



# Through the Eyes of the New Touchweight Metrology

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## Abstract

Studies of strike weight, strike weight ratio and front weight shed new light on the enigma of touchweight and opened new ways for improving the tone and touch of pianos.

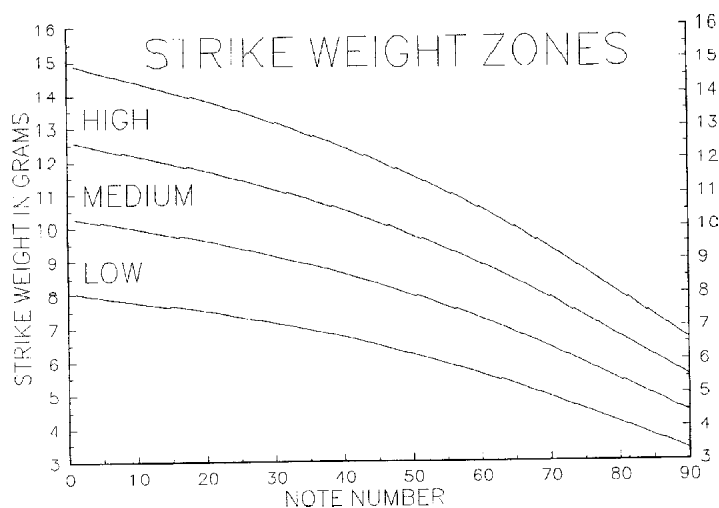
## Introduction

In June, 1996, I published "The New Touchweight Metrology" in the *Piano Technicians Journal*, describing the "Equation of Balance," which links measured weight and weight ratio components, to the traditional touchweight parameters of up weight and down weight in the grand action. This was followed in February, 2000, by "Standard Protocols of the New Touchweight Metrology." From the years leading to these publications up to the present day, I have collected a huge volume of data from an ever-increasing study group of piano technicians who generate data from the use of the New Touchweight Metrology in their work.

Analysis of the data allows us to see the piano action through new eyes and reveals previously unknowable facts. The news is both good and bad. The bad news is that the traditional approach of "x-pound hammers" and down weight creates variable results and a false sense of "doing what's right." The good news is that the New Touchweight Metrology makes it possible to identify and correct elements which undermine the integrity of touch and tone, thereby making it possible to design, manufacture and rebuild pianos to higher standards of quality with a degree of freedom that was previously unimaginable.

## Methods

Over the last eight years the study group provided data –



Graph 1

taken with the standard protocols of the New Touchweight Metrology – on the pianos built or rebuilt between 1888 and 1999. The parts studied include examples of factory original, factory replacement and various supplier-replaced parts. Both quantitative and qualitative assessments were made of levels and smoothness (note-to-note consistency)

TABLE 1 - Normal Strike Weight Zone Delineators in Grams

Note	LOW	MEDIUM	HIGH	Note	LOW	MEDIUM	HIGH		
1	8.0	10.3	12.4	14.8	45	6.5	8.3	10.1	12.0
2	8.0	10.3	12.4	14.8	46	6.4	8.3	10.0	11.9
3	8.0	10.2	12.3	14.7	47	6.4	8.2	9.9	11.8
4	7.9	10.2	12.3	14.7	48	6.3	8.1	9.9	11.7
5	7.9	10.2	12.2	14.6	49	6.3	8.1	9.8	11.6
6	7.9	10.1	12.2	14.6	50	6.2	8.0	9.7	11.5
7	7.9	10.1	12.2	14.5	51	6.1	7.9	9.6	11.4
8	7.8	10.1	12.1	14.5	52	6.1	7.9	9.6	11.3
9	7.8	10.0	12.1	14.4	53	6.0	7.8	9.5	11.2
10	7.8	10.0	12.0	14.3	54	6.0	7.7	9.4	11.1
11	7.7	9.9	12.0	14.3	55	5.9	7.6	9.3	11.0
12	7.7	9.9	11.9	14.2	56	5.9	7.5	9.2	10.9
13	7.7	9.9	11.9	14.2	57	5.8	7.5	9.2	10.8
14	7.7	9.8	11.8	14.1	58	5.7	7.4	9.1	10.7
15	7.6	9.8	11.8	14.1	59	5.7	7.3	9.0	10.6
16	7.6	9.8	11.7	14.0	60	5.6	7.2	8.9	10.5
17	7.6	9.7	11.7	14.0	61	5.5	7.1	8.8	10.4
18	7.6	9.7	11.7	13.9	62	5.5	7.1	8.7	10.3
19	7.5	9.6	11.6	13.9	63	5.4	7.0	8.6	10.2
20	7.5	9.6	11.6	13.8	64	5.3	6.9	8.5	10.1
21	7.5	9.6	11.5	13.7	65	5.3	6.8	8.4	10.0
22	7.4	9.5	11.5	13.7	66	5.2	6.7	8.3	9.8
23	7.4	9.5	11.4	13.6	67	5.1	6.6	8.2	9.7
24	7.4	9.4	11.3	13.5	68	5.1	6.6	8.1	9.6
25	7.3	9.4	11.3	13.5	69	5.0	6.5	8.0	9.5
26	7.3	9.4	11.2	13.4	70	4.9	6.4	7.9	9.3
27	7.3	9.3	11.2	13.3	71	4.8	6.3	7.8	9.2
28	7.2	9.3	11.1	13.3	72	4.8	6.2	7.6	9.1
29	7.2	9.2	11.1	13.2	73	4.7	6.1	7.5	8.9
30	7.1	9.2	11.0	13.1	74	4.6	6.0	7.4	8.8
31	7.1	9.1	11.0	13.1	75	4.5	5.9	7.3	8.7
32	7.1	9.1	10.9	13.0	76	4.4	5.8	7.2	8.5
33	7.0	9.0	10.8	12.9	77	4.4	5.7	7.1	8.4
34	7.0	9.0	10.8	12.9	78	4.3	5.6	6.9	8.3
35	7.0	8.9	10.7	12.8	79	4.2	5.5	6.8	8.1
36	6.9	8.9	10.7	12.7	80	4.1	5.4	6.7	8.0
37	6.9	8.8	10.6	12.6	81	4.1	5.3	6.6	7.9
38	6.8	8.7	10.5	12.6	82	4.0	5.2	6.5	7.7
39	6.8	8.7	10.5	12.5	83	3.9	5.1	6.4	7.6
40	6.7	8.6	10.4	12.4	84	3.8	5.0	6.2	7.5
41	6.7	8.6	10.4	12.3	85	3.7	4.9	6.1	7.3
42	6.6	8.5	10.3	12.2	86	3.7	4.8	6.0	7.2
43	6.6	8.4	10.2	12.2	87	3.6	4.7	5.9	7.0
44	6.5	8.4	10.2	12.1	88	3.5	4.6	5.8	6.9

