Supplementary notes

for

Grand Action Optimization on the Cheap...

...Turn your "Mack Truck" keyboard into a "Ferrari"

A Video Presentation by Glen Cuthbertson

for

CAPT/ACAP X-Country Online Workshop

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CONTENTS:

All diagrams and formulas are from http://stanwoodpiano.com

The “Precision Touch Design™” on David Stanwood’s website opens a window to his documents with full details, charts, and graphs as featured in numbers PTJ magazines over the last few decades.

I highly recommend reading and referring to these articles, as they contain far more information that can be covered with this supplementary document. I only wish to introduce the basics for clarity of understanding the concepts.

David Stanwood Key Balancing Formula

$$FW + BW = (KR \times RW) + (SWR \times SW)$$

FW = Front Weight of key (without action parts) from 1/2” from the front to the balance pin

BW = Balance Weight [determined by the formula (Down Weight + Up Weight)/2]

KR = Key Ratio. Capstan distance to balance pin divided by key front distance to balance pin.

RW = Repetition Weight of the repetition as determined at the heel/capstan contact point.

SWR = Strike Weight Ratio, which is the ratio the key feels at the knuckle/jack contact point.

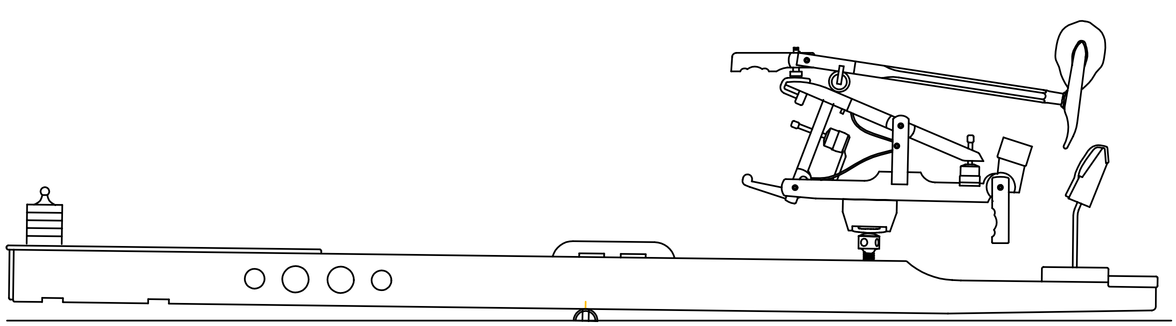
SW = Strike Weight of the hammer/shank as determined at the hammer tail.

David Stanwood Protocols for Weighing Action Parts

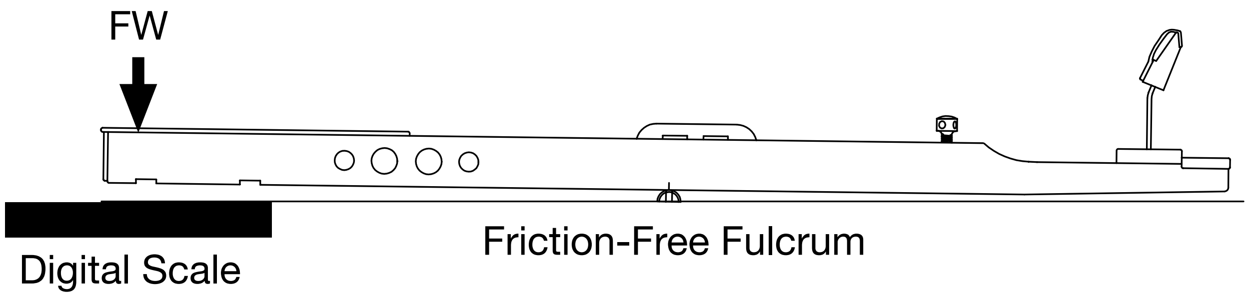
This typical grand action diagram shows the key, the repetition, and the hammer/shank.

Each component is weighed on a digital scale to 0.1 gram tolerances.

A spreadsheet with the appropriate columns is required, along with the various formulas to compute final results. Basic spreadsheet skills are needed to enter the formulas, and plot graphs from the results, which is beyond the scope of this presentation.



