Practical Touch™:
Rapid, Non-invasive Grand Touch Analysis

Mario Igrec, RPT, M.M.

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In Tune Press, LLC
www.pianosinsideout.com
+1 985 231-1248

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The Touch Challenge

Touch challenge in grand pianos

- "Action too heavy/light/fast/slow"
- "I want heavier action for practicing"
- "Doesn't feel right"
- "Why can't my piano play like xyz?"

What do you do?

How do you decide what to change?

Should you modify action parts?

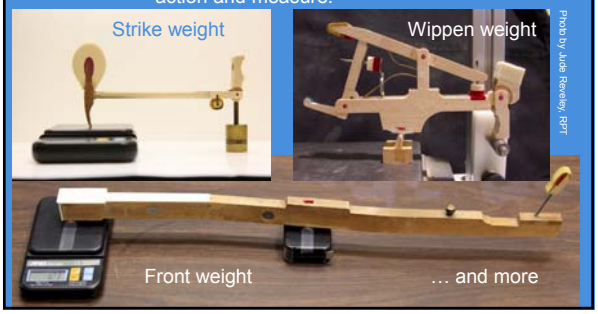
Traditional ways of adjusting touch

- **Friction**, key **leads**
- **Wippen helper springs**? **TouchRail**?
- **Hammers**:
  - Lighten or add weight? How much?
  - How heavy should replacement hammers be?
- **Key ratio? Action ratio?**

Do you know how to proceed?
Do you feel in control?
Are you satisfied with results?

Traditional ways of analyzing touch

- To analyze touch, you need to dismantle the action and measure:



Traditional ways of analyzing touch

- This yields accurate results but:
  - Is invasive: requires dismantling the action
  - Requires hours of work, adding time and expense
  - Not easily portable
  - Removing the parts can change voicing and regulation
  - Can't quote the job immediately

Modern touch solutions

- 1969: **Don Galt** defined balance weight and friction (PTJ 4/1969)
- 1990s: **David Stanwood**, RPT:
  Touch metrology, Precision Touch Design
  - Kit available through Pianotek ($280)
- 2000s: **Darrell Fandrich**, RPT and **John Rhodes**, RPT:
  Mushroom weights
  - Weight Bench™ kit/software ($700+ http://fandrich.com)
- 2000s: **Nick Gravagne**, RPT:
  Action geometry calculator ($150 http://www.gravagne.com)
- 2012: **Fandrich-Rhodes:** Inertial Touch Force (ITF)
  - Hammer mass contributes 80% to inertia; key leads 10%
- 2013: **Rick Voit:** Inertial Key Return,
  Key Force One--an elaborate, expensive device
- 2013: **PTDAE**: Precision Touch Design certification, training
- … but nobody has offered a quick and simple method for evaluating and analyzing touch

Modern touch solutions

- These solutions take the perspective of a total action rebuilding
- You don't know what to expect until you dismantle the action

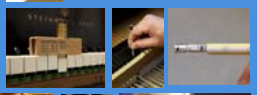
The Practical Touch alternative

Prop up the pedal and measure on F3:

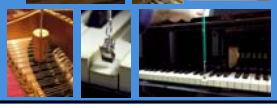
1. Downweight (**DW**), upweight (**UW**)
   (calc balance weight **BW**, friction **F**)

2. **Blow distance**

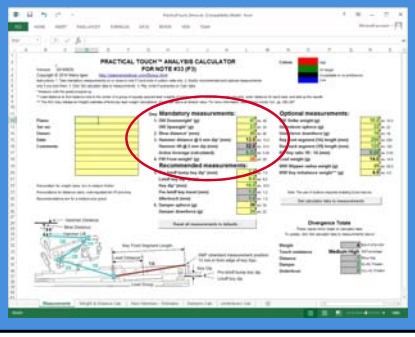
3. **6 mm dip hammer distance**
   (calc **leverage ratio**)



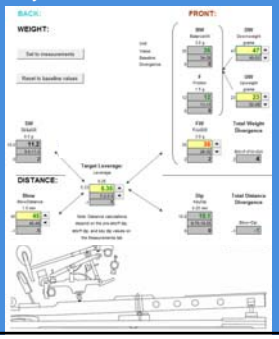
4. Front weight (**FW**)



Enter the measurements in yellow fields:



Play with the numbers in the calculator:



… and you are ready to discuss solutions and give price quote to the customer …

Summary

- **4 measurements** (10 minutes) on 1, 2, or 3 notes around F3
  - Can be done in each new piano you tune
- **Analysis software calculator**:
  - Color-coded: low; medium low; on target; medium high; high
  - Instantly know what you're getting into
  - Instantly know what to tell the customer
- **No disassembly**
  - No action or parts removal
  - Large lid can remain closed

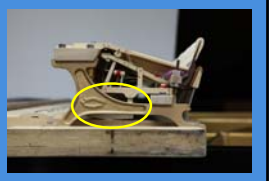
Practical Touch Analysis components

- **Free method**
- **Free one-note analysis calculator**
  (www.pianosinsideout.com/Bonus)
  - Microsoft Excel
  - Apple Numbers on iPad
  - Other tablets
- **Toolkit** ($100)
  Request invoice through www.pianosinsideout.com/Bonus
- **Adjustment calculator** under development

If interested, sign up for the mailing list at:
www.pianosinsideout.com/Bonus

Preconditions and limitations

- **Friction** must be < 15 g
  and parts should not rub
- If wippen attached to key, must **detach** first
  (remove the action first)



- For accurate **distance predictions**,
  (blow distance, key dip)
  good regulation
- **Escapement** (pre-letoff bump) must start *after* 6 mm key travel

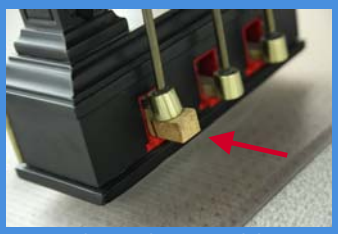
Where to Go Next

- In US: **David Stanwood**:
  Training, certification (http://www.stanwoodpiano.com/)
- In Europe: **PTDAE**
  Precision Touch Design Academy Europe
  (http://ptdae.com)
- Stay tuned for **Practical Touch Adjustment** system (pianosinsideout.com/Bonus)

Measurements: a closer look

Prepare

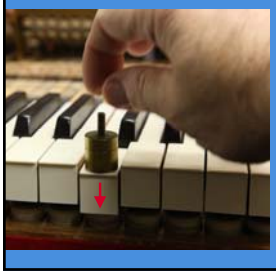
- First, **prop the pedal** up with a wedge

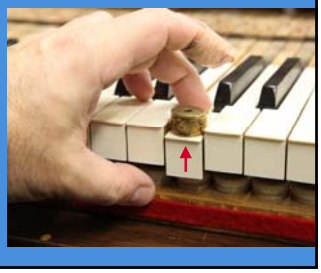


… or wedge up the trapwork lever
… or clamp the damper up

Step 1

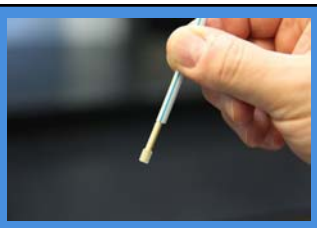
Measure Downweight (**DW**) from c. 4 mm dip,
Upweight (**UW**) between 7 and 4 mm dip
We want all measurements to be close to the 6 mm dip

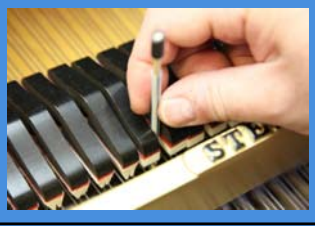




Step 2

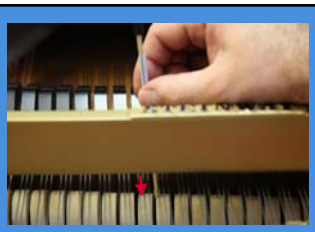
Measure **blow distance**: Hold straw and hammer dip stick, insert between dampers catching the straw on the string

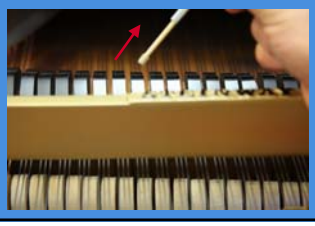




Step 2

Measure **blow distance**: Drop plunger onto hammer, then pinch straw, hold, and pull up.

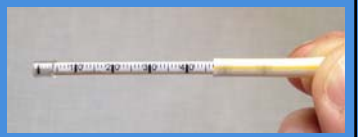


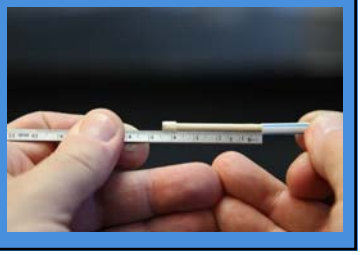


Step 2

Measure **blow distance**: read scale on the stick.

If you use a ruler, deduct 1 mm (string thickness).



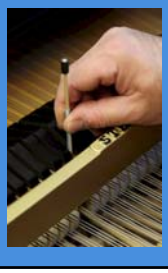


Step 3

Place the **6 mm dip tool** on key 13 mm in from key top edge (Standard Measurement Position), pinch straw and insert between dampers

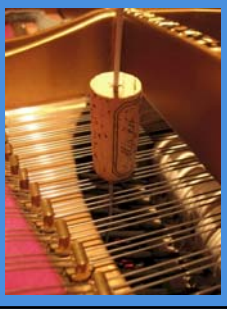
Step 3

Drop plunger onto hammer, pinch straw and remove,
then read the distance (if against a ruler, deduct 1 mm)



Step 4

Lift the **hammer and wippen** away from the key:

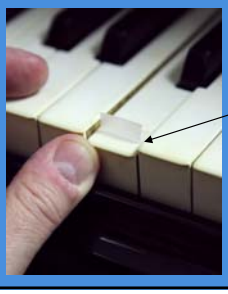


- Hook repetition lever behind post, pull up, and slide cork down.
- Don't displace the repetition spring!

Idea and photo
by Allen Wright, RPT

Step 4

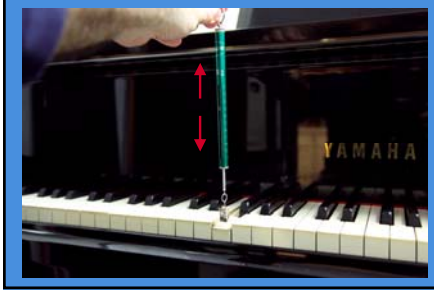
… then measure the front weight (**FW**):
Stick Scotch tape to key top at
Standard Measurement Position (SMP)

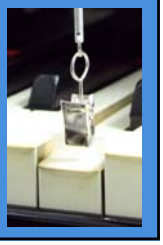


SMP: 13 mm in from edge

Step 4

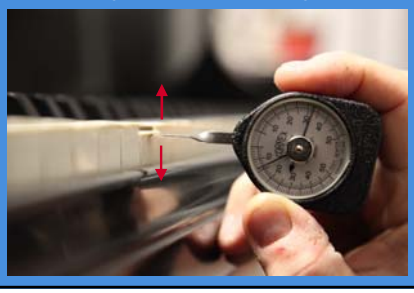
… then measure the front weight (**FW**):
Hook gauge, lift and lower the key.
FW is the average of the two readings.





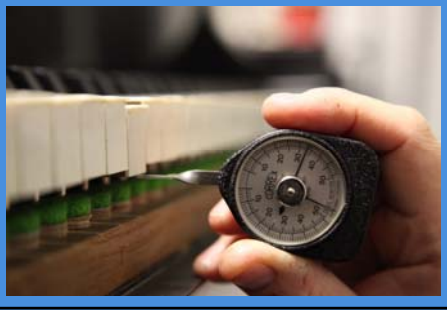
Step 4

… or measure the front weight (**FW**)
under the key top lip:
FW is the average of the up and down readings *plus 1-2 grams*.