(NOTE: To find the hammer weight associated with these strike weight figures, subtract the shank strike weight from the strike weight. If you don't know the shank strike weight I would recommend a value of 1.7 grams as a generic average.)

## New Touchweight Metrology

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of the components studied.

### Results

I will give an overview of the “what’s out there” in terms of the primary components of the New Touchweight Metrology. Analysis graphs show representative characteristics of various action types. The sources of common action anomalies that degrade quality will be shown, as well as the characteristic profiles of high-quality actions.

### Strike Weight Zone Results

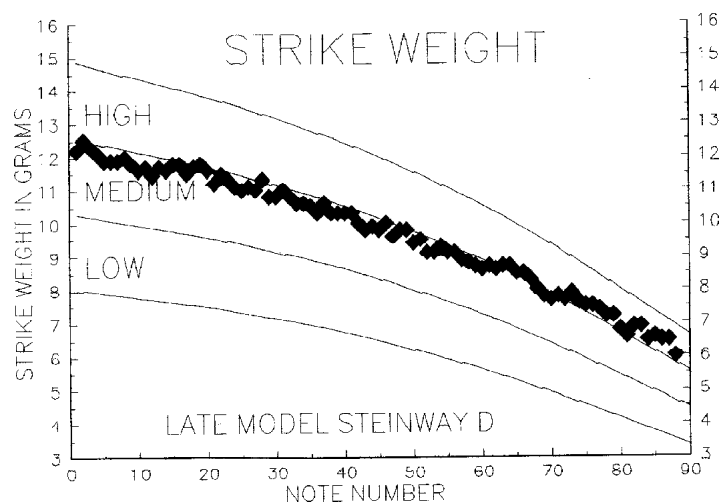
The first result of studying strike weight was the establishment of “Normal” ranges. Nine years of data studies have yielded a consensus within the study group of Normal Strike Weight Zone Delineators as shown in Graph 1. To provide frames of reference within the zone, it is divided equally into three sub-zones that delineate high, medium and low strike weight. The strike weight zone has two distinct characteristics; it is wider at the bass and curved. The values for the zone delineators are given in Table 1.

When looking at strike weight of one piano compared to another it is common to find wide variations in level. As a representative example, Graph 2 shows outlines of two strike weight groupings of late model pianos of a major high quality American made piano. Both groupings are from hammers made in the same factory between 1994 and 1999. One grouping is of pianos with 16.5-pound hammers and the other from pianos with 18-pound hammers. Note that there is considerable overlap and in many cases the 16.5-pound hammer is heavier than the 18-pound hammer. We found this characteristic of overlap to be common in all brands of pianos and replacement hammers as well. In pianos that were custom-rebuilt we found even wider variations of levels. This was traced to the fact that some rebuilders go for extreme weight reduction by maximizing hammer taper while others may taper their hammers minimally.

In regard to the quality of sound from different levels of strike weight, it was generally observed that high strike weights produce more sound energy. For instance, it may be noticed that pianos with high zone strike weights will

produce higher microphone signals than low-zone strike weights. The listener perceives this higher sound energy as an enhanced ability to distinguish the piano in combination with other instruments as in symphony concertos or jazz combos. Also, pianos with high-zone strike weights are generally easier to hear in the back of a big hall or outdoors. Another example is when listening to a piano in a busy restaurant full of talking people, the piano with high-zone strike weights is more easily heard through the din than the piano with low-zone strike weights. From a practical standpoint it was found that ideal voicing of low strike weights is easier to achieve with softer hammers and higher strike weights produce ideal voicing more easily with harder, denser hammers.

