The Stanwood New Action Protocol (SNAP), Part 1

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What follows is a simple workbench method for determining the hammer weight level that produces a medium inertial playing quality in the grand piano. It is a write-up of the workbench demonstration class presented via Zoom for the EuroPiano Congress on September 4, 2022, in Warsaw, Poland, and published in issue #1/23 of the *EuroPiano Journal*.

Our industry holds onto the common belief that high, medium, or low downweights in pianos are associated with heavy, medium, or light playing qualities. Experience teaches that the association is unreliable. It is not unusual to find well-voiced and regulated instruments with normal downweights that feel too heavy or too light when played. Rigorous scientific analyses of grand action dynamics confirm that the underlying and overriding factor is the inertia of the leveraged hammer weights and, to a minor but significant degree, the inertia of the keysticks with their installed key weights. Empirical studies of grand piano actions from the modern era support the same conclusion and verify that the normal range of measured leverage or weight ratios, hammer weight levels, and key weight usage vary widely, regardless of the period of manufacture or the particular make and model of piano.

For every piano action there is a range of hammer weights that will produce a range of inertial playing qualities. The particular action ratio dictates which hammer weight level will produce a desired inertia. Pianos with a hammer weight that is too high for the action ratio will have high hammer inertia and will require a large amount of key weighting mass to balance the action to a normal downweight. This is a recipe for heavy actions and in the worst case produces pianos that "play like a truck." Inversely, when a low action ratio is matched with a low hammer weight, the piano will be more likely to have a "flyaway" quality.

The crucial point in assembling a grand piano action comes when selecting and preparing the hammers for hanging. Finding and installing the right match of hammer weight for the action ratio is the key to producing a desired inertial playing quality in the finished action. Missing in our industry is a simple and practical workbench method that addresses this essential quality control issue. The big question is: *What hammer weight level will produce the desired inertial playing quality?*

A practical method for answering this question comes from simple common sense. It stands to reason that when a grand piano action has a medium number of weights in the keys with a medium downweight and medium friction, the action is likely to have a medium feeling of weight when played. It will have a medium inertia. Determining the hammer weight that fits these parameters is simply a matter of setting up test notes with a medium number of key weights, then finding the hammer weight that produces a medium downweight.

Codifying the meaning of "medium" for this simple approach requires precise definitions of weights. The effect of key weights may be quantified using the front weight (FW) method by tipping the front end of the keystick onto a digital gram scale. Front weight studies of modern pianos put a medium value for C4 at around 27 grams. Downweight (DW) has a friction component that may be factored out by measuring both downweight and upweight (UW) then applying the formula for balance weight: BW = (DW+UW)/2. It is now widely accepted that a medium balance weight is 38g. Friction weight (F), the amount of weight added to balance weight to make the key move for downweight or subtracted from balance weight to make the upweight, may be found as F = (DW-UW)/2. A medium friction weight in the center of the keyboard is 12g, which adds up to make a medium downweight of 38g+12g = 50g and a medium upweight of 38g-12g = 26g. This pairing of a medium front weight of 27g at C4 with a medium balance weight of 38g is associated with pianos that have a medium inertial playing quality. These two values serve as benchmarks that give a frame of reference for associating other pairings of front weight and balance weight for high, medium, or low inertial playing qualities.

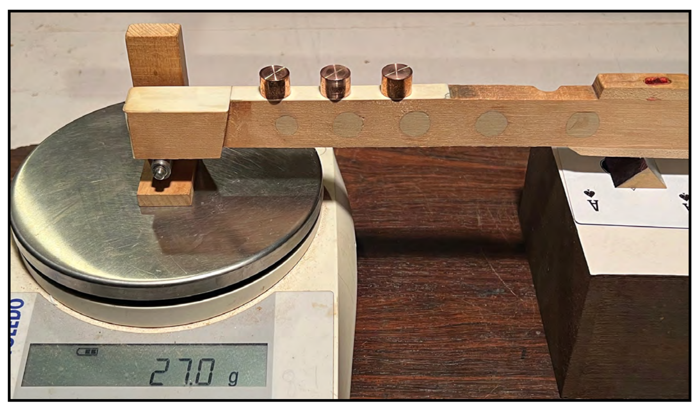

Photo 1: Front weight of 27g mocked up with 13.2g of soft copper key weights using a homemade jig with a wedge and playing cards for leveling.