Protocol for weighing the Front Weight (FW)

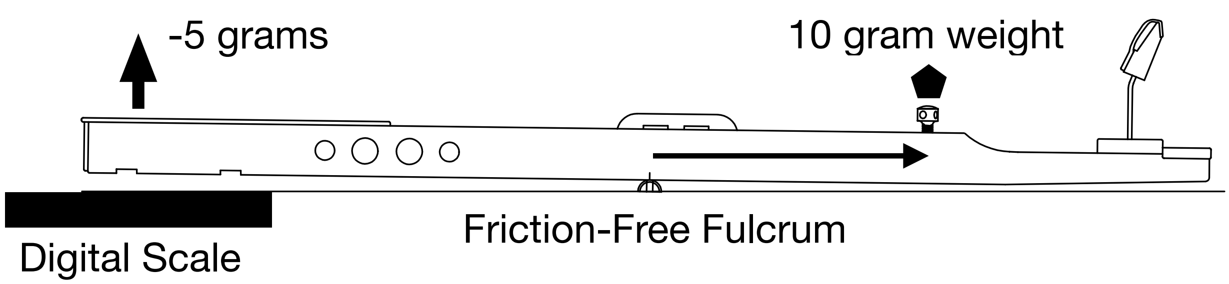


The FW is the weight from the front of the key to the balance pin, or the Friction-Free Fulcrum on the weighing jig. Mounting the key on a jig with ball bearings from old router bits provides very low friction coefficients. This allows the scale to repeatedly weigh to the nearest 0.1 gram.

Tare the scale to zero before weighing each key. This weight is without the action parts on the back. Adjust the final results by adding or subtracting lead from the key.

Enter results in the spreadsheet to the nearest 0.1 gram.

Protocol for weighing the Key Ratio (KR)



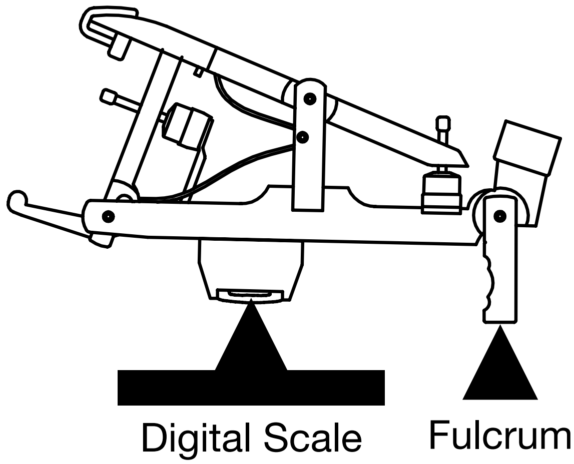
The KR is the ratio of the key front to the balance pin (fulcrum) divided by the capstan to the balance pin (as indicated by the arrow).

This is usually a value of 0.5, and is best determined by weighing on a digital scale.

Place the key on the scale, and tare the scale to zero. Then place the 10 gram weight on the capstan which changes the reading to a number very close to -5 grams. This then becomes the ratio, as 5 grams/10 grams = 0.5 which is now a constant value across the keyboard. Sample a few white keys and black keys to determine an average number.

The 10 gram weight makes this calculation very simple.

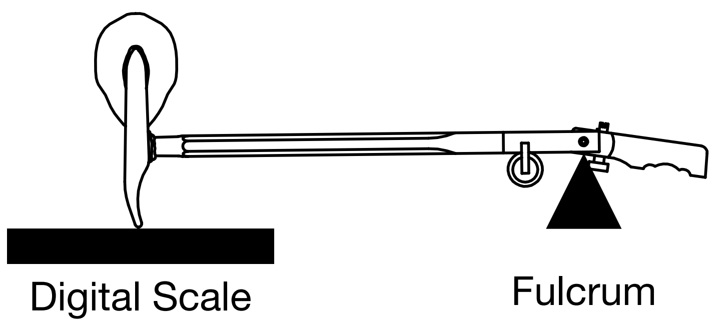
Protocol for weighing the Repetition Weight (RW)



The RW is the weight at the heel/capstan contact point as read on the scale with the flange pin centred on the fulcrum or any other Friction-Free reference point.

Tare the digital scale to zero before weighing the repetition. As these repetitions are practically identical, sample a few to get the average reading to enter into the appropriate column in the spreadsheet. This is in the 19 gram range for most repetitions.

Protocol for weighing the Strike Weight (SR)



The SR is the combined hammer & shank weight as read on the digital scale with the flange pin centred on the fulcrum or any other Friction-Free reference point.

Usually the flange is rotated 90 degrees upwards of the shank and the bottom of the flange is on the point of the fulcrum, not shown in this diagram.

