PIANO TECHNICIANS

Journal

OFFICIAL PUBLICATION OF THE PIANO TECHNICIANS GUILD

November 2017 Vol. 60 No.11

YOUR BUSINESS: YESTERDAY, TODAY AND TOMORROW
THE FORK IN THE ROAD

A PIANO MAKER'S LIFE – PART 2

AURAL STRETCH USING BEAT SPEED WINDOWS

FIVE-POUND COILS OF WIRE, DISPENSED OFF THE OUTSIDE OF THE COIL

TWENTY-FIRST CENTURY TUNING STYLE
WHEN WAVES COMBINE

SMALL SHOP – BIG RESULTS
UPRIGHT PIANO RESTORATION: PART 18

TUNER'S LIFE
THANKS, FELIX: PART 1

Contents

features

November 2017

In Addition

Cover Art

Cover photo by John Parham, RPT

Please submit chapter technical articles, tuning and technical articles, Tuner's Life/Tuner's Health stories and queries via e-mail to:

editor@ptg.org

Please submit tips for TT&T to:

John Parham, RPT
1322 36th Ave NE, Hickory NC 28601
E-mail: TTT@ptg.org

Aural Stretch Using Beat Speed Windows

By Mark Cerisano, RPT
Montreal QC Chapter

The Beat Speed Window method is part of the Go APE aural tuning method for Accuracy, Precision, and Efficiency, created by the author.

Background

Many aural tuners know that octaves must be stretched for the piano to sound good. However, some aural tuners tune without this knowledge; they just tune the octaves until they sound good and are not concerned about how much the piano is stretched.

This can produce very good results, but there can be a variation in the actual octave sizes when octaves are tuned this way. Variation in the reproduction of a result indicates low precision.

Precision refers to the repeatability of a result, while accuracy refers to the correctness of a result. A target that has many bullet holes tightly placed together, but with the average location of the bullet holes off center indicates that the rifle and/or marksman that shot the bullets has good precision, but poor accuracy. A target with the holes widely space around the bull's eye has good accuracy, but *poor precision.* See Figure 1.

Figure 1: Accuracy and precision.

This article deals with how to use beat speeds to aurally create precise and customizable octave stretch.

Octaves

Using beat speeds to tune 4:2 or 6:3 octaves improves precision.

For readers who may not be familiar with the definitions of 4:2 and 6:3 octaves, the following will be a quick introduction. Figure 2 shows two octave notes, N1 and N2, and their partials. In this ideal case only, many upper partials line up perfectly with each other.

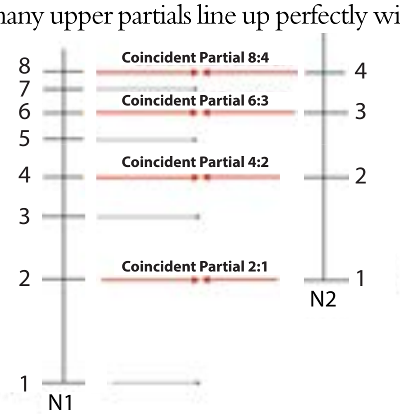

Figure 2: Ideal octave N1-N2.

In reality, the upper partials are not so perfect. They are sharper than predicted in Figure 2. This is called *inharmonicity*; the upper partials are not harmonic with the lowest partial, also known as the fundamental. This is why they are called partials, and not harmonics.

Figure 3 shows our octave, N1-N2, with *inharmonic* partials. Notice how all coincident partials cannot line up at the same time. (Coincident partials are partials that are shared by the two notes in the interval. Only the coincident partials are shown.)

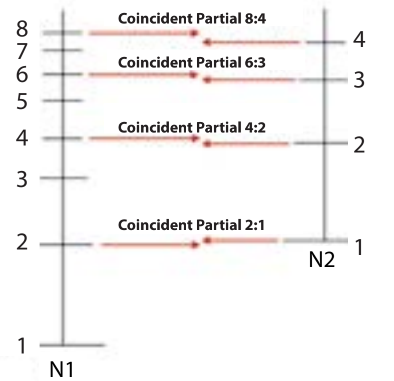

Figure 3: Realistic partials of octave N1-N2.

