But why should they? The remedy is easy. Older flutes may be well loved and cherished, but today, it is relatively easy to buy both a first rate flute and separate head joint which would satisfy the most discerning player who has an open mind.

1. History of the Cooper Scale.

In 1945, Albert Cooper returned from military service back to Rudall Carte & Co, the London flute makers, where he was formerly apprenticed. There he repaired and overhauled numerous makes of flutes, becoming interested in the difference in scales between them. In 1959 he left Rudall & Carte to set up a repair service, but soon began making flutes. He devised an initial scale, based on what he saw as the 'faults and virtues' of those flutes he had measured at R&C and his own reasoning and experience. In 1955, William Bennett was playing a Louis Lot flute rebuilt by Charles W. Morley, probably to a Rudall & Carte scale.* In 1956, whilst in the USA, he tried Haynes and Powell flutes but was dissatisfied both with the scales of the US flutes and of his rebuilt Lot, and began changing the scale according to his ears and performing experience. To do this, he devised a method of removing the tone holes, hard soldering them onto a piece of scrap tube which were then cut out to leave enough remaining material to allow them be to replaced in the new position, a technique known as 'patching.' This ability to adjust one or more tone holes still remains an essential tool in the search for a perfect scale.

A talented and intelligent London orchestral principal, Elmer Cole, calculated the tone hole positions according to Boehm's Schema. The resulting scale was based on tone holes of an equal diameter, 15.6mm. For tonal reasons, flutes require graduated tone holes, becoming smaller as the scale ascends. Cole devised a *'correction graph'* to enable the position for smaller diameter tone holes to be calculated, but found that even further adjustments were required for serious performing. Richard Lee, another London player, was also involved in retuning his flute and, along with Bennett, was in frequent consultation with Cole. All were in regular touch with Albert Cooper, whose home became a clearing house for information on 'the scales.'

Meanwhile, the Taylor brothers, Christopher and Richard together with Alexander Murray, at that time all London Symphony Orchestra players, made their own contributions, based on the Cooper flutes they owned and played and their criticisms of the scale. One of these was that both the top four left-hand notes A, A#, B and C - and the last three right-hand notes – F, F# and G - were too flat. Cole changed his *Correction Graph* to put this right, curving his graph at each end in order to sharpen the left hand notes, and sharpen the foot joint notes too. (C, C# and D). Cooper's pragmatic solution was to use Boehm's Schema but split into two, using a sharper version for the right hand and the usual one for the left, though he too sharpened the A#1, B2 C2 and C#2. These were really variants of the same idea.

* Rudall Carte had a tradition of altering the pitch of flutes by modifying and fitting old keywork to new bodies, a practice going back for many years but alien to the US makers; it may account for the reluctance of US makers to change the scale.

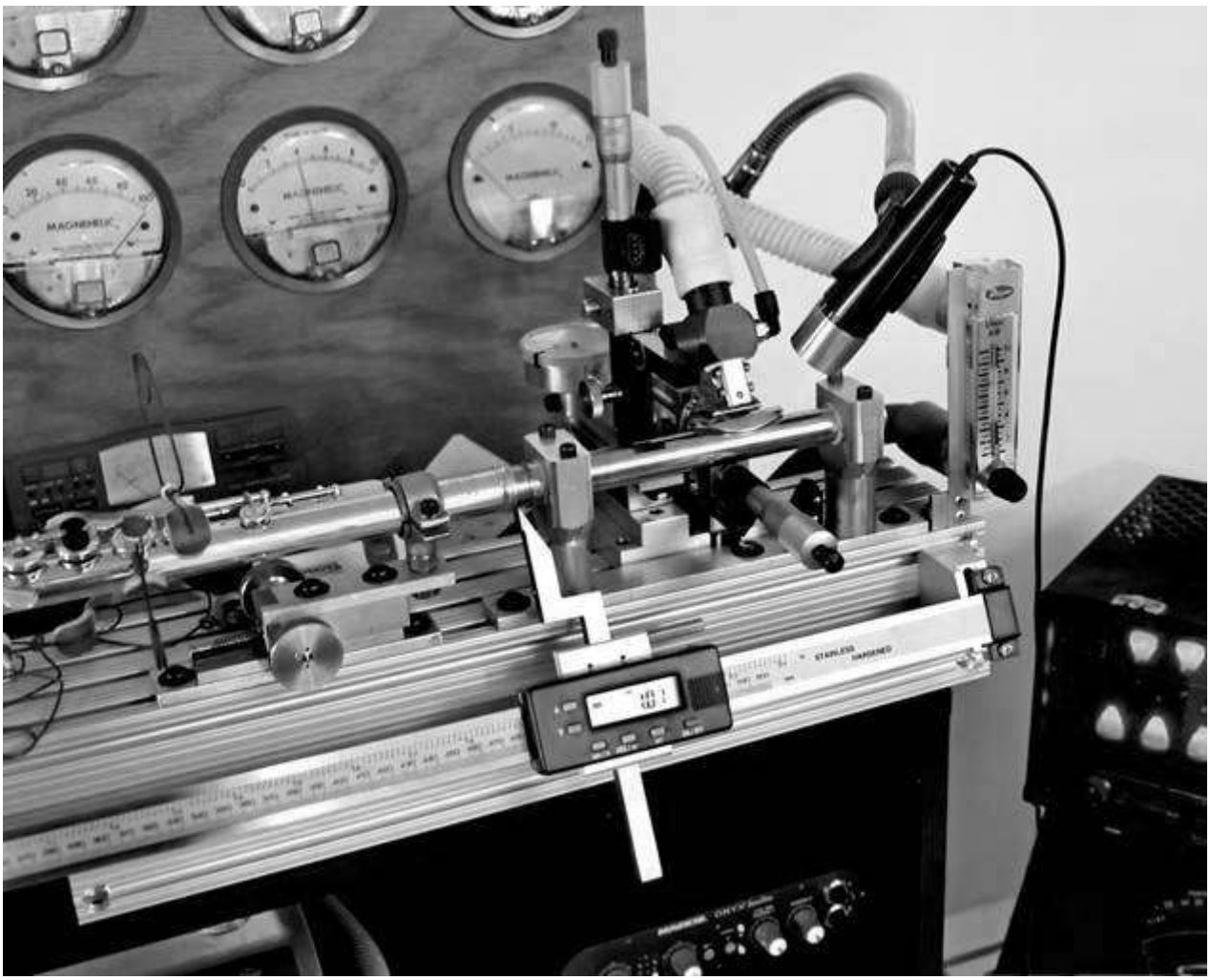
The London players decided that the new Cooper scale was easier to play in tune and as well as ordering a new Cooper flute, asked Cooper to retune their favourite flutes such as Louis Lot, Bonneville, Haynes and Powell, to his scale. Cooper obliged when he had the time and after removing the tone holes, used both Bennett's 'patches' method and also 'swaging' or pushing and persuading the softened silver tube to partially refill the hole, which allowed the tone hole to be repositioned.

