COMPONENT TOUCHWEIGHT BALANCING
BLUEPRINT FOR THE FUTURE

A BRIEF BY

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Component Touch Weight Balancing - Blueprint for the Future

By David C. Stanwood

The conclusions outlined in "Through the Eyes of the New Touchweight Metrology", PTG Journal March 2000, support the vision of an industry wide move towards integration of component touch weight balancing regimens with traditional techniques of piano manufacturing and restoration. This move promises significant benefits to pianists, piano makers, dealers, and piano technicians.

Traditional touch weight balancing relies on down weight and pound felt. This is a crude way to set key leads in the key. Accumulated manufacturing tolerance errors in the hammer weights, shank strike weights, friction weights and overall action ratios add up to produce randomly variable and imprecise results[1] - even in the hands of the best trained and most highly competent factory worker or rebuilding shop technician. As piano technicians, we are frequently required to replace hammers. It is a proven fact that even the best made hammers vary considerably in weight. Yet, to the best of my knowledge, no piano maker in the world includes replacement hammer weight specifications with their instruments. Now it is possible to make pianos more easily and to higher standards with the new found ability to assign precise material specifications and tolerances to each action component. A simple algebraic expression makes it all possible:

The Equation of Balance[2]

Short form: $BW + FW = (KR \times WW) + (R \times SW)$

Long form: $((D + U)/2) + FW = (KR \times WW) + (R \times (SS + HW))$

(A note to engineers... in this equation of moments, the radius is left out of the left side of the expression because its value is 1.)

Every component of the main action is represented here. Balance Weight is the connection with tradition as it incorporates down weight and up weight. It also factors out friction, which may be dealt with as a separate component, and is expressed as Friction Weight:

$$F = (D - U)/2$$

The equation balanced key has specification and tolerance for each component in the equation as follows:

Balance Weight (BW) is specified as desired and it's final value is a function of how close all the other components are made to their specification.

Front Weight (FW) is calculated per US Patent 5585582 as "FW = ((SW x R) +(WW x KR))-BW", and is made by setting key leads using digital scale balancing techniques.

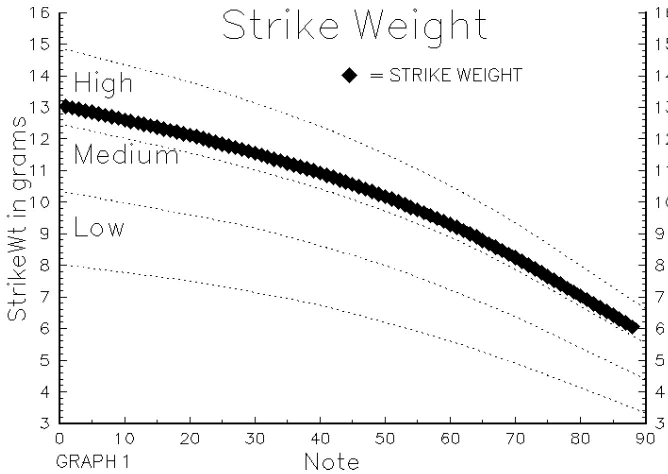
Wippen Weight (WW) is specified as the average existing wippen weights found in the parts used.

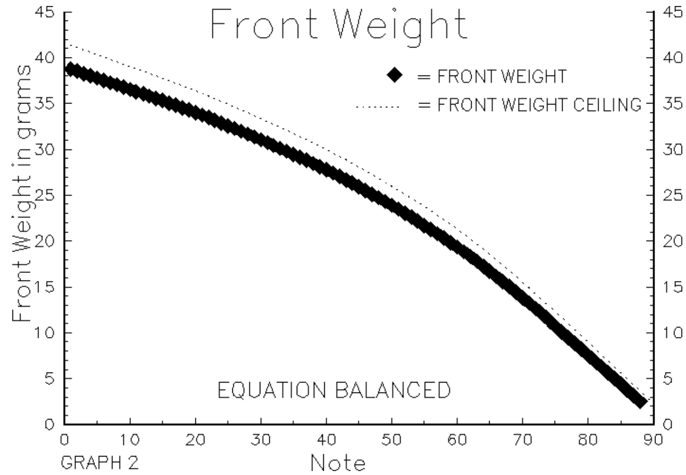
Key Weight Ratio (KR) is specified as the average existing key weight ratios found in the parts used.

