Action Geometry

Richard Davenport
Washburn Piano, Seattle
April 19, 2008

- How To Design an Action
- What Happens When a Component is Changed
- Complete Action Regulation
  - There is very little tolerance in regulation adjustments. Key dip is sacred. Dip is food for the action. How are you going to use your food? All other measurements are worked around dip.

Designing an Action

Mark points

1. Top front of the key.
2. Center of the balance rail hole
3. Directly above the center of the capstan
4. Wippen flange center: center of the center pin
5. Make sure the jack is lined up with the knuckle
6. Center of the hammer flange center pin
7. Top of hammer at the center of the molding

Measurements

The more accurate your measurements are, the more accurate the regulation will be. When designing an action, you start with a line. The first line to start with is the strike line. Working backwards from that point you can design an action. From that point you can plug in the numbers to figure out all the points and the action ration. The action ration is the ration between how far the key moves to how far the hammer moves. A low action ratio, of, say, 1:4, means 1mm of the key = 4mm of the hammer. An action ration is the key movement to the hammer movement. A heavy action gives power, lifting a heavy weight over a short distance, but you give up blow. A 1:6 ratio plays like a bad truck going through molasses on a cold day. Somewhere between 1:4 and 1:6 is 1:5, because it is the best compromise. Most pianos are in good shape between 4.8 and 5.2.

Grand Action Geometry

<u>Goals:</u>

- Maximum power and repetition.
- Consistent touch.
- Consistent tone.
- Customer satisfaction.

<u>Minimum Requirements:</u>

- Parts can be regulated; they are not worn out nor need replacement.
- Friction is correct or correctable with lubrication (no repining).
- Action geometry is correct.
- 10mm key dip yields adequate hammer blow plus aftertouch.

Evaluation:

- Incorrect part(s) (Too heavy or light, wrong dimension)
- Incorrect installation (boring, action spread, back-check angle, capstan location, etc. Hammer boring is incredibly important.)

Spurlock Action Ratio Tester

- Key depressor: to automatically depress a natural by 6mm
- Spans 7 keys
- Place on keys and depress the key 6mm.
- Measure the hammer rise (30mm)
- Divide hammer rise by key travel to obtain action ratio. For every 1mm of key travel, the hammer rises 5 mm. (30mm/6mm=5.0)

Action Components

- Key
- Wippen
- Hammer Shank
- Under-lever

Basic Engineering

- The forces move in two directions. E= arm, F=fulcrum, R=resistance. If the lengths are 2:1, push one end and the other end will move twice or half. In first-class levers, the forces move in opposite directions. The fulcrum is in the middle.
- In all cases, a second-class lever will offer a mechanical advantage. At the same time, the distance relationship is changed. The resistance is in the middle.
- In third-class levers, all forces move in the same direction but with a mechanical disadvantage. The ultimate problems start with the hammer and the knuckle shape. The energy is in the middle.

Everything is a trade-off. Push a door at the hinge and the knob end moves quite a bit, but it is hard to push. Push the door at the nob and it doesn't move very rare, but it is easy to push.

Component Contributions:

- Key (first-class lever)
    - Supplies energy to all other components
    - Converts 10mm of key dip to 5mm of capstan travel.
- Wippen (third-class lever): transfers energy from the key to the jack
    - Uses capstan energy to transfer energy to knuckle
    - Converts 5mm of capstan travel to 7mm of knuckle travel
- Hammer Shank (third-class lever)
    - Uses wippen energy to transfer energy to hammer
    - Converts 7mm of wippen travel to 50mm of hammer travel
    - 46-47mm is used just to move the hammer up. Add the let-off and drop screw, and the last 2-3mm is for after-touch.
- Under-lever (second-class lever)

- Uses key energy to transfer energy to damper head
- Converts 10mm of key dip to 6mm of damper travel.

Spreading the action does not make the touch lighter. Action spread is a sweat-spot relationship that can be figured out without any numbers. Get the numbers right and it will play.

Figure-It-Out Action Ratio Sheet

Figure out which component is the problem.

The way to figure out bearing is to level the bridge pins on the bridge to find out where the bearing is coming from. There should be bearing on both, but there should be more bearing on the front side of the bridge.

.1mm=4thousandths of an inch = thin paper punching

Divide the big number by the little number.

