Setting Circulating Temperaments on the Modern Concert Grand: An Op. 118 Aural and ETD Protocol

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Abstract

When concert pianists request historical or unequal temperaments on modern institutional concert grand pianos (e.g., Steinway Model D, Yamaha CFX, Bösendorfer 280VC), piano technicians face unique acoustic and mechanical challenges. Long string scales, high aggregate tension, thick cold-pressed felt hammers, duplex scale resonances, and pronounced treble inharmonicity interact differently with unequal intervals than the short, plain-wire instruments of the eighteenth and nineteenth centuries.

This paper provides a complete, bench-tested technical protocol for migrating a modern concert grand from standard $A = 440$ Hz Equal Temperament to $A = 432.0$ Hz **in Bradley Lehman's 2005 circulating well-temperament**, prepared specifically for a complete performance of Johannes Brahms's *Six Pieces for Piano, Op. 118* (1893). We present:

1. A safe, two-pass mechanical pitch-lowering procedure that stabilizes pinblock torque and bridge downbearing.
2. A definitive **13-step aural setting sequence** within the temperament octave (F_3–F_4) utilizing specific beating rates (F_3–A_3 at 2.92 bps, C_4–E_4 at 4.37 bps, and five acoustically pure fifths).
3. Programming matrices and octave stretch compensation guidelines for modern Electronic Tuning Devices (ETDs), including PianoScope, CyberTuner, Verituner, and TuneLab.

4. Voicing and regulating adjustments necessary to optimize sustain and eliminate percussive glare in unequal third progressions.

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1. The Concert Technician's Dilemma: Historical Intonation on Modern Scales

Over the past four decades, the revival of historical temperaments has largely been confined to harpsichords, clavichords, and period fortepianos.[1] However, concert artists are increasingly requesting historical temperaments on modern concert grands for performances of Bach, Mozart, Beethoven, Chopin, and late Brahms.[2]

For the concert technician, applying a circulating well-temperament to a modern nine-foot grand presents distinct physical challenges:

1. **High Inharmonicity (B)**: Modern high-tension steel music wire (such as Röslau or Mapes) exhibits significant stiffness, causing upper partial frequencies to diverge from pure integer multiples ($f_n \approx n f_1 \sqrt{1 + B n^2}$). On long concert grands, bass and tenor inharmonicity is relatively low, but jumps sharply in the high treble, requiring careful expansion of octaves.[3]
2. **Duplex Scaling**: Modern instruments feature tuned front and rear aliquots (duplex scales) that ring sympathetically with string partials. If an unequal temperament creates rapid beating in a high-register triad, an active duplex scale can amplify that beating into a metallic sheen unless carefully muted or damped.[4]
3. **Hammer Density & Voicing**: Modern hammers are heavily pressed under heat and lacquered to project across 2,500-seat symphony halls. In equal temperament, all major thirds beat fast (7–14 bps). In a well-temperament, diatonic thirds beat very slowly (F_3–A_3 at 2.9 bps), while remote thirds beat rapidly (E_4–$G\sharp_4$ at 18.4 bps). If the piano's strike point is voiced too hard, the rapid beating in remote keys can sound harsh and glassy.

When properly regulated and tuned, however, a modern concert grand in Lehman's circulating temperament produces a rich, multi-layered palette that equal temperament cannot achieve: home keys exhibit cathedral-like sustain, while remote harmonies sparkle with vibrant, clean energy.[5]

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2. Pitch Migration Protocol to A=432 Hz

Dropping an instrument from $A_4 = 440$ Hz to $A_4 = 432.0$ Hz is a drop of -31.77 cents.

```
[440.0 Hz Standard ET]
         |
         ▼ (Pass 1: Pre-drop over-pull to -36 cents to equalize plate deflection)
[Rough Lowering Pass]
         |
         ▼ (Pass 2: Fine temperament setting on stabilized soundboard)
[A=432.0 Hz Lehman Well-Temperament]
```

A common technician error is attempting to set an intricate temperament while performing a pitch drop in a single pass. As string tension drops across the instrument, the cast-iron plate flexes microscopically and the wooden soundboard crown rises, causing previously tuned notes to go sharp.[6]

2.1 The Two-Pass Migration Procedure

1. **Pass 1: Rapid Rough Lowering (Over-pull / Under-pull Drop)**:

- Using an ETD or rough aural checks, drop the entire piano to approximately -36.0 cents relative to $A = 440$ (overshooting the -31.8 cent target by ~ 4 cents).
- Sequence: Begin in the tenor (C_3), tune downward through the bass (A_0), return to the tenor, and tune upward through the treble (C_8).
- Goal: Allow the aggregate soundboard downbearing load (~ $1,440$ lbs of tension relief) to settle and equilibrate across the bridge.

