The Stanwood New Action Protocol (SNAP), Part 2

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This article describes the Table of Touch Design Elements and the Touch Design Selection Guide for the Grand Piano, first presented at the 2019 New England/Eastern Canada Regional PTG seminar in Hartford 2019 and the 2019 Annual PTG Convention and Technical Institute in Tucson. It is recommended that the reader become familiar with published writings on Touch Weight Metrology in order to fully understand the material presented here. (See stanwoodpiano.com/articles.)

My preceding article, "The Stanwood New Action Protocol (SNAP), Part 1," in the June 2023 issue of the *Journal*, supports the knowledge that inertia of the leveraged hammer weight is the underlying and overriding factor when it comes to piano touch and makes a strong case for the benefits of scaling hammer weight levels to control inertia and produce a desired playing quality. I described the fundamental precept that various pairings of front weight and balance weight are associated with various pairings of action ratio and hammer weight levels which are associated witha a range of inertial playing qualities. This leads to simple work bench methods for setting up actions that focus on testing to find the hammer weights that hit balance weight (BW) and front weight (FW) targets for any desired inertial playing quality. I put forth the pairing of a medium BW of 38 g and medium FW of 27 g at C4 as a central benchmark for touch designs with medium inertial playing quality.

There are many other pairings of BW and FW associated with a range of inertial playing qualities from low to high not only for C4 but for any note across the keyboard. Sorting out all the possible choices of targets for any note on any particular keyboard to produce any desired inertial playing type in the finished action is greatly facilitated by organizing touch design elements into tables with rows and columns that convey the relationships visually. Touch Weight Metrology's Equation of Balance provides the framework for the Table of Touch Design Elements which equates pairings of BW and FW to pairings of strike weight ratio and strike weight, which are associated empirically with a normal range of strike weight inertial qualities.

The Table of Touch Design Elements
for the Modern Grand Piano by David Stanwood

BW + FW = SW x R + WBW(9) ≈ Strike Weight Inertial Quality

Down Weight / Balance Weight / Up Weight for given Front Weight with a 12g Friction Weight | Strike Weight Ratio for Given Strike Weight with a Wippen Balance Weight of 9g

Strike Weight Inertial Quality	FW#5	FW#7	FW#9	SW#5	SW#6	SW#7	SW#8	SW#9	SW#10	SW#11	SW#12	SW#13
HIGH			55/43/31		7.0	6.6	6.4	6.1	5.8	5.6	5.4	5.2
HIGH			54/42/30		6.9	6.5	6.3	6.0	5.7	5.5	5.3	5.1
HIGH			53/41/29		6.8	6.4	6.2	5.9	5.6	5.4	5.2	5.0
HIGH		**55/43/31**	**52/40/28**		**6.7**	**6.3**	**6.1**	**5.8**	**5.5**	**5.3**	**5.1**	
HIGH		54/42/30	51/39/27	7.0	6.6	6.2	6.0	5.7	5.4	5.2	5.0	
HIGH		53/41/29	50/38/26	6.8	6.5	6.1	5.9	5.6	5.4	5.1		
MEDIUM	55/43/31	52/40/28	49/37/25	6.7	6.4	6.0	5.8	5.5	5.3	5.0		
MEDIUM	54/42/30	51/39/27	48/36/24	6.6	6.3	5.9	5.7	5.4	5.2			
MEDIUM	**53/41/29**	**50/38/26**	**47/35/23**	**6.5**	**6.1**	**5.8**	**5.6**	**5.3**	**5.1**			
MEDIUM	52/40/28	49/37/25	46/34/22	6.4	6.0	5.7	5.5	5.2	5.0			
MEDIUM	51/39/27	48/36/24	45/33/21	6.3	5.9	5.6	5.4	5.1				
LOW	50/38/26	47/35/23		6.2	5.8	5.5	5.3	5.0				
LOW	49/37/25	46/34/22		6.0	5.7	5.4	5.2					
LOW	**48/36/24**	**45/33/21**		**5.9**	**5.6**	**5.3**	**5.1**					
LOW	47/35/23			5.8	5.5	5.2	5.0					
LOW	46/34/22			5.7	5.4	5.1						
LOW	45/33/21			5.6	5.3	5.0						

TOUCH DESIGN FW+BW PAIRINGS | STUDIO HAMMER WEIGHTS | CONCERT HALL HAMMER WEIGHTS

Figure 1: The Table of Touch Design Elements.