Key ratio

1. Measure from the top front of the key (1) to the bottom of the center pin hole (2).
2. Measure from the bottom center pin hole (2) to the top center of the capstan (3).
3. Measure from the center of the capstan contact (3) to the center of the center pin of the wippen flange center pin (4).
4. Measure from the center of the wippen flange center pin (4) to the point on the wippen that lines up with the back side of the knuckle core (5)
5. This measurement needs to be accurate within .1mm. Measure twice, by moving half-way through the hammer stroke. Measure at rest and again at let-off. Add the two measurements and divide by two. Measure from the back of the knuckle core (5) to the center of the center of the hammer flange (6).
6. Measure from the center of the hammer flange center pin (6) to the top center of the hammer directly above the center of the hammer core (7).
7. To confirm a 5:1 ratio, measure from the top center of the hammer to the bottom of the string at rest and then with the key depressed 6mm. Subtract the difference, and compare to 6mm key depression. This should be about a 5:1 ratio.

Key 1-2 (E) = _____
Key 2-3 (R) = _____
Key Ratio E/R = _____

Wippen 3-4 (E) = _____
Wippen 4-5 = (R) = _____
Wippen Ratio R/E = _____

Hammer 5-6 (E) = _____ (At rest____ + at Let-Off_____/2 = _____)
Hammer 6-7 (R) = _____
Hammer Ratio R/E = _____

Action Ratio = 1/Key Ratio x Wippen Ratio x Hammer Ratio = _____
"1" divided by key ratio (E/R), Times wippen ratio (R/E), Times hammer ratio (R/E)

Set the blow so you can work with after-touch and drop. The blow distance affects that measurement. The action has to work when measuring. To understand action ratio, you need to know the components of each ratio. These numbers determine what to do.

Action Geometry Worksheet

For notes # 1, #44, #88

Key
(E) Key Front-Balance Hole (1-2)
(R) Balance Hole – Capstan (2-3)
Key Ratio
Capstan Rise (has to be at least 5)
Wippen
(E) Capstan-Flange Center (3-4)
® Flange Center-Knuckle/Jack Contact (4-5)
Wippen Ratio
Shank
(E) Hammer Center-Knuckle/Jack Contact (5-6)
® Hammer Center-Hammer Strike Point (6-7)
Shank Ratio

(Action Ratio) Total Distance Leverage
Total Force Leverage

Down-weight (Enter desired down weight)
Hammer Weight (grams)

Key Dip (usually 10mm)
Total Hammer Rise

Customer:
Make & Model:
Serial #:
Date:

When you change one thing you can see what else changes.
If you want to change the down weight from 52 to 50, the hammer weight needs to drop.
Total hammer rise should be
If the hammer changes .3 gram, the weight at the end of the key changes 1.3 grams.

Trouble Areas

- Action ratio: hammer rise/key dip
- Action spread: jack in window, jack/knuckle, capstan/heel (visual clues). If things are crooked, the action spread is not correct. For example, when the jack is not directly under, the escapement is not clean. Spread is the distance between the hammer center and the wippen center.
- Knuckle/hammer center distance, hammer weight. When there is a weight problem, it almost always falls in this category.
- Key ratio (visual clue: look for a straight capstan line). If the capstan rise isn't at least 5mm, that is the problem. Over 5.3 it could become a problem. Changing the balance point 1mm could correct everything. Calculate the key balance point at 88 and at 1 to determine the balance rail.
- Let-off buttons, drop screws too high or too low (Incorrect hammer boring)
    - Too high: blow distance short because worn out or factory blew it. Scratches the pin block. Over-centering, with all the let-off and drop screws too high, or with them all too low, the action spread will be wrong.)
- Strike point in treble (no tone on last few notes). This is a quick first check.
- Inertia: excessive lead (visual clue: *3-2-1 lead pattern*: 3 in the bass, 2 in the tenor, 1 in the treble, nothing in the high treble
- If there is too much lead, there is a problem. Up-weight is the most important measurement; favor the up-weight. Pianists want to repeat high on the key and feel this. It should get gradually faster as it goes up to note 88.
- Lines of convergence. The line of convergence is the line of least friction. A big point of friction is the knuckle-jack. Trace lines from the center pin of the damper lever to the bottom of the center hole to the wippen flange center to the hammer flange center. Notice that in a well-adjusted action the top of the jack never crosses the line. As long as the underlever felt crosses, you are in the ball park. The capstan to the wippen cushion is about in line.
- The back of the back-check is in line with the molding of the hammer at rest. The radius on the back of the hammer tail should be about 2.5-3" from the end of the hammer, and that is the point of rotation. When the tail jams into the back-check there should be a 30 degree angle, which should make checking marvelous, both on a hard and soft blow.