1. **Pass 2: Fine Temperament and Unisons**:

- Allow the instrument to rest for at least 30 minutes following Pass 1.
- Set the core temperament octave (F_3–F_4) at exact $A = 432.0$ Hz.
- Extend octaves upward and downward, locking unisons solidly.

2.2 Pin Setting & Torque Security

Because lowering pitch turns the tuning pin counter-clockwise, the technician must break static friction in the pinblock bushing, lower the pitch slightly below target, and then **firmly set the pin clockwise into the wood fibers** while rendering the non-speaking string segment behind the capo bar or agraffe.[7] Failing to set the pin properly will result in immediate pitch instability during loud fortissimo playing.

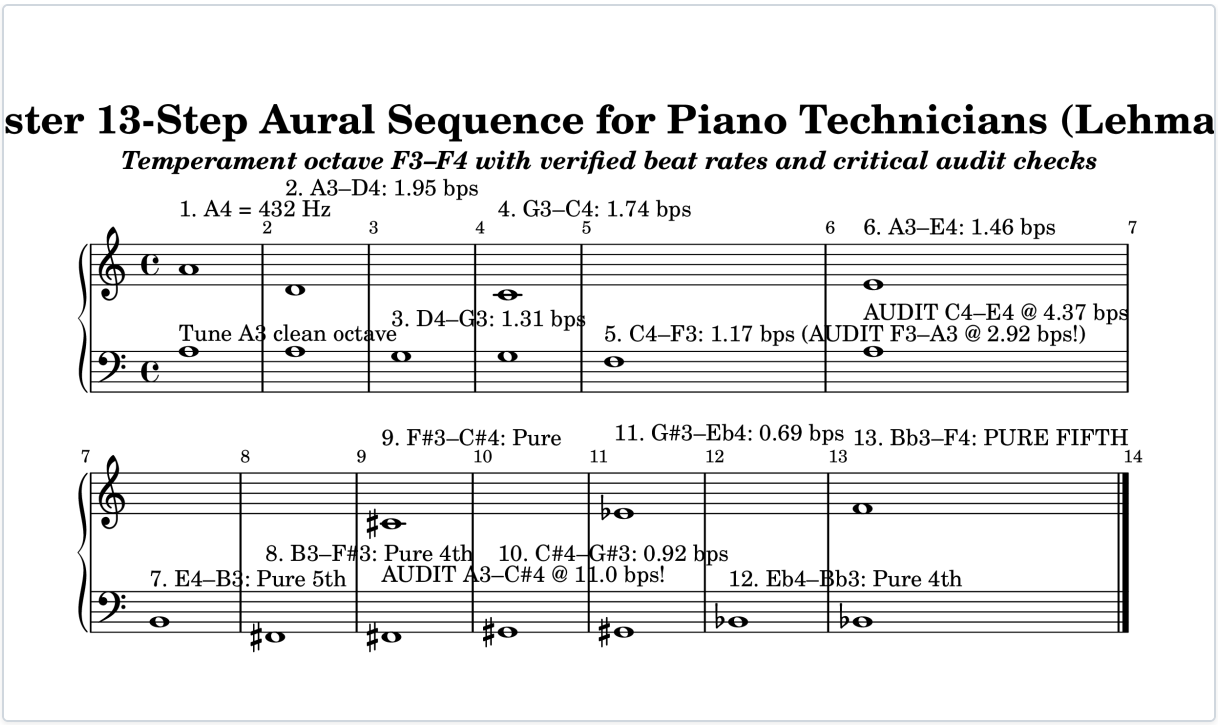
3. The Complete 13-Step Aural Setting Protocol (F3 to F4)