Figure 4 describes four possible sizes for an inharmonic octave.

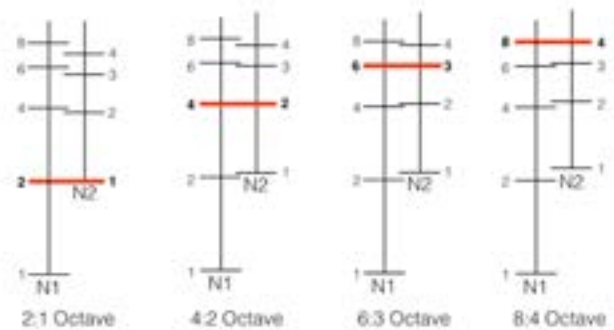

Figure 4: Four possible octave sizes.

Pure, Wide, and Narrow Intervals

Figure 5 describes how we imagine and tune pure, wide, and narrow intervals.

Check Notes

Aural piano tuners use check notes to measure the sizes of intervals that are very close to pure, e.g., intervals like the octave, fourth, and fifth, and their compounds. (Compound intervals are intervals larger than an octave.)

Check notes are notes that are lower than the intervals' notes. The check note is played with each interval note, producing check intervals.

Check intervals measure the relative sharpness of the coincident partials of each interval note.

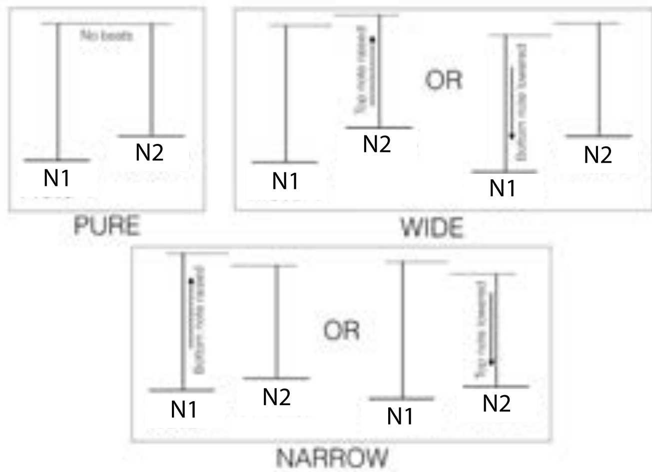

Figure 5: Pure, wide, and narrow intervals.

Figures 6, 7, and 8 illustrate how we use a check note to produce beating check intervals. These intervals are then compared to each other in order to determine the relative sharpness of the coincident partials of each interval note, which tells us if an interval is pure, wide, or narrow.

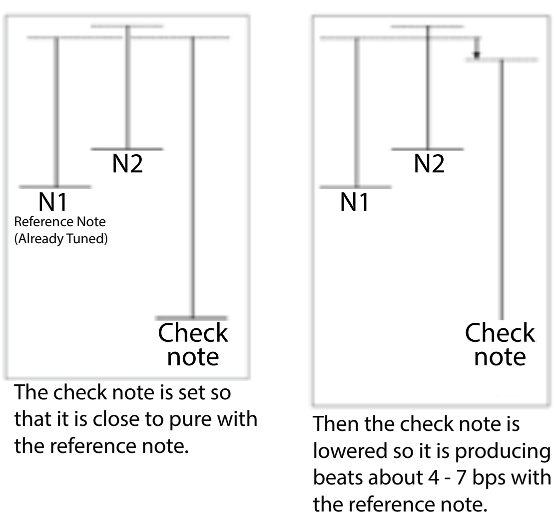

Figure 6: How a check note is set.