<u>Normal Range Measurements</u>

- Knuckle distance = 15.2-17 mm (or more)
- Action Spread = 112.5-113.5mm (or more)
- Key Ratio – 1.8-2.0:1
- Wippen Ratio = 1.4-1.5:1
- Hammer Shank Ratio = 6-7:1 (current production: 6.8-6.9:1)
- Action ratio too high – 5.5 plus: (deep
- Calibrated gram weight to measure tough weight

Tools for Diagnosing Geometry and Touch Weight Problems

- Gram weights to measure touch weight (calibrated)
- Digital gram scale to weigh parts (grams & ounces)
- Dial or digital caliper to measure distances accurately (English & metric)
- English & metric scales (Westcott® 18' is an inexpensive, easy-to-read, clear plastic scale available at Staples)
- Grand action model to practice with (especially action spread)
- Action geometry software or spreadsheet

Different actions require different action ratios. Don't dwell on action geometry unless action doesn't regulate properly or touch weight is an issue. If the blow distance, dip and touch weight are acceptable and visual clues don't indicate problems, geometry is probably correct.

What Happens If…?

In the situations below, indicate whether down-weight (DW), up-weight (UW) and friction (FR) will increase (+), decrease (-) or remain the same (s). Assume the action model is in perfect regulation and weighs off correctly. After making a geometry change, the model will be re-regulated as closely as possible to the original specifications. It may be helpful to think how the two convergence lines will be affected (bottom of balance hole to wippen center/wippen center to hammer center.)

In after-touch, the jack should not be touching the knuckle or the wippen cushion.
The capstan and the wippen bottom should cross the line on a key stroke. The jack never quite crosses the line. Place a 50 gram weight the key over the front rail pin. on 50 grams down, grams up.

Situation 1

Increase correct action spread by 1mm by moving wippen rail (don't relocate capstan under wippen heel).The capstan has not been relocated, but the T1 on front of key, upweight is now 26, gained 1g ram of up-weight and down-weight, and the friction is the same at 12.5 grams.
he button to the wippen spoon is screwed in.
has been moved
Let-off and drop are both too high. The jack is too far under the knuckle, the capstan is no longer under the center, and the blow is too low.

Situation 2

Increase correct action spread by 1mm by moving wippen rail (center capstan under wippen heel) Move the screw out. Now the jack is touching the back of the knuckle and has not enough space.
Move the capstan back under the wippen. The blow is slightly shorter. Re-adjust the hammer height and weigh off the action. Put 53 grams on the front of the key for the new

down-weight. The up-weight is 26. Total friction is 13.5 grams: gained a whole gram. Action spread effects the efficiency more than the touch-weight. The ration is efficient up to 1mm. This changes the angle of the jack to the knuckle as well.

Situation 3

Increase height of wippen heel by 2mm. When new parts don't fit properly, things will be off. An evenly regulated action will split the capstan line evenly. Place a shim on the capstan. The hammer line is now very high. Lower the capstan. Rather than an equal amount above and below the line, the capstan barely crosses the line. Down-weight = 53, up-weight = 25. Gained 1 gram of down-weight, the up-weight is the same, and friction is now +.5 gram. Changing the line of convergence changes the friction, either up or down. All these little bitty friction and convergence details add up to make the overall performance not good enough.

Situation 4

Move knuckle 1mm away from hammer center.
The jack position is changed even with the jack moved back under the knuckle. The jack is barely escaping. Raise the hammer with the capstan so the jack will clear. With 44 grams of down-weight and 21 grams of up-weight, which is an improvement of 6 grams, and up-weight is and improvement of 4 grams. This is not really an improvement, but a workable action. An 18mm knuckle spread means shortening the blow distance more than we want.