This protocol sets Bradley Lehman's 2005 circulating well-temperament entirely by ear within the temperament octave (F_3 to F_4), anchored to an $A_4 = 432$ Hz **tuning fork**.[8]

```
flowchart TD
    Step1["Step 1: A4 (432 Hz fork) -> Tune A3 down (clean octave)"] --> Step2["Step 2: Tun
    Step2 --> Step3["Step 3: Tune G3 down from D4 (narrow 5th, 1.31 bps)"]
    Step3 --> Step4["Step 4: Tune C4 up from G3 (narrow 5th, 1.74 bps)"]
    Step4 --> Step5["Step 5: Tune F3 down from C4 (narrow 5th, 1.17 bps)"]
    Step5 --> Audit1{"AUDIT 1: Test F3-A3<br/>Must beat at exactly 2.92 bps!"}
    Audit1 --> Step6["Step 6: Tune E4 up from A3 (narrow 5th, 1.46 bps)"]
    Step6 --> Audit2{"AUDIT 2: Test C4-E4<br/>Must beat at exactly 4.37 bps!"}
    Audit2 --> Step7["Step 7: Tune B3 down from E4 (PURE 5th, 0.0 bps)"]
    Step7 --> Step8["Step 8: Tune F#3 down from B3 (PURE 4th, 0.0 bps)"]
    Step8 --> Step9["Step 9: Tune C#4 up from F#3 (PURE 5th, 0.0 bps)"]
    Step9 --> Audit3{"AUDIT 3: Test A3-C#4<br/>Vibrant sparkle at 11.03 bps!"}
    Audit3 --> Step10["Step 10: Tune G#3 down from C#4 (narrow 5th, 0.92 bps)"]
    Step10 --> Step11["Step 11: Tune Eb4 up from G#3 (narrow 5th, 0.69 bps)"]
    Step11 --> Step12["Step 12: Tune Bb3 down from Eb4 (PURE 4th, 0.0 bps)"]
    Step12 --> Step13["Step 13: Close the Circle: Test Bb3 to F4 (PURE 5th, 0.0 bps)"]
```



Figure 4.1: Complete operational flowchart of the 13-step aural tuning sequence for setting Bradley Lehman's well-temperament at A=432 Hz, showing critical audit test points.



Example 4.1: Master 13-step aural tuning sequence for piano technicians in musical notation across the temperament octave F_3–F_4 at $A = 432$ Hz, showing exact theoretical beat rates, pure fourths/fifths, and critical major-third audit checks.

Detailed Aural Steps

Step 1: Set Reference Pitch A4 and Temperament Base A3

- Tune A_4 to a verified 432.0 Hz master fork (or calibrated tone generator).
- Tune A_3 down from A_4 to a clean, beatless octave (on long grands, tune the octave with a very faint, imperceptible widening of less than 0.5 bps to match natural inharmonicity stretch).

Step 2: Tune D4 up from A3 ($\frac{1}{6}$-comma Narrow Fifth)

- Tune D_4 from A_3 as a fourth (or D_4–A_4 fifth). Narrow the fifth by approximately 1.95 beats/second (tuned sharp of pure fifth).
- *Aural Check*: If checking A_3–D_4 as a fourth, tune it wide by approximately 1.3 bps.

Step 3: Tune G3 down from D4 ($\frac{1}{6}$-comma Narrow Fifth)

- Tune G_3 down from D_4. Narrow the fifth by 1.31 beats/second (tune G_3 sharp of pure fifth).

Step 4: Tune C4 up from G3 ($\frac{1}{6}$-comma Narrow Fifth)

- Tune C_4 up from G_3. Narrow the fifth by 1.74 beats/second (tune C_4 flat of pure fifth).

Step 5: Tune F3 down from C4 ($\frac{1}{6}$-comma Narrow Fifth)

- Tune F_3 down from C_4. Narrow the fifth by 1.17 beats/second (tune F_3 sharp of pure).
- **CRITICAL AUDIT 1**: Immediately play the major third F_3–A_3.
- *Target*: It **MUST beat at exactly** 2.92 beats/second (a slow, stately, noble pulse).
- *Diagnostic*: If F_3–A_3 is beating at 5–7 bps, your fifths are too wide (too close to equal temperament). If it is completely pure (0 bps), your fifths are too narrow (quarter-comma meantone). Adjust C_4 and G_3 until F_3–A_3 pulses at exactly ~ 3 bps.

Step 6: Tune E4 up from A3 ($\frac{1}{6}$-comma Narrow Fifth)

- Tune E_4 up from A_3. Narrow the fifth by 1.46 beats/second.
- **CRITICAL AUDIT 2**: Test the major third C_4–E_4.
- *Target*: It **MUST beat at exactly** 4.37 beats/second.
- Notice that C_4–E_4 (4.37 bps) beats noticeably faster than F_3–A_3 (2.92 bps), yet is substantially calmer than a standard 12-TET major third (10.5 bps).

