Achieving 21st Century Standards of Excellence in Tuning

Midrange Piano Tuning

How to pass the mandatory aural portion of the PTG RPT Tuning Exam

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Introduction

Piano Tuning standards have taken a Quantum leap during the past 30 years. Listen to any Pop, Jazz, Country and even some Classical recordings with piano from the 1960's or 70's and you will hear immediately how piano tuning has improved. While I have been able to put many ideas from many PTG members into practice, it has been the teachings of Owen Jorgensen RPT and Jim Coleman, Sr. RPT which have made the most difference in my work. I hope to be able to help you tune the piano in a more enlightened way through this article.

The subject here is Equal Temperament (ET). I have adapted some techniques used to tune Historical Temperaments which will make your efforts easier to execute and lead to greater precision and accuracy. I will also include techniques learned from Jim Coleman involving *coincident partials* (explanation of the term to follow). Also included will be techniques used by PTG's Certified Tuning Examiners (CTE) to both effect the Exam Master Tuning and to verify errors on the Exam. Understanding each of these combined Techniques will help you pass and hopefully excel not only at the Exam but in all of your professional work to follow.

ET is the model used for the PTG RPT Tuning Exam. Tuning standards have advanced in recent times principally because of two forces: Electronic Tuning Devices (ETD) and the Exam itself. There has been much discussion about when Equal Temperament came into practice. I'll be the first to say it never has, even to this day, been done with universal success. It is the most difficult of temperaments to effect perfectly. Any error, even of one cent on one note renders it a Quasi Equal Temperament ("quasi" means "almost").

Any error in ET will produce an unintended and often adverse effect. At an Exam, any audible error will result in points scored against you. ETD's have been an important tool in helping piano technicians move closer to the state of perfection demanded by ET and today's standards. PTG has also been a major factor because groups of individuals working together producing a state of perfection by consensus and entirely by ear have raised the level of knowledge and skill among all of its members.

Taking and passing the Tuning Exam is in itself a confirmation that an individual has achieved a standard of excellence. Unfortunately, there are too many technicians today who have learned to tune with an ETD first rather than by ear. They may have a good sense of what sounds ideal and can tune beautiful unisons but sadly, have no concept of how to construct a temperament by ear. This remains an issue among many technicians who believe they deserve the RPT status but are unable to pass the mandatory aural portion of the Exam. This article is intended to help those individuals as well as strictly aural tuners seeking to improve their knowledge, understanding and set of skills.

Isn't Aural Tuning "Counting Beats"?

Not exactly but this is a frequently asked question. Aural Tuning can be described most simply as the *perception and control of beats*. It is not really necessary to count them or even to compare them with any timing device such as a watch or metronome. If you are a beginner or someone who can only tune with an ETD, you will have to practice; there is no way around or substitute for it. You must learn to hear and control the beats of the various intervals used in tuning. The definition of *beats* will follow later in this text.

Musical Intervals Defined

Here is a list of definitions and abbreviations which will be used to indicate the intervals used in tuning:

Fifth: **5th** In music theory, a 5th is known as a *perfect* 5th although in ET, a 5th is *always* tempered. The word *perfect* in music theory is meant to distinguish an interval from *augmented* or *diminished*, which implies another note entirely, not any amount of *tempering* which is normally not considered in music theory. Therefore, I refrain from using the common abbreviation *P5* which means, *Perfect Fifth*.

Many piano technicians have little or no knowledge of music theory and will describe a 5th which has no audible beat as *perfect* or *pure*. These two terms have other more appropriate uses. Hence, there may be a source of confusion. I will describe an interval which has *no audible beat* as *beatless.* A 5th is an interval between two notes, five notes apart from each other on a common (*diatonic)* major scale. Example, C and G (going upwards from C:

Do-Re-Mi-Fa-So). If you are not familiar with the major scales of the keyboard, you may identify the top note of a 5th by counting seven notes, both sharps and naturals, beginning with the note immediately following the bottom note. In a C-G 5th, for example, the note G will be seven half steps above the C. To identify a 5th downward, simply reverse the process.

Fourth: **4th** See the above remarks regarding *perfect, augmented* and *diminished.* A 4th is an interval between two notes, four notes apart from each other on a common (*diatonic)* major scale. Example, C and F (going upwards from C: Do-Re-Mi-Fa). You may identify the top note of a 4th by counting five notes, both sharps and naturals, beginning with the note immediately following the bottom note. In a C-F 4th, for example, the note F will be five half steps above the C. To identify a 4th downward, simply reverse the process.

Major Third: **M3** The same remarks regarding *perfect, augmented* and *diminished* apply. A M3 is an interval between two notes, three notes apart from each other on a common (*diatonic)* major scale. Example, C and E (going upwards from C: Do-Re-Mi). You may identify the top note of a M3 by counting four notes, both sharps and naturals, beginning with the note immediately following the bottom note. In a C-E M3, for example, the note E will be four half steps above the C. To identify a M3 downward, simply reverse the process.

Minor Third: **m3** The same remarks regarding *perfect, augmented* and *diminished* apply. A m3 is an interval between two notes, three notes apart from each other on a commonly used minor scale. Example, C and D-sharp. Technically, in music theory, a m3 would be from C to E-flat but in Piano Tuning, we only refer to the black keys as *sharps* (going upwards from C: Do-Re-Me). Since all sharps and flats in ET are *enharmonic (*not *inharmonic* which has an entirely different meaning). *Enharmonic* simply means that both a sharp and a flat refer to the same note. Example, E-flat and D-sharp are the same exact note and pitch in ET. In this text, I will use the **#** symbol to designate a sharp. Example, D#. You may identify the top note of a m3 by counting three notes, both naturals and a sharp, beginning with the note immediately following the bottom note. In a C-D# m3, for example, the note D# will be three half steps above the C. To identify a m3 downward, simply reverse the process.

Major Sixth: **M6** The same remarks regarding *perfect, augmented* and *diminished* apply. A M6 is an interval between two notes, six notes apart from each other on a common (*diatonic)* major scale. Example, C and A (going upwards from C: Do-Re-Mi-Fa-So-La). You may identify the top note of a M6 by counting nine notes, both sharps and naturals, beginning with the note immediately following the bottom note. In a C-A M6, for example, the note A will be nine half steps above the C. To identify a M6 downward, simply reverse the process.

Octave. No abbreviation will be used. An octave is an interval between two notes, eight notes apart from each other on a common (*diatonic)* major scale. Example, C and C (going upwards from C: Do-Re-Mi-Fa-So-La-Ti-Do). There are twelve half steps in an octave.

Major tenth: **M10** A M10 is an octave plus a M3.

Major seventeenth: **M17** A M17 is two octaves plus a M3.

Tempered Intervals

In theoretical ET, all intervals except the octave are *tempered.* In piano tuning, this means that an interval is adjusted from the point where it would have *no beat*: *beatless*. This term, *beat,* although spelled the same, does not have the same meaning as *beat* used to describe the sound of rhythm in music. It is a technical term used to describe the sound heard when *coincident partials* are mismatched or not exactly in tune with each other.

The words, *partial, harmonic* and *overtone* all refer to the same phenomenon and are generally interchangeable but piano technicians usually prefer to use the word *partial* (used as a noun) when discussing tuning. A partial is one of the higher and usually fainter (but not always) sounds that we hear along with the *fundamental* which is the pitch we think about and recognize when any given string of the piano is struck. The fundamental tone or pitch is also considered to be the *first partial.* Theoretically, an upper or higher partial is an exact multiple of the fundamental pitch, such as twice the frequency, two and a half times the frequency, three times the frequency, etc.