Step 4

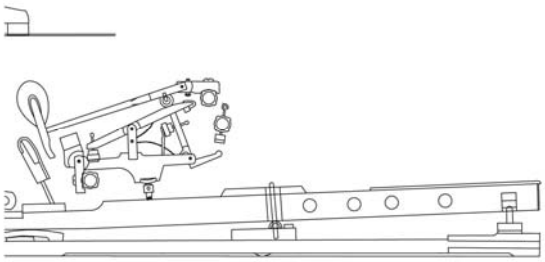
… or measure the front weight (**FW**) under the key
(under Standard Measurement Position):



How the Grand Action Works

What is the piano action?

- A set of levers between the finger and the hammer:



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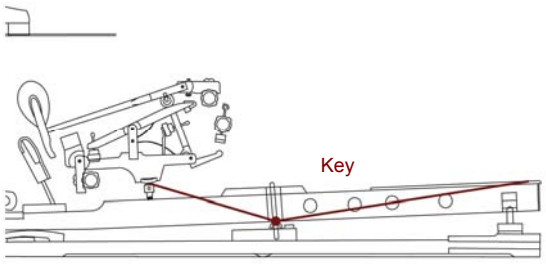

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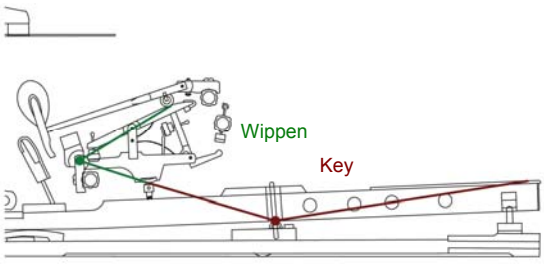

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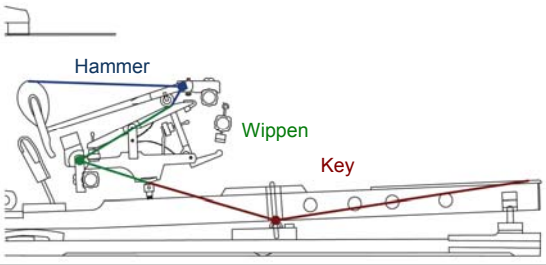
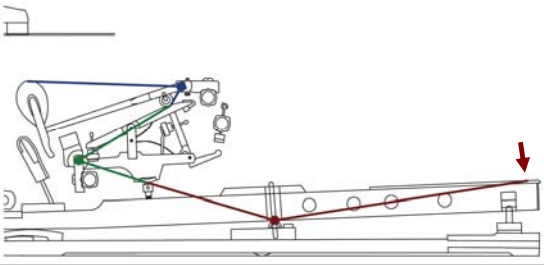


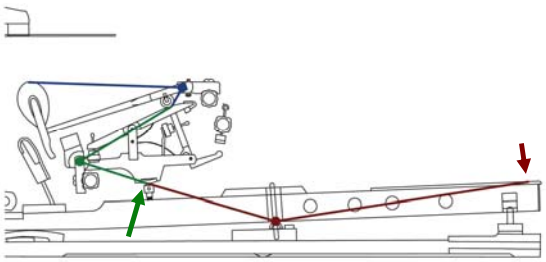
How do the levers work?

- Applying force to the key:



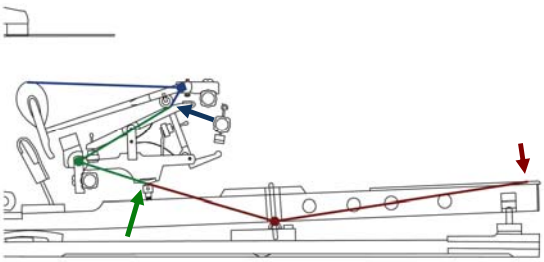
How do the levers work?

lifts the wippen:



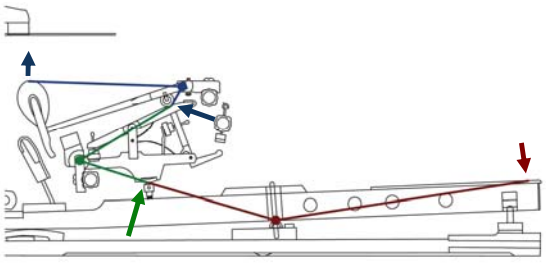
How do the levers work?

which pushes the shank up:



How do the levers work?

and lifts the hammer:



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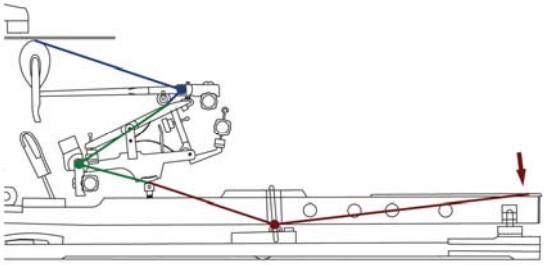

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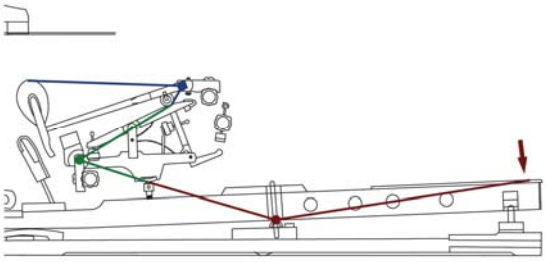

How do the levers work?

The angles within each lever don't matter.
The action could be laid out like this:

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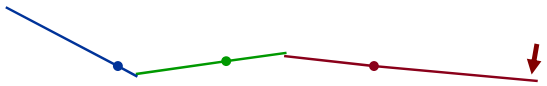
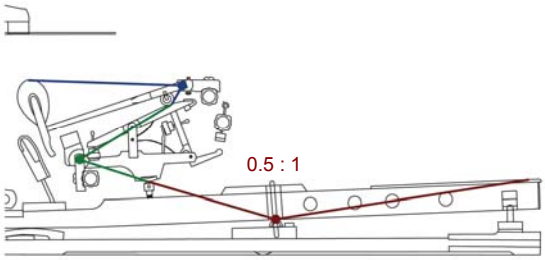


How do the levers work?

- The levers have different ratios, which can be measured geometrically:



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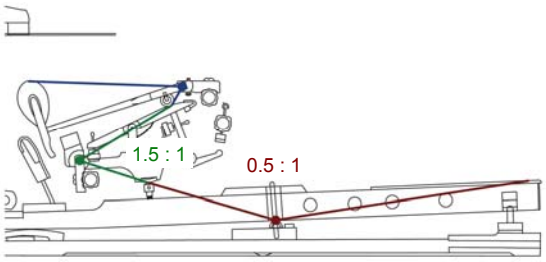

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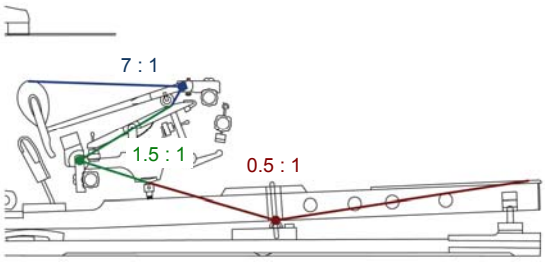
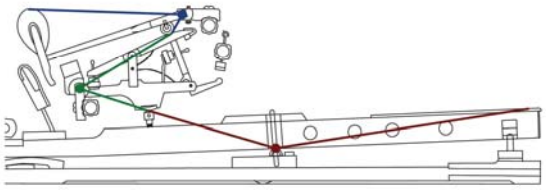


How do the levers work?

- By combining them:

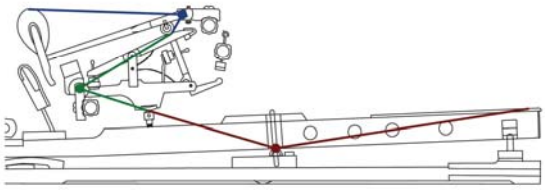
7 : 1 x 1.5 : 1 x 0.5 : 1



How do the levers work?

and reducing:

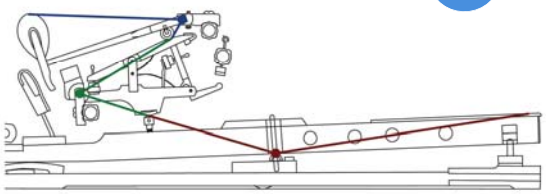
7 x 1.5 x 0.5



How do the levers work?

we can calculate the total **geometric leverage ratio**:

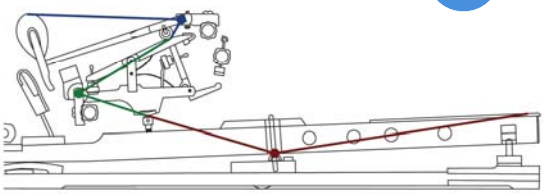
7 x 1.5 x 0.5 = 5.25 : 1



How do the levers work?

How does the **geometric leverage ratio** apply to force?

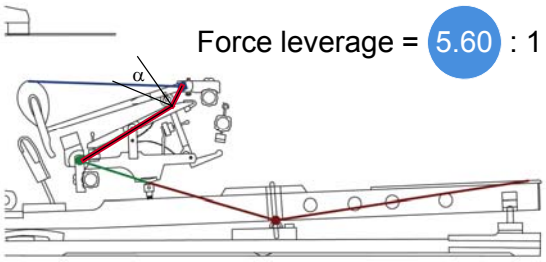
7 x 1.5 x 0.5 = 5.25 : 1



How do the levers work?

Force leverage ratio is higher at rest due to the angle between the wippen and hammer levers:

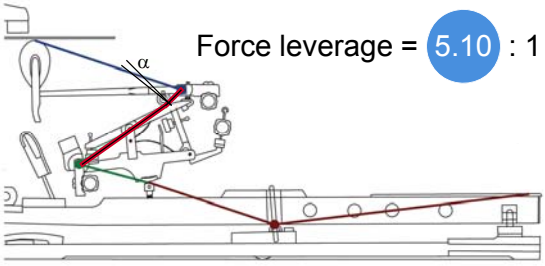
Force leverage = 5.60 : 1



How do the levers work?

… and decreases toward escapement as the angle gets reduced:

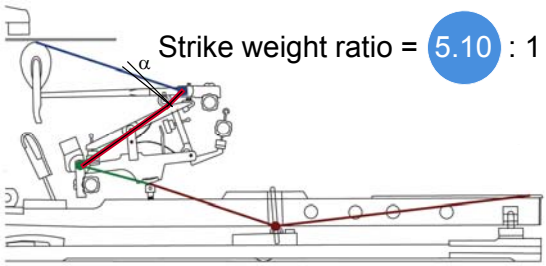
Force leverage = 5.10 : 1



How do the levers work?

Force leverage is almost identical to Stanwood's **strike weight ratio**.

Strike weight ratio = 5.10 : 1



How do the levers work?

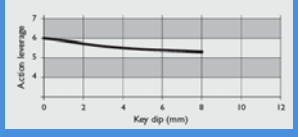
The reduction in force leverage ratio corresponds to the reduction in hammer travel during key stroke:

For key travel 0-2 mm, hammer travels **11.5 mm**

For key travel 6-8mm, hammer travels **9 mm**

Action Leverage Results
for action in Figure 192 on page 78

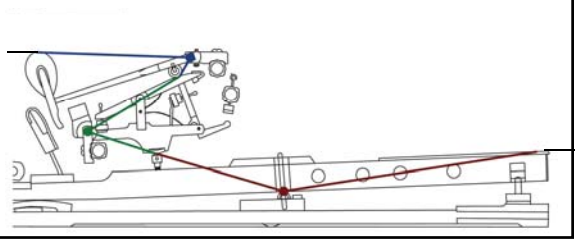
Key Travel	Angle α	Comparing Hammer and Key Travel: Hammer Travel	Comparing Hammer and Key Travel: Leverage	Parts Measured Leverage
0 mm	29°	0.0 mm	?	6.0
2 mm	24°	11.5 mm	5.75	5.78
4 mm	19°	22.0 mm	5.50	5.58
6 mm	14°	32.5 mm	5.42	5.44
8 mm	10°	41.5 mm	5.19	5.36



From *Pianos Inside Out*, p. 284.