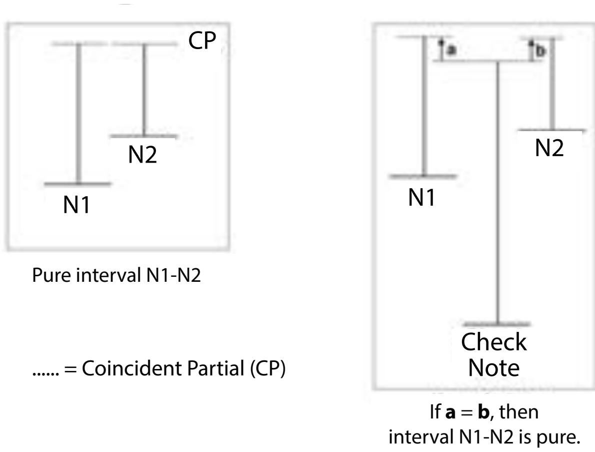

Figure 7: Measuring pure intervals.

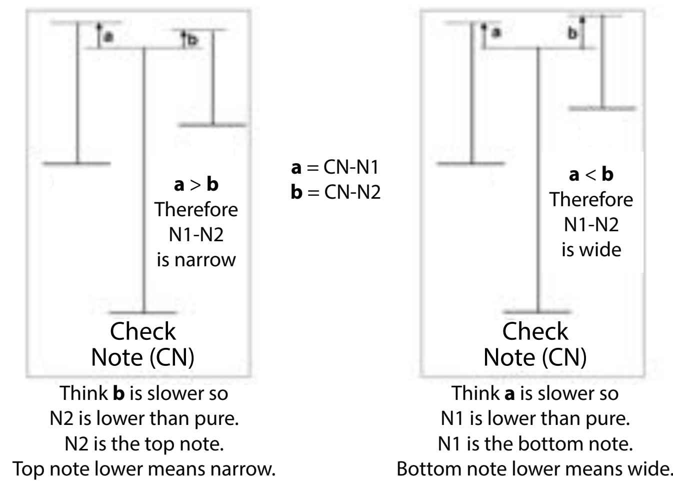

Figure 8: Measuring wide and narrow intervals.

Figure 9 shows how the M3 and the M10 measure the location of the fourth and second partials of our octave, N1–N2, and hence tell us the size of the 4:2 octave.

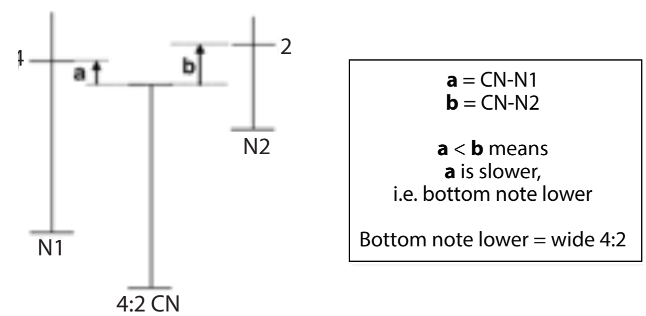

Figure 9: Measuring the 4:2 octave.

Figure 10 shows how the m3 and the M6 measure the location of the sixth and third partials of our octave, N1–N2, and hence tells us the size of the 6:3 octave.

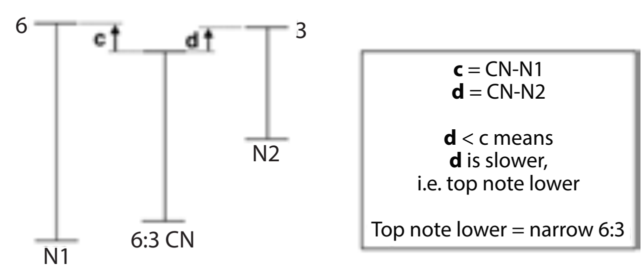

Figure 10: Measuring the 6:3 octave.

"Pure" 4:2 Versus "Pure" 6:3 Octaves

To discuss the most common case of inharmonicity using aural techniques, we need to understand that when we listen to two beat speeds, they may not be the same speed, but they may sound like the same speed. So it is with the check intervals of the 4:2 and 6:3 octaves. On many pianos, these check intervals are so close, that as aural tuners, we hear their check intervals as equal, and therefore judge the octave to be a "pure" 4:2 or "pure" 6:3. (I have shown the term *pure* with quotes to describe an interval that is not pure, but its check intervals are so close that we cannot tell the difference. Indeed, the interval itself sounds pure when we are this close.)