During the 1970's, Trevor Wye began retuning his own flute and was later asked to retune many British orchestral player's flutes to Cooper's Scale using a mixture of Bennett's 'patching' and Cooper's swaging method. During this time, Bennett, Cole and Cooper continued suggesting small amendments to the Scale in the light of criticism and performing experience. Wye incorporated these amendments in his retuning. He also built what became known as an *'Automatic Trevor',* a tube with movable tone holes and a powered blowing apparatus. This experiment was conducted to confirm that the Cooper Scale was indeed correct and although several interesting assumptions were confirmed, the device seemed unable to play octaves accurately and was abandoned.

The correct position of the C#2 hole has been one of the major contentions amongst makers who have struggled over the years with its exact placement. This small tone hole must fulfil seven functions* and needs special management to play it in tune. Its diameter and height also play an important role, the latter not being widely appreciated. Players recommend a variety of ways to control the pitch and colour of C#, but none of these replaces having the tone hole in the correct place.

Working at first independently in the US, Eldred Spell joined in after meeting William Bennett in 1976. Initially skeptical of altering old flutes, he eventually retuned instruments for many of the English principals, including Bennett, Wye, and Geoffrey Gilbert. Being of a scientific/analytical bent, he was particularly bothered by the need to falsify the numbers in order to get a workable scale and has devised many experiments to get at the truth. Most recently, his apparatus which simulates the blowing of the flute,

photographed below, is an attempt to refine some of the less well-known aspects of flute making and scales - such as the displacement graph and the difference in tone hole positions between open and closed flutes. He is hoping too, to establish more exactly the correct 'scale length;' that is the total length of the flute from C1 to C2.



See another photo at the end.

Meantime, William Bennett's continuous experiments with flute scales and the diameter and height of the tone holes, resulted in several important changes to Cooper's original Scale. His dogged persistence in seeking perfection has been largely responsible for this revision of Cooper's Scale. Bennett's Scale, which he has already given to several makers, is similar to Cooper's but with minor personal alterations.

As 'the Scale' developed and players offered their opinions, Cooper updated his figures and gave the latest revision to anyone who asked for it. Over time, he gave the latest scale to different makers. Just a few years ago, he said: *'Cooper's Scale? What's that? There isn't 'a' Scale. There is a constant revision taking place so that, at any one time, there is a set of figures which you can use to design your flute, but these will change in the light of experience. I altered the scale a little as the years went by, mostly according to certain criticisms levelled at it. I now feel that I have more or less reached the end of the road scale-wise.'*

Several versions of Cooper's Scale appear to be used by makers, perhaps passing on the figures to each other, or measuring sample flutes, but the translation from one maker to another has resulted in inaccuracies. In the past few years, we three have questioned the most commonly used set of figures of the original Cooper's Scale supplied by Cooper as manufactured by leading flute makers. These were the general observations: middle D seemed to be a little flat; the left hand Bb and B are too flat; both C2 and C#2 sharp are too high - perhaps because the open hole correction had not been correctly calculated.