The Table of Touch Design Elements (Figure 1) is based on what pianos are normally found to be in the real world based on extensive touch weight metrology studies.

These elements include the normal ranges of downweight (D) 45–55 g, balance weight 33–43 g, upweight (U) 21–31g for a medium friction weight of 12 g. The formula for balance weight is (U+D)/2. The formula for friction weight is (D-U)/2. Normal strike weights are based on the four reference scales published in the March 2000 *Journal*. These scales define a normal zone divided into equally spaced low, medium, and high zones.

	FRONT WEIGHT REFERENCE SCALES						STRIKE WEIGHT REFERENCE SCALES									
	Medium Zone Front Weight							Studio Strike Wt				Concert Hall Strike Wt				
	N	FW#5	FW#6	FW#7	FW#8	FW#9	N	SW#5	SW#6	SW#7	SW#8	SW#9	SW#10	SW#11	SW#12	SW#13
	1	34.4	36.1	37.8	39.5	41.2	1	10.3	10.8	11.4	12.0	12.5	13.1	13.7	14.2	14.8
	2	34.2	35.9	37.6	39.3	41.0	2	10.2	10.8	11.4	11.9	12.5	13.1	13.6	14.2	14.7
	3	33.9	35.6	37.3	39.0	40.7	3	10.2	10.8	11.3	11.9	12.4	13.0	13.6	14.1	14.7
C1	4	33.7	35.4	37.1	38.8	40.5	4	10.2	10.7	11.3	11.9	12.4	13.0	13.5	14.1	14.7
	5	33.5	35.2	36.9	38.5	40.2	5	10.1	10.7	11.3	11.8	12.4	12.9	13.5	14.1	14.6
	6	33.3	34.9	36.6	38.3	40.0	6	10.1	10.7	11.2	11.8	12.3	12.9	13.4	14.0	14.6
	7	33.0	34.7	36.4	38.0	39.7	7	10.1	10.6	11.2	11.7	12.3	12.8	13.4	14.0	14.5
	8	32.8	34.5	36.1	37.8	39.5	8	10.0	10.6	11.1	11.7	12.2	12.8	13.4	13.9	14.5
	9	32.6	34.2	35.9	37.6	39.2	9	10.0	10.6	11.1	11.7	12.2	12.8	13.3	13.9	14.4
	10	32.3	34.0	35.7	37.3	39.0	10	10.0	10.5	11.1	11.6	12.2	12.7	13.3	13.8	14.4
	11	32.1	33.8	35.4	37.1	38.7	11	9.9	10.5	11.0	11.6	12.1	12.7	13.2	13.8	14.3
	12	31.9	33.5	35.2	36.8	38.5	12	9.9	10.4	11.0	11.5	12.1	12.6	13.2	13.7	14.2
	13	31.6	33.3	34.9	36.6	38.2	13	9.9	10.4	10.9	11.5	12.0	12.6	13.1	13.7	14.2
	14	31.4	33.0	34.7	36.3	37.9	14	9.8	10.4	10.9	11.4	12.0	12.5	13.1	13.6	14.1
	15	31.1	32.8	34.4	36.1	37.7	15	9.8	10.3	10.9	11.4	11.9	12.5	13.0	13.6	14.1
C2	16	30.9	32.5	34.2	35.8	37.4	16	9.7	10.3	10.8	11.4	11.9	12.4	13.0	13.5	14.0
	17	30.7	32.3	33.9	35.5	37.2	17	9.7	10.2	10.8	11.3	11.8	12.4	12.9	13.4	14.0
	18	30.4	32.0	33.7	35.3	36.9	18	9.7	10.2	10.7	11.3	11.8	12.3	12.9	13.4	13.9
	19	30.2	31.8	33.4	35.0	36.6	19	9.6	10.2	10.7	11.2	11.7	12.3	12.8	13.3	13.9
	20	29.9	31.5	33.1	34.7	36.4	20	9.6	10.1	10.6	11.2	11.7	12.2	12.7	13.3	13.8
	21	29.7	31.3	32.9	34.5	36.1	21	9.5	10.1	10.6	11.1	11.6	12.2	12.7	13.2	13.7