Situation 5

Moving the knuckle closer to the hammer center is not a good idea. First, the jack has to be re-adjusted under the knuckle front-to back, but by shortening this distance, there is a significant increase in pressure. Therefore more lost motion needs to be created. This also creates an angle on the jack. The repetition lever also needs to be changed. Let-off is not blocking. Run the drop screw down first, then adjust let-off, then re-adjust drop. The jack is actually jammed against the back of the window in the wippen. Do weigh-off, starting with a 60 gram down-weight, and 30 gram upweight. Downweight is 10 grams heavier, down weight is 5 grams heavier, and friction is up 2.5 grams. The knuckle can be moved away from the hammer center 1mm. Movement towards the hammer center yields negative results.

Situation 6

Angle capstan 8 degrees toward back-check (center under wippen heel). The capstan distance is now changed. Blow needs to be changed. Down-weight is 47 and 22 grams up. Down-weight and up-weight are both improved 3 grams. Friction is better as well.

Situation 7

If 8 degrees is good, is a 15 degree angle better? Up 22, down 47, which is identical to 8 degrees, except that only a small portion of the capstan contacts the cushion all the way through the stroke. This will bear out the wippen heel cushion prematurely.

Situation 8

If the key ratio is less than it was: move the balance rail pin 4mm closer to the player. Down=56, up=28. Friction is 1.5 grams heavier. This is why many keyboards had heavier leads and a sluggish response.

Situation 9

This is the opposite of 8. Move the capstan back under the wippen cushion. Down=46, up=21, friction is 12.5. By changing the balance point of the key, any problem can be fixed. Any key work you do, you will lose money.

Situation 10

Add 1 gram to the hammer. Clip a weight on the underside of the shank and your action weight goes up by 5 grams. Strengthen the repetition spring slightly. Down=55, up=29. This is a better way to add weight than by adding jiffy weights to the keys, which add inertia and makes the keys more sluggish. A light hammer compromises regulation, repetition and tone. File the hammer, add a weight to the hammer. This makes the feel heavier.

Situation 11

Add 1 gram to the wippen. Down 51, up 26. To lighten these weights, drill holes in the center of the wippen. Friction remains the same. When you bore out a wippen, it makes the inertia totally different.

Situation 12

Install smaller diameter knuckle. Down=44, up=14. Now place a knuckle with one that is .005 smaller. Now we have to raise the hammer. Let-off is close. Down=44, up=15. With a smaller knuckle, there is less friction with the jack and the knuckle, convergence is closer, the jack escapes and returns more quickly.

Situation 13

Under-center hammer 2mm. (boring distance too long) The hammer is moved closet to the front. Down=46, up=15. Friction=15.5. this is not a good idea.

Situation 14

Over-center hammer 2 mm (boring distance too short) Correct the blow distance, let-off and drop have to come up. Down=40, up=15. As you shorten the hammer blow distance, the shank comes up higher, and the easier it is to get it moving: the inertia goes down. Since the hammer shank is closer to the horizontal at rest it takes less energy to break inertia. The convergence line is much closer than in the earlier examples. This is an easier way to pick up lower down-weight and less friction (2.5 grams better than the original sample).

Realistic Grand Regulation
For Power and Repetition

Israel Stein gives the bench test for regulation in Santa Clara. If you want to pass the PTG exam, loosen everything up. Richard Davenport's measurements are to concert specs. For example, Richard's let-off is very close. His only set spec is dip.

Which is more important, power or repetition? We need both. If we just had to make the note play once, we could have an incredibly powerful action. A rock musician plays three chords for a thousand people; a jazz musician plays 100 chords for three people.

Maximum Power:
Jack remains under knuckle for the longest possible time. This means longer blow distance and closer let-off.

Fastest Repetition:
Jack escapes and returns under knuckle in the shortest possible time.

Preparation

- You can't regulate until you have correct friction. Check all action centers and keys for correct friction. Make necessary repairs. Re-pin every center: hammer, repetition, jack, wippen flange center. When you re-pin, you increase the friction on the repetition lever to 9-10 grams.
- Replace any worn parts. Pay attention to knuckle
- Inspect \capstans, drop screws and key pins for burrs. Polish metal parts and lubricate w/ MacLube 480. Sand repetition levers and jacks with 600 grit and lube with 480
- Lightly spray knuckles, wippen heel cushions and repletion levers with 480
- Line up action parts, tighten screws, abed key frame.
- Make sure action has positive repetition spring tension, hammers are off rest rail and drop is set below let-off. Put the hammer in check and it should stay.