The three of us have been in contact over the years regarding changes and improvements, but recently more often because of our common agreement that Cooper's scale is no longer fit for purpose. Although not absolutely satisfied, we agree that we have progressed far enough to publicly declare our

findings and make this new scale available for use by makers if they wish. In fact, we urge them to do so. The RCS is free to use as required.

** It is open for C#2; D2; Eb2; C#3; D3; Ab3; A3*

Below is an example of the kind of discussion that used to take place about flute scales:-

* A note from Cooper to Bennett, c.1986:- *Dear Wibb, I wish I had paid more attention to the calculations of the R.H. holes of the Jack Moore flute. Enclosed are my original calculations of which there are 2 errors. Firstly – the F# was wrongly placed, see red ink correction. Secondly – having done the F# correction, all the RH holes should be sharpened .2mm. Take notice of the green ink figures. The odd peculiar R.H. hole size threw me. I hope you can alter the stick as indicated, or let me alter it. I still think the R.H. holes I indicated as flat, are still a bit flat, but not as bad as first indicated. A.C.*

2. Intonation Control by flutists

The intonation of most flute players is inconsistent worldwide, professional players included and varies from country to country. In many countries, it is masked by a virtuoso technique and a rich tone leading the listener to be captivated by these attributes, but disguising the underlying problem. The flute doesn't naturally lend itself to big dynamic changes which persuades the performer to use only small nuances so as to veil changes in pitch. Players avoid playing loudly and softly because, sensibly, they prefer to steer clear of intonation difficulties. *Don't bother with loud and soft playing. It is easier to play with minimal expression.*

As the air speed/pressure is lowered to play softly, the pitch drops; when the air speed and pressure rises when playing louder, the pitch also rises. At the extreme ends of the nuances, the rise and fall in pitch is considerable and apart from the recorder, the flute is unique in this - unlike the remainder of the woodwinds. Reed instruments have a 'built-in' correction which operates to their advantage and which accounts for the fact that other winds don't have the same pitch differences when playing loudly and softly as flutes. When the clarinettist wishes to play softly, they blow less hard –which lowers the pitch - but at the same time they *reduce the aperture between the reed and mouthpiece.* If they didn't do that, the note would be breathy or disappear completely and this action also has the effect of preventing the pitch from dropping. This is an over-simplification, but the same idea works for the double reeds too though players still have to correct the relatively small changes in pitch between forte and piano, but not to the same degree as flutists. Reed instrument players indeed have to control the pitch but it is not as *variable* as on the flute. We flutists have to learn a different technique to play accurately in tune.

What is important is not how to correct a flat or sharp note, but the perfect control of intonation which allows the player to use loud and soft notes, crescendos and diminuendos to be truly expressive, something exceptional amongst flute players worldwide.

This technique involves using the jaw and lips to raise the air stream and uncover the mouth hole when making a diminuendo to prevent the pitch from dropping and has been set out in detail elsewhere.* Some teachers suggest that moving the jaw is wrong; others suggest that the lips must remain relatively still; others again that pitch is controlled by a procedure called 'support' (the Holy Word of Teaching); others again suggest correcting the pitch by rolling the flute in and out; some performers suggest, '*Think sharp'*; another well-known player confessed, '*I have had the socket of the headjoint highly polished so that I can move the headjoint in with my left hand when a pp passage is imminent!*' A famous professor was more than once observed tugging his ear lobe when the student's intonation was appalling, though no practical corrective solution was offered.

Some of these techniques might help to correct a *pianissimo* flat note, but are flawed as a method of playing expressively. Some are just silly. Even so, a number of players have managed to play quite well in tune, perhaps learning to control their intonation by instinct, or even being forced to do so for survival in our competitive profession.

* Practice Book One – Tone. Trevor Wye. (Novello) pp 34 - 37

3. Twelve popular misconceptions about flutes and intonation.

* **Fingers and Key height**: '***Keep your fingers close to the key cups; your technique will be faster and neater.'*** This popular culture of keeping the fingers close to the keys - and of repairers keeping the key cups low – encourages a faster performing speed and a neater technique, a practice found mainly among flutists. Other woodwinds keep their fingers fairly clear of the holes or the notes would be flat, but this has the same effect on the flute. If the player uses an open hole (French Model) flute and plays with the fingers almost touching the keys, it will result in a slightly muted tone and some flatter notes. In fast passages, of

course, it is not significant, but in slow tunes, close fingers will affect the intonation. Players who adopt this technique are in effect playing a closed hole flute.

Repairers and players like the 'feel' of a closer mechanism, but when the key cups are too close to the tone holes, the sound is very slightly muted, more so on closed hole cups than open. The foot joint cups should be no less than 3.8mm above the tone hole and as much as 4mm; the right and left hands ideally the same This will ensure the clearest tone and correct intonation.

* **The C# sharp problem:** '***There is no 'correct place' for the C# hole. It is up to the performer*'** There is a very *good* position in which to place the C#2 tone hole and we three have spent several years of experimenting to determine where this should be. The note still needs care and practice to centre the tone, but the pitch is adequate. On most flutes, including the original Cooper Scale, it is too sharp, a common complaint. Putting fingers down in the right hand to correct a sharp C#2 should not be necessary and in any case, only allows the player to create extra resonance so that the *timbre* may be altered. Adding fingers also alters the partials (harmonics) and though it does help with technical stability, it hardly affects the pitch.