Tare the digital scale to zero before weighing each hammer and enter the reading into the appropriate column in the spreadsheet. Adjust the final weight either by sanding material off, or adding 1/8” solder pieces into holes drilled into the hammer molding.

Protocols for Using the Formulas

$$FW + BW = (KR \times RW) + (SWR \times SW)$$

The formula is algebraically rearranged to solve for the Front Weight as follows:

$$FW = (KR \times RW) + (SWR \times SW) - BW$$

This formula is inserted into the spreadsheet column that calculates the final Front Weight (FW).

Some of these variables in the formula are constant values, namely:

(KR) Key Ratio,
(RW) Repetition Weight,
(SWR) Strike Weight Ratio
(BW) Balance Weight

Of these variables, only the KR and RW are weighed and entered into the designated columns.

The Strike Weight Ratio is a constant value across the keyboard, but is not easily determined.

Rearranging the formula to solve for the SWR, we get:

$$SWR = [FW + BW - (KR \times RW)] / SW$$

Because Friction Weights and Strike Weights vary quite a bit across the keyboard, the resultant Front Weights as set in the factory with traditional methods do not transition smoothly across the keyboard.

Therefore, the SWR value cannot be constant across a typical action, no matter what piano brand you are looking at. Some will be better than others, but none are “perfect”.

If using this formula to find the ideal SWR, find the “best key” near the middle of the keyboard with the desired DW and the strongest UW. Make this key the “standard” that the rest of the keyboard should match when the action is done.

To solve this equation, all the variables must be determined beforehand and entered into the formula. It doesn’t hurt to sample a few “ideal” keys for and average number. Once the SWR is calculated, use this as a constant value across the keyboard.

Reasonable SWR values is around 5.75 to 6 which is often the action ratio determined by other methods.

The Balance Weight is found with this simple formula:

$$(DW + UW) / 2 = BW \text{ (Balance Weight)}$$

DW = Down Weight that a key slowly lowers down
UW = Up Weight that a key can slowly raises up

Example:

(50 gram DW + 20 gram UW) / 2 = 35 gram BW

This would be a wonderful piano to play, very responsive and easily controlled at all dynamics. It would not strain the hands and would feel very fluid under the fingers.

Example:

(70 gram DW + 40 gram UW) / 2 = 55 gram BW

This would be an awful piano to play, far too heavy and tiring for a pianist, risking potential hand injuries in aggressive playing.

The best BW range is between 35 and 38. Excessive BW reveals serious touch weight issues.

The Friction Weight is found with this simple formula:

$$(DW - UW) / 2 = FrW \text{ (Friction Weight)}$$

Using the same numbers from both of these examples, we find that the spread between them is the same, giving the same friction numbers.

(50 gram DW - 20 gram UW) / 2 = 15 grams friction (key with action parts included)

(70 gram DW - 40 gram UW) / 2 = 15 grams friction

This shows that two different actions can have the same friction coefficient, but feel entirely different to play.

Reducing total key friction as much as possible and careful action regulation does not solve touch weight issues of very heavy actions. These examples show why many actions need careful balancing to a desired set of parameters to obtain the best performance.

Replacement hammer sets are often heavier than the original sets, creating excess DW. Every extra gram of SW increases the DW by at least 5 grams.

This problem is compounded with the fact that original key leads installed in the traditional manner DID NOT compensate for varying frictions and jagged Strike Weights across the keyboard. Strike Weights from replacement hammers add new variables that skewer results even further.

The wider the spread between the DW and UW, the more friction an action has.

A 60 gram DW and 10 gram UW has a 50 gram spread, resulting in 25 grams of total friction. That is way too much, and merely adding more key leads to overcome higher friction to meet the “desired” DW of 50 grams only adds more total key inertia.

The “static” touch weight may be “on the money”, but the kinetic energy required to play such an action is excessive, making it tiring to play with very poor repetition.

Keep the total key friction as low as possible, in the 12-15 gram range. Lower friction than this is impossible to achieve. A 50 gram DW cannot have a 40 gram UW, with a total key friction of only 5 grams. Not gonna happen!!!

Very low DW has very low UW, leaving no room for normal friction levels in modern actions. Sooner or later the FrW or the BW of the key is reached, with a neutral rotational bias. Keys will “float” up and down or “bounce”, and is rendered unplayable.

DW in the 50 gram range with UW at least 20 grams produces a BW between 35 & 38 for the best results.