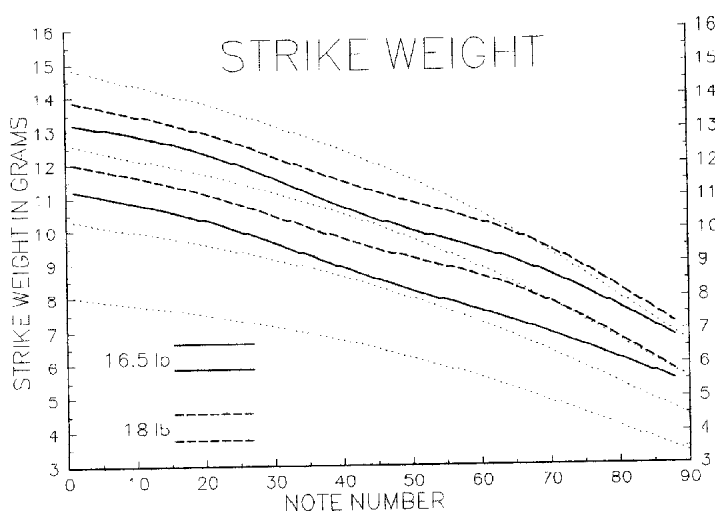
Wide variations in strike weight smoothness from piano to piano were found to be quite common. To get an idea of



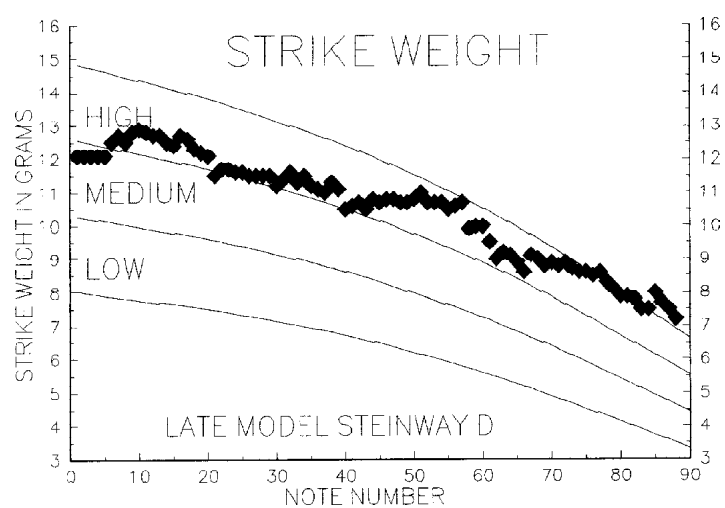
Graph 3

the extremes, consider two examples of factory-produced strike weights in late-model New York Steinway concert grands. An example of an unusually smooth set of strike weights is shown in Graph 3 and a set of unusually jagged strike weights is shown in Graph 4. Note the difference of 0.8 grams between notes 51 and 52. This degree of strike weight anomaly is quite commonly found in all makes of piano.

Investigations turned up several common variables that



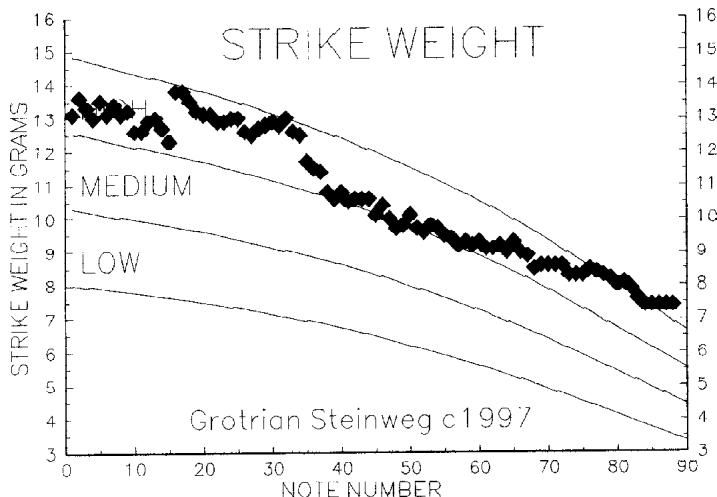
Graph 2



Graph 4

contribute to producing strike-weight jaggedness.