*** '*Open and closed hole flute scales are the same*'** This is a fallacy and irresponsible of flute makers to ignore basic acoustics just to simplify the manufacturing process. It is more economical for the maker to 'tool up' making one flute body for both open and closed hole flutes but is a lazy approach, and assumes the customer doesn't care. Manufacturers producing both open and closed hole flutes with the same scale are surely working on the fact that the customer *doesn't know*.

The air vibrates in a curved cone above the tone hole. The top of the cone is interrupted by the key cup and pad but a hole in the cup allows a more venting, resulting in a sharper note. Ideally, all tone holes should have open cups above them and experimental flutes using this idea are currently available for use by extended technique aficionados, but for the normal orchestral player, the five open cups* as on a 'French Model' flute offer several alternate fingerings and can help to tune otherwise difficult notes, particularly in the third octave. Eldred Spell's experiments have established that the left and right hand open cup correction is different.

* E, F, F#, A & A#

*** *Different versions of 'equal temperament'*** Examples from makers brochures:- *'A mathematically constructed scale'; '...offers perfect intonation', 'After many years we have perfected a true scale which allows you...'* etc., etc.

Makers inventing their own versions of equal temperament is analogous to making different lengths of a foot-rule with the inches unevenly placed. Guitar frets are uniformly placed by all makers according to equal temperament.

As Elmer Cole, Albert Cooper and other flute makers have revealed, Boehm's Schema, a way to mathematically calculate the position of the tone holes set out in 1847 to give us a good scale, *doesn't actually work quite well enough in practice*. That is to say, the math takes us to a starting point: from there on, there are a number of variables which are not completely understood, but include the open hole allowance, the key rise and the tone hole diameter correction. This much is known: we three had to experiment and change the scale figures accordingly. We are not *completely* satisfied that the scale set out below is the last word, but it is much better than older versions of Cooper's Scale and better than any popular flute maker's scales today.

At the time of writing, (March 2011) we have just acquired a cheap flute allegedly built to Cooper's Scale which required the removal and replacement of no less than eight tone holes to turn it into a playable flute.

*** *'It is not flutes which are out of tune, but flutists'*** Actually, it's both. An eminent flute maker made this statement many years ago while making flutes at A-435 to be played at A-440 or higher! The manufacturing quality of these flutes was beyond question, but like a horse with three legs, a serious setback for the performer, yet many esteemed players performed on these flutes, perhaps not exploring much in the way of dynamic change but building a successful career playing them. One wonders how much better it would have been for them to have an accurately tuned flute rather than spending a lifetime correcting – with some skill - the mistakes of the maker.

***** '***Open hole flutes are better'.*** Both can be good: the tone is not affected by only the five open cups (see above), but if that were true, there would be five good notes and seven poor ones. Many flutes,

both open and closed hole models, have key cups *which are not open enough* - in other words, they do not rise sufficiently above the tone hole. As our scale below shows, part of the **RCS** allows appropriate ventilation below the key cup. Keeping the cups closer to the tone holes is splendid for speed and dexterity, but muffles the tone and flattens the pitch. Our advice is to ask your repair person to ensure that the foot joint and right hand key cups are open to 3.8mm. at the front, and the G# and left hand keys and thumb keys almost the same. This will ensure that the fullest tone will be possible.

Blocking up the open holes because of a faulty hand position should be seen only as a short term solution even for one key cup. Those with small hands are advised to use this temporarily - or change to a closed hole flute.

***** '***You can get used to any flute and play it well in tune. I just takes time*.**' It is true that a skilled player can get used to a poorly scaled flute and - depending on their ears and ability - can adjust and play reasonably well in tune: others aurally less fortunate may play with faulty intonation but will probably never know it, though their colleagues may know. But why start off with a three-legged horse? A well constructed scale will allow the greatest technical and musical freedom.

***** *'**There is no perfect scale; players just have to get used to and adjust to what they have'*** True, they can, depending on their skill, but why should they? This is the same as suggesting that a badly tuned violin can be played in tune by an accomplished performer by 'getting used to what they have'. This is an excuse by uninformed flute makers to justify their ignorance about flute scale design. A poorly designed scale will hamper the development of a performer. Times are so competitive now that the sensible student must ensure his career has the fewest obstacles.

*** *Can the listener tell whether the flute has a good scale?*** Yes, and with experience, quite often. When a student is having problems with intonation, we can make a good guess as to the probable scale and often the maker too. The characteristics of some flutes (flat Bb2s & B2s and a sharp C2 & C#2, etc.) is a fingerprint as to its general derivation.