The following should be considered carefully if repetition helper springs are used. Consider the main formula again:

$$FW + BW = (KR \times RW) + (SWR \times SW)$$

The equal sign (=) represents the balance rail pin on the key. Changing only one variable without changing the other variables will “upset the apple cart” one way or another.

The BW (Balance Weight) is NOT a tangible part of the action, but a MATHEMATICAL value to “balance” the equation, hence the name. If you were to place this as an actual weight on the end of a key, the key should have a neutral rotational bias.

Reducing the FW but leaving the rest of the variables intact makes the left side of the formula lighter, which increases the DW on the left side of the formula.

Once the fixed variables are set (BW, KR, RW, SWR) the only changes made is to the SW and FW. The SW takes precedent, following the smooth SW curve, and should be changed as little as possible. The FW is then calculated and the key weight adjusted accordingly.

A heavier DW allows Repetition helper springs to reduce DW. The Repetition Weight multiplied with the Key Ratio is usually around 9 grams. Helper springs can reduce this weight to zero or slightly negative numbers, further reducing FW in the key to meet desired Down Weights.

For example, if we don’t use a repetition helper spring, then:

$$FW = (0.5 \times 19 \text{ gm}) + (5.75 \times 10 \text{ gm}) - 35 \text{ gm which makes } FW = 32 \text{ gm}$$

If we use a repetition helper spring to make the repetition “float” with 0 grams, then:

$$FW = (0.5 \times 0.0) + (5.75 \times 10 \text{ gm}) - 35 \text{ which makes } FW = 22.5 \text{ gm}$$

Both of these calculations, (one without the repetition helper spring and the other with the repetition helper spring) would produce a "balanced" key with the same desired DW, but the second option noticeably reduces the key inertia.

Less key mass means less inertia, both in playing, and in key repetition, as hammers have less mass to push to return the key to rest. The hammer "feels" the key lead inertia more than a pianist, so key repetition is improved with lighter keys and helper springs.

A word of common sense and caution: Don't make repetition helper springs the main source of reducing DW in a key. The repetition helper spring should not be responsible for the entire task. The spring tension would eventually become too great for the the hammer shank leverage to overcome, never mind the rest of the key.

In other words, the helper spring tension should not be aggressive, but just enough to take the weight of the repetition out of the formula, or perhaps even give a gentle "negative" value where the repetition has a mild upward bias that the hammer shank still easily overcomes.

There is no danger of "over doing" mass reduction. Hammer strike weights still need to be within normal ranges to impart enough energy into the strings. Matching soundboard impedances with the right hammer weight still requires careful consideration to choose the right set, which is beyond the scope of this presentation, and my experience.

Hammers heavier than necessary for good tone only make actions heavier and less responsive.

Keep the hammers light as possible without sacrificing tonal output to help control touch weight issues.

Let’s consider a typical spreadsheet so that we see where everything goes.

“Sampledorfer” Grand Action Demo

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Key	DW	UW	BW	FrW	*	FW	FW	FW	FW	KR	RW	SW	SW	SW
C1	50	20	35	15	-	**	33.5	32.3	1.2	0.5	19.6	10.5	10	0.5

Here is a series of columns from left to right (with four left out for size restraint issues marked with the *)

Column 1 is the key
Column 2 is the original Down Weight
Column 3 is the original Up Weight
Column 4 is the Balance Weight - calculated as: (DW + UW) / 2
Column 5 is the Friction Weight - calculated as: (DW - UW) / 2
Column 6 would be four more similar columns with the DW, UW, BW, FrW of the final results
Column 7 is the Front Weight Ceiling (from David Stanwood’s charts, marked with **)
Column 8 is the original Front Weight
Column 9 is the final Front Weight - calculated as: (0.5 x 19.6) + (10 x 5.75) - 35
Column 10 is the weight difference between the original and final Front Weights
Column 11 is the Key Ratio (a constant value)
Column 12 is the Repetition Weight (a constant value)
Column 13 is the original Strike Weight
Column 14 is the final Strike Weight as plotted with a smooth curve on a graph
Column 15 is the weight difference between the original and final Strike Weights

If you print this sheet out, you can’t see the formulas when double clicking the selected cells, but if you view this on your device, you should be able to view the formulas with the various values and the corresponding cells.

The formulas are in columns 4, 5, 9, 10, 14 and15. Double clicking on them will reveal the formulas.

This is only a “sample” spreadsheet, and can be modified as needed for your own requirements. Plotting various columns will graph the results for before and after evaluation of Down Weights, Friction Weights, Strike Weights, and Front Weights.