Most people, even musicians do not perceive (hear) partials. Even many piano technicians go their entire career saying that they do not hear them. Others consider hearing partials as essential to tuning. Not to worry however,

because when we hear *beats* in any interval, we are hearing partials which are mismatched or not exactly in tune with each other. Indeed, to reiterate, the very essence of aural tuning depends upon the ability of the tuner to *perceive and control beats*. The term *partial* is preferred over the others because in piano tuning which involves *inharmonicity,* only one set of *coincident partials* may ever match or be in tune with each other at any given time. This is not true of other instruments such as the pipe organ whose tones have no *inharmonicity*.

When you play any of the intervals used in piano tuning, you will naturally have sets of partials from each string which sound side by side or *coincide*, thus you have what are known as *coincident partials.* But to complicate matters greatly and give the tuner the ultimate and nearly unsolvable problem and challenge, all piano strings bear a phenomenon known as *inharmonicity.* Basically, this means that the upper partials are not exact mathematical multiples of the fundamental tone, as they are thought of theoretically. They are almost always somewhat sharper than a theoretical partial would be and the higher the partial, the more exaggerated the sharpness. Inharmonicity occurs because a piano's string is made of steel which has a certain stiffness factor to it which distorts what otherwise would fit a theoretical mathematical model.

For this reason, even the octave, when properly and optimally tuned, may have a slight beat in it as will be suggested in this text. Although virtually none of the classic books on tuning refer to an octave as being *tempered*, for all intents and purposes, today's enlightened knowledge about tuning dictates that an octave surely must be tempered, even if to a barely perceptible degree. It is an important distinction that is made among the finest aural tuners. Virtually all modern ETD programs provide for it too.

In fact, as mentioned earlier, an octave can only have one set of coincident partials matching at any given time. Often, as will be suggested in the following procedure, an octave may be tuned so that in fact, there are no partials which match exactly. It is possible to have one or another set of matching partials or to tune so that neither set is exactly matching and to still hear a beatless sound. It is also possible to tune so that one of the higher sets of coincident partials matches and a slight beat is produced. It is also possible to have a compromise between one set of partials and another and still hear a very slight beat. As you will see, the latter is what will be suggested as the optimum way to tune the central octaves.

Note or Piano Key Identification used in Piano Tuning

Rather than referring to each note or key of the piano from 1 to 88 as many older texts do, I will use the identification system conceived by Hermann Helmholz, a 19th Century scientist who gave us much of our preliminary understanding of the *Science of Equal Temperament.* The three very lowest notes of the piano are the "0" (zero) octave, A0, A#0 and B0. Beginning with the lowest C on the piano, all notes within that octave are identified with the number "1". Example, C1, C#1, D1, etc., all the way to B1. The next C is C2 and all of the notes within that octave are identified with the number "2". The same follows for each octave, all the way to the top C which is C8. *Middle* C is identified as C4.

Part 1 of the Tuning Exam, which must be tuned aurally, includes all of the notes from C3 to B4. It is imperative that all tuners of today familiarize themselves with this system of note identification. It is what is used on the Tuning Exam and by all modern ETD programs. Part 2 of the Tuning Exam covers all notes from C1 to B7. Under current rules, an ETD *may* be used to in Part 2 and it may be used to your advantage to correct any errors made in Part 1.

Equal Temperament Tuning Axioms

All 5ths must be *narrowed.* All 5ths in ET must be tempered slightly from the point where they are beatless. To *narrow* a 5th, you may flatten slightly the top note or sharpen slightly the bottom note.

All 4ths must be *widened.* All 4ths in ET must be tempered slightly from the point where they are beatless. To *widen* a 4th, you may sharpen slightly the top note or flatten slightly the bottom note.

If there has ever been a source of confusion for you about why a 5th must be narrowed and a 4th must be widened, try this simple demonstration for yourself. On a piano nearly already well tuned, tune F4 from F3 so that it sounds as a beatless octave. Now, find A#3 and flatten it slightly until both the F3-A#3 4th and the A#3-F4 5th are beatless. Now, sharpen the A#3 slightly. You will have *tempered* both the 4th and 5th intervals within the F3-F4 octave. The F3-A#3 4th will be *widened* and the A#3-F4 5th will be *narrowed.*

Did you notice that both *intervals*, the 4th and the 5th contain the same notes? They are just upside down versions of each other. Similarly, a m3 and a M6 also contain the same notes. See the proper way to temper them which follows. Octaves, 4ths and 5ths may be considered to be the Slowly Beating Intervals (SBI) in piano tuning

The amount of tempering in 4ths and 5ths in ET is very slight. It is made even less than is considered theoretically correct because of the effect of inharmonicity. If you consider that an octave must be made slightly wide of beatless, then it means that a 5th must be only very slightly tempered, usually only about one beat every two seconds, a little slower than the theoretical rate. A 4th however, will beat about one beat every second, just very slightly faster than the theoretical rate. Theoretically again, 4ths and 5ths are about 2 cents tempered from the point where they are beatless, using an ETD. But when inharmonicity is factored in, they end up being only from 1 to 1.5 cents tempered.

All M3's must be *widened*. M3's are widened considerably from the point where they are beatless. In fact, the amount is approximately 14 cents wide compared to the mere 1.5 cents of a typically tempered 4th or 5th. Therefore a M3 will have a *rapid beat* to it.

All m3's must be *narrowed*. m3's are narrowed even more than M3's are widened from the point where they are beatless. In fact, the amount is approximately 16 cents narrow compared to 14 cent wide M3 and the mere 1.5 cents of a typically tempered 4th or 5th. Therefore a m3 will have a *very rapid beat* to it. Since a M6 is an *upside down* m3, a M6 must consequently be a *widened* interval.

The M3, m3, M6, M10 and M17 are all considered to be *Rapidly Beating Intervals* (RBI).

Fine versus *Rough* tuning

This article describes in detail how to fine tune a piano. You may well know that a fine tuning cannot be accomplished unless the piano is already almost perfectly tuned. You will need to get your piano close first either with your ETD or by simply going through the tuning the way you have been used to aurally as quickly as you can to get it to a point where it will accept a fine tuning. However, if you are working with a piano which has been detuned as it is for the Tuning Exam, you may indeed follow this procedure to move each note which is unknown as to whether it is sharp or flat into place.

Strip mutes versus wedge mutes

There is much discussion about which method is better and I will cover that in a later article but for the purposes of this study and the Tuning Exam, you will need to strip mute the piano from C3 to C5 (the two octaves on either side of Middle C, C4). At the Exam, the piano will be detuned in a way that you would usually not find it: the notes will be alternately sharp and flat rather than all flat or all sharp as you may typically and usually find. This avoids the special challenge of raising or lowering the pitch but the piano is still quite out of tune.

Temporarily Tune…?

In the steps for tuning which I give in this article, you will often see the words, *temporarily tune*.... This is an elementary step. It is intended to help you get from an unknown point to one you are sure of. Just as with elementary steps in Algebra, when truly fine tuning, or attempting to locate and correct small errors in a refinement process, you may skip the elementary step when you are quite sure of where the pitch of the note to be tuned is and simply make your fine adjustment. However, if there is at any time any doubt about a particular interval, such as a 5th being wide rather than narrow for example, the best way to get back on track is to use the *temporarily tune* feature which is suggested in this text.