For our discussion of aural stretch, we will concern ourselves with pianos with inharmonicity that results in the octaves around the temperament, near F3-F4 and A3-A4, that sound the best when tuned as "pure" 4:2 / "pure" 6:3. (There can be other octave inharmonicities in pianos. The reader is encouraged to look for books and PTG Journal articles by the author that describe these situations.) We will also use the temperament octave F3-F4 as the reference, but the method can be used with any temperament octave.

The First Section Above the Temperament Octave: Tuning "Pure" 4:2 Octaves (F♯4 – B4)

The first section above the temperament octave where stretch can be set depends on which octave is used as the temperament octave. When using the F3-F4 temperament octave, this starts at F♯4. Since our piano likes "pure" 4:2 octaves, we will continue producing "pure" 4:2 octaves until we get to the second section. We will use the P4 Window (defined later) to produce our pure 4:2 octaves and to confirm that the size of our perfect fourths (P4s) within the temperament octave have not changed and are still wide. (In equal temperament, P4s are wide and can be confirmed with the M3/M6 test, where the M6 beats faster than the M3, described below.)

How We Will Write and Describe Relative Beat Speeds

As stated above, the P4 is confirmed wide with a M3/M6 test, where the M6 beats faster than the M3. In our discussion, we will write this as M3 < M6, the Wide P4 Test, which can be read as "The major third beats slower than the major sixth," or as "The major sixth beats faster than the major third." Both are correct, and both confirm a wide P4. For example, when testing the P4 A3-D4, we use F3 as the check note, which produces the following check intervals:

M3 = F3-A3
M6 = F3-D4

And to confirm this specific P4 as wide, we are looking for the following relationship: F3-A3 < F3-D4. This can be read as "F3-A3 beats slower than F3-D4," or as "F3-D4 beats faster than F3-A3." Both are correct, and both confirm a wide P4.

Relative Beat Speeds Within Windows

Within all the windows that we will discuss, the beat speeds fall into two relative categories, slow and fast. Where the window occurs and what note is being tuned will affect the absolute speeds of all the beats, but relative to each other, i.e., there are just two beat speeds within any one window—slow and fast. The figures used to show each window below have these relative speeds marked.

The P4 Window

After we tune the temperament octave, F3-F4, we will use the P4 window to tune F♯4.

The P4 is wide in equal temperament, confirmed by using the M3/M6 test. So, when tuning our first note (F♯4) in the first section above the temperament, we can use the following checks, which give us our first window, the P4 Window: (See Figure 11.)

M3 = M10 < M6

Tunes a pure 4:2 (M3 = M10)
Confirms a wide P4 (M3 < M6)
Confirms a narrow P5 (M6 > M10)

Notice how this test also conveniently confirms our P5 as narrow. Fifths are narrow in equal temperament.

For our note, F♯4, we are looking for D3-F♯3 = D3-F♯4 < D3-B3.

Within this window we have the following confirmations: (See again Figure 11.)

Tunes a pure 4:2, F♯3-F♯4 (D3-F♯3 = D3-F♯4)
Confirms a wide P4, F♯3-B3 (D3-F♯3 < D3B3)
Confirms a narrow P5, B3-F♯4 (D3-F♯4 < D3-B3)

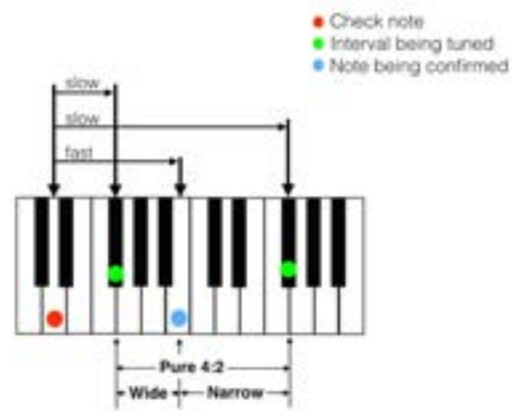

Figure 11: The P4 Window.