Key Height/Dip, Blow Distance

- Establish workable key height. Piano dictates limits. (Fallboard clearance key slip, front rail pin height.)
- Set white key height 18-22 mm above the key slip. (Front of key should appear slightly rectangular.)
- Black key height is slightly lower than glue joint between sharp and key stick. This is sometimes 12mm or ½ inch.
- Make sure that at least 4mm of front rail pin remains inside of the key bushing when key is at rest.
- Set three samples and perform complete regulation on all sample keys before leveling entire keyboard.
- Problems usually occur after re-felting the key frame.

- Before changing backrail cloth or balance rail punchings, measure key height with the old back rail cloth. Install new back rail cloth that produces a white key height 1mm lower. The new back-rail cloth should be 1mm higher.
- After replacement with correct balance rail cloth punching, new white key height should be 1mm higher than with worn parts to compensate for wear.
- Determine blow distance by setting a 10-10.5 mm key dip on samples (lightly deeper dip for concert grands).
- Acceptable distances are between 44-47 mm. If key dip produces less than a 44mm or more than a 47mm blow distance, there is probably a geometry problem.
- Set white key height, black key height, white key dip, black key dip. If weights are used to hold keys up, key height will be slightly higher than with the top action.
- Do all fine regulation at the piano.

Action Regulation Demonstrations

- **Jack**
    - Correct Position under Knuckle
        - Jack in line with edge of knuckle core
        - Jack contact point tangent to knuckle
        - Maximum power and repetition
    - Jack Too Far Under Knuckle
        - Longer travel increases friction (loss of power)
        - Requires more time to return (loss of repetition)
        - The let-off distance is unaffected. Let-off can be done any time during the regulation process.
    - Jack Not Far Enough under Knuckle
        - Causes jack to cheat
        - No power or repetition
        - Put a foam strip between the jack tender and the let-off button to produce the same effect.
- **Repetition Lever/Jack**
    - Correct Clearance
        - No lost motion
        - Stable hammer line
        - Maximum power
        - Fastest repetition
        - Jack needs to be slightly pushed to go back. Steinway calls this "rolling the fly." You should be able to feel the jack slightly lift the knuckle.
    - Too Much Clearance
        - This is the opposite of too tight
        - Lost motion
        - Unstable hammer line
        - Lost power
        - Lost repetition

        - Press the repetition lever. Watch to see how much lost motion there is between the jack and the knuckle. You should not be able to move the repetition lever. There should be no repetition.
    - Too Little Clearance
        - Action plays once but can't reset
        - Repetition lever can't help support knuckle
        - No power, no repetition, no stable hammer line, won't play more than once.
- **Let-off** too close
    - No escapement
    - Hammer blocks, muting string
    - Possible jack tender breakage
    - Let-off needs to be regulated
- **Drop** Too Far
    - Repetition lever contacts drop screw before jack contacts let-off button)
        - Robs power/slows repetition
        - Compresses spring as lever moves lower
        - Compromises click
    - Drop Too Low: Too Close
        - Jack contacts let-off button before repetition lever contacts drop screw (lost power
        - Loss of control in soft playing due to double striking
        - No click
        - Use your two middle fingers from black to white note. Get a rhythm,. As soon as you touch the front cushion you can feel differences of .001". Don't look at anything: you can feel it.
    - Proper Drop (repetition lever escapement)
        - Drop screw contacts repetition lever as jack tender contacts let-off button.
        - Then add a hair more drop.
    - **Back-checks** (hammer catching distance)
        - Correct hammer checking distance 10-12 mm
        - At rest, center of hammer molding parallel to back of back check
        - Checking 10-12 mm from string with hammer tail half way down back check under-felt.
        - Best balance of power and repetition
        - 30/60/90 degree angles
        - Excessive Distance
            - Either it is checking at the right height, but not parallel, or it is checking low.
            - Hammer felt may contact back-check top during repetition
            - Inconsistent power and repetition
        - Insufficient Distance
            - At rest, too little space between back of hammer and front of back-check