Strike Weight (SW) is specified as desired and is made by adding or subtracting hammer weight.

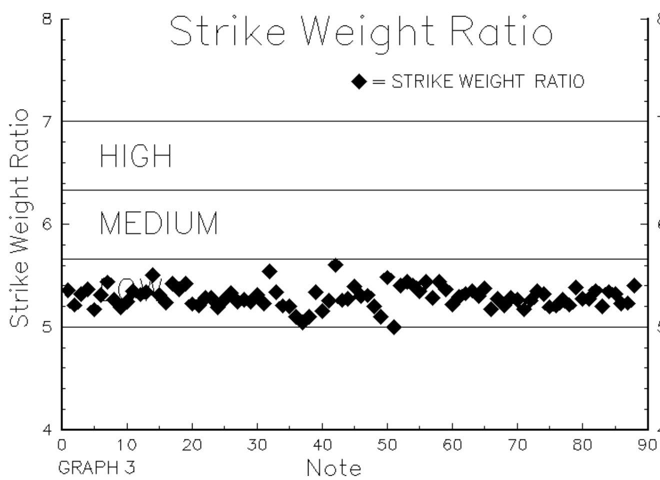
Strike Weight Ratio (R) is specified as the average existing strike weight ratios produced.

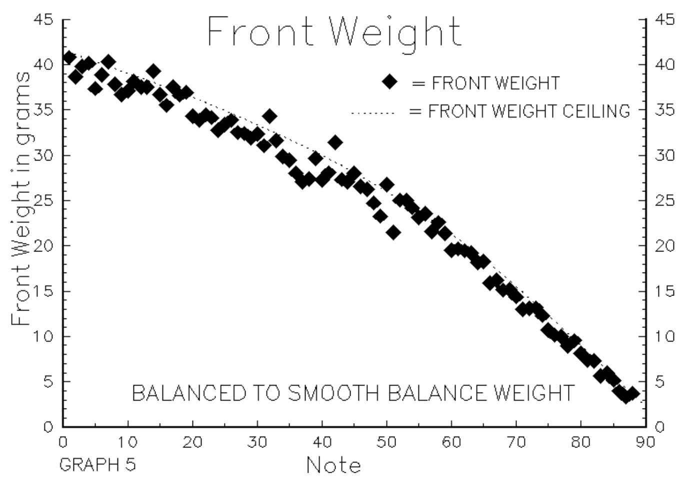
In Graph 1 we see a typical set of smooth strike weights as produced by equation balancing. In Graph 2 we see the equation designed smooth front weights.





In traditionally balanced actions where strike weight is smooth and keys leads are set using smooth balance weight[3], or smooth down weight and smooth friction[4], the strike weight ratio variations express themselves as variations in the front weights. Graph 5 shows the front weights that would result from an action with the strike weights of Graph 1 and the strike weight ratios of Graph 3. Note that the front weight variations mirror the pattern of strike weight ratio variations.





This has ramifications for the viability of key lead placement when parts are changed. One of the main factors contributing to the natural variation of strike weight ratios is the variation of knuckles. Since the knuckle is mounted so close to the shank center pin, small variations in knuckle placement or quality contribute significantly to producing variations in strike weight ratio. When parts wear or are replaced down the road, the meaning of the front weight variations are diminished or lost as they only made sense relative to the strike weight ratio variations that existed at the specific time when the key leads were set in the keys. (The problem is made much worse when strike weights are not made smooth or friction not accounted for, as is mostly the case in the old world.)

With the equation balanced key, the variations in strike weight ratio will come and go but balance weights will always be very close to an average smooth set of values (as in Graph 7). The important thing is that the pianist feels and appreciates the smoothness of front weights. They will prefer the front weights of Graph 2 resulting from equation balancing over those of Graph 5. Once front weights are set, as in Graph 2, they never need to be changed, even when parts are replace down the line. With equation balanced front weights the age old expression "don't touch the key leads. They were done right at the factory" finally rings true.