Using Confirmations to Find Drifted Notes

A powerful benefit of the Beat Speed Window Method is the ability to find notes that have drifted by confirming whether or not they still fit into these windows. In the example above, B3 is not being tuned or even used to tune F♯4 directly, but if there isn't a clear confirmation that the P4 F♯3-B3 is still wide and that the P5 B3-F♯4 is still narrow, we may have a case where B3 has drifted since it was first tuned, or that we incorrectly tuned it in the first place. It doesn't matter which—just retune it and move on.

The Second Section Above the Temperament Octave: Tuning Pure 12ths (C5 – E5) Using the P5 Window

We have used the pure 4:2 to tune the notes up to and including B4. Starting at C5, we could continue to use the P4 window, but by using the P5 Window, we can start to tune pure perfect 12ths (octave plus perfect fifth). We will just write 12 from now on and assume we mean a P12. The test for the pure 12th is M6 = M17.

The P5 Window to Tune Pure 12ths

The test for the narrow P5 is M6 > M10. By adding the M17, we get the P5 Window:

M6 = M17 > M10

Within this window we have the following confirmations: (See Figure 12.)

Tunes a pure 12th (M6 = M17)
Confirms a narrow P5 (M6 > M10)
Confirms a wide 2:1 octave (M10 < M17)

Most octaves that are tuned to a "pure" 4:2 or "pure" 6:3 have a wide 2:1.

Tuning our first note in the second section above the temperament octave, C5, we use these intervals:

G♯2–F3 = G♯2–C5 > G♯2–C4

Within this P5 Window we have the following confirmations: (See again Figure 12.)

Tunes a pure 12th, F3–C5 (M6 = M17)
Confirms a narrow P5, F3–C4 (M6 > M10)
Confirms a wide 2:1, C4–C5 (M10 < M17)

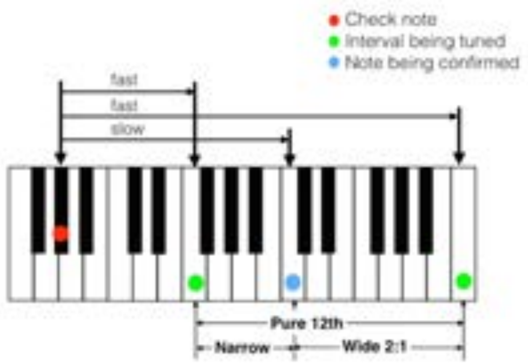

Figure 12: The P5 Window.

The Third Section Above the Temperament Octave: Tuning Pure 12ths Using the Expanded P4 Window (F5 - B5)

We used the P4 Window in section 1 to tune pure 4:2. Now we can add the pure 12th test to the P4 window to create the Expanded P4 Window.

Reaching down into the temperament for reference notes as we go higher in the piano has the double benefit of using reference notes that do not have cumulative error that results when we use notes outside the temperament to tune other notes outside the temperament. Also, as we enlarge our check intervals, the interval speeds decrease, which counteracts the increase in beat speed that is happening because we are going higher up the keyboard.

We add the pure 12th test (M6 = M17) to the P4 Window (M3 = M10 < M6) to get the Expanded P4 Window, as shown: (See Figure 13.)

M3 = M10 < M17 = M6

Here are the confirmations and interval sizes that it produces:

Confirms pure 4:2 (M3 = M10)
Confirms a wide 2:1 (M10 < M17)
Tunes a pure 12th (M6 = M17)
Confirms a wide 4:1 double octave (M3 < M17)
Confirms a narrow P5 (M6 > M10)
Confirms a wide P4 (M3 < M6)

Starting at F5, the Expanded P4 Window is:

C♯3–F3 = C♯3–F4 < C♯3–F5 = C♯3–A3

And here are the specific intervals tuned and confirmed within this window: (See again figure 13.)