        - Hammer tail may contact back check on way up (especially on hard blow)
        - Inconsistent power and repetition
    - When dip & let-off are correct, press the key down. At the point of let-off there should be 1-2mm between top of back-check and bottom of the tail.
- **Repetition Spring**
    - What the Repetition Spring Affects
        - Affects repetition lever-to-jack clearance by giving an unrealistic feel of lost motion. That little tiny bump becomes the difference between it working and not working. This affects the hammer line.
        - Double-striking can happen if it is too strong.
        - Turn down the drop screw until it goes into back-check: the stop screw. This is not the right way to do it, but it does create back-check. There is a compromise between the repetition spring and the drop screw.
        - A close distance will change the jack-knuckle line. To tell if it's too much, grab the back of the key and release it. It should not snap and it should not fall.
        - Perhaps the most important effect is in the drop. When you increase the spring tension, the drop line will be higher.
        - If the spring is weakened, the drop will be farther away.
    - Correct Repetition Spring Strength
        - Hammer rises smoothly
    - Spring Too Strong
        - Hammer pops out of back-check with a bump felt at the key
        - Robs power during let-off
        - Double strikes during soft playing
        - Click too pronounced
    - Spring Too Weak
        - Loss of repetition (may not repeat at all)
        - Hammer may catch back-check on way up (causing jack to cheat); no power
        - Unstable hammer line
        - Proper click impossible
- **Center Pins**
    - Hold a flange tightly on the table and wiggle the shank. If you can feel the movement, it's too loose. *Hammers* move 43mm. A well-pinned hammer will swing 5-6 times with new parts; for used parts, maybe 6-7 swings. The swing should reflect the weight that it is supporting.
    - *Wippens* must drop by their own weight. Basically all could be re-pinned with 5 grams, since the wippen moves only about 2mm. Do repetition levers 9-10 grams with butterfly springs. You should have to tap the wippen to make it go down.
    - With butterfly spring wippens, *jacks* can be re-pinned as tightly as possible. The jack should be about 5 grams.

    - When there is no movement and everything goes straight up and down, the entire action motion is more powerful. Re-pinning hammer centers produce better attack, sustain, and feel. The pinning of the repetition lever and the jack optimize the playing ability.
- **Capstans (**The after-touch adjustment screw)
    - Correct
        - Allows jack to escape on soft blow
        - Allows a gap between front of jack and window felt
        - Regulates aftertouch
        -
    - Hammers Too high
        - Causes jack to block in window felt
        - Possible for tender to break
        - Loss of power and repetition
        - Optimum click impossible
    - Hammers too low
        - Lost motion
        - Jack can't escape from under knuckle; piano unplayable
        - No aftertouch, no click
- **Damper Lift** (Damper Timing)
    - Correct Damper Lift
        - Damper begins to lift half-way through hammer blow distance.
        - Facilitates proper sostenuto function.
        - Facilitates proper damper stop rail clearance.
        - The pedals and sostenuto won't work if there is not enough clearance on the damper stop rail.
    - Timing Late
        - Damper felt may not clear the tri-chords
        - The piano plays lighter because the key is already moving.
        - Sostenuto lever may jam against underlever tab
        - May affect damper stop rail clearance if key end felt is too thin
    - Timing Early
        - Even though action plays, "touch" feels heavy.
        - Soft playing very difficult, hard to control, takes more effort.
        - May affect damper stop rail dclearnane if key end felt is too thick.
- **Synchronizing Double Escapement**
    - Standardize the adjustments
        - Jack and repetition lever escapements occur simultaneously
        - Regulation must be uniform (blow, dip, let-off, drop, springs) from note to note. Standardize blow distance and hammer line
            - Aftertouch must be consistent from not to note.
                - Go through each adjustment and decide which are too deep and which are too shallow.
    - Aftertouch: Testing and Making Uniform
        - Close your eyes
        - Move note to note at steady pace