How do the levers work?

We measure **force leverage ratio** by depressing the key a known amount and measuring how far the hammer rises:



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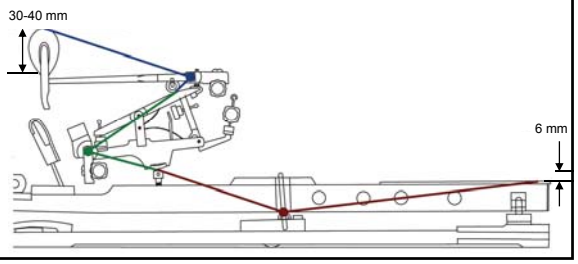
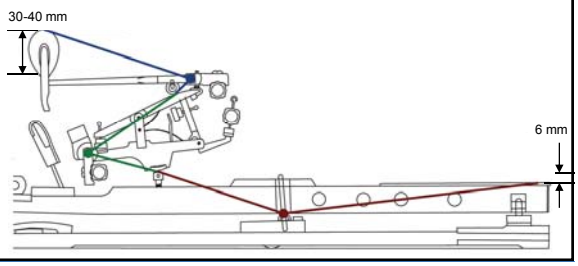


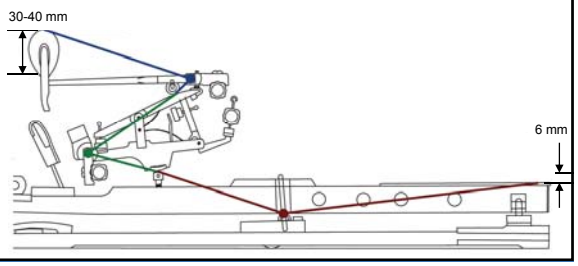
How do the levers work?

In Practical Touch we depress the key 6 mm and get an *average* of ratios between 0 and 6 mm key dip.



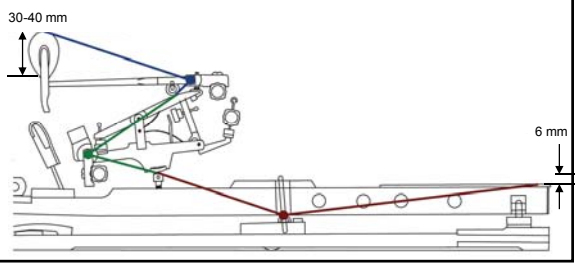
How do the levers work?

Example 1:
30 mm : 6 mm = 5.0 : 1 avg. ratio



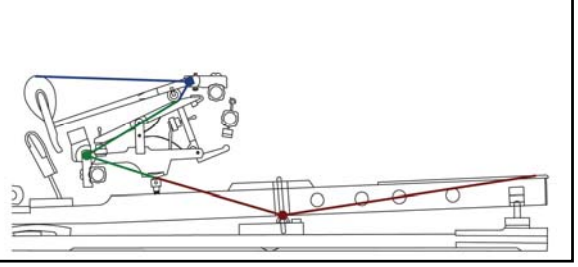
How do the levers work?

Example 2:
36 mm : 6 mm = 6.0 : 1 avg. ratio



Action as a single lever

- To better visualize the action leverage ratio, let's reduce the action to a see-saw:

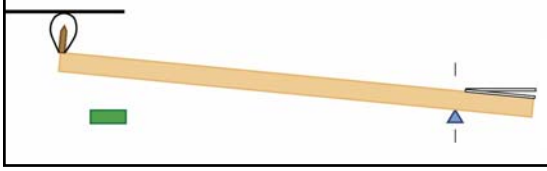


Action as a single lever

… or a very long key with the fulcrum (axis of rotation) far off center:

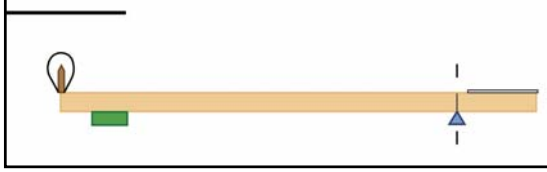
Action as a single lever

… or a very long key with the fulcrum (axis of rotation) far off center:



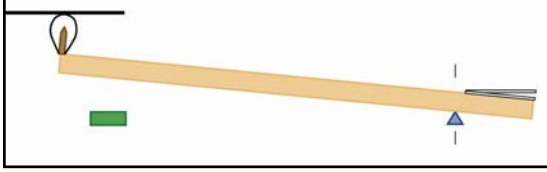
Action as a single lever

… or a very long key with the fulcrum (axis of rotation) far off center:



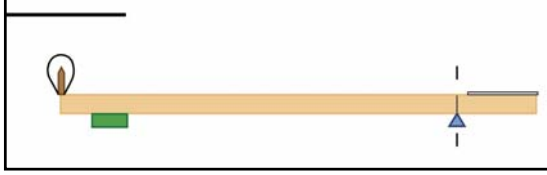
Action as a single lever

… or a very long key with the fulcrum (axis of rotation) far off center:



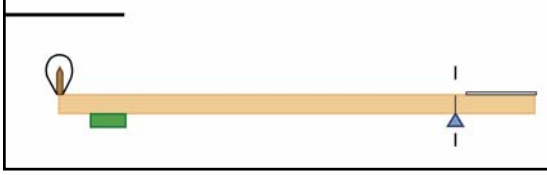
Action as a single lever

… or a very long key with the fulcrum (axis of rotation) far off center:



Action as a single lever

… by observing the weights and distances on either end:



Action as a single lever

Our extra long key translates:

Action as a single lever

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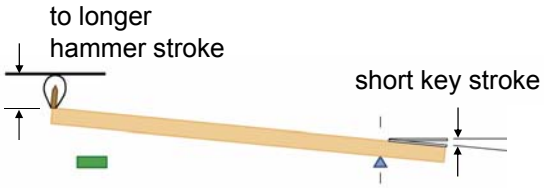
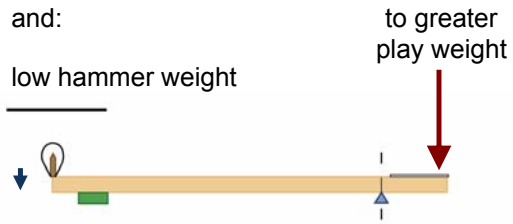


Action as a single lever

Our extra long key translates:

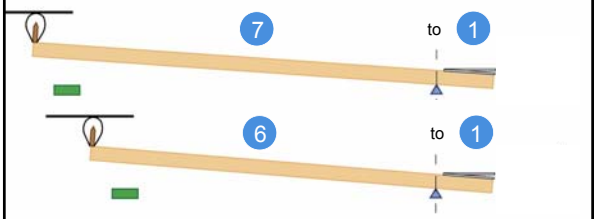


Action as a single lever

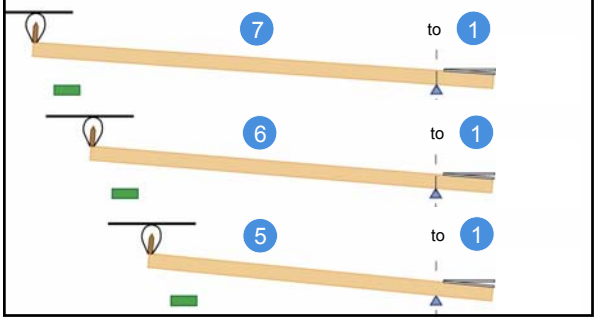
We can measure one end and calculate the other

In mid-19th century, the leverage was:

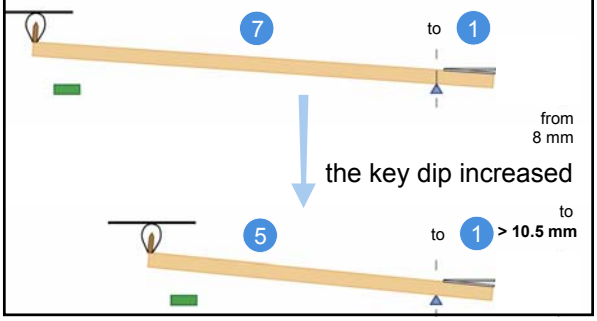
By the 1920s, the leverage decreased to:



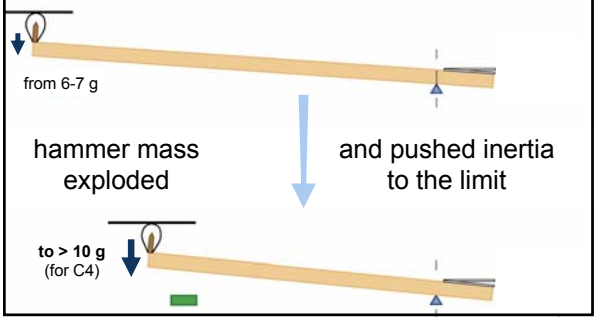
and in pianos made today the leverage is as low as:



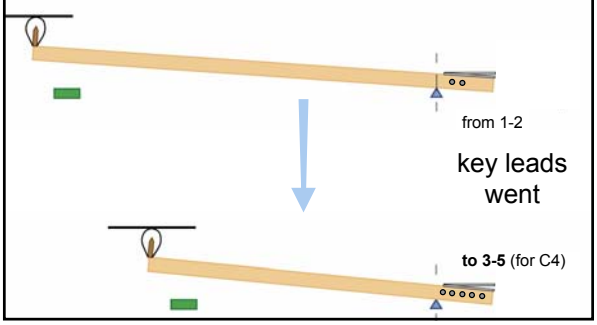
As the action leverage shrunk:



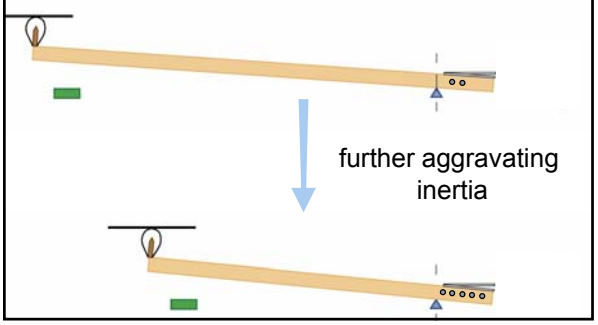
As the action leverage shrunk:



As the action leverage shrunk:



As the action leverage shrunk:



Why did action leverage shrink?

- Since Beethoven (c. 1800), race for loudness
- Scale tensions: 2 tons to >20 tons by 1880
- Bellies got stiffer and heavier
- Had to increase the hammer:
  - Mass
  - Felt density and tension
- For the player to move the added mass, had to:
  - Lower action leverage ratio
- Consequence:
  - Greater key dip, higher sharps
  - More key leads
  - The need for wippen assist springs, TouchRail, magnets, etc.

Why Use Balance Weight?

Why use balance weight?

- **Balance weight** (**BW**) is the average of (halfway between) downweight (**DW**) and upweight (**UW**):

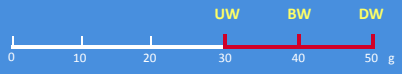
Why use balance weight?

- **Balance weight** (**BW**) is the average of (halfway between) downweight (**DW**) and upweight (**UW**):

- Without friction:
  - Depress the key with 40.001 g
  - Return the key with 39.999 g
- With 10 g friction:
  - Depress the key with 40 + 10 = 50 g
  - Return the key with 40 – 10 = 30 g
- With 20 g friction:
  - Depress the key with 40 + 20 = 60 g
  - Return the key with 40 – 20 = 20 g

Why use balance weight?