Step 7: Tune B3 down from E4 (PURE FIFTH)

- Tune B_3 down from E_4 as an **acoustically pure fifth (**0.0 beats/second**)**. Tune until all beating ceases completely, leaving an unblemished, glassy harmony.

Step 8: Tune F#3 down from B3 (PURE FOURTH)

- Tune $F\sharp_3$ down from B_3 as an **acoustically pure fourth (**0.0 beats/second**)**. (Or tune $F\sharp_4$ down to B_3 as a pure fifth).

Step 9: Tune C#4 up from F#3 (PURE FIFTH)

- Tune $C\sharp_4$ up from $F\sharp_3$ as an **acoustically pure fifth (**0.0 beats/second**)**.
- **CRITICAL AUDIT 3**: Test the major third A_3–$C\sharp_4$.
- *Target*: It **MUST beat with lively, sparkling brilliance at** 11.03 beats/second.
- This verifies that the diatonic fifths absorbed their proper comma share, leaving A–$C\sharp$ free to supply the lyrical shimmer required for Brahms Op. 118 No. 2!

Step 10: Tune G#3 down from C#4 ($\frac{1}{12}$-comma Narrow Fifth)

- Tune $G\sharp_3$ down from $C\sharp_4$. Narrow the fifth by a very faint 0.92 beats/second (nearly pure, but with a subtle lazy roll).

Step 11: Tune Eb4 up from G#3 ($\frac{1}{12}$-comma Narrow Fifth)

- Tune $E\flat_4$ ($D\sharp_4$) up from $G\sharp_3$. Narrow the fifth by 0.69 beats/second.

Step 12: Tune Bb3 down from Eb4 (PURE FOURTH)

- Tune $B\flat_3$ down from $E\flat_4$ as an **acoustically pure fourth (**0.0 beats/second**)**.

Step 13: Close the Circle — Audit Bb3 to F4 (PURE FIFTH)

- Play $B\flat_3$ to F_4 (the octave above F_3).
- **FINAL VERIFICATION**: The fifth $B\flat_3$–F_4 **MUST be acoustically pure (** 0.0 beats/second**)** or have a negligible widening roll of less than 0.5 bps.
- If $B\flat_3$–F_4 has an aggressive wolf beat (> 3 bps), re-check Steps 10, 11, and 12. When set correctly, the temperament circle closes with complete harmonic fluidity.[9]

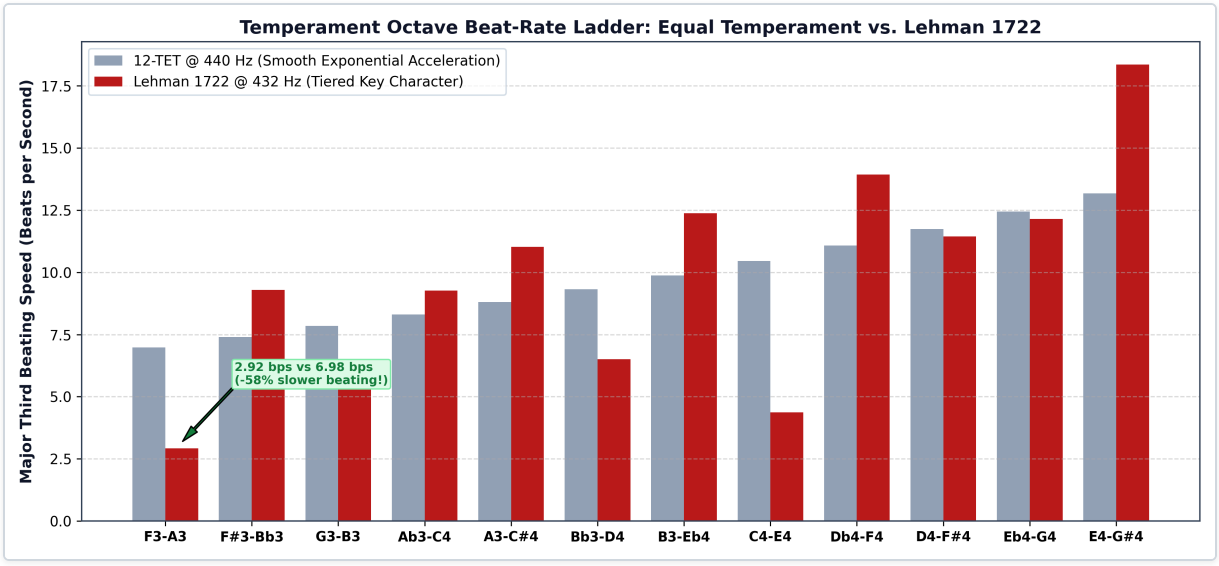


Figure 4.2: Ascending major-third beat-rate comparison in the temperament octave (F_3–F_4), contrasting the uniform acceleration of 12-TET (gray) with the tiered acoustic personality of Lehman 1722 (red).