To find the hammer weight that will produce a medium inertia, set up a test note at C4 with a medium front weight of 27g, then find the hammer weight that produces a medium balance weight of 38g. Preparation for the test requires fully regulated parts to be used, with particular attention paid to easing and dry lubricating key bushings. The C4 front weight is temporarily set to 27g with layout weights taped to the top of the key (Photo 1). A special weight-testing hammer may be prepared with a plastic mounting screw inserted into the underside of the tail (Photo 2). There are six holes drilled into the test hammer close to the center line. The holes receive calibrated weights for adjusting the test hammer weight to one of seven standard hammer weight reference scales #4 – #10 for C4, which span a range of 2.8g. The test weights are made of six equal lengths of soft lead-free soldering wire that have a combined weight of 2.8g or 0.47g each. With all the holes empty, the test hammer is calibrated to a scale #4 weight. Adding a weight brings it up to scale #5 and so on up to scale #10. Reference tables are available at stanwoodpiano.com/hammerweight. Mount the empty test hammer in the correct position out on the shank. Measure downweight and upweight then calculate (DW+UW)/2 = BW. Keep inserting weights into the hammer to find the closest weight that yields a 38-gram balance weight (Photo 3). The same test may be applied to additional adjacent natural keys to confirm an average result. The indicated scale number from the test hammer weight reference table serves as a guide for selecting the new hammer set of an appropriate weight level and also as hammer weight specifications for each note. Custom made hammer weight scales may also be produced using graphing spline tools so long as the level around the middle of the scale is close to the test result for C4.

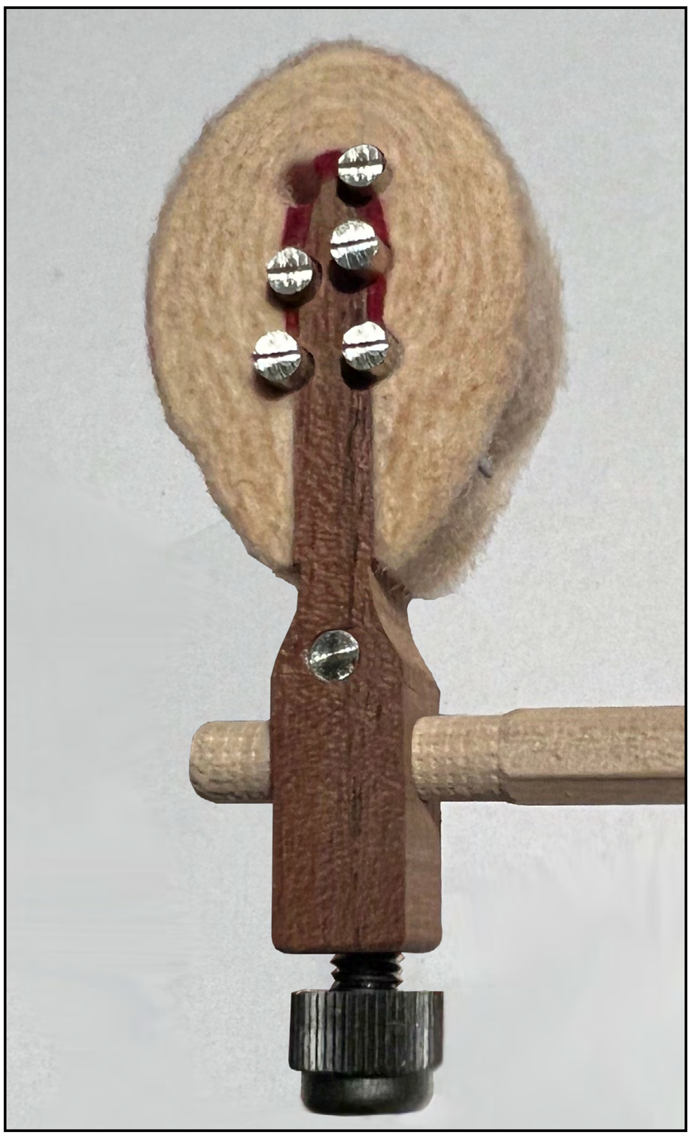

Photo 2: Test hammer with 5 lead-free soft metal inserts for a C4 hammer weight scale #9.