Confirms pure 4:2, F3–F4 (M3 = M10)
Confirms a wide 2:1, F4–F5 (M10 < M17)
Tunes a pure 12th, A♯3–F5 (M6 = M17)
Confirms a wide 4:1, F3–F5 (M3 < M17)
Confirms a narrow P5, A♯3–F4 (M6 > M10)
Confirms a wide P4, F3–A♯3 (M3 < M6)

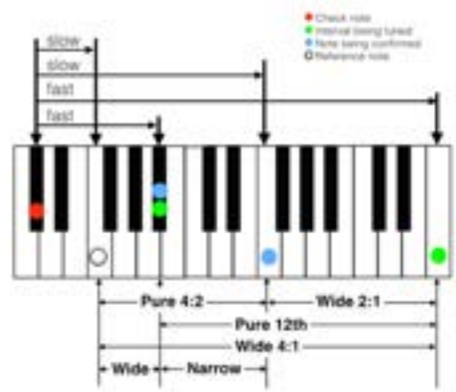

Figure 13: The Expanded P4 Window.

The Fourth Section Above the Temperament Octave: Tuning Pure 19ths (C6 - E6) Using the 6:2 P5 Window

When we get to C6, we could continue to use the Expanded P4 Window, M3 = M10 < M17 = M6, with notes G♯3–C4 = G♯3–C5 < G♯3–C6 = G♯3–F4.

But take a look at that last interval, G♯3–F4. Didn't we tune F3–F4 as a "pure" 6:3 octave using F3–G3 = G♯3–F4? The test for that was m3down = M6, the test for the pure 6:3.

Note: All the check intervals have had the check note as the bottom note of the check interval until now. This is the first time we are going below the check note for the other check interval note. That is why the interval is written as m3down. From now on, to save space, we will just write it as *m3d*.

The 6:2 P5 Window for Tuning Pure 19ths

Let's add that m3d to the Expanded P4 Window to produce the 6:2 P5 Window. (See figure 14.)

M3 = M10 < M17 = M6 = m3d

We call this the 6:2 P5 Window because the first and last intervals of the window are the M3 and the m3d. The M3 and m3d test the size of the P5 at the second coincident partial, the 6:2 partial. This interval is narrow in equal temperament.

Notice the M17 = m3d? That's the test for a "pure" 19th (two octaves plus a perfect fifth).

Remember that we are defining "pure" as an interval whose check intervals are so close we cannot tell if they are different speeds, and they therefore sound equal to our ear.

The intervals tuned and confirmed within the 6:2 P5 Window are the same as those tuned and confirmed within the Expanded P4 Window, with the exception of those produced by the addition of the m3d interval. Therefore, we will only analyze the new intervals tuned/confirmed by the addition of the m3d interval. (See figure 14.)

M3 = M10 < M17 = M6 = m3d

Confirms a narrow 3:2 P5 (m3d > M3)
Confirms a narrow 6:2 P12 (m3d > M10)
Tunes a pure 19th, double octave + fifth (m3d = M17)
Confirms a pure 6:3 (m3d = M6)

Starting at C6, the 6:2 P5 Window is:

G♯3–C4 = G♯3–C5 < G♯3–C6 = G♯3–F4 = F3–G♯3

The specific intervals tuned and confirmed within this window are: (See again figure 14.)

Pure 4:2, C4–C5
Wide 2:1, C5–C6
Pure 12th, F4–C6
Pure 6:3, F3–F4
Wide 4:1, C4–C6
Narrow P5, F4–C5
Wide P4, C4–F4
Narrow 6:2 P12th, F3–C5
Narrow 3:2 P5, F3–C4
Pure 19th, F3–C6

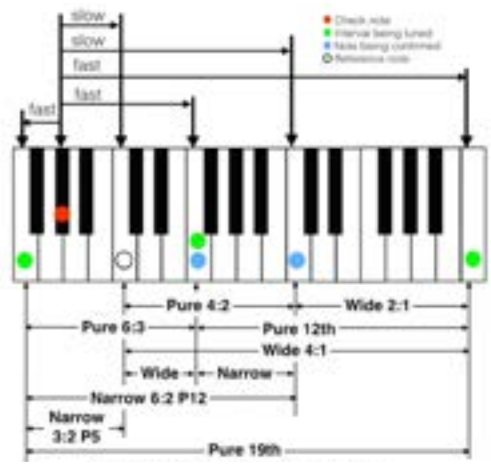

Figure 14: The 6:3 P5 Window.