	22	29.4	31.0	32.6	34.2	35.8	22	9.5	10.0	10.5	11.1	11.6	12.1	12.6	13.2	13.7
	23	29.1	30.7	32.3	33.9	35.5	23	9.5	10.0	10.5	11.0	11.5	12.1	12.6	13.1	13.6
	24	28.9	30.5	32.1	33.6	35.2	24	9.4	9.9	10.4	11.0	11.5	12.0	12.5	13.0	13.6
	25	28.6	30.2	31.8	33.4	34.9	25	9.4	9.9	10.4	10.9	11.4	11.9	12.5	13.0	13.5
	26	28.3	29.9	31.5	33.1	34.7	26	9.3	9.8	10.3	10.9	11.4	11.9	12.4	12.9	13.4
	27	28.1	29.6	31.2	32.8	34.4	27	9.3	9.8	10.3	10.8	11.3	11.8	12.4	12.9	13.4
C3	28	27.8	29.4	30.9	32.5	34.1	28	9.2	9.7	10.2	10.8	11.3	11.8	12.3	12.8	13.3
	29	27.5	29.1	30.6	32.2	33.7	29	9.2	9.7	10.2	10.7	11.2	11.7	12.2	12.7	13.3
	30	27.2	28.8	30.3	31.9	33.4	30	9.1	9.6	10.1	10.7	11.2	11.7	12.2	12.7	13.2
	31	26.9	28.5	30.0	31.6	33.1	31	9.1	9.6	10.1	10.6	11.1	11.6	12.1	12.6	13.1
	32	26.6	28.2	29.7	31.3	32.8	32	9.0	9.5	10.0	10.5	11.0	11.5	12.1	12.6	13.1
	33	26.3	27.9	29.4	30.9	32.5	33	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
	34	26.0	27.5	29.1	30.6	32.1	34	8.9	9.4	9.9	10.4	10.9	11.4	11.9	12.4	12.9
	35	25.7	27.2	28.7	30.3	31.8	35	8.9	9.4	9.9	10.4	10.9	11.4	11.9	12.4	12.8
	36	25.4	26.9	28.4	29.9	31.4	36	8.8	9.3	9.8	10.3	10.8	11.3	11.8	12.3	12.8
	37	25.0	26.6	28.1	29.6	31.1	37	8.8	9.3	9.7	10.2	10.7	11.2	11.7	12.2	12.7
	38	24.7	26.2	27.7	29.2	30.7	38	8.7	9.2	9.7	10.2	10.7	11.2	11.6	12.1	12.6
	39	24.4	25.9	27.4	28.9	30.4	39	8.6	9.1	9.6	10.1	10.6	11.1	11.6	12.0	12.5
C4	40	24.0	25.5	27.0	28.5	30.0	40	8.6	9.1	9.6	10.0	10.5	11.0	11.5	12.0	12.4
	41	23.6	25.1	26.6	28.1	29.6	41	8.5	9.0	9.5	10.0	10.4	10.9	11.4	11.9	12.4
	42	23.3	24.8	26.3	27.7	29.2	42	8.5	8.9	9.4	9.9	10.4	10.8	11.3	11.8	12.3
	43	22.9	24.4	25.9	27.4	28.8	43	8.4	8.9	9.3	9.8	10.3	10.8	11.2	11.7	12.2
	44	22.5	24.0	25.5	27.0	28.4	44	8.3	8.8	9.3	9.7	10.2	10.7	11.1	11.6	12.1
	45	22.1	23.6	25.1	26.5	28.0	45	8.3	8.7	9.2	9.7	10.1	10.6	11.1	11.5	12.0
	46	21.7	23.2	24.7	26.1	27.6	46	8.2	8.7	9.1	9.6	10.0	10.5	11.0	11.4	11.9
	47	21.3	22.8	24.2	25.7	27.2	47	8.1	8.6	9.0	9.5	10.0	10.4	10.9	11.3	11.8
	48	20.9	22.3	23.8	25.3	26.7	48	8.1	8.5	9.0	9.4	9.9	10.3	10.8	11.2	11.7
	49	20.5	21.9	23.4	24.8	26.3	49	8.0	8.4	8.9	9.3	9.8	10.2	10.7	11.1	11.6
	50	20.0	21.5	22.9	24.4	25.9	50	7.9	8.4	8.8	9.3	9.7	10.2	10.6	11.1	11.5
	51	19.6	21.0	22.5	23.9	25.4	51	7.9	8.3	8.7	9.2	9.6	10.1	10.5	11.0	11.4
C5	52	19.1	20.6	22.0	23.5	24.9	52	7.8	8.2	8.7	9.1	9.5	10.0	10.4	10.9	11.3
	53	18.7	20.1	21.6	23.0	24.5	53	7.7	8.2	8.6	9.0	9.5	9.9	10.3	10.8	11.2