Photo 3: Checking for a 38g test balance weight.

An alternative method is used when a lighter hammer is indicated for the desired inertia quality, but a heavier hammer is required tonally, as say for concert hall pianos. The solution then is to reduce the action ratio by such means as moving the capstan line or balance point of the keys, or increasing the radius from the hammer center pin to the center of the knuckle. In these cases, the desired hammer weight (HW) is used on the test notes in combination with the specified test FW. The ratio is reduced as needed so that the key tests out to the specified balance weight. (Note that when ratio is reduced, dip must be deeper and/or blow must be shorter, and this is a limiting factor.)

Order hammers that are a little heavier than the indicated scale number, then bring the weight of each hammer down to specification by carefully reducing width and/or controlling the tapering. Small lengths of soft metal wire calibration weights may also be carefully swaged into the hammer moulding for increasing weight if need be. The test hammer in Photo 2 has an example of a swaged calibration weight just above the shank.

With the hammer weights scaled to specification and the keys balanced to the medium balance weight of 38g, the keys will have a medium number of key weights in them, and the inertial playing quality will be medium. Actions with lighter inertial playing qualities are also very popular. The solution in these cases is to use lower test values for front weight and/or balance weight for a lower inertia. Higher inertia will result from the use of higher test values for front weight and/or balance weight.

The rationale behind this simple approach may be explained and supported with Touch Weight Metrology: For a range of hammer weight values, there is a range of strike weight ratio (R) values that will produce the specific combination where R equals a FW of 27g plus a BW of 38g. Table 1 shows the relationships according to the equation of balance (which uses the measure of strike weight, not hammer weight). The static values of FW and BW are equal to the upward static force at the front of the key from the leveraged strike weight (SW) along with the upward static force at the front of the key from the leveraged weight of the wippen on the capstan, called the wippen balance weight (WBW), which has an assigned medium value of 9. The strike weight ratio (R), solutions in the table are calculated as: R = (FW+BW–WBW)/SW.

	FW + BW =	SW x R + WBW	
Lower PDO SW#5	27 + 38 =	8.6 x 6.5 + 9 = 65	less dip/more blow
SW#7	27 + 38 =	9.6 x 5.8 + 9 = 65	
Higher PDO SW#9	27 + 38 =	10.5 x 5.3 + 9 = 65	more dip/less blow

Table 1: C4 solutions for balanced key with medium inertial playing quality.

In Table 1, the strike weights span the two-gram "medium" range from SW #5 up to SW #9, which is in the minimal Concert Hall Hammer Weight category. PDO stands for Potential Decibel Output and is an important consideration tonally in choice of hammers. The calculated strike weight ratio values turn out to describe what experience teaches is a conservative normal range from 5.3 – 6.5.

Note that both sides of the equation when solved are equal to 65. For C4, this value, called the top action balance weight, is associated with a medium hammer inertia quality. When a higher or lower balance weight is combined with lower or higher front weight, the association with a medium hammer inertia quality is similar as long as the total is 65g. A total of 70g is associated with a heavy inertia quality and 60g is associated with a light inertial quality.

For actions with wippen support springs, always determine balance weight with the spring disengaged. For instance, in the conservative classic set-up with springs supporting just the wippen weight, the spring will reduce the balance weight by approximately nine grams. The C4 test balance weight in this case will be 38g + 9g = 47g. The test front weight for a medium hammer inertia will be 27g – 9g = 18g. In this case BW + FW is 47g + 18g = 65g. With the support spring hooked up and adjusted, the 47g balance weight is brought down 9g to a medium 38g balance weight or even lower if desired. This set up will have a noticeably lower inertia quality because the reduced front weight level will produce lower keystick inertias.