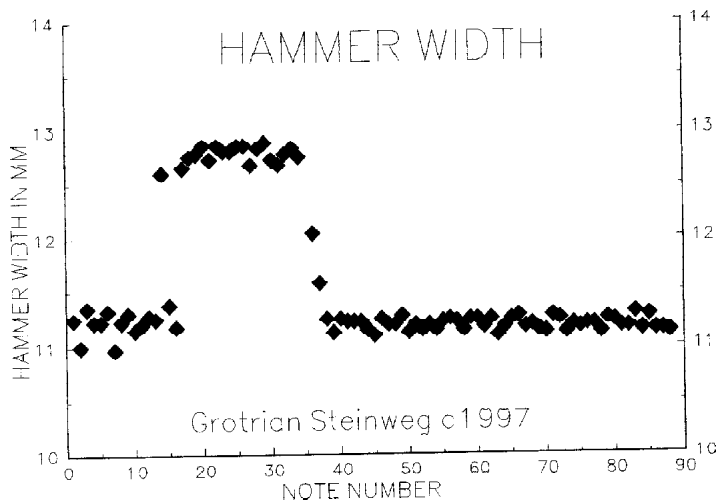
Variations in hammer width cause variations in strike weight and this was found to be an industry wide problem. An example which clearly demonstrates the relationship



Graph 5

between hammer width and strike weight is shown in Graph 5, which shows strike weights – from the factory – of a late-model Grotrian with Renner hammers. Hammer widths for the same piano are shown in Graph 6. Note the elevated section of hammer widths between notes 16 and 34. In this case a hammer width increase of about 1.6mm translated into an increase in the strike weight of about 1.0 gram or about 0.6 gram per mm. Strike-weight jaggedness was found to be especially common in the bass section where a small variation in hammer width causes a larger difference in strike weight due to the larger area of felt.

It was a surprise to find that a very common source of strike-weight anomalies comes from variations in the wood

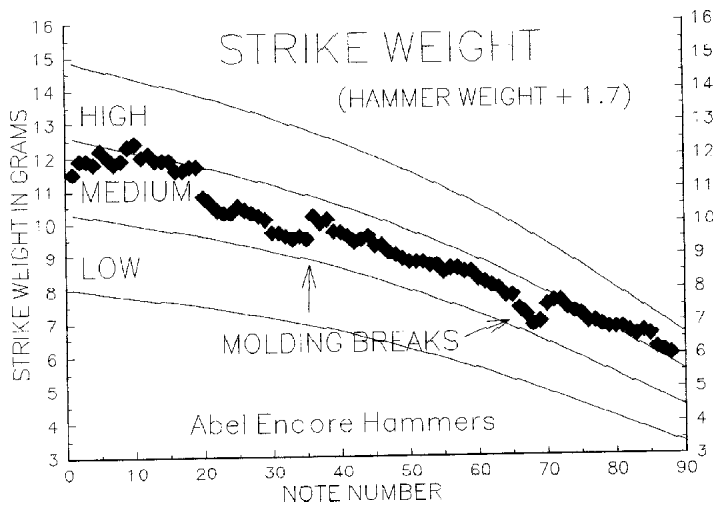


Graph 6

density of the hammer moldings that produce jags in the strike weight where a section of heavy molding adjoins a lighter section of molding. A typical set of recently made German replacement hammers by Abel is shown in Graph 7. Note the jags in strike weight that coincide with joints in the hammer molding wood. Note that the difference in

strike weight between notes 35 and 36 is 0.7 grams.

Yet another cause of strike-weight jaggedness comes from variations in shank strike weights. Analysis of a typical



Graph 7

set of high-quality German shanks made by Renner is shown in Table II. Note that in this case the difference in weight between the heaviest and the lightest full shank is 0.6 grams. Also note that the lightest full shank is lighter than the heaviest narrow shank.

A marked correlation of strike weight smoothness with the tone and touch was found. Pianos with smoother strike

TABLE II — Shank Count vs. Shank Strike Weight in grams		
FULL SHANKS	Number of shanks	Weight in Grams
	2	2.1
	8	2.0
	10	1.9
	23	1.8
	17	1.7
	7	1.6
	1	1.5
NARROW SHANKS	2	1.7
	8	1.6
	6	1.5
	2	1.4
	2	1.3

weights generally had a more satisfying quality of tone and touch. Much of the data came from studying actions in which qualities of tone and touch were noted, the strike weight measured, hammer weight added subtracted as needed to produce a smooth strike weight curve as shown in graph 8, then action quality was reassessed. Time and time again pianists noted improved tone and touch with smoothed strike weights. A significant reduction in the need for conventional voicing methods, such as needling, in pianos with smoothed strike weights was also noted.

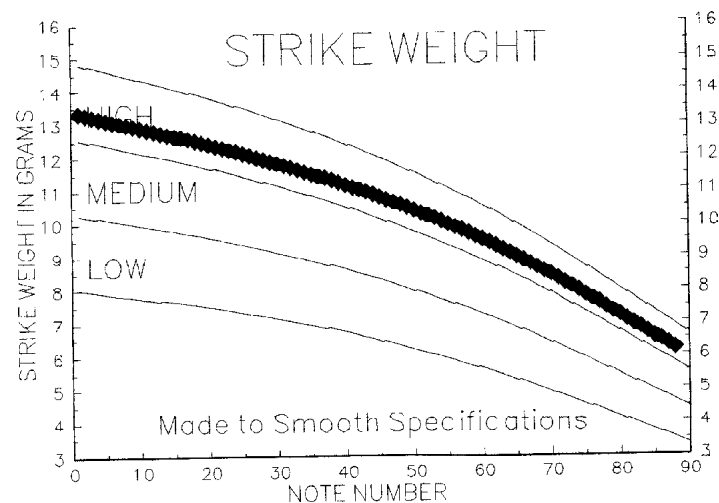
In an effort to know more about the threshold of perception to strike weight changes we first used pianos that had been strike-weight smoothed as in Graph 8. Then we raised the general level of strike weight by uniform increments with the addition of “small binder clips” to the