	54	18.2	19.7	21.1	22.5	24.0	54	7.7	8.1	8.5	9.0	9.4	9.8	10.3	10.7	11.1
	55	17.7	19.2	20.6	22.1	23.5	55	7.6	8.0	8.4	8.9	9.3	9.7	10.2	10.6	11.0
	56	17.3	18.7	20.1	21.6	23.0	56	7.5	7.9	8.4	8.8	9.2	9.6	10.1	10.5	10.9
	57	16.8	18.2	19.6	21.1	22.5	57	7.4	7.9	8.3	8.7	9.1	9.5	10.0	10.4	10.8
	58	16.3	17.7	19.1	20.6	22.0	58	7.4	7.8	8.2	8.6	9.0	9.5	9.9	10.3	10.7
	59	15.8	17.2	18.6	20.0	21.5	59	7.3	7.7	8.1	8.5	9.0	9.4	9.8	10.2	10.6
	60	15.2	16.7	18.1	19.5	20.9	60	7.2	7.6	8.0	8.4	8.9	9.3	9.7	10.1	10.5
	61	14.7	16.1	17.6	19.0	20.4	61	7.1	7.5	7.9	8.4	8.8	9.2	9.6	10.0	10.4
	62	14.2	15.6	17.0	18.4	19.9	62	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.9	10.3
	63	13.7	15.1	16.5	17.9	19.3	63	7.0	7.4	7.8	8.2	8.6	9.0	9.4	9.8	10.2
C6	64	13.1	14.5	15.9	17.3	18.7	64	6.9	7.3	7.7	8.1	8.5	8.9	9.3	9.7	10.0
	65	12.6	14.0	15.4	16.8	18.2	65	6.8	7.2	7.6	8.0	8.4	8.8	9.1	9.5	9.9
	66	12.0	13.4	14.8	16.2	17.6	66	6.7	7.1	7.5	7.9	8.3	8.7	9.0	9.4	9.8
	67	11.4	12.8	14.2	15.6	17.0	67	6.6	7.0	7.4	7.8	8.2	8.5	8.9	9.3	9.7
	68	10.9	12.2	13.6	15.0	16.4	68	6.5	6.9	7.3	7.7	8.0	8.4	8.8	9.2	9.5
	69	10.3	11.7	13.0	14.4	15.8	69	6.5	6.8	7.2	7.6	7.9	8.3	8.7	9.0	9.4
	70	9.7	11.1	12.4	13.8	15.2	70	6.4	6.7	7.1	7.5	7.8	8.2	8.6	8.9	9.3
	71	9.1	10.5	11.8	13.2	14.6	71	6.3	6.6	7.0	7.4	7.7	8.1	8.4	8.8	9.2
	72	8.5	9.9	11.2	12.6	14.0	72	6.2	6.5	6.9	7.3	7.6	8.0	8.3	8.7	9.0
	73	7.9	9.2	10.6	12.0	13.4	73	6.1	6.4	6.8	7.1	7.5	7.8	8.2	8.5	8.9
	74	7.3	8.6	10.0	11.4	12.7	74	6.0	6.4	6.7	7.0	7.4	7.7	8.1	8.4	8.8
	75	6.6	8.0	9.4	10.7	12.1	75	5.9	6.3	6.6	6.9	7.3	7.6	8.0	8.3	8.6
	76	6.0	7.4	8.7	10.1	11.4	76	5.8	6.1	6.5	6.8	7.2	7.5	7.8	8.2	8.5
C7	77	5.4	6.7	8.1	9.4	10.8	77	5.7	6.1	6.4	6.7	7.0	7.4	7.7	8.0	8.4
	78	4.8	6.1	7.5	8.8	10.1	78	5.6	6.0	6.3	6.6	6.9	7.3	7.6	7.9	8.2
	79	4.1	5.5	6.8	8.2	9.5	79	5.5	5.8	6.2	6.5	6.8	7.1	7.5	7.8	8.1
	80	3.5	4.8	6.2	7.5	8.8	80	5.4	5.7	6.1	6.4	6.7	7.0	7.3	7.7	8.0
	81	2.8	4.2	5.5	6.8	8.2	81	5.3	5.6	6.0	6.3	6.6	6.9	7.2	7.5	7.8
	82	2.2	3.5	4.9	6.2	7.5	82	5.2	5.5	5.8	6.2	6.5	6.8	7.1	7.4	7.7
	83	1.6	2.9	4.2	5.5	6.8	83	5.1	5.4	5.7	6.0	6.4	6.7	7.0	7.3	7.6
	84	0.9	2.2	3.5	4.9	6.2	84	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.1	7.4
	85	0.3	1.6	2.9	4.2	5.5	85	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3
	86	-0.4	0.9	2.2	3.5	4.8	86	4.8	5.1	5.4	5.7	6.0	6.3	6.6	6.9	7.2
	87	-1.0	0.3	1.6	2.9	4.2	87	4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.7	7.0
	88	-1.7	-0.4	0.9	2.2	3.5	88	4.6	4.9	5.2	5.5	5.8	6.0	6.3	6.6	6.9