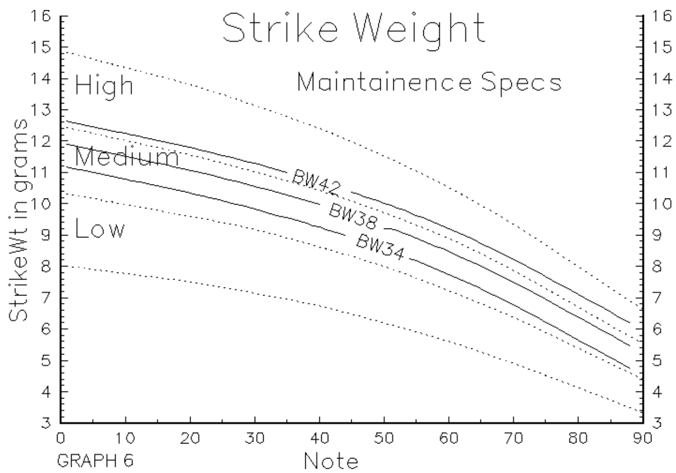
In the equation balanced key, with front weight set permanently, higher or lower strike weights mean higher or lower touch weight. In the world of equation balanced actions, technicians manipulate touchweight by adjusting hammer weights to make a desired strike weight level. Piano makers provide the technician with strike weight specification guidelines for light, medium, or heavy action. Piano makers would logically base the design of their strike weights on the range over which strike weights are expected to vary based on the range of weight variation produced in the hammer making process. Medium strike weights would represent the middle of the range. This means that piano manufacturers could go on pushing pianos out their doors without actually making strike weight to a specification. The difference is that if refinement of the touch is desired, there are specifications to guide the technician in the field.

Table I shows how a set of strike weight specifications might look.

Table I - Strike Weight Specifications in grams

Note	Light (BW34)	Medium (BW38)	Heavy (BW42)
1	11.2	11.9	12.6
2	11.1	11.9	12.6
3	11.1	11.8	12.5
4	11.0	11.8	12.5
5	11.0	11.7	12.5
6	11.0	11.7	12.4
7	10.9	11.6	12.4
8	10.9	11.6	12.3
9	10.8	11.6	12.3
.	.	.	.
.	.	.	.
.	.	.	.
80	5.7	6.4	7.1
81	5.5	6.3	7.0
82	5.4	6.2	6.9
83	5.3	6.0	6.8
84	5.2	5.9	6.7
85	5.1	5.8	6.5
86	5.0	5.7	6.4
87	4.9	5.6	6.3
88	4.8	5.5	6.2

Graph 6 shows the three levels of light, medium, and heavy strike weights of Table I, along with the expected balance weights. The range between light and heavy is close to the range of variation in hammer weights that would typically be expected from a hammer maker making hammers to specifications from the piano manufacturer.



In the old world of key balancing the piano technician would add key lead to lower the touchweight, but this actually makes the action heavy in the dynamic mode (while playing) by virtue of the increased mass and the associated inertia.

In the new world of equation balanced components, the technician takes weight off the hammer to make the action lighter. This reduces down weight and up weight proportionately. To make the touch heavier the technician adds weight to the hammer, thereby making the action heavier and increasing down weight and up weight. The addition of hammer leads to the hammer molding has been found to be an effective and reliable method for increasing hammer weight as shown in figure 1. A hole is drilled in the molding and a piece of 0.109" diameter pure lead wire is inserted and pressed between anvils to expand and hold it tightly in the hole. This method has been practiced by many technicians over many years with no problems such as split moldings or leads coming loose and making noise. It is an effective an valid method for increasing hammer weight with no down side.