Using an Untuned Note as a Reference

Many people are puzzled by this concept. How could it be? The test note is only used as a point of reference. Remember, this is fine tuning. Yes, the note must be close to where it should be ultimately but more precisely, should be in a *convenient* place. It may be sharpened or flattened slightly to produce a very rapid beat; up to nearly the limit of discernibility so that listening for any difference between the two tested intervals can be more easily perceived. When tuning this exercise in ET, you'll only need to use a test note for the initial pitch, A4 and for the first two octaves, A3-A4 and F3-F4.

The "Marpurg" Shortcut

This will be useful for anyone attempting the PTG Tuning Exam or when aurally pitch raising a piano. I call it "Marpurg" because the sequence for tuning follows that of the *Marpurg-Neidhardt Quasi Equal Temperament,* however, the goal in this exercise is a rough but fairly good approximation of a true Equal Temperament (ET). As mentioned, it can get you very close, very quickly, which should be your goal at first when attempting the Tuning Exam or tuning any piano which is very much out of tune.

1. First, set your A4 pitch. If pitch raising, try to estimate how many beats flat the A4 is to the tuning fork. For every three beats flat, set your A4 pitch one beat sharp. If the piano is extremely flat, simply tune the A4 a few beats sharp for the first pass. For the Exam, you will have already done your Pitch Score. If it was reasonably good and passing, leave A4 where it is. If the score was failing, you do have another chance at it in Part 2. If your score was passing but only barely so, try again to match the A4 to as beatless as possible unison to the tuning fork. If practicing tuning, simply tune your A4 as a good unison to the fork. Skip for the moment, the fine verification procedure which will be explained later.

2. Tune A3 to A4 to a beatless octave. Approach the beatless point from the flat side and stop just as you hear the beat in the octave disappear. Again, skip for the moment the fine verification procedure. It is not really necessary at this point.

3. Estimate the F3-A3 M3. Forget about "7 beats per second". Use only your instincts to tell you that you have the moderately beating sound that you usually hear. If you cannot yet distinguish or perceive the rapid beats of the M3's, try simply playing F3 and A3 together and listen carefully to the "purring" sound.

4. If you have trouble with this and you are still practicing, go ahead and use your ETD in the program mode and tune just the notes, F3, A3, C#4, F4 and A4. Move the bottom note, F3 up and down slightly to see if you can hear what sounds as a *vibrato* like sound. It is not a true vibrato, the pitch is not going sharp and flat as a string player's does but the *interference* of the coincident partials, the 5th partial of F3 and the 4th partial of A3 are about 14 cents apart from each other. Therefore, they beat as rapidly as if you had one string of a unison at 0.0 and the other at plus or minus 14 cents. The latter would sound very out of tune but curiously enough, M3's in ET have a pleasant, musical sound to them, much like what a moderately fast vibrato of a string player would produce.

5. Tune the F3 note up and down slightly until your ear catches this vibrato like sound. Return the note F3 to what your ETD program says is correct. Now play A3 and C#4 together to see if you can hear a slightly faster "purr". Then play C#4 and F4 and notice again an even faster but still only slightly so, "purr". Now, finally, play the F4 and A4 together and you should hear a very fast "purr", about the limit that you can discern. Play F3-A3, then F4-A4. The F4-A4 M3 will beat or "purr" twice as fast as the F3-A3 M3.

6. Now, detune the F3 by a few cents flat, tune the A3 again by ear so that it sounds perfectly beatless to the A4. If it already sounds that way to you, leave it there. Detune C#4 a few cents sharp and then the F4 a few cents flat. This is to give you something to practice aural tuning with, much as the way you would find the piano detuned for the Tuning Exam.

7. After having heard the sound the ETD provides for the F3-A3 M3, try to replicate that. *Estimate* the sound of the F3-A3 M3. It is a *moderately* fast sound. Yes, it is supposed to be about 7 beats per second but almost no one can estimate that perfectly. So, as a beginner, don't knock yourself out trying to do what almost no one can do. There will be a way to prove or disprove your estimate after tuning just two more notes.

8. If you are still unsure of your estimate, try moving F3 sharp and flat and notice that when flattening, the beating becomes very fast. If you move it flat enough, the F3-A3 M3 will sound "sour" and beat so rapidly that you can't discern the beats. If you sharpen F3 enough, the beats will slow down noticeably or even stop. If the F3 is sharp enough, the M3 will become beatless. If you reach that point, play the F3-A3 M3

and it should sound “dead” or even “flat” to you. It will have a “lifeless” sound to it. Try to find the spot where the F3-A3 M3 beats *moderately* fast. That will be *close enough* for the moment!

9. From whatever estimate you made for the note F3, tune F4 from F3, again as a beatless octave. This time, approach from the sharp side and flatten F4 just until you hear the beats in the octave disappear.

10. Listen again to the F3-A3 M3 that you estimated. Now, listen to the A3-C#4 M3 for whatever sound you get. If it is a very fast beating “sour” sound, you will need to flatten C#4. This will be the case if you detuned C#4 sharp by a few cents as I indicated. If the beating is very slow and gentle, you will need to sharpen C#4. Sharpen or flatten C#4 as needed and first make the A3-C#4 M3 beat as closely as you can the *same* (for the moment, temporarily) as the F3-A3 M3. Now, listen to the C#3-F4 M3. If your initial estimate for the F3-A3 M3 was fairly close, the C#4-F4 M3 should beat very fast compared to the A3-C#4 M3.

11. This is because each contiguous M3 must beat slightly faster going up and slightly slower going down. This is the well known, *4:5 ratio of contiguous M3’s* which will be explained later in this text. However, for the moment, all you really need to be able to perceive is a slightly slower/faster relationship. It is a small difference, not very small but not large either.

12. Now, sharpen C#4 slightly, about the amount you would using an ETD to correct a slow roll of the pattern to a full stop, about 1 or 2 cents worth. Now, play the F3-A3 M3, then the A3-C#4 M3. Do you hear a slightly faster sound in the upper M3? Now, play the C#4-F4 M3. Is it faster yet? If you got C#4 too sharp, the A3-C#4 M3 would sound *much* faster than the F3-A3 M3 but the C#4-F4 M3 would sound about the same or even slower than the A3-C#4 M3. Either one of the latter is incorrect. Any two contiguous M3’s that sound the same or very nearly so is incorrect. Anytime an upper M3 of any two contiguous M3’s is slower than the lower, the relationship is *inverted* and this indicates that the middle note of these two contiguous M3’s is markedly sharp.

13. If you didn’t tune C#4 quite sharp enough, the F3-A3 M3 and the A3-C#4 M3’s would still sound too similar and the difference between the A3-C#4 M3 and the C#4-F4 M3’s would be too great. Sharpen or flatten C#4 until you find just the right *balance* between the three contiguous M3’s F3-A3, A3-C#4 and C#4-F4. Remember that no two contiguous M3’s may sound exactly alike and certainly, no upper M3 of any two contiguous M3’s may sound slower than the lower.

14. Once you are satisfied that you have a slight progression in the three contiguous M3’s, F3-A3, A3-C#4 and C#4-F4, the final M3, F4-A4 will prove or disprove whether the initial estimate of the F3-A3 M3 was correct or not. If the F4-A4 sounds much faster than the C#4-F4 M3 below it, it means that the F3 is too flat and needs to be raised by a small amount, perhaps a 2 cents worth or so. If the F4-A4 M3 sounds about the same as the C#4-F4 M3, the F3 is very slightly too sharp, only about 1 cent’s worth. If the F4-A4 M3 is slower than the C#4-F4 M3 below it, the F3 is about 2 cents or more too sharp. It’s as simple as that.