The Fifth Section Above the Temperament Octave: Tuning Pure 22nds (F6 to B6) Using the 8:4 Window

Look at the 6:2 P5 Window again.

M3 = M10 < M17 = M6 = m3d

The test for a pure 8:4 octave is m6down = M3. However, the 8:4 octave is almost always narrow due to inharmonicity. In that case, we get this relationship:

M3 < m6down

In all the windows, there are only two speeds, slow and fast. The two speeds are different by about 12%. We won't be far off if we say that the m6d in the 8:4 test is faster than the M3 by about 12%.

We can now put the M3 in the slow camp, and add the m6d to the fast camp, by simply adding the m3d to the 6:2 P5 window to create the 8:4 Window, like this: (See figure 15.)

M3 = M10 < M17 = M6 = m3d = m6d

See the M3 in both relationships above? There are actually the same M3. Look at the 6:2 P5 Window tuning F6:

C♯4–F4 = C♯4–F5 < C♯4–F6 = C♯4–A♯4 = A♯3–C♯4

Now look at the test for a narrow 8:4 F3–F4.

F3–F4: F3–C♯4 > C♯4–F4

See? Both have the M3, C♯4–F4. The C♯4–F4 M3 in the Pure 6:3 window belongs in the slow camp. That makes the m6d, F3–C♯4, belonging in the fast camp.

Look at the 8:4 Window again: (See figure 15.)

M3 = M10 < M17 = M6 = m3d = m6d

You can go back to the Pure 6:3 Window discussion to review all the pure intervals created within that window, but since it would take too much space, we will just look at the implications of adding the m6d to this window and see what kind of intervals are tuned and confirmed.

Narrow 8:4 (m6d > M3)
Narrow 8:2 (m6d > M10)
Pure 22nd (m6d = M17)
Pure P11, octave + P4 (m6d = M6)
Pure 8:6 P4 (m6d = m3d)

When tuning F6 using this window, all the pure intervals and confirmed intervals found in the Pure 6:3 Window are included, as well as the following that are produced by this 8:4 Window used to tune F6 as a pure 22nd. (See again figure 15.)

C♯4–F4=C♯4–F5 < C♯4–F6 = C♯4–A 4= A♯3–C♯4=F3–C♯4

Narrow 8:4 F3–F4 (m6d > M3)
Narrow 8:2 F3–F5 (m6d > M10)
Pure P11 F3–A♯4 (m6d = M6)

Pure 8:6 P4 F3–A♯3 (m6d = m3d)
Pure 22nd F3–F6 (m6d = M17)

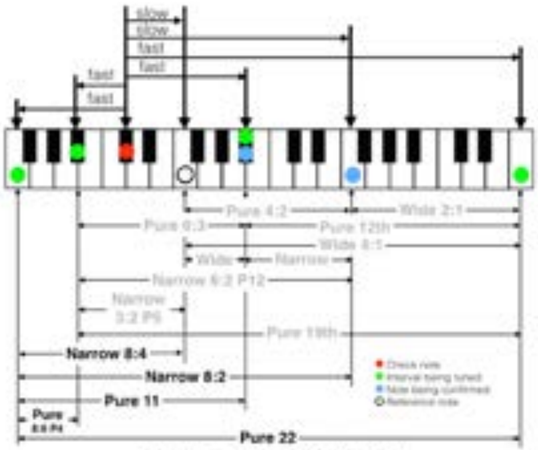

Figure 15: The 8:4 Window.

The Sixth Section Above the Temperament Octave: Tuning When Beat Speeds are Too Fast to Hear (C7 - C8)

In this section of the piano, the beat speeds are too fast to hear, so aural tuners must rely on their sense of what a pure interval sounds like directly, without using check notes.

The actual note where the aural tuner switches from beat speed tests to listening directly can be lower than C7. You can switch whenever you feel it is too difficult to hear.

Starting at C7, the aural tuner can listen to each of the pure intervals tuned within the 8:4 Window, and just play them directly and confirm their purity by ear.

For example, tuning C7: (See Figure 16.)