- **Balance weight** (**BW**) is the average of (halfway between) downweight (**DW**) and upweight (**UW**):

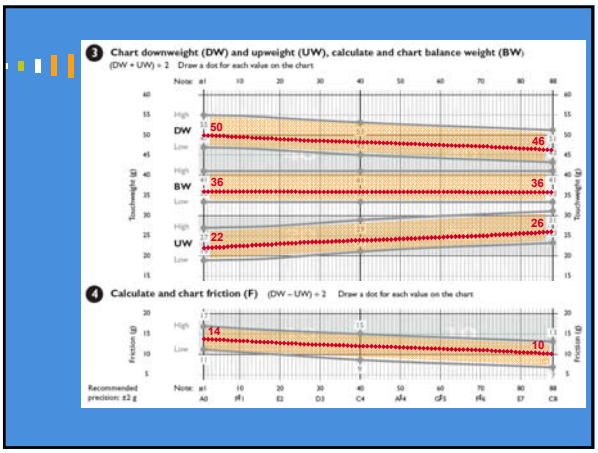


The math is:

BW = (DW + UW) / 2
BW = (50 g + 30 g) / 2
BW = 80 g / 2
BW = 40 g

Why use balance weight?

In an ideal world, **Friction** would progress smoothly throughout the keyboard.



Why use balance weight?

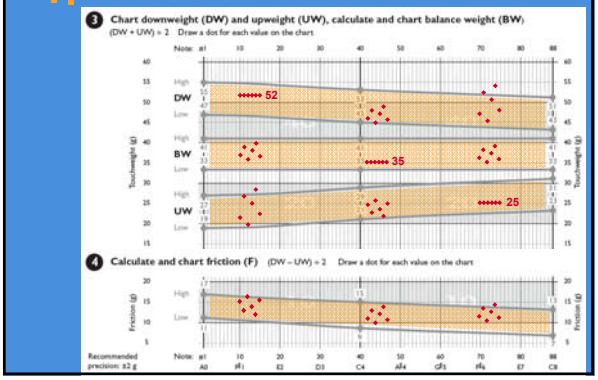
In real world, even in best grands **Friction** varies by 2-4 g. In older grands, by 4-8+ g.

Remember, friction changes over time.

How does uneven friction affect touch if we aim for a smooth:

- DW
- BW
- UW?

Why use balance weight?



Why use balance weight?

- If DW is consistent, UW varies by **twice as much** as BW
- If UW is consistent, DW varies by **twice as much** as BW
- If BW is consistent, DW and UW vary by **same amount**

Why use balance weight?

- **Friction** (**F**) is half the difference between downweight and upweight:

  F = (DW - UW) / 2

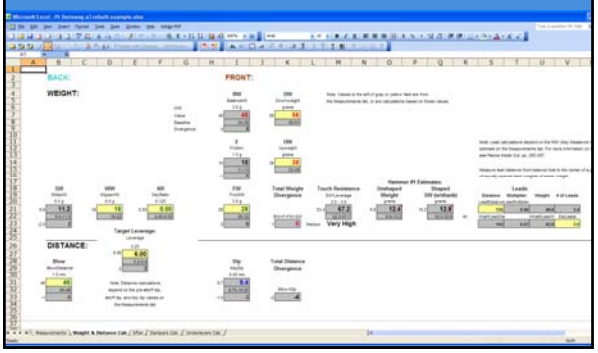
- Friction:
  - Turns BW into DW and UW
  - Makes swing door harder to push than return
  - Makes clutch hard to push than return
- Even friction = consistent DW, UW

Scenarios

Scenario 1: 1920 Steinway A III rebuilt

- Action rebuilt
- Complaints:
  - Plays like a truck
  - Feels spongy
  - Hurts hands
  - Can't play softly
- Large, wide hammers
- Shallow key dip
- Action parts high quality
- Keys feel sluggish
- Backaction heavy, may have high friction

Scenario 1: 1920 Steinway A III rebuilt



Scenario 1: 1920 Steinway A III rebuilt

What are our options?

- More leads in keys?
- Wippen helper springs, Hans Velo's magnets, Scott Jones' TouchRail?
- Change action leverage?
- Lighten hammers?

Scenario 1: 1920 Steinway A III rebuilt

The wonder of action leverage ratio…

Like gears in your car's transmission:
reduce speed to climb a steeper hill
(lift heavier hammer)

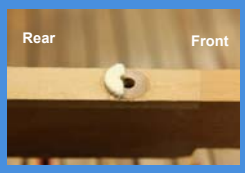
Effects of action leverage:

Inversely proportional:	
Blow distance	Key dip
SW (strike weight)	BW (balance weight) + F (friction) + FW (front weight)
Proportional:	
Inertial resistance	

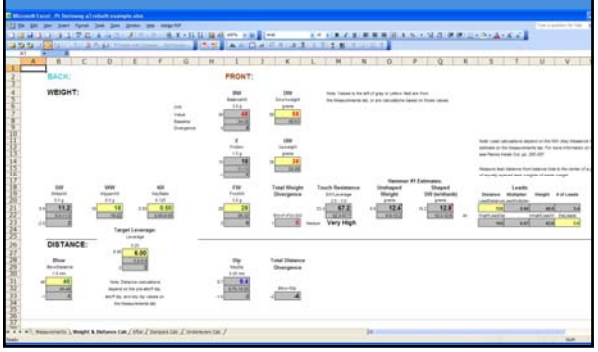
Scenario 1: 1920 Steinway A III rebuilt

To reduce action leverage:

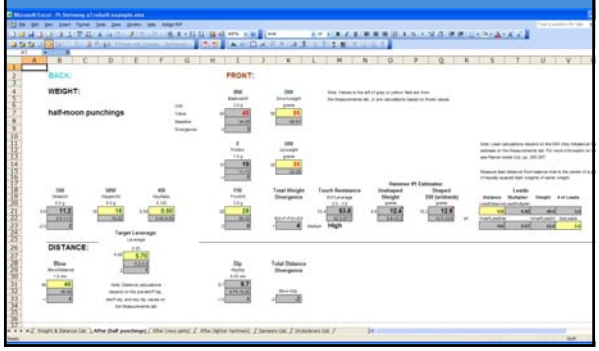
- Half-moon punchings
- Move knuckles away from center pins
- Replace shanks (and wippens)
- Move key capstans toward balance rail
  (and move wippen heels?)



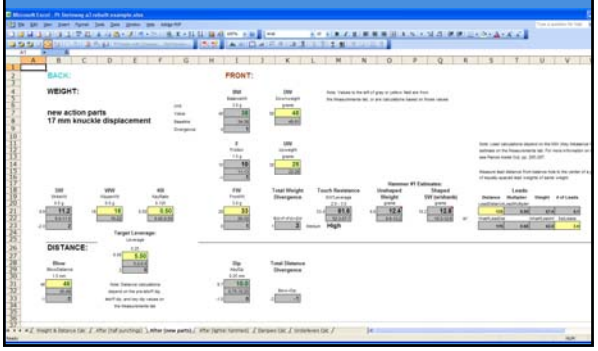
Scenario 1: 1920 Steinway A III rebuilt **before**



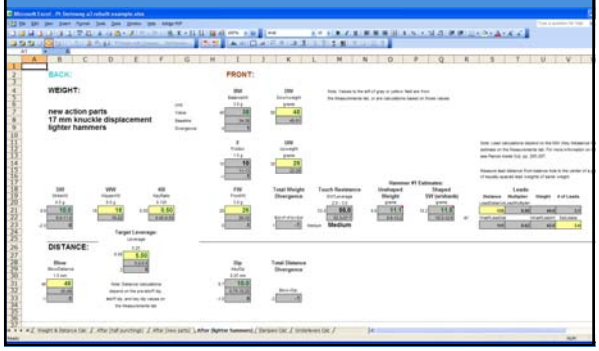
Scenario 1: 1920 Steinway A III rebuilt **after** w/HALF-MOON PUNCHINGS



Scenario 1: 1920 Steinway A III rebuilt **after** w/17 mm KNUCKLE SHANKS



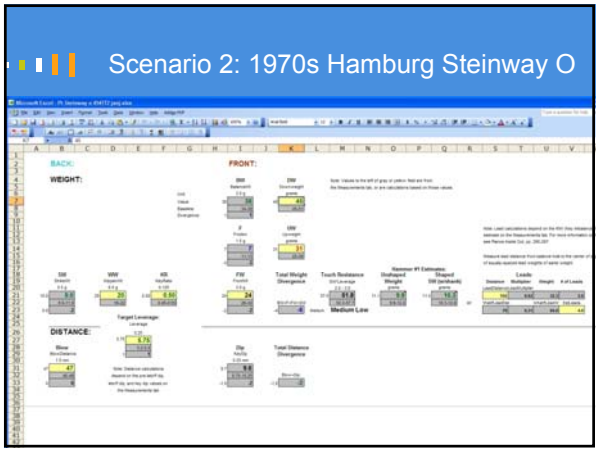
Scenario 1: 1920 Steinway A III rebuilt **after** w/LIGHTER HAMMERS



Scenario 2: 1970s Hamburg Steinway O

- Modern Hamburg Steinway with 17 mm knuckle distance, in good overall condition.
- Tone strident and somewhat nasal.
- Hammers filed multiple times.
- Action feels light.

Scenario 2: 1970s Hamburg Steinway O

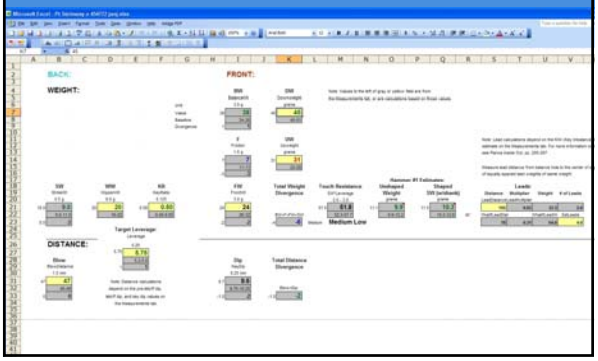


Scenario 2: 1970s Hamburg Steinway O

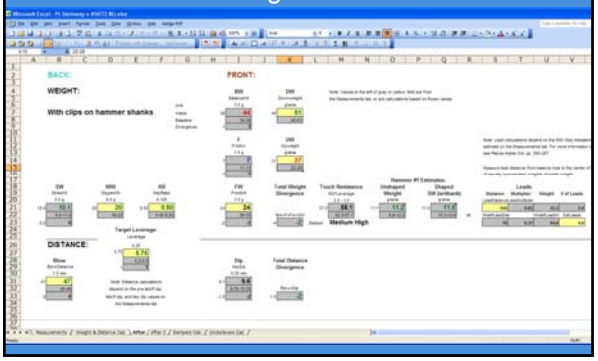
Solutions:

- Temporarily increase hammer weight with clips, lead wire
  This will change the tone
- Replace hammers
  (use the Practical Touch calculator to determine desired SW and leverage by playing what-if scenarios with FW).
- Repin or replace parts to increase friction
- Reduce action leverage (with half-moon punchings?)