15. If you find that F3 needs correcting, bear in mind which way and by how much. If the C#4-F4 and F4-A4 M3’s are too similar, you will only need to flatten F3 by about 1 cent’s worth. Try to visualize in your mind what making a 1 cent correction would be: a very slow roll of the pattern to a full stop, perhaps about the smallest amount you are able to make. If the C#4-F4 is much slower than the F4-A4 M3, the F3 is perhaps 2 cents or more too flat. Sharpen it accordingly. If the F4-A4 M3 is much faster than the C#4-F4 below it, the F3 is perhaps 2 cents or more too sharp. Flatten F3 accordingly.

16. If you have made a correction of F3, then you must now immediately correct F4 by the same amount, either sharp or flat. Again, sharpen F4 from F3 until you hear an obvious beat in the F3-F4 octave, then Flatten F4 just until you hear the beat stop and the octave sounds beatless.

17. Now, listen to the entire span of contiguous M3’s F3-A3, A3-C#4, C#4-F4 and F4-A4. If the relationship was improper before making the correction to F3, you should now find it either completely correct or at least, improved. You may or may not have to move C#4. It should take only one or two corrections from the initial estimate of the F3-A3 M3 to find what seems to be a perfect relationship of all contiguous M3’s from F3 to A4.

18. For sure, this much has been quite difficult and is so for most people, even experienced professionals. But getting the initial span of contiguous M3's from F3 to A4 anywhere close to being correct will provide the foundation for the entire rest of the midrange from which anyone could hardly make a large enough error to produce a failing score on the exam. So, as difficult as it may seem, this *framework* is important and essential. It is also gratifying because the entire rest of the temperament octave and midrange will seem simple and easy in comparison. Indeed, if you are at a Tuning Exam and you have spent 30 minutes getting this much right and have only 10 minutes to complete the rest, you still have plenty of time to do it and be assured of a passing score!

19. There are many sequences which people use to tune a temperament. I provide for you later in this text the one I believe is the easiest to remember but also gives you the most amount of

    checks or *feedback* possible for each note tuned as you go. However, with time running short during a Tuning Exam or for a pitch raise tuning, you don't have to know or remember any sequence at all or use any of the fancy "untuned note" checks or even understand them. An exam detuned piano or a piano needing a pitch raise will be too far out of tune for any of those to be useful anyway, so for the moment, just skip all of that.

20. From each of the lower notes you have tuned, F3, A3 and F4, find both a 4th and 5th from each note. Start with F3. Find the note a 4th above it, A#3 and flatten or sharpen it until you first make the F3-A#3 4th sound beatless, then sharpen A#3 slightly to temper the interval. The amount will be about 1.5 cents. Bear that in mind as you temper the interval. Visualize doing it as described above when making corrections. All 4ths and 5ths have a very slow beat in them.

21. Now, find the note a 5th above F3 or preferably in this case, a 4th below F4, C4. (A 4th is a slightly more reliable interval to tune than a 5th because its partials are slightly higher and there is only one set of audible coincident partials and therefore a 4th can be less confusing and more easily perceivable than a 5th). Sharpen of flatten C4 from F4 until the C4-F4 4th sounds beatless first, then flatten C4 slightly to temper the interval, just as you did with the F3-A#3 4th.

22. From A3, find the note a 4th above it, D4 and tune a beatless 4th first, then sharpen D4 to temper the 4th as above. Then, find the note a 5th above A3, E4 and tune a beatless 5th first, then flatten E4 to temper the 5th as above.

23. From C#4, find the note a 4th below it, G#3 and tune a beatless 4th first, then flatten G#3 to temper the 4th as above. Then, find the note a 5th below C#4, F# and tune a beatless 5th first, then sharpen F#3 to temper the 5th as above.

24. With a beatless sounding octave, 4ths and 5ths will sound very similar. With a slightly stretched octave, 4ths will sound very slightly faster than 5ths but in no case, should a 4th beat any more than about 1 beat per second and neither a 4th nor 5th should sound beatless.

25. Now, there are only three more notes to tune in the temperament octave, F3 to F4. They are G3, B3 and D#4. From C4, tune G3 from it as a 4th, beatless first then flatten slightly as above to temper it. Compare the resultant G3-D4 5th if you wish and have time, for similarity. Tune B3 from F#3 as a 4th as you did the others and compare the results with the B3-E3 4th above it. Finally, tune D#4 as a 4th from A#3, as you did before and compare it to the 5th from G#3. You now have all notes of the F3-F4 octave tuned!

26. To get the rest of the notes in the midrange roughly in place, C3 to E4, quickly tune beatless sounding octaves E3-E4, D#3-D#4, D3-D4, C#3-C#4 and C3-C4. Above the temperament octave, tune beatless sounding octaves from F#3-F#4, G3-G4, G#3-G4 (skip A3-A4, it is already done!), then A#3-A#4 and finally B3-B4. You are done with the entire midrange! Furthermore, if this is the most you have had time for, you will still most probably pass Part 1 of the Tuning Exam!

Fine Tuning the midrange: Setting the Initial A4 Pitch

Sound the A-440 pitch source, a tuning fork or audible electronic tone and try to match the A4 string to it exactly, no beats. When satisfied with that, sound the note F2 and A4 together. You may use the Sostenuto pedal to hold these two dampers open. (If the piano has no Sostenuto pedal, you may use the damper pedal in the same way as the Sostenuto, sound the notes first, then press the pedal).

Listen to the rapid beat between F2 and A4. Make sure, first of all, that the F2-A4 interval is a wide M17th. If you are unsure, adjust the F2 until the F2-A4 Major 17th (M17th) is beatless and then flatten F2 until the M17th has a very rapid but still discernable beat. Now compare that rapid beat with the beating between F2 and your pitch source. If they seem exactly the same, it proves that A4 is tuned perfectly to the pitch source. If there is a difference, some adjustment must be made.

If you hear a slight discrepancy, all you have to do is adjust your A4 up or down by the slightest amount to make the F2-A4 test match exactly. If the piano's F2-A4 is slightly faster than the piano/pitch source F2-A4, the piano's A4 is slightly sharp and conversely, if the piano's F2-A4 is slightly slower than the piano/pitch source F2-A4, the piano's A4 is slightly flat.

At the PTG Tuning Exam, you are allowed 5 minutes for this procedure but luckily, if you should fail, you will be given a second chance. The tolerance is very small and the rules are strict. Even just one full beat per second is a failing score. In many circumstances, an absolutely perfect A4 at 440 may not be required but in high profile circumstances such as live concerts or recordings, it is and that is why the Exam places such high importance on it.

Setting the F3-F4 Temperament Octave with the 4:5 Ratio of Contiguous Major 3rds[1].

1. Tune A3 an octave from A4.

1a. First make what sounds like a beatless octave, then flatten A3 slightly until you hear a *very* slow beat, about one beat in every two seconds.

1b. Test the A3-A4 octave for a compromise between a 4:2 and 6:3 octave. These numbers do not indicate ratios unreduced to their lowest common denominator in this circumstance. A 4:2 type octave has the 4th partial of the lower note matching, exactly in tune with, or beatless with the 2nd partial of the upper note. A 6:3 type octave has the 6th partial of the lower note matching the 3rd partial of the upper. For more on these octave types, see my article, *Aural Tuning Tests for 2:1, 4:2 and 6:3 Type Octaves.*

Different pianos have different amounts of inharmonicity. On pianos with lower inharmonicity, the tests may reveal that the octave sounds very still and pure and satisfies both 4:2 and 6:3 tests. On pianos with very high inharmonicity, a clear distinction will be heard. Pianos of moderate inharmonicity will offer only a barely perceptible distinction.