The question is raised that that adopting component touch weight balancing techniques in manufacturing will increase production time. The reality is that the time taken is at least the same or less, with the added benefit that low skilled workers can install key leads using a digital scale and a list of front weight specifications. Using digital input specifications opens the door to machine or CNC controlled balancing as well. US patent #5,796,024 describes the definitive production method for balancing keys in the piano factory using standardized key weighting patterns. With this method holes are drilled to a pre-determined pattern. The pattern is designed so that key leads of a specified weight placed at a specified position will have a specified smooth effect on the front weight. The pattern is designed to be just under the final specified smooth front weight. For instance if the front weight of the keys without key weights in them averages 4.0 grams, then the pattern is designed to the final front weight specification minus 4.0 grams. The holes are drilled for the pattern. Then, before installing the pattern key leads, each key is placed on the scale and a small amount of lead is added to make each front weight 4.0. Then the key leads are added in the pattern holes, bringing the front up to its final specification. With this method the key balancer has one front weight specification instead of 88.

So in the new world of component key balancing the unskilled worker may achieve results that far exceed those of the mostly highly skilled worker in the old world. Fine tuning hammer weight may be left to the outside technician. The job of the factory then is to maintain quality control of hammer weight levels and action set up to maintain desired strike weight ratio levels. In respect to this, equation balanced actions exhibit the unique property that the balance weights become an expression of strike weight ratio which relates to overall leverage. This is because the two primary weight components of front weight and strike weight are made very precisely to smooth weight specifications. (wippens need not be balanced) Therefore, if the yielded balance weight is off specification, it has to be the result strike weight ratio errors. Note that the balance weight inconsistencies of Graph 7 mirror the strike weight ratios inconsistencies of graph 3. These errors occur naturally in all piano actions to a greater or lesser degree depending on the quality of the construction. This property provides a useful tool for factory quality control checks of the touch design. Balance weights that are consistently out of tolerance indicate something is awry in the setup.

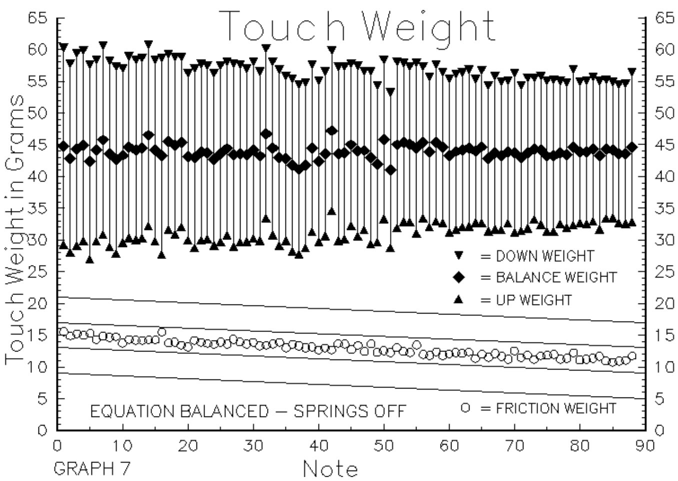
In the application of component touch weight balancing in the rebuilding of piano actions, the technician should follow certain protocols in respect to action geometry.

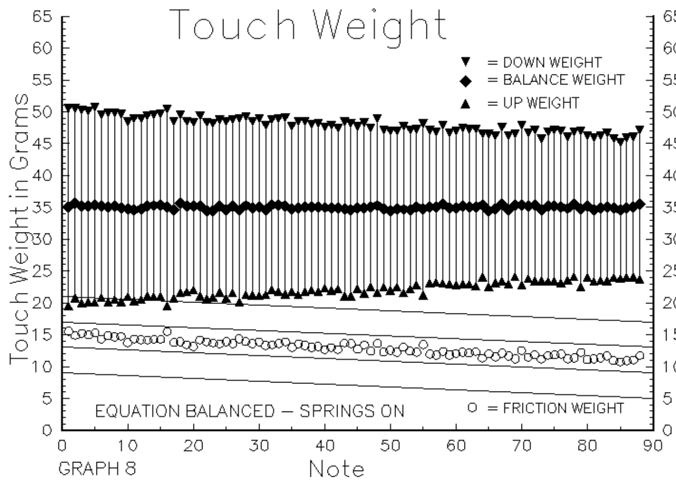
I put action geometry into two classes: Arc geometry and leverage geometry. Arc geometry involves the interaction of arcs and relates to action spread, heel thickness, knuckle thickness, center pin heights and the like. The technician should check that arc geometry is within minimum standards. Leverage geometry relates to the leverage yielded from the multiplication of key ratio, wippen ratio, and shank ratio. The primary leverage variables are knuckle distance from core to hammer center and key ratio. One problem is that actions may have workable arc geometry but poor leverage geometry. The attributes of both types must be considered.