Figure 2: Front Weight and Strike Weight reference scales.

Further gradation of the strike weight normal zone is achieved by equally dividing each zone into four divisions. This creates 13 equally spaced reference scales. The low zone includes SW scales #1–#5, medium zone SW scales #5–#9, and high zone SW scales #9–#13. Low zone scales are associated with pre-Dolge machine-style hammer production and are not normally offered by hammer makers, so they are not included in the Table of Touch Design Elements. Included are medium zone SW scales #5–#9, referred to as "Studio Weight," which are appropriate for smaller rooms, and high zone SW scales #9–#13 referred to as "Concert Hall Weight," which have a higher potential decibel output and are appropriate for large rooms or halls (Figure 2).

Front weight reference scales are similarly defined by equally spaced medium zone scales #5, #6, #7, #8, and #9 (Figure 2). Scale #9 is the front weight ceiling, which I published in the March 2000 *Journal*. Front weight scale #7 is the benchmark for medium front weights across the keyboard and includes the C4 benchmark of 27 g that defines the middle of the medium zone. The FW reference scales are slightly different from scales I've distributed in the past to make C4 values easy to remember. FW#5 for C4 is 24 g instead of 23.6 g. FW#7 is 27 g instead of 26.8 g. FW#9 is unchanged at 30 g. The strike weight ratio normal range is 5.0–7.0, with 5.0 level requiring the deepest dip and shortest blow and 7.0 level requiring the shallowest dip and longest blow. Calculations with the equation of balance use an assigned medium wippen balance weight (WBW) value of 9 g. (The normal range is 8–10 g.)