The test note for a 4:2 type octave is a M3 below the lower note. Therefore, sound F3 and A3, listen to that rate of beating (you may temporarily adjust the F3 slightly sharper or flatter to make a more conveniently *very* rapid beat), then sound F3 and A4. If the two intervals beat exactly the same, then the octave is a 4:2 type. The test note for a 6:3 type octave is a m3 above the lower note. Therefore, sound A3 and C4, then C4 and A4.

You may also adjust the note C4 so that it provides a more conveniently usable rapid beat but the A3-C4 m3 *must* be a *narrowed* interval for the test to work correctly. The narrower the m3 is, the more rapidly it will beat. If you are tuning a piano which has been detuned for the Tuning Exam and are thus unsure whether the A3-C4 m3 is narrow or not, adjust C4 first until it creates a beatless m3, then flatten C4 until it beats very rapidly. If you are tuning a piano which is already nearly well tuned, you may want to sharpen C4 slightly, because the interval may already beat too rapidly to discern. Sharpen C4 until the interval still beats very rapidly, at or near the limit of discernibility but not so rapidly that it becomes a useless blur.

Ideally, you will want find the point where the octave sounds very nearly beatless but still has a very slow beat, lilt or swell to it and the test for the 4:2 octave finds the upper interval beating slightly faster than the test for the lower interval and the test for the 6:3 octave finds the test for the upper interval beating slightly slower than the test for the

1The commonly used expression, *4:5 Ratio of Contiguous M3rds* is not quite mathematically precise. The true ratio is 4:5.0396842. This is also the equivalent of 1:1.26 rather than 1:1.25. However, this distinction is far too small to really be of practical importance in aural tuning.

lower interval. Neither test should reveal both intervals beating exactly the same, however, the difference between the two will indeed be very slight and perhaps difficult to discern. In some cases, when you reach the point of ambiguity, you have in fact, found the exact compromise you are looking for.

If the test for the 6:3 octave finds the upper interval faster than the lower, the octave is too wide and should have an unacceptably fast sounding beat in it; it needs to be narrowed to conform to the ideals above. In this case, sharpen A3 slightly. If the octave sounds beatless and the test for the 4:2 octave is good but the 6:3 octave test shows the upper interval beating slower than the lower, there is not quite enough stretch in the octave. A3 should be flattened slightly to conform to the ideals above.

2. Estimate the F3-A3 M3rd.

2a. Tuning ET requires making a good estimate, not just guessing. The most important estimate is the approximately 7 beats per second of the initial F3-A3 M3. It takes practice. You may, in the beginning, sharpen F3 until it forms a beatless M3 with A3. It may sound quite peculiar to you. It will have been raised 14 cents from where it usually is. Yet, this is the sound the ancient 1/4 Comma Meantone Temperament had.

To practice, you may get a metronome and set it to 60 beats per second. Get that rhythm going in your mind, then turn off the metronome and flatten F3 until you hear 3 beats per second. Now, set the metronome to 120. Get that rhythm in your mind and flatten F3 until you hear 3 beats per tick at 120. This would be 6 beats per second. It is almost right and you will find that on some very compromised scales, such as spinets, consoles and baby grands, this is in fact the proper rate.

Turn the metronome back to 60, get that rhythm in your head and flatten F3 just slightly more and see if you can hear 7 beats per tick of the metronome. This is also the equivalent of 4 beats per tick of a metronome set at 104. Remember, this is only an initial estimate, it is not just a guess, it is a place to start which may have to be adjusted later but the piano itself will tell you when and if it will. You may, however find any such comparisons to a metronome unnecessary if you follow the directions below carefully. On the other hand, for true beginners at perceiving RBI's this kind of practice will help reveal the RBI's to your perception when there had been no such ability before.

3. Tune F4 to F3, an octave.

3a. Use the same procedure as for the A3-A4 octave. Tune the octave beatless first, then sharpen the F4 slightly and test for a compromise between a 4:2 and 6:3 octave as you did with the octave A3-A4. The test note for the F3-F4 4:2 octave is C#3. Adjust it for a conveniently beating (*very* rapid and wide, *not* narrow) C#3-F3 M3. The test note for the F3-F4 6:3 octave is G#3. Again, adjust G#3 for a conveniently beating (*very* rapid and narrow) F3-G#3 m3.

4. Tune C#4 from A3, a widened M3 which beats a little faster than the F3-A3 M3. If you are unsure whether the A3-C#4 is wide or narrow, adjust C#4 until the A3-C#4 M3 is beatless first, then sharpen C#4 until the A3C#4 M3 beats a little faster than the F3-A3 M3. The ratio of beating is 4:5. This means, for every 4 beats you hear from the F3-A3 M3, you should hear 5 beats from the A3-C#4 M3. These are not *beats per second,* per se, but merely a comparison. A more detailed explanation will follow.

Now listen to the resultant M3, C#4-F4. Is there also a 4:5 ratio of beating between the M3's A3-C#4 and C#4-F4? Is there also a 4:5 ratio of beating between the M3's C#4-F4 and F4-A4? If your initial F3-A3 M3rd estimate were too slow, the F4-A4 would also be too slow, the 4:5 ratio would be improper with the C#4-F4 M3 below it. It may be so slow as to be easily heard when it should beat *very* fast, near the limit of discernibility. On the other hand, if your initial F3-A3 M3 estimate were too fast, the F4-A4 M3 will also beat too fast and the C#4-F4 M3 will end up the same speed or slower than the A3_C#4 it. The latter would indicate an entirely *too* fast F3-A3 M3. If the initial F3-A3 M3 is entirely too fast, the C#4-F4 and F4-A4 M3's will have a difference in speed much greater than 4:5 could ever be. This would easily be heard.

The 4:5 ratio of contiguous M3rds is your key to a theoretically correct ET, adjusted for inharmonicity. Consider the 4:5 ratio to be a *small* difference but not a *very* small difference. It can easily be perceived. You may even disregard the numbers if that helps. Just search for that small difference between any two contiguous M3's. The

lower M3 must be slower than the upper but not very much, just a little. Conversely, the upper M3 must be faster than the lower but also not very much, just a little. Any two contiguous M3's can *never* beat *exactly the same*. This would indicate a small error. Certainly, if the lower of two Contiguous M3's were to beat faster than the upper, it would indicate a substantial error.

Important! *Always* move both F3 and F4 together when making a correction

If these ratios have not worked out, a chain of *progressively increasing in speed* M3's, F3-A3, A3-C#4, C#4-F4 and F4-A4, then you must go back to F3 and adjust that initial M3rd that you estimated at 7 beats per second, either slightly sharper or flatter as the tests for the M3's above it indicate. When you do that, *immediately* tune the F4 octave with F3, following the procedures found in step 3. This is *very* important! Both the A3-A4 and F3-F4 octaves must have the same, precise width. So, if you adjust F3, you must also adjust F4 to create again that same compromise between a 4;2 and 6:3 type octave.

When you have adjusted both F3 and F4, then listen again for a proper sounding 4:5 ratio of difference in the entire chain of M3's from F3 to A4. Bear in mind that the F4-A4 M3 should beat *very* rapidly, at or near the limit of discernibility. If it beats so fast that it has a *sour* sound and you can't really hear the beats, just a blur, it is an indication that it is too fast. On the other hand, if the F4-A4 has an easily heard gentle beat, it is an indication that it is too slow. If the F4-A4 M3 interval is either too fast or too slow, look for other 4:5 ratios which don't seem quite right either. You'll surely find the culprit.