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shanks. Attaching the clips as shown in Photo 1 increases the strike weight by 1.0 gram. Pianists commented on the tone and touch before the addition of the clips. After a short wait while the clips were being attached, they were able to try the piano again and comment on the change. It



**Graph 8**

was found that a 1.0-gram increase produces such a large change in quality that pianists consistently felt it was "like a different piano," with a marked increase in dynamic touchweight and a distinct mellowing of the tone. An increase of 0.5 gram produced a significant change that could be perceived even by the average amateur pianist.



**Photo 1 — Attaching small binder clips to hammer shanks.**

### Strike Weight Ratio

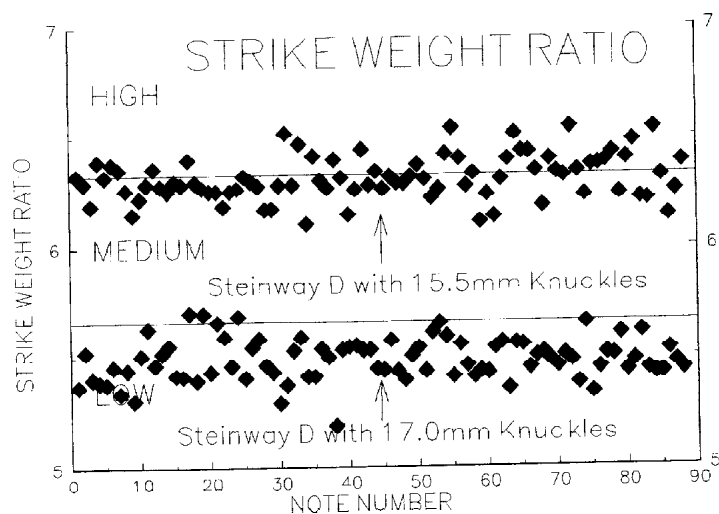
The "Normal" zone of strike weight ratio was determined to be from 5.0 to 7.0. As a frame of reference the zone is sectioned equally in thirds as in Table III. The leverage referred to is the leverage that the pianist exerts on the hammer. Low strike weight ratios correspond to a high leverage (more like a crow bar) and vice versa.

Wide variations in strike weight ratio levels exist throughout the industry. Graph 9 shows two pianos of the same make and model but with radically different ratio

**TABLE III — Strike weight ratio zones**

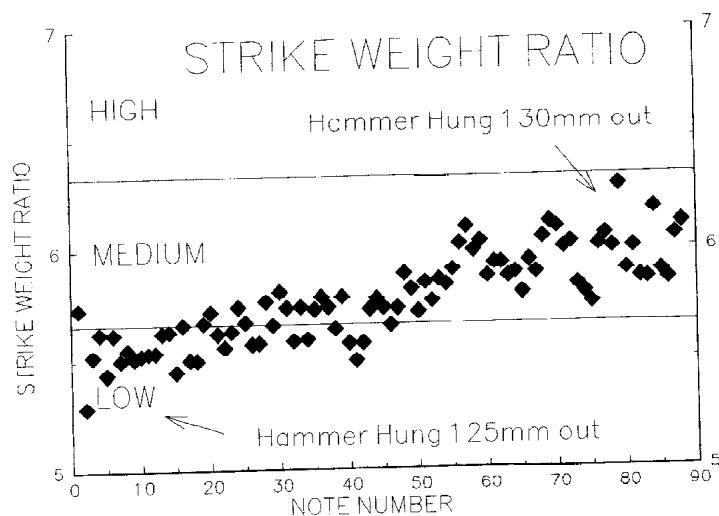
<b>HIGH</b>	7.0 - 6.3	(Low Leverage)
<b>MEDIUM</b>	6.3 - 5.7	(Medium Leverage)
<b>LOW</b>	5.7 - 5.0	(High Leverage)

levels. In this case the principle variable was traced to the fact that the action with the higher ratio used shanks with knuckles mounted 15.5mm out from the center pin to knuckle core, as opposed to the other with knuckles 17mm out. Additional principle variables that affect overall strike



**Graph 9**

weight ratio levels include key ratio and capstan/heel position. Also the distance that the hammer is hung from the hammer center affects strike weight ratio as shown in Graph 10. Note that in this example, in the bass end the strike weight ratio is 5.5 with the hammers hung 125mm out on the shank, whereas in the treble end with the hammers hung at 130mm out, the ratio increases to 6.1.