The left side of the Table of Touch Design Elements gives Touch Design pairings of BW + FW for a normal range of strike weight inertial playing qualities. There are three columns for FW#5, FW#7, and FW#9 for front weight reference scales that span the medium zone. Each column contains 11 rows of D/BW/U that span their normal range. The table is organized so that the sum of BW + FW of all cells in any row will all be the same. On the right side of the table are nine columns for strike weight levels spanning the studio strike weight range and the concert hall strike weight range. Each column contains rows of calculated strike weight ratios for values spanning the normal range. Strike weight ratio values are calculated using FW#7 and SW table values for C4 using the formula R=(BW+27-9)/SW. According to the equation of balance, for any cell, the product of the column SW x R + WBW9 will be equal to the sum of BW + FW for any given row. Every row is associated with strike weight and strike weight ratio pairings that are then associated with strike weight inertial qualities labeled in the left margin. The row with the benchmark of a medium D/BW/U of 50/38/26 g with the medium FW scale #7 defines a medium strike weight inertial quality. The high SW inertial quality row is defined by high D/BW/U of 55/43/31 with a medium FW scale #7. The low SW inertial quality row is defined by low D/BW/U of 45/33/21 with a medium FW scale #7. The low/medium/high SW inertial quality zones in the left margin column each span five rows. The calculated R values will prove out for any note across the scale even though the table values are calculated for C4. This is because FW and SW reference scales relate to each other mathematically (FW Ceiling or FW#9 = SW#9 x R5.6 + WBW9 - BW38).

An error exceeding 0.1 of calculated R is found at the near ends of the table because SW/FW reference scales diverge into the bass and converge into the treble, therefore the table is most accurate between C2 and C6.