Each time you make a slight adjustment in the F3 and F4, you will know whether to adjust C#4 as well. Each adjustment will bring you closer to perfection. Most importantly, you will have done it without ever actually *counting* beats! You may never know for sure what the initial F3-A3 M3, approximately 7 beats per second is exactly supposed to sound like but you it won't ever really be necessary! It is all done by comparison, *not* counting! You will find that it is easier to know when the 4:5 ratio is *incorrect* than to be absolutely sure that it is correct. Any two contiguous M3's which beat the same or very nearly so is an improper relationship. Certainly, if the upper M3 beats slower than the lower, it is *very* improper. Too big of a difference between the two M3's is also improper. It's as simple as that.

In summation of these first but *critical* first steps, work over these 4 intervals, all M'3s: F3-A3, A3-C#4, C#4-F4 and F4-A4 until the two octaves, A3-A4 and F3-F4 have the proper compromise and the 4 M3rds all ascend or progress in beating at a 4:5 ratio. When you have this framework firmly established, any other small errors you may make afterwards will be minimized and be fairly inconsequential.

Not getting these initial steps correctly however will lead to a guessing game and some kind of dilemma later on. There can only be as a result, some interval(s) somewhere which do not fit the concept of ET.

5. Tune F#3 from C#4, a tempered 5th.

5a. Since ET is an Atonal Temperament, using a pattern which follows the Cycle of 5ths is not advisable. It will inevitably lead to uneven M3's which give the temperament a certain *color*. Those kinds of ideas will be shown in later articles about other kinds of temperaments but for a true ET, no interval can be favored over another.

The best, in my opinion and certainly the easiest sequence to remember therefore, does not follow the Cycle of 5ths and is attributed to Oliver C. Faust. It is known as the *up a M3, up a M3, down a 5th* sequence. The late, John Travis RPT also used it in his book, *Let's Tune Up.* Oliver Faust was a contemporary of William Braide-White who authored the book, *Piano Tuning and Allied Arts.* While the latter is a classic text, from which many, if not most piano technicians of today have studied, he does advocate a sequence which follows the Cycle of 5ths.

Although decades of piano technicians have used that sequence, it is my personal belief that the majority of them never achieved a perfected ET by doing it. Only the most skilled piano technicians, using some other kinds of techniques not found in that book, have been able to overcome the built-in *obstacle to perfection* which is created by following a Cycle of 5ths sequence. The reason is clear and simple. In following a Cycle of 5ths sequence, the tuner is forced to make several estimates upon unproven estimates. This, in my view amounts to mere *guessing.* The problem which results is in the *compounding of errors.* In the Braide-White style sequence, there are four SBI's (4ths and 5ths) which must be first estimated before there is a single RBI (a M3) which can even be heard. Then,

there is nothing with which to compare it. There can only be a sense of whether it is too fast or too slow. The only recourse is to *backtrack* through the sequence. Unfortunately, this often leads to 4ths and 5ths which are too tempered or too nearly beatless. The problem is not really solved.

Up a M3, Up a M3, Down a 5th

In setting the F3-A3 and A3-C#4 M3s, we have already set our first *up a M3, up a M3* sequence, now we will set our first *down a 5th*, which is the F#3-C#4 5th.

5b. Temporarily tune F#3 from C#4, (down a 5th) to a beatless 5th. Listen to the resultant F#3-A3 m3. It will beat rapidly, yes but not the *very* rapid beat that a m3 should have. Now, sharpen F#3 very slightly so that the F#3-C#4 5th beats about 1 beat every two seconds. This is again an estimate, not a guess. Now, listen to the F#3-A3 m3 and note that it has increased in speed to a *very* rapid beat. This is because the interval has been narrowed further from the way it had been when the F#3-C#4 5th was tuned temporarily beatless. Remember that in ET, all 5ths are narrowed and all 4ths are widened. M3's and M6's are widened and m3s are narrowed. Any individual note may be sharpened or flattened to adjust an interval's tempering to cause it to be wider or narrower.

6. Tune A#3 from F4, a tempered 5th.

6a. This will indeed be following the *up a M3 sequence*. The sequence merely *identifies* the note to be tuned, not the note *from* which it is tuned, namely the last note. We avoid tuning from the last note tuned if possible because it has not yet been proven beyond a reasonable doubt. We try to avoid any possibility of a cumulative error. So, instead of tuning the A#3 from F#3 which was only an estimate, temporarily tune A#3 a beatless 5th from F4, which has previously been well proven and established. Now, listen to the resultant F#3-A#3 M3. And compare it to the F3-A3 M3. Play the two sets of intervals alternately, back and forth. Since you temporarily tuned the A#3-F4 5th beatless, the F#3-A#3 M3 should sound too slow. Now sharpen A#3, making the A#3-F#4 5th have a slight beat, the same as you did the F#3-C#4 5th.

6b. Listen to the resultant M3, F#3-A#3 and compare it to the initial F3-A3 3rd. It should beat just a *very* small amount faster (about 1/2 beat per second). This is an even smaller difference from the 4:5 Ratio of Contiguous M3's. If it does not seem correct, try adjusting both the F#3 and the A#3 sharper or flatter to improve it. Both the F3-C4 and F#3-C#4 5ths should still have the same amount of tempering. The F#3-A#3 M3 should beat only very slightly faster than the F3-A3 M3, not exactly the same and certainly not more slowly. Do not make one 5th beatless and the other too tempered.

Listen to the two 5ths which have now been established, the F#3-C#4 5th and the A#3-F4 5th, Even though they are far apart from one another, they should still have a very similar tempered sound.

Also, the A#3-C#4 m3 will beat *very* rapidly, perhaps faster than can be discerned. This is, in fact, the correct sound. C4 is about the upper limit for discernibility of m3's. If the A#3-C#4 m3 has a rapid beat but one that you can perceive easily, it is one indication that the A#3 may need to be sharpened. If that is the case, cross check A#3 with both F3 and F4 and listen for the very slow beat. If either the F3-A#4 4th or the A#4-F4 5th sounds too close to being beatless, then you have two indicators that A#3 needs to be sharpened. Remember that a 4th should beat slightly faster than a 5th.

Do you now grasp the advantage that following this sequence has? There really is a way to make an estimate, then prove or disprove it each step of the way. Refinements can be made in extremely small increments and checked for improvement in a corresponding interval immediately. If you are an ETD user, try visualizing a very slowly moving display that you are trying to make stop with the slightest of movements. Using your imagination this way may help you become accustomed to tuning in a way that had previously been foreign and unworkable for you. When you are satisfied with the F#3-A#3 M3, move to the next step.

7. Tune D4 from A3, a tempered 4th.

7a. This will be the next *up a M3* sequence but again, rather than tuning a M3 from a note which may still be slightly in error, tune the note from one which you are very sure of, the A3. Temporarily tune D4 from A3, a beatless 4th.

Listen to the resultant beat between the M3, A#3-D4. It should sound too slow by both contiguous M3's tests and adjacent M3 interval comparison. Try the contiguous M3's F#3-A#3 and A#3-D4. The A#3-D4 should sound obviously too slow. Also try the adjacent M3's A#3-C#4 (which you are now *very* sure of) and the temporarily tuned A#3-D4. Again, the A#3-D4 should sound obviously too slow by comparison. Both tests will show that D4 needs to be sharpened.