*** *Correct the flatness in pitch by rolling the flute in/out with your hands*** (from a published booklet on '*steps to acquiring good intonation'*. This booklet also contains: '*slide your finger off one of the five open holes when flat...,* and practice to become proficient at that technique'). Moving the flute inwads or outwards with the hands should never be an option to remain in tune when using dynamics. There is quite enough to do expressively - while keeping a careful control over the tone - without rolling the flute in and out. It is a ridiculous solution for pitch control and will lead to instability and poor performing habits. It can be used of course, as a means of flattening a note when note-bending, and it is used in contemporary music. Sliding the fingers off too, will correct a temporarily flat note and is useful for special, or alternative fingerings, but is useless as a long term solution to pitch control and expression.

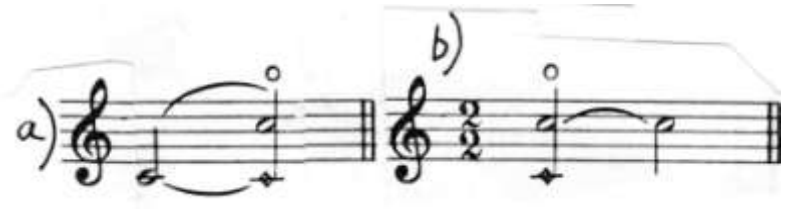
***** '***Correct sharpness by making more room inside your mouth and throat'*.** Unless this action also affects covering the mouth hole, it is unlikely to affect the pitch of a note**.** It may however affect the tone and harmonic balance, but as a device to be used for by a performer for seriously controlling the pitch and for expressive purposes, it is nonsense.

***** '***The 'Donut' improves top E'*** True, but only a very little - but it also seriously lowers the quality of A1 & A2, and in most cases, makes these notes flat. The authors have collectively removed several *donuts* from flutes both to good effect and to the delight of the player. Some makers have enlarged the A hole to make it sharper so as to insert a donut, but this has also spoiled the quality of the note.

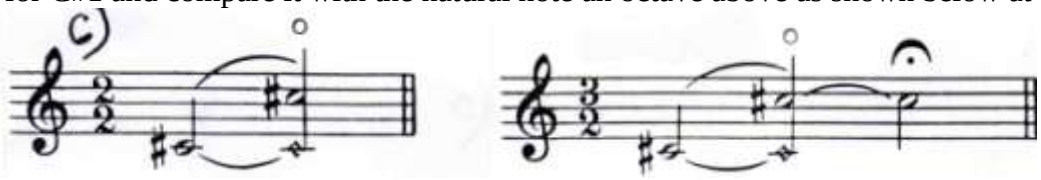
4. Is your Flute in Tune?

This checking process will take a little time and is best done where there is quiet. Allow at least 30 minutes to complete it and be *prepared to repeat it on successive days* as each day may produce slightly different results. We three are quite experienced in this technique after testing hundreds of flutes. You will need a lot longer.

1) Warm the flute thoroughly for a few minutes and then play low C, hereafter called C1.
Move up to the second harmonic, C2, by over blowing, as illustrated at *a).*



Now take your fingers off the keys to compare the second harmonic of C1 to the natural note an octave above - C2 - as at *b).* If it is not exactly an octave, adjust the headjoint, moving it in or out until the two Cs - the second harmonic of C1 and the normal C2 - are as closely as possible at the same pitch. *Do not move your lips or make any alteration to the intonation with your lips.* Just accept what the flute is telling you.
2) Repeat this for C#1 and compare it with the natural note an octave above as shown below at *c).*

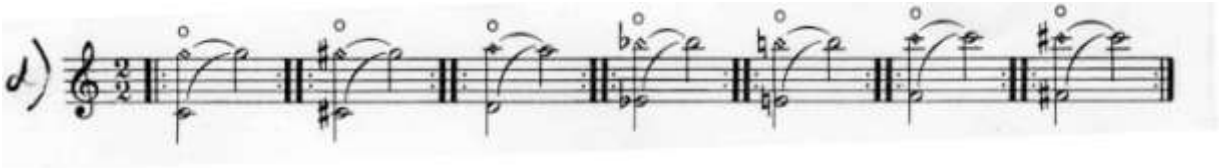


Typically, the two C#s are not in tune, even though the two C naturals are. This illustrates the problem we face: the maker may not have constructed the scale carefully enough. If the two Cs are in tune, the two C#s should also be in tune. It is a common problem and we will return to it later.
3) Now check the pitch of C1 and C2, this time with your tuning machine: probably the upper one is sharp and the lower one flat. If this difference is small, don't worry about it yet. The important step is to ensure the two Cs are as nearly as possible in tune using both the harmonics and the machine to check them. This ensures you have the correct octave-length.

Before the next step, read the following carefully:- you will be using 3rd harmonics (a twelfth above the fundamental) to check the pitch of the second octave of your flute. Unlike 2nd harmonics (octaves), the 3rd harmonics should be slightly sharper than the natural note*. What you have to do is determine the difference between the two notes or the *degree of sharpness.* You must train your ear to hear the *degree of difference.*

* This is the difference between natural 'just intonation' and man- made Equal Temperament.