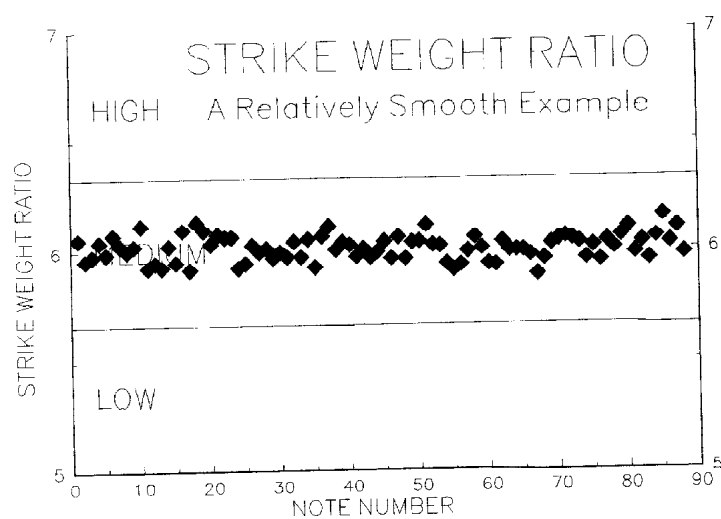


**Graph 10**

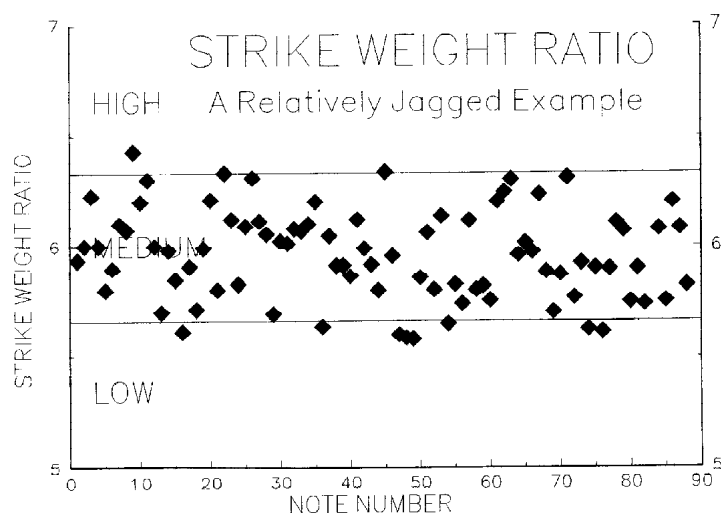
Generally, it was found that pianos with higher strike weight ratios require lower strike weights to produce a normal-feeling action while actions with lower strike weight ratios require higher strike weights to produce a normal feeling action. If strike weight ratio is below 5.0, actions usually require too much dip, a short hammer blow dis-

tance and they tend to lose power. If strike weight ratio is above 7.0 actions become too heavy (even with very light hammers), with very shallow dip and long hammer blow needed.

Strike weight ratios were found to be generally jagged. An example of very smooth strike weight ratios in a late model Hamburg Steinway D is shown in Graph 11. An example of a particularly jagged strike weight is shown in Graph 12, which depicts strike weights in a rebuilt action that had replacement knuckles glued in rather poorly with many cocked to the front or back. Sometimes specific anomalies may be traced to such things as a capstan or knuckle out of line but, for the most part, a jagged strike weight ratio is just normal background variation.



Graph 11, ABOVE, and Graph 12, BELOW.



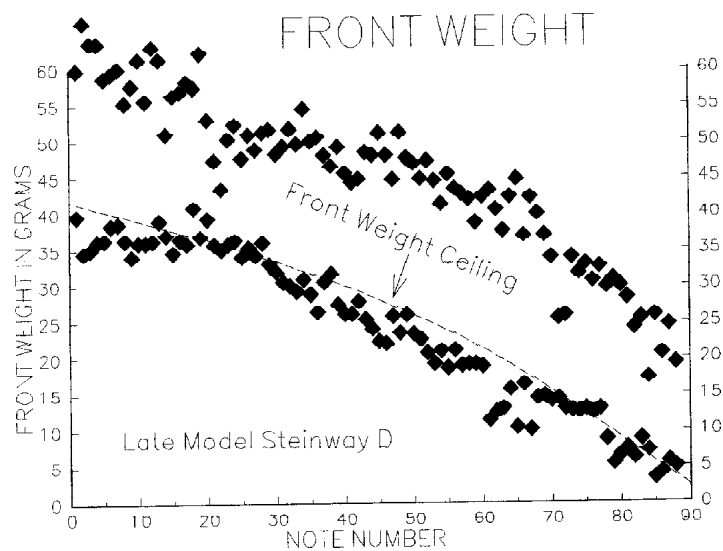
### Front Weight

The question “is there too much lead in the keys?” may be partly answered by measuring front weight because its value is determined mainly by the number and displacement of key leads in the key. Table IV gives a proposed set of values for maximum recommended front weight. If front weight is above these values it may be considered excessive. At this stage this may serve as a frame of reference called “Front Weight Ceiling.”