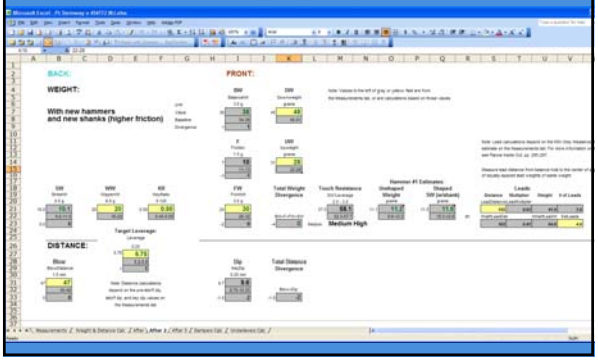
Scenario 2: 1970s Hamburg Steinway O **before**



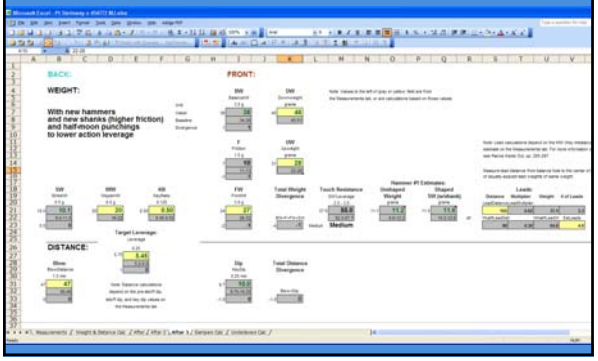
Scenario 2: 1970s Hamburg Steinway O **after** WITH 1 gram CLIPS



Scenario 2: 1970s Hamburg Steinway O **after** WITH NEW HAMMERS



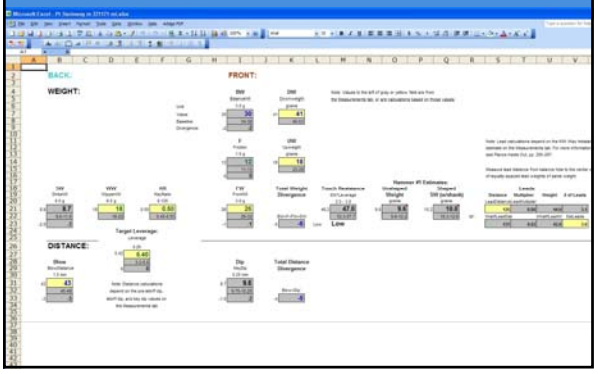
Scenario 2: 1970s Hamburg Steinway O **after** WITH HALF PUNCHINGS



Scenario 3: verdigris 1924 Steinway M

- Original-condition piano
- Worn, reshaped hammers
- Action stuck from verdigris, candidate for new parts
- After defrictioning, action is light, flyaway
- Action leverage ratio is surprisingly low

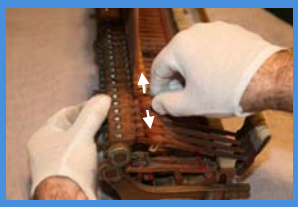
Scenario 3: verdigris 1924 Steinway M



Scenario 3: verdigris 1924 Steinway M

Solution:

- Temporarily treat all center pins with Protek CLP, break friction by moving parts along center pins



Scenario 3: verdigris 1924 Steinway M

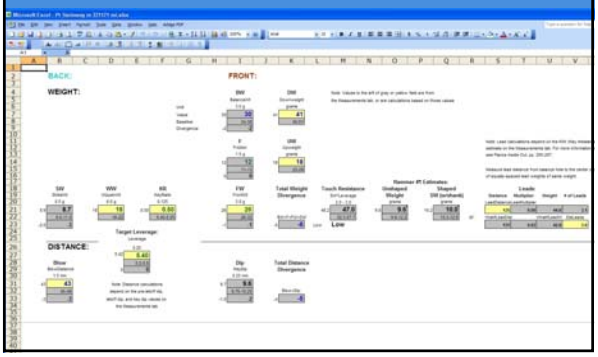
Solution:

- Temporarily treat all center pins with Protek CLP, break friction by moving parts along center pins
- Add 2 clips to increase hammer weight (graduate clips down to 1 clip in treble)

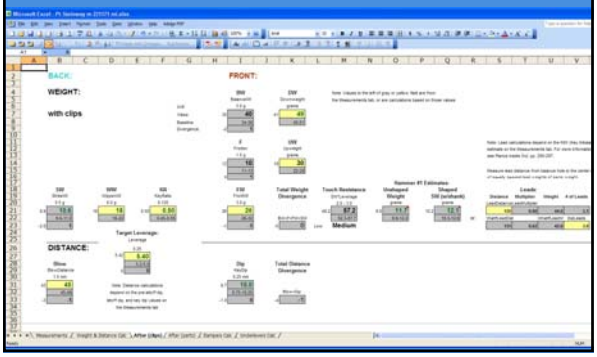
or:

- Install replacement shanks with knuckles at 15.5-16.0 mm from center pins
- Install 16-17 lb (size 4) replacement hammers (unshaped hammer #1=c. 10.5 g) if tonally justified
- Adjust touch with additional leads as needed

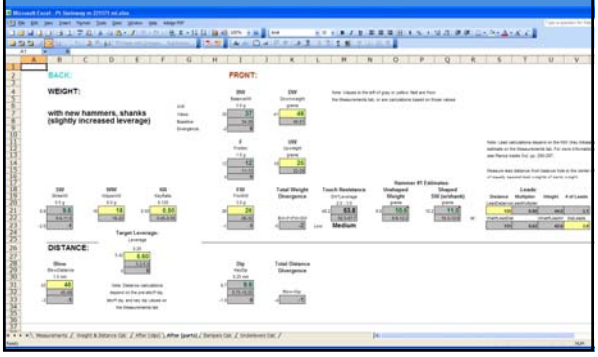
Scenario 3: verdigris 1924 Steinway M **before**



Scenario 3: verdigris 1924 Steinway M **after** WITH CLIPS



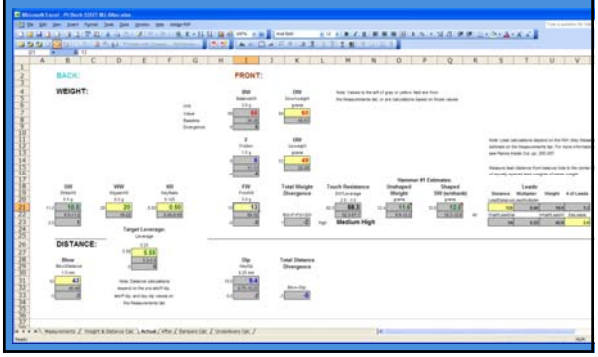
Scenario 3: verdigris 1924 Steinway M **after** WITH NEW PARTS



Scenario 4: 1910 Bechstein 220 with new action

- Action and keyboard were replaced in 1970s?
- Modern-size hammers installed
- Very few leads in keys
- Complaints:
  - Action uneven
  - Action hard to control in *pp*
  - Action springy, "too fast"
- The owner likes the tone (strong, modern)

Scenario 4: 1910 Bechstein 220 with new action



Scenario 4: 1910 Bechstein 220 with new action

Solutions:

- Keep the hammers
- Keep the parts
- Increase friction?

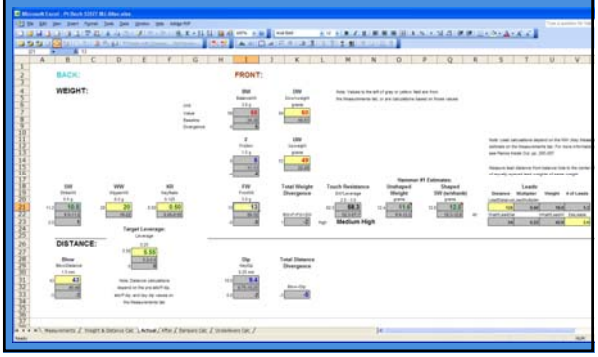
and:

- Install wippen assist springs ("original" feel)

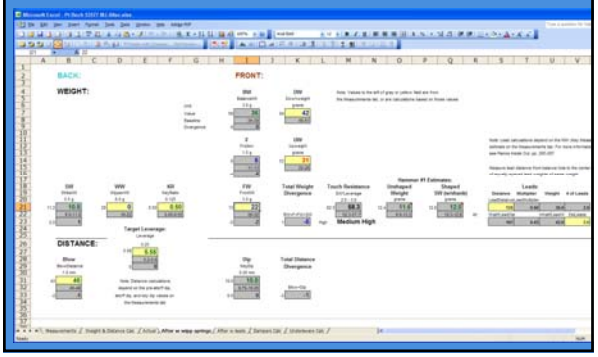
or:

- Add key leads (more modern feel)
- Increase key dip
- Increase blow distance

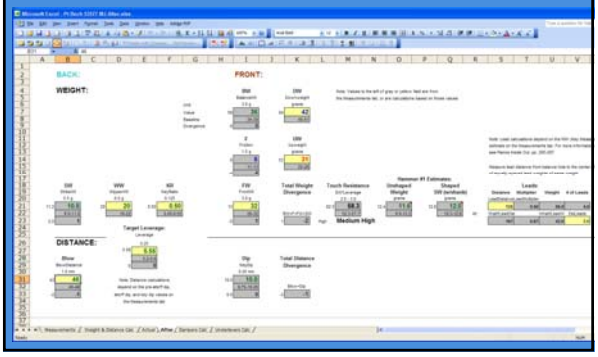
Scenario 4: 1910s Bechstein 220 with new action **before**



Scenario 4: 1910s Bechstein 220 with new action **after** w/WIPP SPRINGS



Scenario 4: 1910s Bechstein 220 with new action **after** w/LEADS



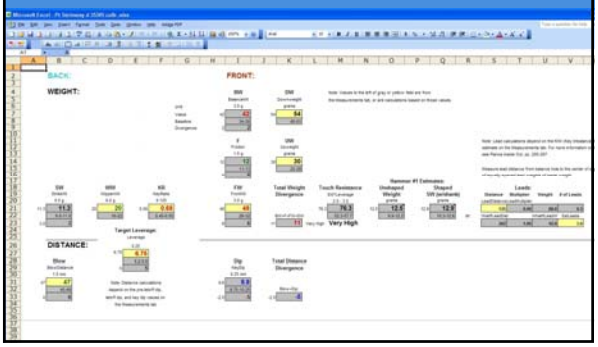
Scenario 5: 1878 Steinway concert grand with huge hammers

- 12 mm wide, size 6 modern kotibe molding Hamburg hammers installed
- Tone big, modern, but overwhelms the belly in *ff*
- New modern action parts with 17 mm knuckles
- Action feels heavy, inert, awkward
- Poor repetition

Note:

- Very high AR (6.7 : 1)
- Unusually high key ratio (0.68 : 1)

Scenario 5: 1878 Steinway concert grand with huge hammers



Scenario 5: 1878 Steinway concert grand with huge hammers

Solutions:

- Reduce hammer weight by thinning hammers

  (CAREFULLY use router or planer for already installed hammers, Spurlock jig for table saw for new hammers)

Scenario 5: 1878 Steinway concert grand with huge hammers

Solutions:

- Reduce hammer weight by thinning hammers

  or:

- Install lighter replacement hammers

  (but don't remove staples)

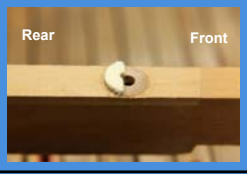
Scenario 5: 1878 Steinway concert grand with huge hammers

Solutions:

- Reduce hammer weight by thinning hammers

  or:

- Install lighter replacement hammers
- Reduce AR by reducing key ratio with half-moon punchings (this reduced AR by 0.3-0.4)



Scenario 5: 1878 Steinway concert grand with huge hammers

Solutions:

- Reduce hammer weight by thinning hammers

  or:

- Install lighter replacement hammers
- Reduce AR by reducing key ratio with half-moon punchings (this reduced AR by 0.3-0.4)
- Remove key leads to adjust BW, plug holes

Scenario 5: 1878 Steinway concert grand with huge hammers

Solutions:

- Reduce hammer weight by thinning hammers

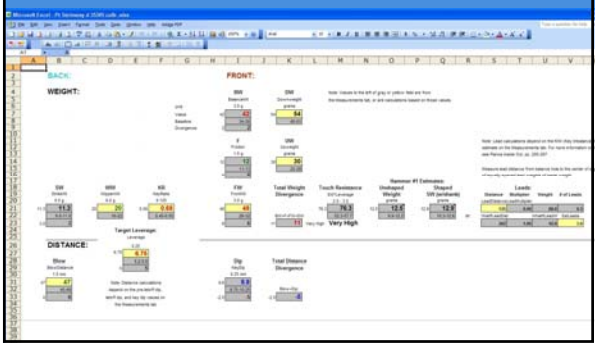
  or:

- Install lighter replacement hammers
- Reduce AR by reducing key ratio with half-moon punchings (this reduced AR by 0.3-0.4)
- Remove key leads, plug holes

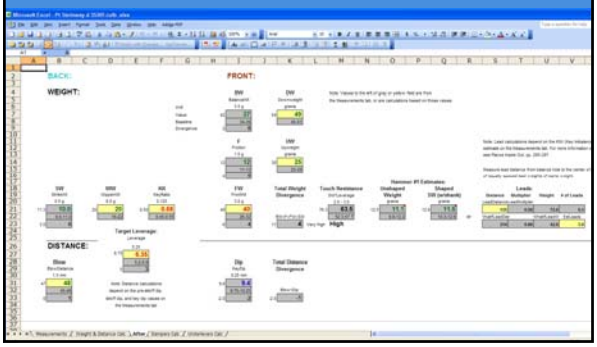
  and/or:

- Redesign, make new keyboard with lower KR?