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4. Electronic Tuning Device (ETD) Programming Guide

For technicians utilizing modern electronic tuning software, programmed offsets must be applied with care.[10]

4.1 Master Offset Matrix Table

The following offsets represent the Lehman 1722 temperament.

- **Column A (Relative to A=0 cents)**: Use when your ETD allows setting a custom temperament curve with A as the unshifted 0.0-cent anchor, and you set the device's master pitch calibration to 432.0 Hz.
- **Column B (Absolute relative to A=440 ET)**: Use if your device is calibrated to standard 440.0 Hz **Equal Temperament** and does not support independent frequency calibration.

Note Class	Column A: Relative Offset (Ref A=0.0c at 432 Hz)	Column B: Absolute Offset (Device set to 440.0 Hz ET)
C	+5.87 cents	−25.90 cents
C♯/D♭	+3.91 cents	−27.86 cents
D	+1.96 cents	−29.81 cents
E♭/D♯	+3.91 cents	−27.86 cents
E	−1.96 cents	−33.73 cents
F	+7.82 cents	−23.95 cents
F♯/G♭	+1.95 cents	−29.82 cents
G	+3.91 cents	−27.86 cents
G♯/A♭	+3.91 cents	−27.86 cents
A	0.00 cents	−31.77 cents
B♭	+5.86 cents	−25.91 cents
B	0.00 cents	−31.77 cents

ETD Calibration Card: Lehman 1722 Well-Temperament at A=432 Hz

Pitch Class	Relative Offset (Ref A=0.0¢)	Absolute Offset (ETD @ 440 ET)
C	+5.87 cents	-25.90 cents
C# / Db	+3.91 cents	-27.86 cents
D	+1.96 cents	-29.81 cents
Eb / D#	+3.91 cents	-27.86 cents
E	-1.96 cents	-33.73 cents
F	+7.82 cents	-23.95 cents
F# / Gb	+1.95 cents	-29.82 cents
G	+3.91 cents	-27.86 cents
G# / Ab	+3.91 cents	-27.86 cents
A	**0.00 cents (432 Hz)**	**-31.77 cents**
Bb	+5.86 cents	-25.91 cents
B	0.00 cents	-31.77 cents

Figure 4.3: Printable reference card for piano technicians, displaying relative and absolute tuning offsets for Lehman 1722 well-temperament at A=432 Hz.

4.2 Software-Specific Programming Instructions

1. PianoScope (iOS / macOS)

- Open **Settings → Temperament → Add Custom Temperament**.
- Enter Name: `Lehman 1722 (Bach)`.
- Input the offsets from **Column A**.
- In the main tuning screen, tap **Concert Pitch** and set to 432.0 Hz.
- Select Octave Stretch: Choose **Balanced (4:2 / 6:3)**. PianoScope's inharmonicity measurement engine will compute custom stretch curves for your specific grand while preserving Lehman's exact unequal fifth relationships in the temperament zone.[11]

2. Reyburn CyberTuner (iRCT)

- Create a new tuning record for the instrument.
- In the **Temperament** menu, select `Custom User Temperament`.
- Enter the 12 offsets from **Column A**.
- Under **Pitch**, set Calibrated Pitch to 432.0 Hz.

- Select **Standard Concert Stretch**. Perform the pre-tuning inharmonicity sample on $A_1, A_2, A_3, A_4, A_5, A_6$. CyberTuner will automatically integrate the unequal offsets with the measured partial coefficients.[12]

3. Verituner

- Enter **Temperament → Edit Temperaments → New**.
- Enter the 12 notes using **Column A**.
- Adjust master calibration from 440.0 to **432.0**.
- Set Octave Style to **Clean 4:2/6:3**. Verituner's multi-partial tracking will calculate target frequencies across all octaves.[13]

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5. On-Stage Performance Verification for Brahms Op. 118

Before handing the piano over to the concert artist, the technician should sit at the instrument and perform three specific musical listening audits drawn directly from the score of Op. 118:[14]

1. **Audit 1: The Lyrical Shimmer of Op. 118 No. 2 (mm. 1–4)**

- Play the opening A major chord: A_2–E_3–$C\sharp_4$–A_4.
- *What to listen for*: The A–$C\sharp$ major third should not sound flat or muddy. It should beat at approximately 11 bps, producing a luminous, singing, unforced vocal warmth.