At the present time the custom designing and modification of piano actions using equation balancing is the realm of trained specialists. Technicians who wish to learn more about these techniques may educate themselves by attending PTG seminars or seeking the advise and skill of a growing new strata of specialized technicians who are trained and skilled in the art and science of component key balancing.

Finally I would like to comment of the resurgent use of wippen support springs as seen my own retrofits, retrofits I have provided to many technicians over the years, and in the "Turbo wip" available by Renner USA. As I have stated in the past, I feel that this is an under utilized and widely misunderstood resource that we should consider as a touch weight design option. They have been used in many fine pianos such as Steinway, Bosendorfer, Bechstein, and many European makes with great success. They have also been abused as a crutch to fix action problems that are better solved by redesigning action ratio or hammer weight.

In the equation balanced action wippen support springs offer a nice way to resolve errors in balance weight caused by strike weight ratio variations. Graph 7 shows an action equation balanced and designed for 88 wippen support springs but with the springs disconnected. Note the elevated balance weight, down weights and up weights as well as the associated friction weights. In this equation balanced action the front weights and strike weights are perfectly smooth so any remaining jaggedness in the balance weight is the result of strike weight ratio variations. Graph 8 shows the same action with wippen support spring hooked up and adjusted to smooth out the balance weight errors. In this case we adjusted the balance weight to 35 grams to follow classic Steinway touch weight specifications. Support springs come with the added advantage that touch weight levels may be adjusted as desired to a wide range of levels to suit individual need.





This task is made infinitely easier by the addition of balance weight regulating screws as shown in figure 2. These screws are presently installed as a retrofit. With increased demand for the application of wippen support springs we hope to see action manufacturers pick up on this design and offer it to technicians or piano makers as a new parts option.

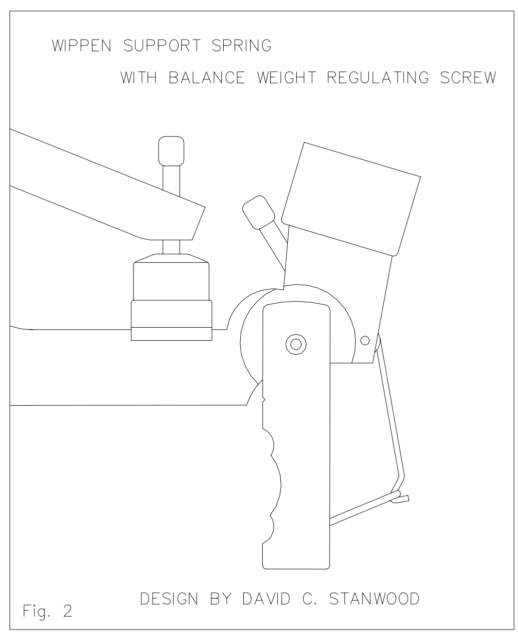


Fig. 2

Conclusion

We must break our habit of associating down weight with the dynamic feel of the action when it is played. Dynamic touch is a function of weight and ratio characteristics for which specifications and tolerances may now be written according to the equation of balance. This gives us freedom to produce any action type with specifications to keep us on track and aid in trouble shooting. The integrity of balance is maintained by making replacement parts to written specifications provided by the manufacturer or component touch weight specialist.

FOOT NOTES

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[1] Refer to "Through the Eyes of the New Touchweight Metrology", PTG Journal, March 2000

[2] For the derivation of the equation of balance refer to "The New Touchweight Metrology" by David C. Stanwood, PTG Journal, June 1996

For a glossary of terms, abbreviations, and updated measuring procedures, refer to "Standard Protocols of the New Touchweight Metrology" by David C. Stanwood, PTG Journal, February 2000.

[3] Refer to "Mastering Friction with the Balance Weight System" by David C. Stanwood, PTG Journal, November 1990.

[4] Refer to "Grand Piano Touchweight, Part II" by Bill Spurlock, PTG Journal, January 1991