TABLE IV - Front Weight Ceiling in grams

Note	FrontWt	Note	FrontWt	Note	FrontWt	Note	FrontWt
1	41.3	23	35.5	45	28.1	67	17.4
2	41.1	24	35.2	46	27.7	68	16.8
3	40.8	25	34.9	47	27.3	69	16.2
4	40.6	26	34.6	48	26.9	70	15.5
5	40.3	27	34.3	49	26.4	71	14.9
6	40.1	28	34.0	50	26.0	72	14.3
7	39.8	29	33.7	51	25.6	73	13.6
8	39.5	30	33.3	52	25.1	74	13.0
9	39.3	31	33.0	53	24.7	75	12.3
10	39.0	32	32.7	54	24.2	76	11.6
11	38.8	33	32.4	55	23.8	77	11.0
12	38.5	34	32.1	56	23.3	78	10.3
13	38.3	35	31.7	57	22.8	79	9.6
14	38.0	36	31.4	58	22.3	80	9.0
15	37.8	37	31.0	59	21.8	81	8.3
16	37.5	38	30.7	60	21.3	82	7.6
17	37.2	39	30.4	61	20.8	83	7.0
18	37.0	40	30.0	62	20.2	84	6.3
19	36.7	41	29.6	63	19.7	85	5.6
20	36.4	42	29.3	64	19.1	86	5.0
21	36.1	43	28.9	65	18.6	87	4.3
22	35.8	44	28.5	66	18.0	88	3.7

It is an understatement to say that wide variations in front weight levels are found throughout the industry. Consider the two late-model New York Steinway concert grands, weighed off in the factory, as shown in Graph 13.



Graph 13

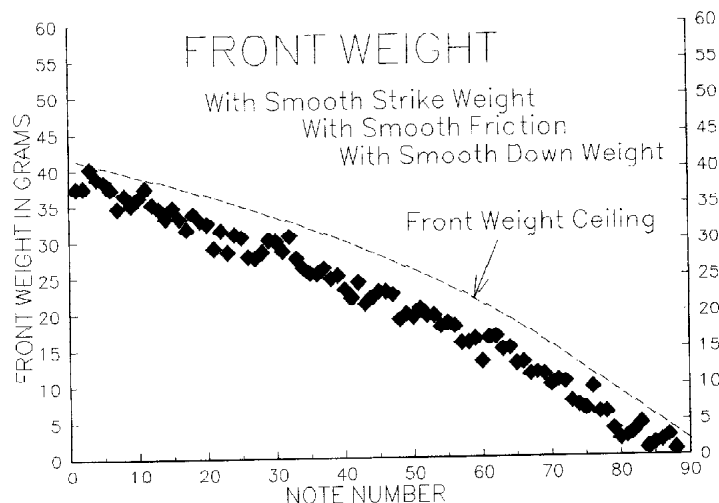
As to the quality of various front weight levels, it was found that actions with high zone front weights tend to be heavy and slower in repetition, while actions with lower front weights tend to feel lighter and have faster repetition. The best repetition was found in actions with high strike weight and low front weight.

It is also an understatement to say that wide variations in front-weight smoothness exist throughout the industry. An example of very smooth front weights as produced with the traditional approach, that relies on pound hammer weight and down weight specifications, is shown in Graph

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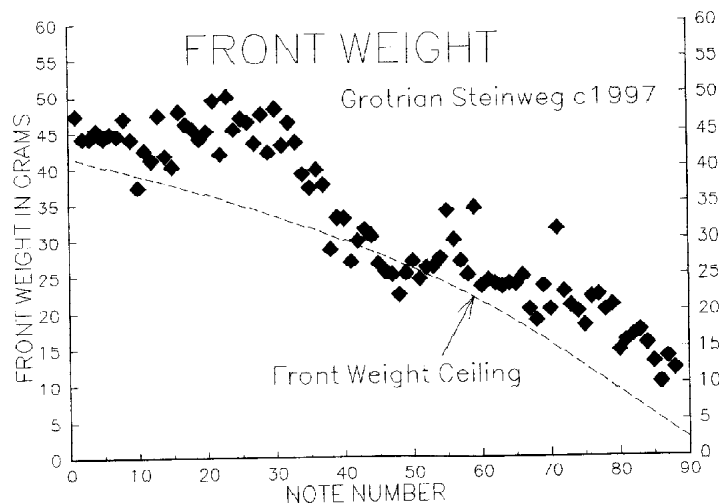
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Graph 14