Scenario 5: 1878 Steinway concert grand **before**



Scenario 5: 1878 Steinway concert grand **after**



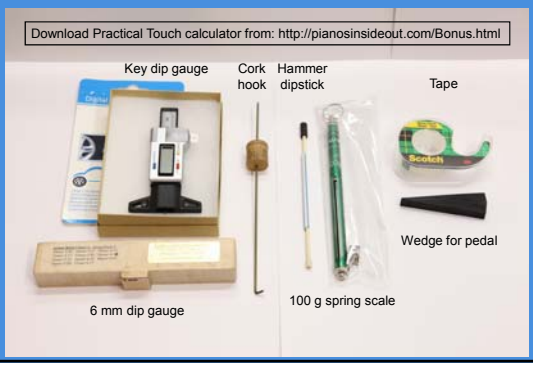
The Startup Toolkit

The startup toolkit

- Trend-setter in piano tech fashion:

The startup toolkit

Download Practical Touch calculator from: http://pianosinsideout.com/Bonus.html



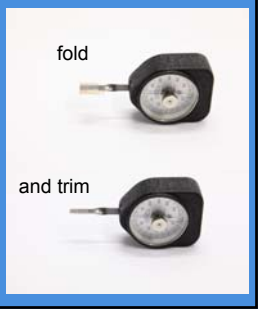
The startup toolkit

- Gauges and scales are calibrated
  unless otherwise noted
- Spreadsheet download:
  http://pianosinsideout.com/Bonus
- Send email to info@pianosinsideout.com
  to be notified when kit becomes available
- Kit will be available for purchase at
  www.pianosinsideout.com/Bonus

Additional tools (not included in the kit)

Mouse tape

- Reduce friction in gram gauges with PTFE mouse tape
  (or any thin "slick tape")

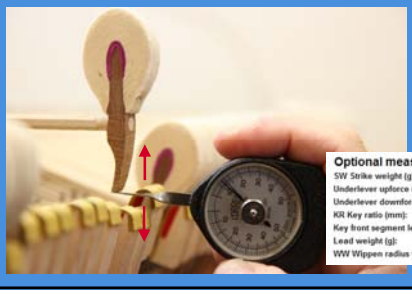


Mouse tape

Mouse tape ensures more precise measurements

Mouse tape

- Measure strike weight (**SW**) with gram gauge
  (shank horizontal)



Deduct 0.2-0.3 g and enter under Optional measurements

Optional measurements:

SW Strike weight (g):	9.6
Underlever upforce (g):	23
Underlever downforce (g):	17
Kit Key ratio (mm):	0.50
Key front segment length (mm):	250
Lead weight (g):	14.0
WW Wippen radius weight (g):	20.0

Dampers and Touch

Dampers and Touch

Remove wedge from under the pedal

Measure **damper up force**, **down force**

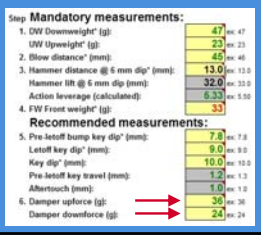
Dampers and Touch

Wedge felts should be *above* strings

(wedge felt friction can alter the reading by 10 g+)

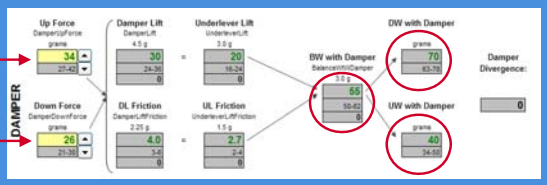
Dampers and Touch

Enter damper forces in the spreadsheet:



Dampers and Touch

The Dampers Calc tab:



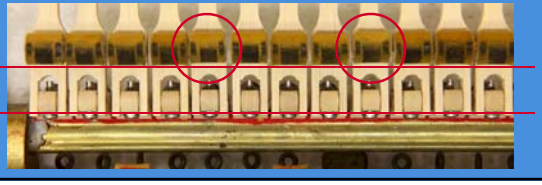
… shows increase in action touchweight

Damper friction contributes to action sluggishness (**UW** increases less than the **DW**)

Precision in Perspective

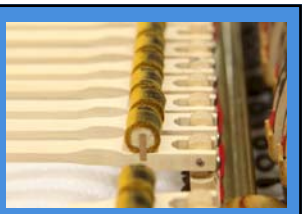
Precision

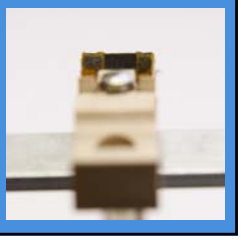
- Piano parts change
  - Wear, compacting
  - Swell and shrink
  - Felt and leather gives
  - Wood flexes
- Friction and touchweight
  - Depend on multiple felt-metal interfaces; metal oxidizes
- Leverage
  - Built-in deviations in tubular rails: flange angles



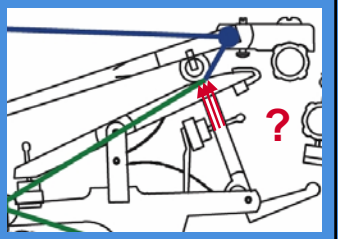
Precision

- Knuckles
  - Variations in size and position
  - Wear





Precision

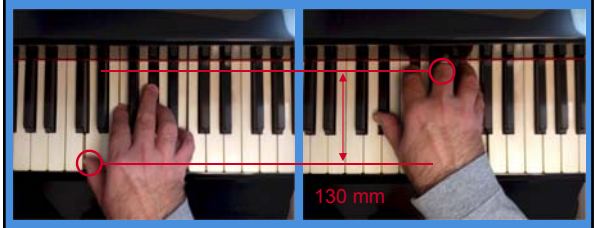


- Knuckles
  - Variations in size and position
  - Wear
  - Where exactly does the jack transfer force to knuckle?
- Balance punchings, half-round dowels, half-moon punchings
- Strike weight
  - Consistency important for inertia
  - Variations in finest pianos

Precision

- Consider **touch point** variations of which the pianist is not even aware:

1. 2.



Precision

- Taking the baseline configuration for note F3, the difference between 1) and 2) would be:

Photo 1:

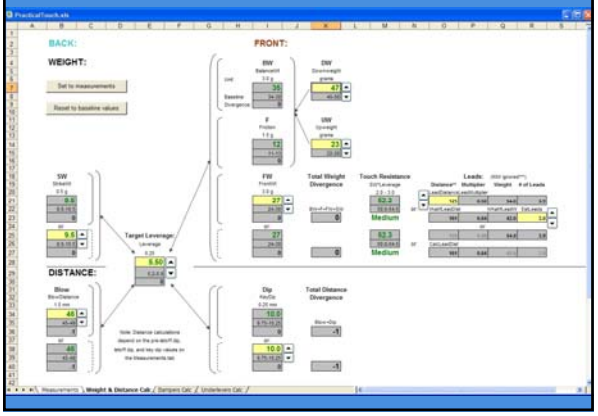
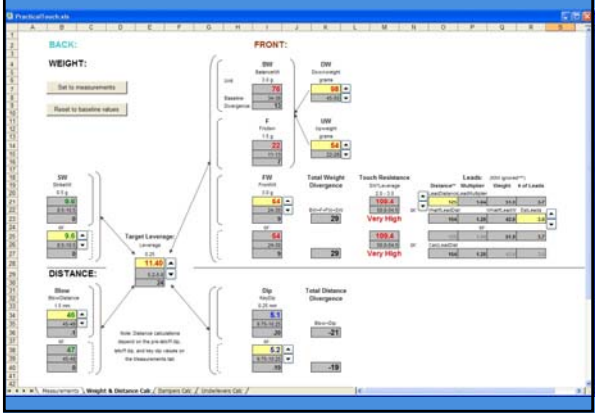


Photo 2:



Precision

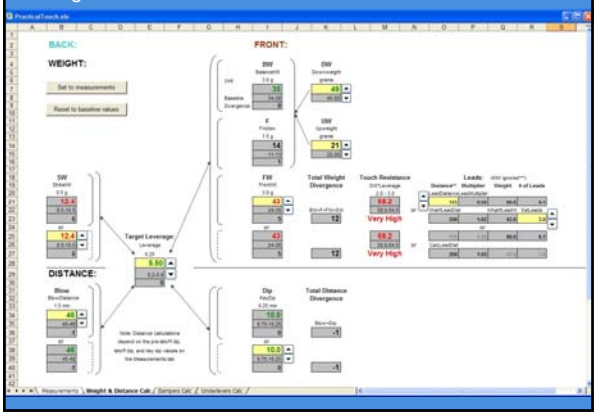
- Summary of changes due to moving the touch point 130 mm in from SMP on a key with a front segment length of 250 mm:
  - Balance weight **117%**: 35 to 76 g
  - Friction **83%**: 12 to 22 g
  - Weight divergence **29** points (0 to 29)
  - Touch resistance **109%**: 52.3 to 109.4
  - Front Weight **100%**: 27 to 54 g
  - Leverage **107%**: 5.5 to 11.4

Precision

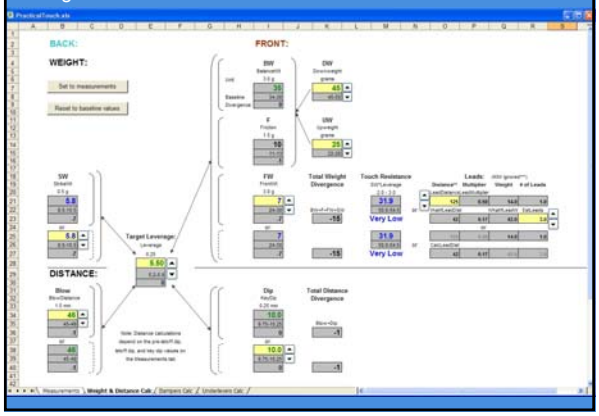
- Consider typical variations in **strike weight**:
  - Note #1: 12.4 g
  - Note #88: 5.8 g

We are comparing both to the baselines for note F3

12.4 g:



5.8 g:



Precision

- Summary of discrepancies between note #1 and note #88
  - Friction **-28.5%**: 14 to 10 g
  - Weight divergence **28** points (12 to -15)
  - Touch resistance **-53.2%**: 68.2 to 31.9
  - Front Weight **-83.7%**: 43 to 7 g

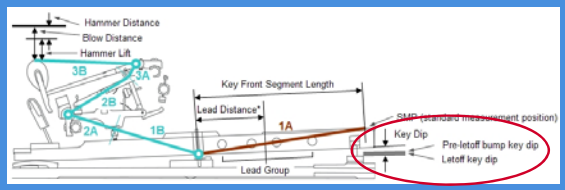
Precision

- Effect of **damper lift force** variations on touch
  in a well-maintained piano when playing without pedal:
  - Note #1:
    - DW: **28 g** (**60%**: 47 to 75 g)
    - UW: **20 g** (**87%**: 23 to 43 g)
  - Note #88:
    - DW: **0 g** (**0%**)
    - UW: **0 g** (**0%**)
  - Add the above to the strike weight (**SW**) discrepancies between notes #1 and #88 that we looked at in preceding slides.
  - … and consider that wedge dampers in the tenor section can increase the **DW/UW** spread by **5-10 more grams**

Optional Measurements

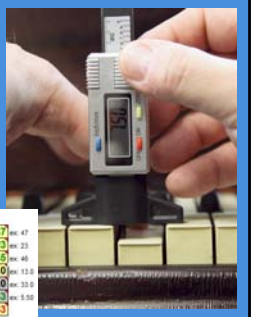
Optional

5. To refine key dip calculation:
Pre-letoff dip, **letoff dip**, **Key dip**



Optional

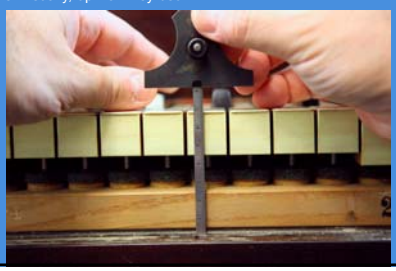
5. Measure **key dip**,
letoff dip,
pre-letoff dip
with key dip gauge
and enter in spreadsheet:



Step	Mandatory measurements:		
1.	DW Downweight* (g):	47	ex: 47
	UW Upweight* (g):	23	ex: 23
2.	Blow distance* (mm):	45	ex: 46
3.	Hammer distance @ 6 mm dip* (mm):	13.0	ex: 13.5
	Hammer lift @ 6 mm dip (mm):	32.0	ex: 33.0
	Action leverage (calculated):	6.33	ex: 5.50
4.	FW Front weight* (g):	33	
	Recommended measurements:		
5.	Pre-letoff bump key dip* (mm):	7.8	ex: 7.8
	Letoff key dip* (mm):	9.0	ex: 9.0
	Key dip* (mm):	10.0	ex: 10.0
	Pre letoff key travel (mm):	1.2	ex: 1.3
	Aftertouch (mm):	1.0	ex: 1.0
6.	Damper upforce (g):	36	ex: 36
	Damper downforce (g):	24	ex: 24

Optional

5. Measure **key dip**,
letoff dip,
pre-letoff dip
or visually, up from key bed



Optional

5. Measure **key dip**,
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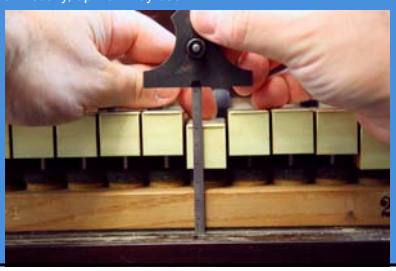
pre-letoff dip
or visually, up from key bed



Optional

5. Measure **key dip**,
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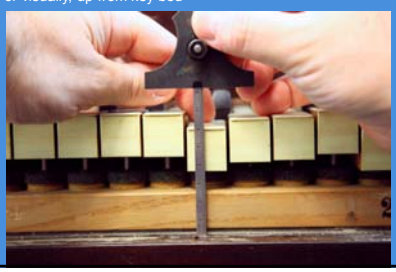
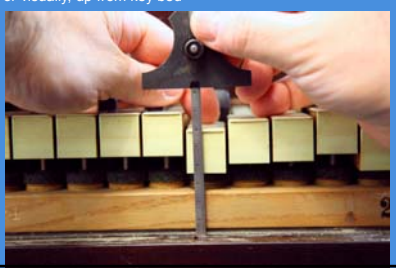
pre-letoff dip
or visually, up from key bed



Optional

5. Measure **key dip**,
letoff dip,
pre-letoff dip
or visually, up from key bed



Optional

5. Measure **key dip**, **letoff dip**, **pre-letoff dip**
or with tapered dip block

Optional

5. Measure **key dip**, **letoff dip**, **pre-letoff dip**
or with tapered dip block

Optional

6. For damper force calculations:
Measure **damper up force**, **down force**

Optional

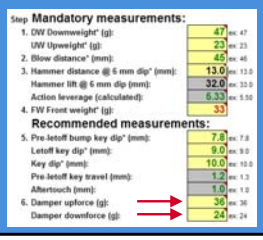
6. First **remove wedge** from under the pedal!

Optional

6. Wedge felts should be *above* strings
(wedge felt friction can alter the reading by 10 g+)

Optional

6. Enter damper forces in the spreadsheet:



Step	Mandatory measurements:		
1.	DW Downweight* (g):	47	ex: 47
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2.	Blow distance* (mm):	45	ex: 46
3.	Hammer distance @ 6 mm dip* (mm):	13.0	ex: 13.0
	Hammer lift @ 6 mm dip (mm):	32.0	ex: 33.0
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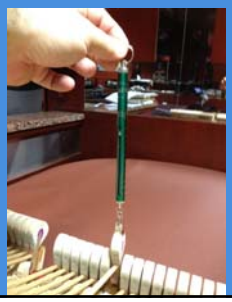
	Letoff key dip* (mm):	9.0	ex: 9.0
	Key dip* (mm):	10.0	ex: 10.0
	Pre-letoff key travel (mm):	1.2	ex: 1.3
	Aftertouch (mm):	1.0	ex: 1.0
6.	Damper upforce (g):	36	ex: 36
	Damper downforce (g):	24	ex: 24

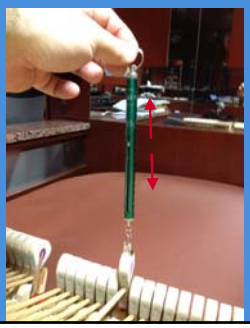
Optional

7. To confirm SW calculation:
Measure strike weight (**SW**) (pull out action).



Optional

7. Measure strike weight (**SW**) (pull out action).



Immobilize the key

Clip the spring gauge on hammer under crown, then lift and lower the hammer. SW is the average of the two readings.

Enter under Optional measurements

What Are We Measuring?

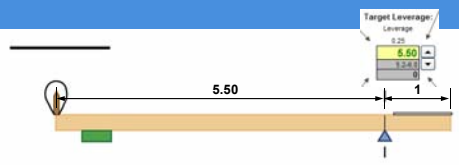
What are we measuring?

Because the action is laid horizontally, we can measure forces as weights.

To simplify, we treat rotational forces (torque) as linear, vertical forces

What are we measuring?

In this example, the action has a leverage ratio of 5.5 : 1:

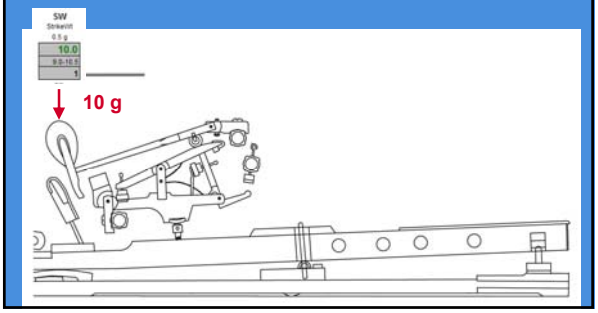


What are we measuring?

On the back end, the key lifts the **SW** (hammer strike weight):

What are we measuring?

On the back end, the key lifts the **SW** (hammer strike weight):



What are we measuring?

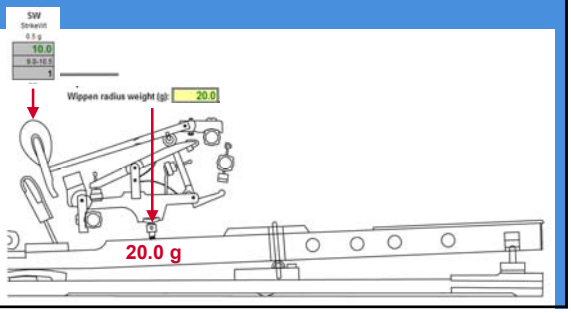
To balance the SW, the weight needed on the other end is 55 g:

What are we measuring?

The back segment also carries the wippen weight:

What are we measuring?

The back segment also carries the wippen weight:

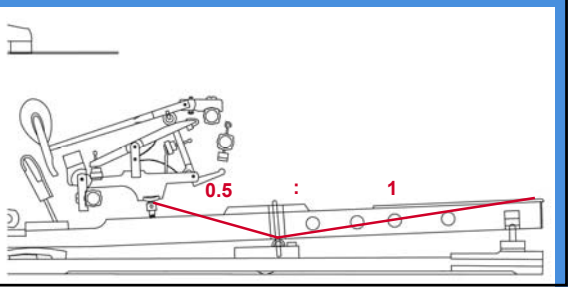


What are we measuring?

… which acts on the key at the key leverage ratio of approx. 0.5 : 1:

What are we measuring?

… which acts on the key at the key leverage ratio of approx. 0.5 : 1:



What are we measuring?

… adding 10 grams to the front end:

10 g x 5.50 = 55 g

20.0 g x 0.50 = 10 g

What are we measuring?

Together, the two weights are:

55 g

+ 10 g

What are we measuring?

Together, the two weights are 65 g:

= 65 g

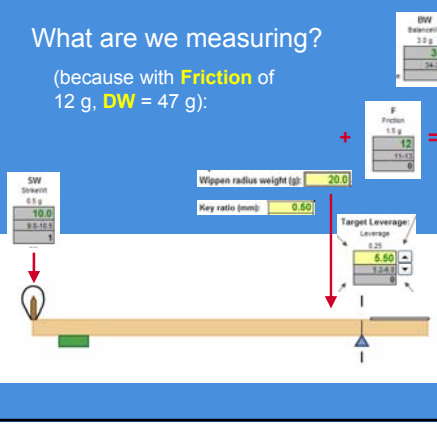
What are we measuring?

Since we want the **BW** (balance weight) to be 35 g:

= 65 g

What are we measuring?

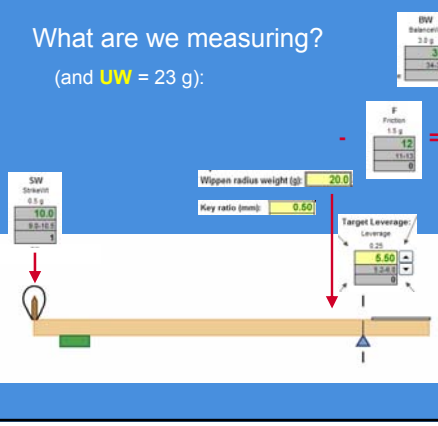
(because with **Friction** of 12 g, **DW** = 47 g):



= 65 g

What are we measuring?

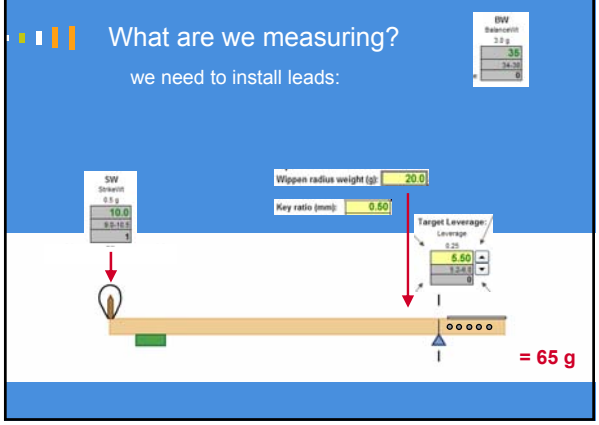
(and **UW** = 23 g):



= 65 g

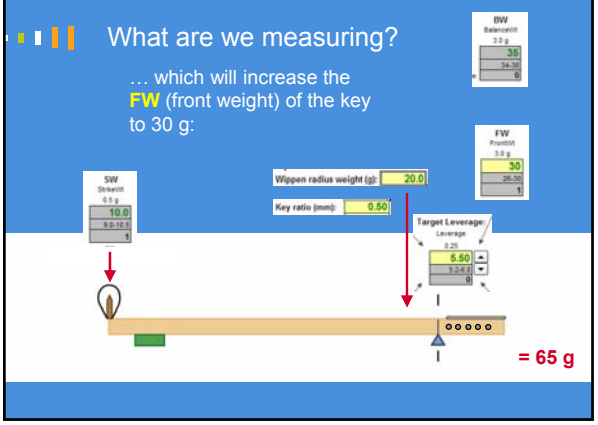
What are we measuring?

we need to install leads:



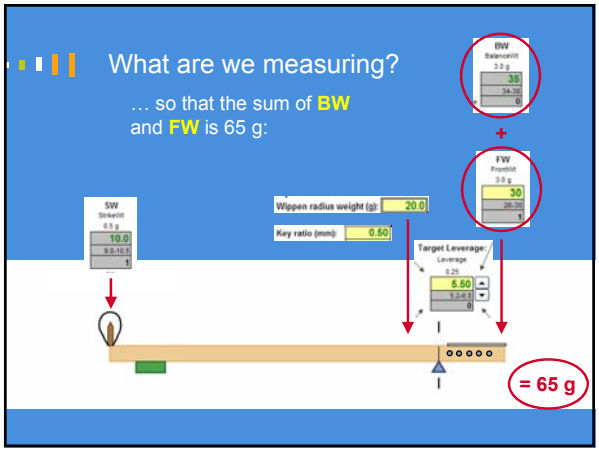
What are we measuring?