Now sharpen D4 so that the A3-D4 4th beats about 1 beat per second, then try again the contiguous M3's, F#3-A#3 and A#3-D4, listening for the 4:5 ratio. Then try the adjacent M3 intervals, A3-C#4 and A#3-D4 for smooth progression. Adjust D4 to make both of these tests work properly. As a result, you should also hear that the F3-D4 M6 beats slightly faster (but not *very* much faster and also not exactly the same) as the F3-A3 M3. Also, listen to the two 4ths which have been created: the F3-A#3 4th and the A3-D4 4th. Even though they are relatively far apart, they should still sound very similar to each other. You have this time, *four* tests to prove the last note tuned!

8. Tune G3 from D4 a tempered 5th.

8a. This is the weakest spot in the whole sequence because you have no choice but to tune from the last note which was tuned. However, now that all of the previous notes are more certain and anything that wasn't working quite right has been shifted around until it does, it is quite reliable to tune from that last note which had been tuned in this instance. After all, it had four tests to confirm it! Temporarily tune G3 from D4, a beatless 5th. Listen to the resultant m3, G3-A#3. Compare it to the F#3-A3 m3. It should sound too slow by comparison.

Now sharpen G3 slightly to produce about 1/2 beat per second 5th with D4 as you did with previous 5ths. Listen for a faster beating G3-A#3 m3 which should now sound similar to and a *very* small amount faster than the F#3-A3 m3.

9. Tune B3 from F#3, a tempered 4th.

9a. As before, don't tune your *up a M3* from a mere estimate. Tune it from the far more reliable note, F#3. Temporarily tune B3 from F#3, a beatless 4th. Listen to the resultant M3, G3-B3. Play in sequence, the M3's F3-A3, F#3-A#3 and the temporarily tuned G3-B3. It will sound obviously too slow, indicating that the B3 needs to be sharpened.

Also, the B3-D4 m3 will beat too slowly for a m3 that high in the scale. At this point, it should have a *very* rapid beat but once properly tuned, it should beat so rapidly as to be an indiscernible blur.

Now sharpen B3 from F#3 so that the F#3-B4 beats about 1 beat per second. Listen to the resultant M3, G3-B3. Does it progress well and properly with the M3's below it, F3-A3, F#3-A#3? If not, try adjusting both notes of the G3-B4 M3 interval until it does but bear in mind not to make either the G3-D4 5th or the F#3-B3 4th either too tempered or to close to beatless. The G3-D4 5th should beat slightly slower than the F#3-B3 4th. A 5th should have barely perceptible beat (one beat every 2 seconds) and a 4th should have a slow, 1 beat per second type pulse. Now the B3-D4 m3 should beat so rapidly as to be a nearly indiscernible blur. You also now have 3 4ths to compare. Even though they are not adjacent to each other, they should still all have a very similar tempered sound: F3-A#, F#-B (adjacent) and A3-D4. When satisfied with the G3-B3 M3, move on to the next step.

10. Tune D#4 a tempered 4th from A#3.

10a. Again, tune your *up a M3* from the more reliable, A#3 rather than from the estimate you just made. Temporarily tune D#4 a beatless 4th from A#3. Listen to the resultant M3, B3-D#4. It should beat too slowly to satisfy the Ratio of Contiguous M3rds and adjacent M3rds tests. Sharpen D#4 until the 4th has the approximate 1 beat per second tempering, then use the 4:5 Ratio of Contiguous M3's and adjacent M3's tests for all previously tuned M3's and adjust for smoothness and appropriateness. You also have three 5ths to compare: F#3-C#4, G3-D4 and A#3-F4. There are now four 4ths to compare as well: F3-A#3, F#3-B3, A3-D4 and the 4th you last tuned, A#3-D#4. When you are satisfied with all interval relationships, move on to the next step.

11. Tune G#3 a tempered 4th from C#4.*

11a. Yes, we are going *down a 5th* from D#4 to locate the new note to be tuned but again, use the much more reliable C#4 as a reference rather than the last note which was tuned. Temporarily tune G#3 a pure 4th from C#4.

The temporarily tuned m3, F3-G#3 should sound too slow when compared to the two m3's above it, F#3-A3 and G3-A#3. Also, the G#3-D#3 5th should have too fast of a beat to be a properly tempered ET 5th. Both will indicate that G#3 should be flattened.

Now, flatten G#3 to make the G#3-C#4 4th tempered by about 1 beat per second. Now compare the speeds of the m3's F3-G#3, F#3-A3 and G#3-B3 for smoothness. Remember, a m3 is a *narrowed* interval. Making the F3-G#3 m3 *narrower* by flattening G#3 will increase its speed. Now check the G#3-D#4 5th. It should now sound slightly slower than the G#3-C#4 4th. There will also now be three adjacent 5ths, F#3-C#4, G3-D4 and G#3-D#4. Play them in succession. There will also be anther 5th after a skip of just one 5th, the A#3-F4 5th. Play them all and compare for similarity. All should sound very similar, with the same amount of tempering in each. The G#3-C# 4th should also sound similar to the F3-A#3, F#3-A#3 4ths below it and the A3-D4 and A#3-D#4 4ths above it. When you are satisfied with all interval relationships, move on to the next step.

12. Tune C4 from F3, a tempered 5th.

12a. As before, tune the *up a M3* sequence from the more reliable note, F3 rather than the estimate you just made for G#3. Temporarily tune C4 a pure 5th from F3. This should also result in a beatless C4-F4 4th. Listen to the resultant M3, G#3-C4. It should beat too fast to be in line with the previous adjacent M3's. Also, the A3-C4 m3 should sound too slow. Compare it to the m3's below it. Flatten C4 slightly to get the 1/2 beat per second tempering in the F3-C4 5th and the approximate 1 beat per second tempering in the C4-F4 5th.

Now listen to see if the G#3-C4 M3 falls into a proper sequence with the adjacent M3's below it. The A3-C4 m3 will now be a *very* rapid, nearly indiscernible blur. There will also be four adjacent 5ths, F3-C4, F#3-C#4, G3-D4 and G#3-D#4, all in a row, plus A#3-F4 after a skip of one 5th interval. All should sound very similar, each having about the same tempered sound. There will likewise be six adjacent 4ths in a row, F3-A#3, F#3-B3, G3-C4, G#3-C#4, A3-D4 and A#3-D#4, plus D4-F4 after a skip of just one 4th interval. All of these 4ths should also have the same similarly tempered sound. When satisfied with all interval relationships, move on to the next step.

13. Tune E4 a tempered 5th from A3.

13a. This is the last of the *up a M3* sequences and just as before, tune the E4 from the most reliable note you have, A3 rather than from the estimate you just made. Temporarily tune E4 from A3, a beatless 5th. Listen to the resultant M3, C4-E4. It should beat too fast to conform to the 4:5 Ratio of Contiguous M3rds test with the M3 G#3-C4 below it. It will also not form a smooth progression with the adjacent M3s. leading up to and past it. The B3-E4 4th will beat too fast when compared with the other 4ths below it. All tests will indicate that E4 must be flattened. Flatten E4 to create the proper slight tempering in the A3-E4 5th and see if this satisfies all of the above tests with contiguous M3's, adjacent M3's, and adjacent 4ths and 5ths.

No Temperament Sequence is Perfect

Getting a perfect compromise involves building upon what you have done but also going back and making corrections to resolve dilemmas which arise later. Once you have the F3-F4 octave tuned, play all of the 5ths, play all of the 4ths and play all M3's and M6's. Listen for any M3's which are unevenly progressing, too slow or too fast and any 4ths or 5ths which are too pure or too tempered.