Continue to the next step:
4) Play C1 again, this time over blowing it until it produces the 12th above, G2, as at *d)* below. Compare this harmonic with the natural G2. There should be a difference, but is the gap large or is it small as it should be? Though small, the difference should just be discernable. Make a note of the size of the difference or gap. *Do not make any alteration to the intonation with your lips or jaw.* It is tempting, driven by fear about what you may find, to 'adjust' the intervals so as to justify the money spent on your 18ct gold cherished flute.
c) Play C#1 and by over blowing to the 3rd harmonic, compare it to the natural G#2. Make a note of the degree of difference in pitch. Now play D1 and compare it with A2. Continue through Eb1 comparing it with Bb2; E1 comparing it with B2(3) and then F1 comparing it with C3. You can make a 'double check' here between the 4th harmonic of C1 (C3) and the 3rd harmonic of F1, also C3. Finally, check the C#s, using both 3rd and 4th harmonics.



You will have to be patient, making a note of how large the gap is between the natural middle register note and the harmonic. There should be a small difference, the harmonic usually being sharper. It is the *degree of sharpness* you are noting. The amount of swing of your tuning machine indicator between the two notes, may also be helpful.

Depending on your flute, there will probably be varying differences between each middle register note and it's harmonic. More importantly, does the difference between the two notes vary much as you change notes? There may even be one or more notes where the harmonic note is actually *flatter* than the natural note you are comparing it with and if so, add this to your list as it is an important pointer.

Note:- 1) On some flutes, D2 is sharp and pulling out the *foot joint* – (yes, the *foot),* may largely, though not completely, correct this. So, if your flute has a sharp D2, pull the foot out a little, and repeat the experiments above. You have to do this because you are using the four foot joint notes, low C, C# D and Eb (five notes if you have a low B foot) to check the middle register notes, and this will affect the overall results.*
2) Head joints can affect the general intonation though it is rare to find such a badly made head that both the tone and the octaves are defective. However, we three have come across head joints which play C#3 flatter compared with C#2. Sometimes the problem is with C2 and C3 as well as C#2 and C#3 and there may be several reasons why this is so. So, when checking your flute's intonation, if possible, check your head joint on another flute as it could be the head joint which has the problem.

Finally, after all these checks, which may take a few days or more to complete, you might find that your flute is quite well in tune. Then again, you may find that your 18 carat gold masterpiece has been constructed to an imperfect scale and that the difference between the natural note and the harmonic of the lower note is too variable. At the very least, though pleased, disappointed, puzzled, cross, angry, or perhaps doubting the validity of this test and of your own ears, *now you know.*

* You may find that there seems to be no logic in your findings, and you may also question whether the low notes – which are used to check the upper notes - are themselves in tune.

Flute Retuning: Though you might improve your flute by the means set out below, if the scale is particularly bad, you might also think about changing the flute. If on the other hand, it seems just a little out, you could try improving the tuning yourself. There are two possibilities:- one is to do this using the **RCS** set out below; the other is to put plastic putty in those holes which seem the sharpest, thus bringing them in line with the in-tune notes. Making the tone holes smaller with putty will make little difference to the tone if only a small amount is used.

To use the **RCS**, you will need:- A craft knife; a good screwdriver which will perfectly fit the screws and rods of your flute; a piece of wooden dowel about 3/8ths inch (10-15mm) which will fit inside your flute of about 20 inches (50cm) long; a two foot steel rule (about 60cm); plasticene, playdo or children's modelling clay and epoxy paste. You are better off with a 'Vernier guage' too; this will measure accurately the diameters of the tone holes. Mark up the dowel with the **Revised Cooper's Scale** using the rule and a craft knife to make sharp, thin lines across the dowel (see diagram 1 below). It is not easy to do this accurately by eye, but always look directly down on the rule to estimate the fractions of millimetres, and with care, you will get to within 0.2 or 0.3 of a mm, which will be enough to do a rough but reasonable retuning job. Carefully mark the dowel crossways so as to make these marks easily seen inside the flute. When the mechanism is removed and the dowel is put into the flute, you will see which tone holes are too sharp or too flat. Although the flat ones can't be moved without major rebuilding, the sharp holes can be temporarily made flat with playdo or kid's modelling clay just to establish if this procedure has improved the intonation. (see diagram below). In effect, what you are doing is making all the sharper notes flatter to match the others. Later, if after playing on it for a few days this retuning experiment makes a difference to you, the flute can be more permanently tuned with epoxy resin paste to replace the playdo. The interior of each tone hole will need cleaning with spirit and lightly scratched to assist in the adhesion of the paste. Even then, the amount of resin can be altered later by filing or cutting, as you become more experienced in this technique.

The other way is simply to flatten the notes which need altering according to your written notes first with playdo. Then play the flute for a few days and then recheck using harmonics once again. Using either playdo or more permanent epoxy putty will not damage your flute in any way.

If the scale is very defective though, it is better to change the flute.