… which will increase the **FW** (front weight) of the key to 30 g:



What are we measuring?

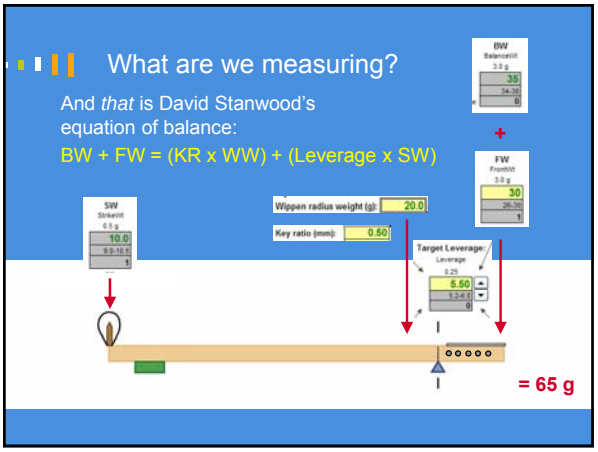
… so that the sum of **BW** and **FW** is 65 g:



What are we measuring?

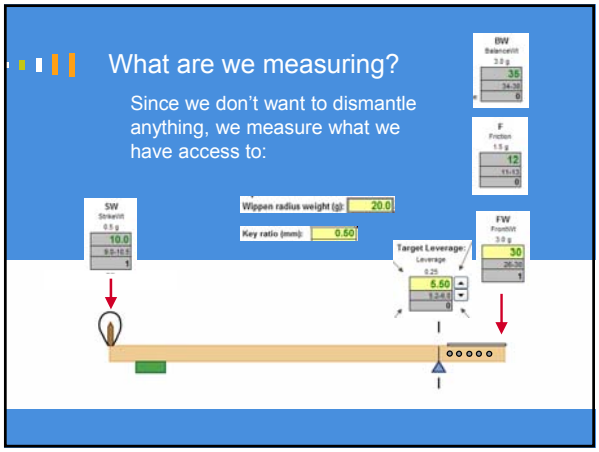
And *that* is David Stanwood's equation of balance:

BW + FW = (KR x WW) + (Leverage x SW)



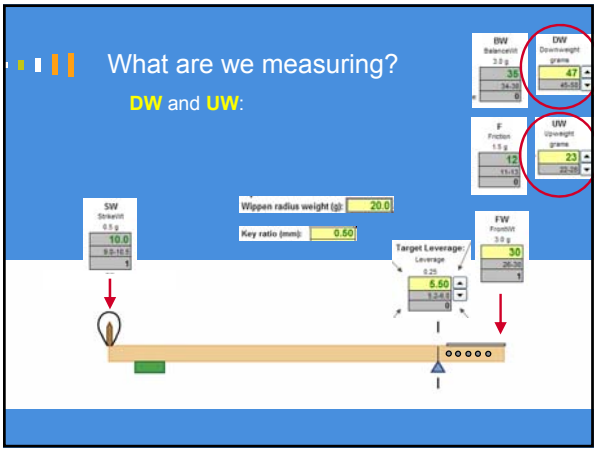
What are we measuring?

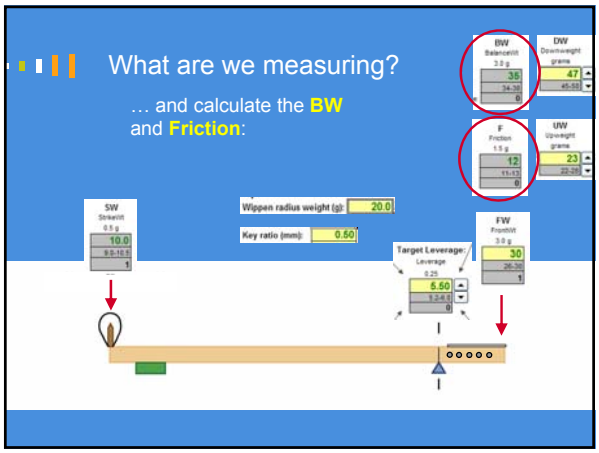
Since we don't want to dismantle anything, we measure what we have access to:

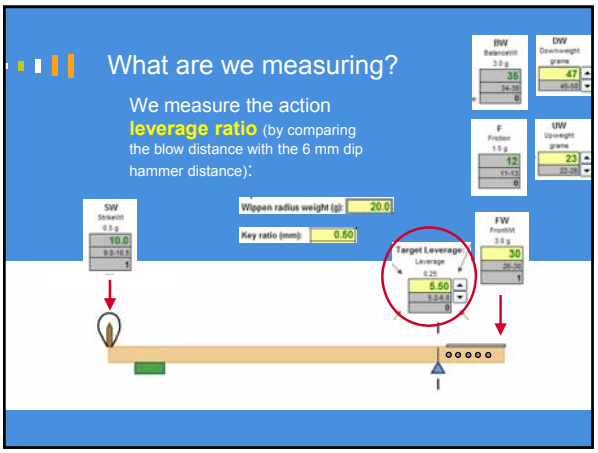


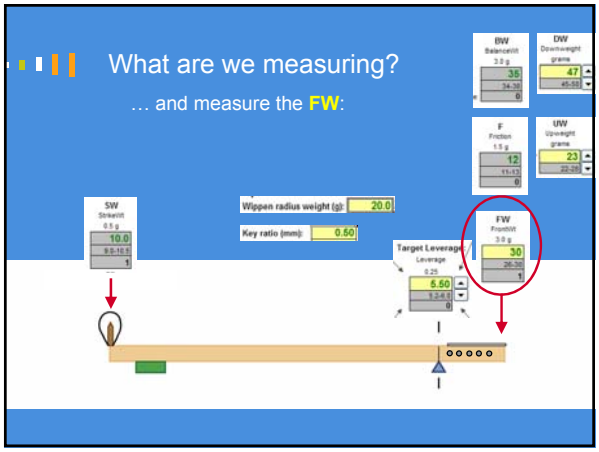
What are we measuring?

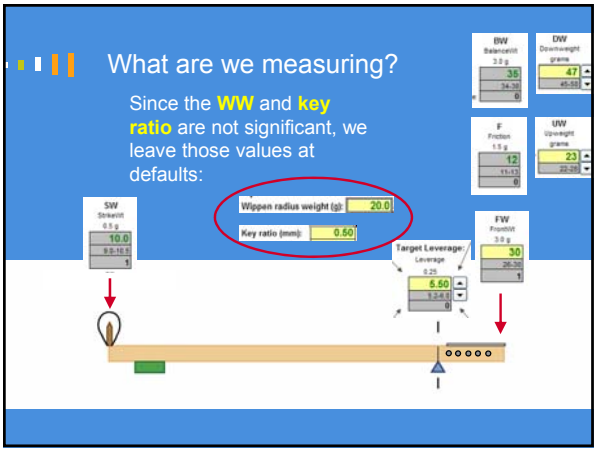
DW and **UW**:

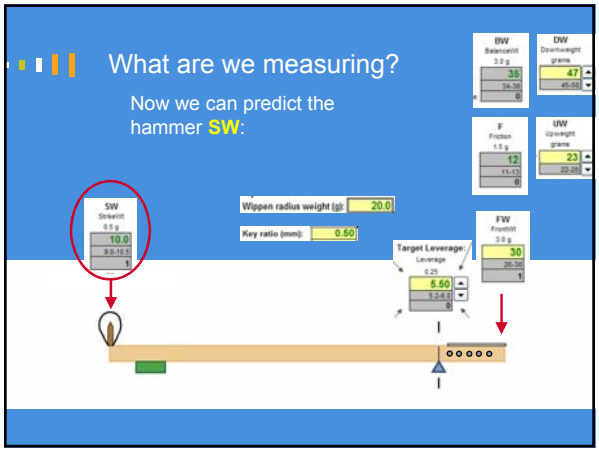


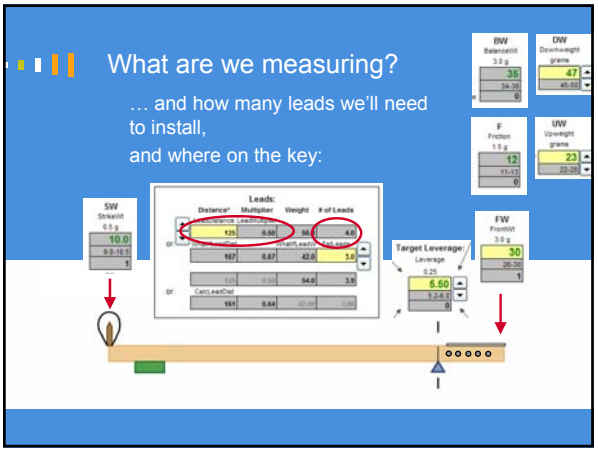






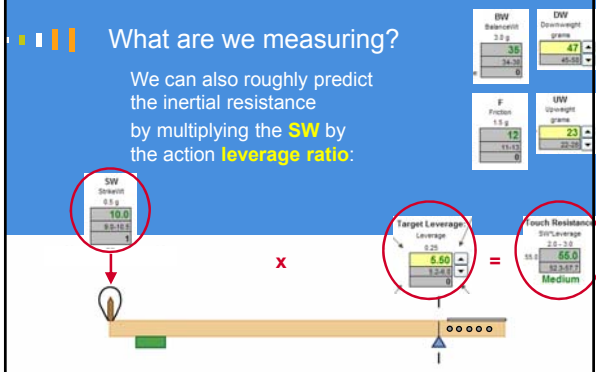






What are we measuring?

We can also roughly predict the inertial resistance by multiplying the **SW** by the action **leverage ratio**:



What are we measuring?

Distance relationships involve the hammer **blow distance** and **key dip**:

What are we measuring?

We measure the **blow distance** and calculate the **key dip**

What are we measuring?

Since the key dip prediction isn't particularly valuable, we can leave key dip measurements at defaults:

Measurement Tips

Measurement tips

- Calibrate measurement tools

To calibrate:

Unscrew top nut

Turn threaded shaft in or out

... until the mark is at the correct notch

Tighten top nut against the lower one to lock shaft in place

Measurement tips

- Calibrate measurement tools

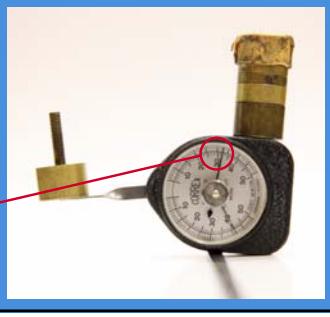
Repeat with a heavier weight

Measurement tips

- Calibrate measurement tools

Measurement tips

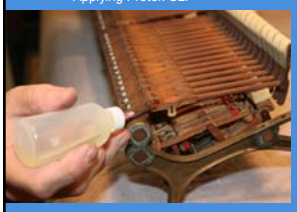
- Calibrate measurement tools



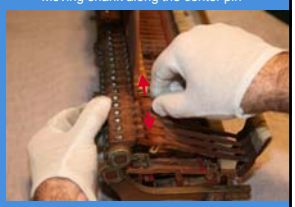
Measurement tips

- Reduce action friction

Applying Protek CLP



Moving shank along the center pin



Measurement tips

- Reduce action friction

Measurement tips

- Clean key mortises

Measurement tips

- Ease balance holes
- Taper balance holes if keys don't drop back under their own weight

Measurement tips

- If you suspect an unusual configuration, you may need to measure the action spread,

Measurement tips

… measure individual levers, compare to a known good action. Involve an experienced rebuilder.

Thank you!

Download class handout from:
www.pianosinsideout.com/Bonus

Please fill out a class evaluation