When you detect an error, use the Ratio of Contiguous M3's test first. Any two contiguous M3's which have an improper relationship will inevitably reveal a corresponding 4th or 5th which is either too pure or too tempered. When you are sure of which note needs to be corrected, make the correction and test to see if all the intervals now have their proper relationship to each other. Keep going over the F3-F4 octave until you have eliminated all unevenness. You may also play all the m3's up to C4. Beyond that, they become practically indiscernible. You may also use the little known 5:6 Ratio of Contiguous m3's in the same way as you use the 4:5 Ratio of contiguous M3's, as a diagnostic tool while remembering that a m3 is a narrowed interval. As with the 4:5 Ratio of Contiguous M3's, it will be easier to detect an error than it will be to be absolutely sure that any particular relationship is correct.

Expanding the temperament to fill out the C3-C5 midrange

The hardest work has now been done. First, moving lower, tune E3, D#3, D3, C#3 and C3 as octaves, making them sound beatless at first. Next, test each note with the 4ths and 5ths above them, leaving the 5ths a little less

tempered sounding than the 4ths. You should expect to be flattening each note very slightly if you truly tuned a beatless sounding octave first. Now test for the 4:5 Ratio of Contiguous M3's, beginning with C3 and going up in half steps. Also, listen for a smooth progression of adjacent M3's. Listen to all adjacent 4ths and 5ths. For the ultimate refinement, listen to all m3's from C3 at the bottom to C4 at the top. Again, when you detect an error, prove it first with the 4:5 Ratio of Contiguous M3rds test which will reveal which 4th or 5th may be too pure or too tempered.

Octaves should sound very nearly beatless but it is good and proper for them to have a very slow beat which helps them satisfy all of the other interval relationships. As a final test, use the 5:6 Ratio of Contiguous m3rds for ultimate refinement of the C3-C4 range.

Next, tune the F#4, G4, G#4, (A4 has already been tuned, *don't* move it), A#4, B4 and C5. (At the Tuning Exam, the mandatory aural midrange portion excludes C5). Tune them first as beatless sounding octaves, then as you did with the octaves below F3, check 4ths and 5ths first, then M3's and M6ths. Once you reach the F4-A4 M3 and/orC4-A4 6^{th}, drop down to C3 and play M10's beginning with C3-E4 and continue up to G#3-C5. (C5 is excluded on the Tuning Exam).

The 4:5 Ratio of Contiguous M3rds will cease to be useful much beyond the F4-A4 M3 because beyond that point, M3's will beat so rapidly as to be indiscernible. Also, M6's will also be practically indiscernible past the C4-A4 M6. But you can still check for an even progression form A4 to C5 by playing the M10ths. Make your 5ths less tempered sounding than your 4ths, keep your octaves just slightly expanded from the point where they sound completely beatless and have your Rapidly Beating Intervals (RBI), the M3's, m3's, M6's and M10's progress smoothly. From C4-F4 and higher, the 4ths will probably start to increase in speed slightly but 5ths in the area between F4 and C5 may slow down conversely. This is the natural effect of compensating for inharmonicity by properly stretching the octaves. If an error is detected in the RBI's, prove it by finding a SBI, the octaves, 4ths and 5ths which is either too tempered or too pure and correct it. Test again for smoothness in the RBI's. Keep going over the entire midrange until all errors seem to be eliminated.

Proceeding as described above will result in a mandatory aural tuning of the midrange on the Tuning Exam which will surely pass. If you usually use an ETD, this will certainly take practice on your part in order to perfect your skills. Don't be daunted or feel overwhelmed. Aural tuners who try for the first time to use an ETD are similarly frustrated and challenged.

The best way to become a Piano Technician who tunes to the highest of today's and the future's standards is to master both Aural and Electronic tuning. If you usually use an ETD, you may take comfort in the fact that you only have to tune the midrange by ear. When you get that done at a passing level, you may use your ETD to retune everything according to its calculated program on Part 2 of the Exam. Most skilled ETD users do pass the rest of the Exam with high scores.

Summary Sequence for Tuning Equal Temperament

In the F3-F4 Octave

Set the initial A4 pitch to 440 Cycles per Second. Use the test note F2 to verify.

1. Tune A3 an octave from A4. Use both the test notes F3 and C4 to create a compromise between a 4:2 and 6:3 type octave.

2. Estimate the F3-A3 M3. Approximately 7 beats per second.

3. Tune F4 to F3, an octave. Use both the test notes C#3 and G#3 to create a compromise between a 4:2 and 6:3 type octave, exactly the same as you did in step 1.

4. Tune C#4 from A3, a widened M3. Listen to the speed of the F3-A3 M3 which you estimated and make the A3-C#4 M3 beat slightly faster at a ratio of 4:5. Check the progression of contiguous M3's from F3 to A4. If you change F3, you must also Change F4. Check progression again until satisfied that all contiguous M3's from F3 to A4 have a 4:5 ratio of beating.

5. Tune F#3 from C#4, a tempered 5th. (Down a 5^{th}). Check the F#3-A3 m3 for a *very* rapid beat.

6. Tune A#3 from F4, a tempered 5th. (Up a M3 to find the note to be tuned). Check A#3-C#4 m3 for *very* rapid beat. Check progression of adjacent M3's F3-A3 and F#3-A#3. Also compare F3-A#3 4th and A#3-F4 5th.

7. Tune D4 from A3, a tempered 4th. (Up a M3 to find the note to be tuned). Check contiguous M3's F#3-A#3 and A#3-D4 for 4:5 ratio. Check progression of adjacent M3's A3-C#4 and A#3-D4. Also compare F3-A#3 and A3-D4 4th for similarity.

8. Tune G3 from D4 a tempered 5th. (Down a 5th to find the note to be tuned). Check G3-A#3 m3 for *very* rapid beat. Also Compare G3-D4 and A#3-F4 5ths for similarity.

9. Tune B3 from F#3, a tempered 4th. (Up a M3 to find the note to be tuned). Check progression of adjacent M3's F3-A3, F#3-A#3 and G3-B3. Also check adjacent 4th's F3-A#3 and F#3-B3 plus C4-F4 for similarity.

10. Tune D#4 a tempered 4th from A#3. (Up a M3 to find the note to be tuned). Check contiguous M3's G3-B3 and B3-D#4 for 4:5 ratio. Check progression of adjacent M3's A3-C#4, A#3-D4 and B3-D#4. Also check adjacent 4ths A3-D4, A#3-D#4 plus C4-F4 for similarity.

11. Tune G#3 a tempered 4th from C#4. (Down a 5th to find the note to be tuned). Check F3-G#3 m3 for *very* rapid beat and progression of adjacent m3's F3-G#3, F#3-A3, G3-A#3 and G#3-B3. Also check adjacent 4ths F3-A#3, F#3-B3 plus G#3-D#4 for similarity.

12. Tune C4 from F3, a tempered 5th. (Up a M3 to find the note to be tuned). Check progression of adjacent m3's from F3 to C4. Check progression of adjacent M3's from F3 to C4. Also check adjacent 4th's from F3 to D#4 plus C4-F4. Also check adjacent 5ths from F3 to D#4 plus A#-F4.

13. Tune E4 a tempered 5th from A3. (Up a M3 to find the note to be tuned). Check contiguous M'3 G#3-C4 and C4-E4. Check all adjacent M3's and M6's from F3 to F4. Check all adjacent 4ths from F3 to F4. Check all adjacent 5ths from F3-F4. Also check adjacent m3's from F3 to C4 as well as contiguous m3's from F3 to C4 for 5:6 ratio.

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