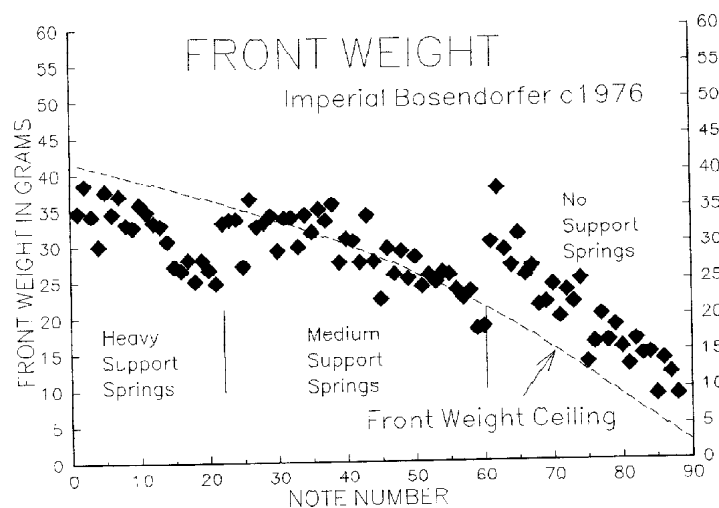
14. This kind of result is produced when strike weight and friction are fairly smooth. An example of a very jagged front weight is shown in Graph 15. This kind of result is produced when strike weight and friction are very uneven. In this example we see how the elevated strike weights between notes 16 and 34 (See Graph 5) create elevated front weights in that section. Also notice the elevated front weights of notes 55, 59 and 71. The hammer flange bushings in these notes were extremely tight, leading one to believe that more lead was added to the key at the time of weigh-off in order to overcome friction and make a specified down weight.



Graph 15

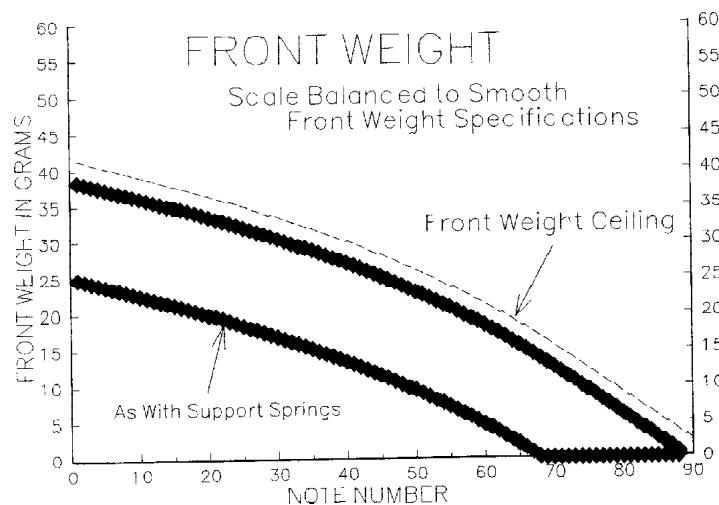
Major front-weight jaggedness was found in almost all factory-balanced pianos that incorporate wippen support springs (also known as helper or wippen-assist springs). The example shown in Graph 16 is a Bösendorfer Imperial concert grand. Note the jag in front weights where support spring size changes at note 22 and again where springs end, at note 61.

A definite correlation between smooth front weights and smooth action response was found. Jagged front weights are associated with uneven action response and smooth front weights are associated with smooth action



Graph 16

response. The highest ideal of front-weight smoothness is exhibited in keys that have been digitally scale-balanced using smooth front weight specifications as described in U.S. Patent 5585582, Dec. 17, 1996. The examples in Graph 17 show two sets of front weights balanced with the patented process. The set of front weights that are lower were designed for the Bösendorfer Imperial of Graph 17 with 88 wippen support springs.



Graph 17

## Conclusions

Based on the findings it may be concluded that the pound rating of a hammer is useful only in the most general sense and as a hammer-weight specification it is essentially meaningless. Considering that 0.5 gram changes in strike weight were found to be significant to the pianist and that multiple strike weight variables commonly produce note-to-note variations of 0.5 grams or greater, it may be concluded that a majority of pianos may be significantly improved by taking efforts to eliminate these anomalies. Furthermore, the first-hand experience of the study group supports the conclusion that strike-weight smoothing is a voicing foundation which is essential for production of the best possible tone, with the added benefit that it significantly reduces



the need for smoothing the voicing of individual hammers with needles or hardeners.

The linked relationships between strike weight, strike weight ratio and front weight offer the best clues for understanding dynamic touchweight. Whereas down weight gives a false reading of how the piano will feel when played, the measurement of actual key pressure needed in the act of playing requires high-tech measuring devices and is beyond the scope of practical utility. However, associating particular action qualities with particular combinations of strike weight, ratio and front weight offers a practical approach to designing the dynamic feel of an action.

Adding key leads to make a specified down weight without regard for strike weight, strike weight ratio and friction is analogous to taking Valium and sweeping your problems under the rug. Technicians, as well as piano manufacturers, who take on the task of balancing actions should learn to choose design components that yield a desirable strike weight ratio level to match a compatible strike weight level. Key leads should be added to the keys using methods that produce the smoothest possible front weight.

Wippen support springs are misunderstood by many and this valuable resource has been crudely applied in the past due to the lack of touchweight knowledge. Technicians who proclaim they should be “cut off” only display their own ignorance. Rather than discard this valuable heritage we should look more deeply into the benefits of wippen support springs and learn how they may be successfully incorporated into the design of touchweight. ■