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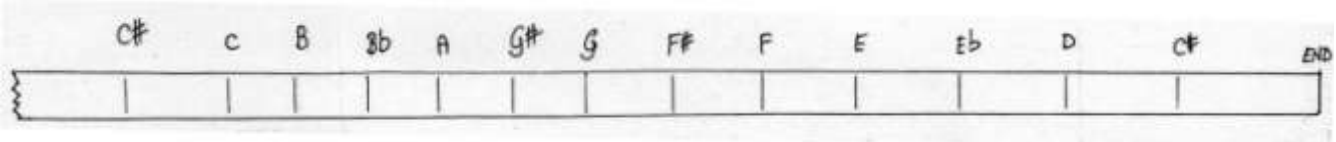
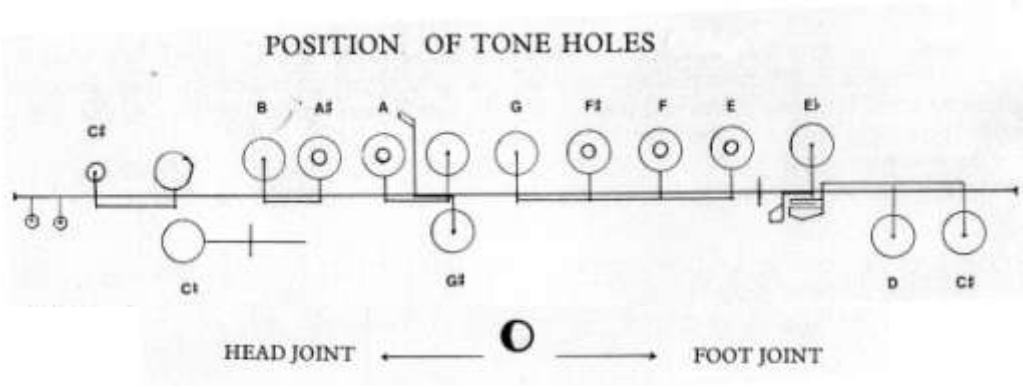


Note that if you are used to a faulty scale, you can still play it reasonably well in tune in slow pieces with clever use of the embouchure and, like most people, you can also get used to the out-of-tuneness, perhaps even thinking it is other players who are wrong. It is extraordinary how many of our commercial

CDs – by celebrated performers – have poor intonation and how common it is to hear a sharp C#2 & C#3, a flat D3 and sharp Eb3 and E3. The performer becomes used to hearing it like that.

The diagram below may help in understanding the geography of the tuning procedure and the lower diagram shows where the putty should be inserted.



Our Advice on Buying a new Flute. Enquire from the maker whether they make open and closed hole flutes to different scales. Though they may be famous, reputable and long established, if they do not, try elsewhere.

Don't go 'gold' mad. Currently, a very fine performing flute is available worldwide and is silver plated nickel silver. The market price of precious metals is not governed by acoustics.

Use the checks above to find out how the flute scale has been devised. Be careful of the company who claims to have their 'own scale', unless it is carefully checked using the method above.

Treat the head joint and flute as separate items. It may be a good head joint, or it may be ordinary. Test them separately. Usually, the head joint is made in a different part of the factory, and only meets its mate at the final stages of assembly. A violinist never buys a 'violin outfit'; the bow and violin are purchased separately. Some dealers and makers allow the flute to be purchased separately from the headjoint, a sensible arrangement. With pressure from the purchaser, others may follow. Test a new head joint on a flute you are familiar with.

5. A Plea to Teachers, Players and Makers.

This article is not written in anger but in desperation. We three have many friends who are teachers, players and makers and we value that friendship. Though many years have passed since the first Cooper Scale was introduced, some improvements to it have taken place, but not universally. We three have all been involved in flute engineering and are wholly aware of the problems of re-tooling when changing the flute scale. We fully appreciate it is a very expensive exercise and would need careful consideration for commercial reasons. We just want to see some movement so that, on the other end of the spectrum, the performing level of our craft will improve. At every class we three teach, there are defective flutes being played, an intolerable situation.

Teachers: Please help your students obtain a flute with a reasonable scale. Then teach young players how to control the pitch of a note to play correctly in tune. If you don't know, find out. This will lead to greater expression, more interesting concerts and will bring us in line with the rest of the woodwind and strings. You owe it to your students. In later life, let them look back at you as an enlightened teacher who gave them a head start in a competitive world. It is to your shame if you do not.

Players: Please check your flutes. The checking process requires patience. When in doubt, seek advice. Ask your flute maker about open and closed hole scales. You are the ones who can change the current state of flute making by demanding a better instrument. Read behind the wording in their brochures and their claims. Demand answers - whether in platinum, gold or nickel silver! You are the customer.