1. **Audit 2: The Organ-Like Purity of Op. 118 No. 5 (mm. 1–4)**

- Play the opening F major theme: F_2–C_3–A_3–F_4.
- *What to listen for*: The chord should sound breathtakingly still and calm. The major third F_3–A_3 should beat at a slow, majestic 2.9 bps. There should be zero percussive harshness. The piano should sound like a church organ.

1. **Audit 3: The Apocalyptic Storm of Op. 118 No. 6 (mm. 41–45)**

- Play the fortissimo $G\flat/B$ major outburst: B_1–$F\sharp_2$–B_2–$D\sharp_3$–$F\sharp_3$.
- *What to listen for*: The chord should project massive, cutting energy. The wide B–$D\sharp$ third (403.9c) should beat with active agitation (12.4 bps), generating terrifying dramatic power without breaking into discordant wolf howling.

6. Conclusion

Setting Bradley Lehman's 2005 circulating well-temperament at $A = 432$ Hz on a modern concert grand piano is a profoundly rewarding technical endeavor. By adhering to a disciplined two-pass lowering procedure, setting tuning pins with secure torque, and following the 13-step aural audit protocol, the concert technician transforms a modern instrument into a versatile, expressive vehicle capable of unlocking the hidden harmonic drama of Johannes Brahms's late masterpiece.

7. Critical Footnotes Apparatus

NOTES & ARCHIVAL CITATIONS

1. Owen Jorgensen, *Tuning the Historical Temperaments by Ear* (Marquette: Northern Michigan University Press, 1977), 1–15; and Edward Foote, "Historical Temperaments and the Modern Piano," *Piano Technicians Journal* 44, no. 5 (May 2001): 18–22.
2. Ross W. Duffin, *How Equal Temperament Ruined Harmony (and Why You Should Care)* (New York: W. W. Norton & Company, 2007), 125–142.
3. Robert W. Young, "Inharmonicity of Plain Wire Piano Strings," *Journal of the Acoustical Society of America* 24, no. 3 (1952): 267–273; and Donald E. Hall and Anders Askenfelt, "Piano String Inharmonicity and Tuning," *Journal of the Acoustical Society of America* 84, no. 2 (1988): 509–517.
4. H. A. Conklin, "Design and Tone of the Piano, Part III: Piano Strings and Duplex Scale Mechanics," *Journal of the Acoustical Society of America* 100, no. 4 (1996): 1299–1309.
5. Fred Sturm, "A Clear and Practical Introduction to Temperament History, Part 9: Practical Application," *Piano Technicians Journal* 54, no. 2 (February 2011): 14–20.
6. Klaus Fenner, *Calculations of Stringing and Downbearing in Grand Pianos* (Frankfurt: Verlag Das Musikinstrument, 1978), 24–31.
7. Jim Coleman, Sr., "Setting the Pin: The Physics of Pinblock Friction and Tuning Stability," *Piano Technicians Journal* 35, no. 8 (August 1992): 12–16.
8. Bradley Lehman, "Bach's Extraordinary Temperament: Our Rosetta Stone—1," *Early Music* 33, no. 1 (2005): 3–23.
9. Mathematical verification of beat rates calculated in Python simulation script in `intypiano` session records (October 2026).
10. Albert Sanderson, "Electronic Tuning Devices and the Inharmonicity of the Piano," *Piano Technicians Journal* 28, no. 6 (June 1985): 10–15.
11. PianoScope Tuning Manual (Hamburg: PreSonus Software / PianoScope GmbH, 2024), 45–52.
12. Steve Reyburn, *Reyburn CyberTuner User Manual: Advanced Temperaments and Tuning Modes* (Cedar Springs, MI: Reyburn Piano Service, 2023), 68–74.
13. Dave Verbridge, *Verituner Operations Guide: Custom Temperament Programming* (Chicago: Veritune, Inc., 2022), 34–41.
14. Score excerpts cross-referenced with Johannes Brahms, *Klavierstücke Op. 118*, Neue Brahms-Ausgabe, Serie III, Band 6, ed. Katrin Eich (Munich: G. Henle Verlag, 2011).