I, and the many associates here and abroad who use my Precision Touch Design methods, have been matching scaled strike weights with ratio levels for desired inertial playing qualities for many decades. Early on, it became empirically clear which combinations are likely to produce a medium inertia with a 38g balance weight. The front weights from those solutions are similar to those recommended with this new protocol. There are also a number of available approaches that have been engineered by others that utilize the most rigorous scientific analyses using complex computational methods with distance, weight, and moment arm calculus. When those hammer weight solutions for a 38g balance weight with medium inertia are applied, a similar medium front weight level is produced. Therefore, this simple approach is in effect a reverse engineering of computational methods that end up with similar results. This supports the fundamental precept:

Specific combinations of front weight and balance weight are associated with particular inertial playing qualities.

Many benefits are gained from scaling hammer weights to achieve a desired inertial playing quality. They include:

1. Hammer weight is the major factor influencing the inertial response in each key. It stands to reason that scaling hammer weights improves the smoothness of response from key to key at all dynamic levels. Pianists find it much easier to gauge and control the stroke and tone on pianos with scaled hammer weights.
2. Hammer weight scaling improves voicing smoothness. Studies reveal that unscaled hammer weights in finished pianos commonly have significant random variations. Lighter hammers need softer felt for ideal voicing. Heavier hammers need denser felt for ideal voicing. Therefore, it is impossible to produce the smoothest voicing when adjacent hammers have significant differences in weight. Well-voiced, weight-scaled hammers have a cleaner sound that both pianists and listeners love and appreciate.
3. Scaling hammer weights for normal levels of inertia is the antidote for the longstanding epidemic of actions made with hammers that are way too heavy for their ratio. Fewer extra high inertia actions in the world mean fewer kinesthetically-related injuries to pianists worldwide.
4. Front weights mirror hammer weights. Smoother hammer weights mean smoother front weights and smoother keystick inertia. Pianists notice and appreciate the added feeling of consistent connection and feedback they feel from the keys under their fingers.
5. Actions with smooth front weights require little or no alteration to the key weighting when hammers are replaced to their specified weights, thereby maintaining the integrity of balance for the life of the piano. This honors and respects the craft of keymaking.

Historically, the piano-making industry has resisted scaling hammer weights in the production of pianos, even those of the highest quality. (To my knowledge there is no piano manufacturer in the world today using published hammer weight specifications.) The challenge is being met with great success in the hands of small production high-end piano makers and technicians who specialize in the upgrading, customization, and restoration of instruments in the aftermarket. Smoothing out hammer weights for a desired inertial quality simply produces a more predictable and manageable response from key to key. This helps and supports the pianist fundamentally as to the technique required to play and perform on the piano. If the response of the notes is inconsistent, pianists must learn how to deal with it. It takes specific techniques with much skill gained from training and practice. When pianists play on pianos made with scaled hammer weights for a normal inertia, the degree of difficulty for the technique needed to play is lower. This promotes a safer and more relaxed musical playing experience for all and elevates the art of the piano. Experience proves it is well worth the effort for all the rewards. Scaling hammer weights to control inertia is simply good for the business and the culture of pianos and piano making. ☐

Further Reading:

Stanwood, D. "The New Touch Weight Metrology," *Piano Technicians Journal*, June 1996. Also available at stanwood-piano.com/PTJournalJune1996.

Stanwood, D. "Standard Protocols of the New Touch Weight Metrology," *Piano Technicians Journal*, February 2000. Also available at stanwoodpiano.com/PTJournalFebruary2000.

Stanwood, D. "Looking at Grand Pianos Through the Eyes of The New Touchweight Metrology," *Piano Technicians Journal*, March 2000. Also available at stanwoodpiano.com/PTJournal-March2000.

Stanwood, D. "Hammer Weight Reference Tables," stanwood-piano.com/hammerweight.

***David Stanwood, RPT**, graduated from the Advanced Piano Technology course at North Bennet Street School in 1979. In the 1990s, he pioneered the field of Touch Weight Metrology and created his trademarked Precision Touch Design method for predictably improving the touch and tone of pianos. David received the North Bennet Street School Distinguished Alumni award in 2007 and was inducted into the PTG Hall of Fame in 2019.*