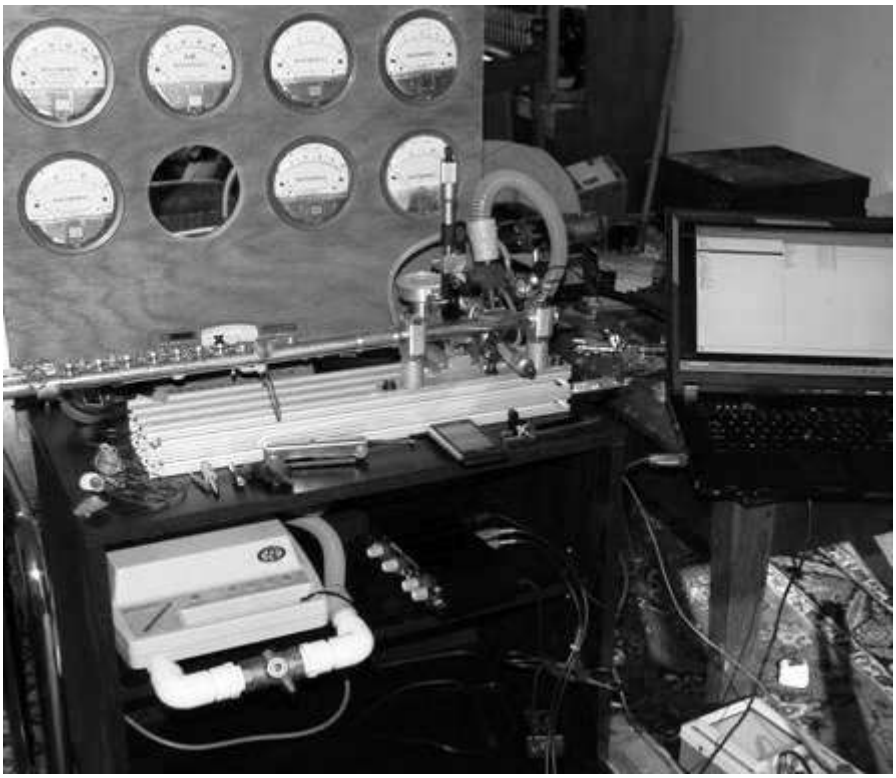
Makers: Please check out our **RCS**. It may not be completely perfect yet but it is better than the flute scales you are using. All guitar makers use the same logical fret positions and they wouldn't sell any if they didn't, so why not flute makers? Please use closed hole and open hole corrections; it makes life easier for us teachers and players.

We three believe that *there is a desperate need to have someone in your workshop who is a fine player, has an open mind and possessed of very good ears and who is enthusiastic about engineering*. Such players are out there. You listen too much to performers whose intonation skills may not always match their fame.

Finally. Flute makers seem more interested in the fine engineering and the cosmetics of their craft. While we are still buying their flutes, why should they worry? One flute maker wrote recently, '*No worries! We're selling lots if flutes whether the scale could be improved or not'*. Another is reliably reported to have said last year, *'We sell many precious metal flutes to Asian countries. We must be getting it right'* No, you are not. It is the makers, the players and the teachers who are getting it wrong. They and you, just don't know.

A well-known maker threatened legal action to one of us for remarks made during a master class. As a lawyer remarked to me, '*that usually suggests you may be right'*.

The photo below is another of an automatic flute blowing apparatus recently built by Eldred Spell to help answer some questions we three have had about open hole corrections, the scale length and other important related matters.



6. The Revised Cooper Scale (RCS) A=441)

This is based on an octave scale length from C1- C2 of 324.1mm. This is adequate for playing at 440-442cps.

Instructions:- To check a flute or to mark up a stick:- measure your tone hole diameters to see if they are close to, or the same as those in the first column. Read the figures in the column which describes your flute, A, B or C. The large C# (B/C# trill) has also been shown. On a C foot, the end of the flute is C natural and on a B foot, the end of the flute is B or 0.00.

The Figures

	Tone hole diameter	**A** **C Foot** **(Closed hole)**	**B** **C Foot** **(Open hole)**	**C** **Low B foot** **(Open hole)**
Low B	***15.6***	---	---	0.00
Low C		0.00	0.00	45.5
C#		43.35	43.35	81.85
D		77.7	77.7	116.2
Eb		101.1	110.1	148.6
E	***14.2***	141.8	140.1	178.6
F		169.5	168.25	206.75
F#		197.7	196.45	234.95
G		223.5	223.5	262.0
G#	***13.5***	248.2 (if **12.8** then 248.65)	248.2 (if **12.8,** then 248.65)	286.7 (**12.8**: 287.15)
A		271.1	269.95	308.45
Bb		293.15	292.15	330.75
B		314.0	314.0	352.5
C		333.65 (if **12.8** then 334.1)	333.65 (if **12.8.** then 334.1)	372.15 (**12.8**: 372.6)
C# large		352.4 (if **12.8** then 352.85)	352.4 (if **12.8,** then 352.85)	390.9 (**12.8**: 391.35)
C# (This tone hole should be deeper than others by 0.5mm)	***6.7***	363.8	363.8	402.3
D (trill)	***7.5***	382.8	382.8	421.3
D#		398.7	398.7	437.2

The 'End Correction' (the distance from the end of the flute to the centre of the low C# hole): 7mm. This figure has already been added to the final figures. The open hole corrections (Eldred Spell, March 2011) E: 1.7; F: 1.25; F#: 1.25; A: 1.12; A#: 1.1.

A scale at A=443/4 will be available soon

March 2011