C6–C7	Pure 4:2 (Too hard to hear. Tune a pure 2:1)
G5–C7	Pure 11th
F5–C7	Pure 12th
F4–C7	Pure 19th
C4–C7	Pure 22nd

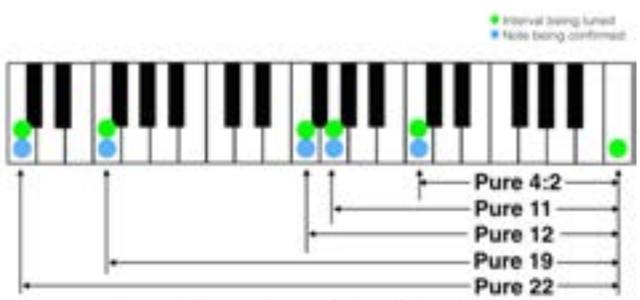

Figure 16: Tuning the high treble.

Sections

Figure 17 shows where on the piano the different windows can be used. The bass is tuned using the 8:4 Window to tune the bottom note and confirm that all the higher notes haven't drifted. The extreme bass and treble are not tuned using check notes. They are tuned by listening directly to the intervals because the beat speeds created by the check notes are too difficult to hear. The boundaries where the tuner changes from using check notes to tuning directly are not fixed. The tuner will change whenever the beats are too difficult to hear.

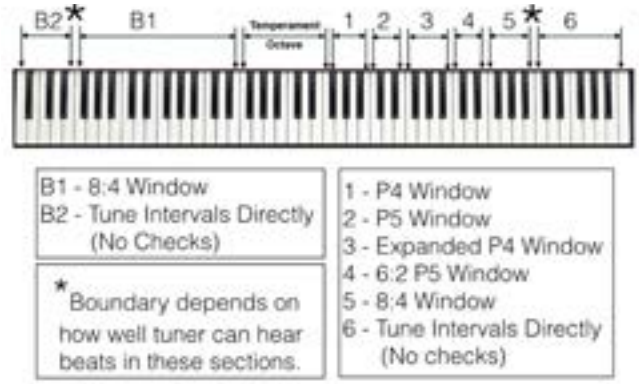

Figure 17: The Window Areas.

Conclusion

This may be a new way to tune for some technicians, but they are encouraged to examine the benefits of adding this procedure to their skill base. Using beat speed windows will improve the following skills:

1. **Fewer Errors.** The Beat Speed Window method confirms the pitch of notes as the tuner uses the window to tune the main note being tuned. This allows the tuner to catch drifted notes before they are needed to tune other notes. This produces a self-correcting feature in the method.
2. **Improved Speed, Accuracy, and Precision.** The windows are very small, as small as 0.5 cents. This produces precise and fast tunings. In fact, Beat Speed Windows, with their self-correcting feature, can be used to tune minor pitch raises with one pass without needing as much overpull as other methods.
3. **Improved Tuner's Ear.** Constantly focusing on these faster, higher-beating partials trains the ear to be better at filtering out specific partials at will. This skill doesn't just appear out of nowhere. You have to show the brain and the ear what you want them to get better at hearing.
4. **Filter Out Ambient Noise.** The skill of being able to focus on specific partials means that you are filtering out unwanted frequencies and noises that could frustrate or confuse a tuner who is not able to filter well. Aural tuners who can focus on specific partials at will are able to tune in noisy environments without as much difficulty.
5. **Customized Stretch**. For pianos that need narrow 6:3 octaves around F3–F4 and A3–A4, the tuner has a choice at the P19. You can stretch more, so that the P19 is pure but the other intervals are wide, or keep it narrow and keep the 11/12/22 pure.
6. **Clean Bass Intervals**. Tuning below the temperament octave is just a matter of producing the same interval tests contained in the 8:4 Window. The tuner may find that the octave may suffer when trying to keep all the larger intervals pure. In this case, compromise and choice must occur. ◻

Mark Cerisano, RPT, *earned a bachelor's degree in engineering from Queen's University in 1988. Hundreds of people have taken his tuning and repair classes through <howtotunepianos.com>. He has also taught at the national level.*