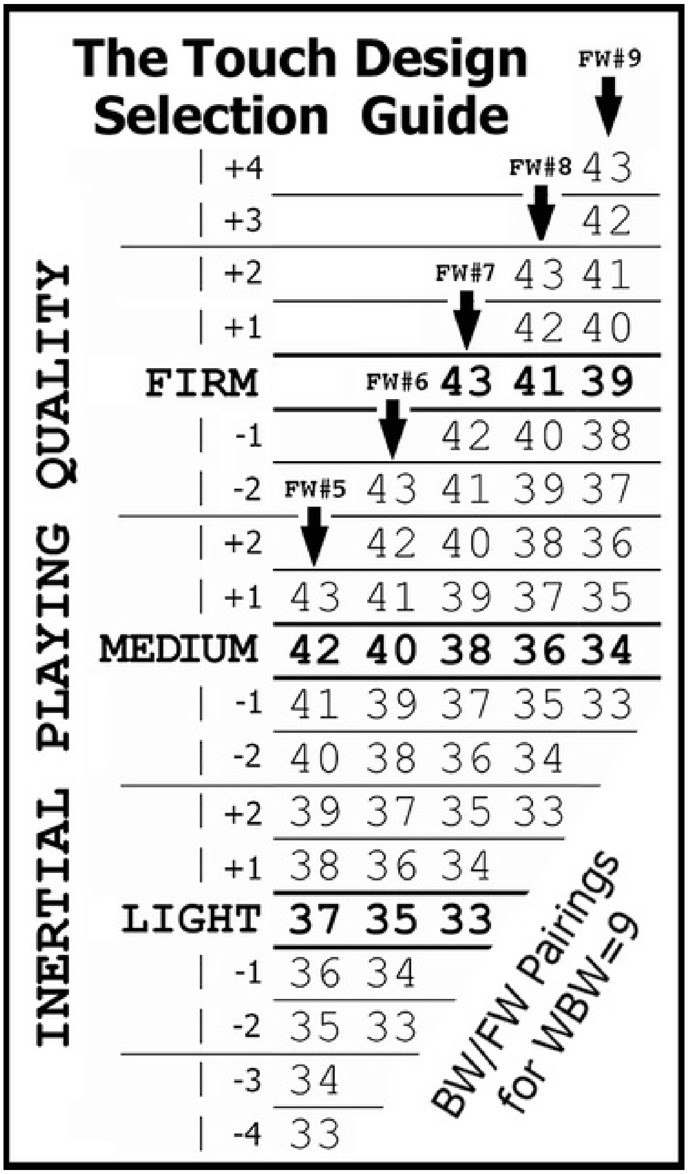

Figure 3: The Touch Design Selection Guide.

The Table of Touch Design Elements provides deeper insights into the underlying and overriding influence of the leveraged hammer weights, but it does not account for higher or lower keystick inertias, which play a minor but significant role in inertia. The Touch Design Selection Guide (Figure 3) provides BW and FW targets with an accounting for higher or lower front weight levels and keystick inertias. The Selection Guide uses the balance weight and front weight values from the Table of Touch Design Elements. The medium benchmark FW#7 column provides BW and FW pairings associated with the normal range of inertial playing qualities indicated in the left margin. Compensation for the higher front weights and associated higher keystick inertias in the FW#9 column may be approximately achieved by shifting the column up by one row. Compensation for the lower front weights and associated lower keystick inertias in the FW#5 column may be approximately achieved by shifting the column down by one row (Figure 2). Additionally, the Selection Guide includes all five FW scales that span the medium front weight zone.

Corrections are necessary for variations in wippen balance weight levels. Both tables are built on calculations using a medium WBW of 9 g, but normal WBW levels in pianos range from 8–10 g. For example, with a given pairing of BW+FW, if the WBW level is 8 g, the proportion of the sum resulting from the product of SW and ratio pairings is 1 g higher. This pushes the inertial quality rating into the next higher row. To compensate for this, the inertial qualities column in the left margin of both tables should be shifted down one row for a WBW level of 8 g or up one row for a WBW level of 10 g.

The tables are relevant to the standardized Érard-Hertz action design types of the modern era that do not incorporate the use of wippen support springs. Results are most relevant when arc geometry, hammer and wippen center pin elevations, spread, bore, magic line, and knuckle diameters are within normal standards. Also, it is important to consider that calculation of strike weight ratio uses SW and FW measures which are repeatable and reliable. The table calculations also use balance weight which is calculated from the less reliable and repeatable measures of up- and downweight. These two measures are more subjective and open to varying interpretations of hammer movement or subtle friction effects. Consider as well that the concept of balance weight is based on the assumption that friction is equal in either direction when measuring up- and downweight. This assumption has proven to be generally true, but exceptions of varying degree are normal, and this affects the accuracy of balance weight. Also, it is a fact that action ratios are not necessarily consistent from key to key because balance rail pins, capstans, and knuckles are not always in perfect alignment. Therefore, the best practice when using BW + FW targets for setting up and balancing an action is to rely on multiple sample notes to confirm and establish the average level across the keyboard. Comparing the strike weight ratio method to distance ratio methods, it has become evident over the years that the Spurlock/Erwin jig for determining the ratio of hammer to key travel produces similar results to the strike weight ratio method.

Circling back to the first article in this series, I stated, "It is not unusual to find well-voiced and regulated instruments with normal downweights that feel too heavy." We see this example in the Touch Design Selection Guide: A key with a #9 FW and a BW of 38 g produces a downweight of 50 g with a normal friction, but the Guide clearly puts the example in the High Inertial Playing Quality zone. The Table of Touch Design Elements and the Touch Design Selection Guide illustrate the reasons for high, medium, and low inertial playing quality. These are powerful tools based on empirical truths that are self-evident. They provide real world solutions for achieving any desired state of balance in the finished piano, using language that all piano technicians can understand and bring to their workbenches. ◻

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