        - Depress each key with both middle fingers, feel click escapement
        - Level of hammers after drop must be even not to note
        - Hammer too low = too much click
        - Hammer too high = too little click
        - Let-off, drop, key dip, repetition springs most common points to adjust
        - Test black key by comparing adjacent white keys (white, black, white)
    - Trouble-Shooting
        - If you have something that defies explanation, check the lines of convergence.
        - Action Spread
            - Too narrow increases
        - Knuckle Center to Hammer pin center
            - The closer the knuckle
        - Key Ratio
        - Capstans
    - Pedal Regulation
        - Each pedal has two stops: on and off
            - Unacorde, Sostenuto & damper pedal OFF:
                - Usually found in pedal box under rear of pedals. Some makers (Mason & Hamlin) stop pedals at tfront of pedal box. Used to determine height of pedals at rest
            - Unacorde pedal ON:
                - Stops action shifty at treble end of keybed with adjustable screw and or trap lever under keybed
            - Sostenuto Pedal ON
                - Usually found under keybed either as an adjustable threaded rod with lock nuts or a capstan or hard felt which stops trap lever. Limits blade's upward travel.
                - Any time moving up or down, correct with the rod.
                - Forward and back adjustments with the screws will also change the height.
                - Adjustment is a circular process.
                - If the tabs aren't all in a row, shim or singe.
                    - Get a piece of brass and grind it down to paper thin and attach it to a soldering iron. Singe the felt on the tab.
                    - To make the tab go down, put a piece of balance rail punching between the tab and the pedal.
            - Sustain Pedal On
                - Trapp lever

        - Play a black key to establish the stop in the trapp work before adjusting the up-stop rail.
            - Press the pedal down and adjust the rail until there are 2mm between the tray and the bottom of the levers so that it doesn't stop the pedal.
    - Lost Motion: Adjusting pedal rods
        - Unacorde
            - Lentght dadjusted until there is slight lost motion before action begins to move. Action must be seated at bass end. Check with paper
        - Sostenuto
            - Length adjust so blade is 45 degrees
- Conclusion
    - Make sure parts will regulate and friction is addressed.
    - The idea of action ratio is important. Based on standard parameters, you can figure out what is wrong.
    - If you don't know what is going to happen, don't do it. If you don't have the answer, get the answer.
    - Include action regulation with every service call. Don't "tune" pianos: "service" pianos.
        - To get me to your house to service your piano and possibly tune it will be this much. From that point on, I charge this much per hour.
        - Tell exactly what is wrong with the piano even if it is
        - Getting in the front door is the key to making a living.
        - If you more than the other people in your town, then you will make a living. The more things you are good at, the more money you will make in business.
        - "I represent the welfare of your piano. I am not a tuner, I am a technician. I know everything that could possibly go wrong with your piano."
        - "I'm semi-retired and I'm not taking any new clients." The phrase you want to hear is, "Money is no object."
    - Business practices.
        - Take your shoes off.
        - Clean the piano. Work in service along with tuning.
        - You are your own advertisement.
            - If you don't have the answer, get the answer. They want a positive outcome.
        - A recommendation is the best advertising.
        - Most people don't know what is right or wrong, but you do.
        - The next technician will see what you did.

Grand Regulation Troubleshooting

1. Key dip is correct, but aftertouch is insufficient.
    a. Set samples and level hammers.
    b. Hammer line is probably too low.
2. When playing staccato chords, adjacent keys bounce.
    a. Adjust glide bolts. They are up too high and not bedded.
    b. Glide bolts are retracted.
    c. Balance rail not bedded.
3. When playing staccato chords, adjacent hammers bounce.
    a. Glide bolts extended too far.
    b. Back and/or front rail not bedded.
    c. Tap the front rail.
    d. Tap the back rail with a long screwdriver.
    e. Turn up the glide bolts and make sure they knock.
    f. Start with the middle, then left, then middle then right, until they are all knocking.
    g. When it gets dry, front & back bolts are not bedded.
4. Piano plays normally at soft to medium volume, but hammers won't play on a hard blow.
    a. Jacks not adjusted far enough under knuckle core.
    b. Jack "cheats" on hard blow.
    c. Back checks are not catching. They need to move closer.
5. Piano plays normally at soft to medium volume. Hammers respond to a firm blow but keys are very hard to depress; yet keys and action parts return freely to rest.
    a. Back-checks too close. Hammer tails catch on way up.
6. Hammer occasionally drops below normal hammer line and will not respond to key; yet when lifted with a hook to hammer line it will play.
    a. Repetition spring too weak and/or jack too high relative to repetition lever top.
7. Hammer stays at hammer line, yet will not respond to key after a slow release.
    a. Jack is too high relative to repetition lever.
    b. Repetition spring may be too weak.
8. After repetition springs are adjusted to specification, hammer line goes out of alignment whenever piano is played. Capstans are again regulated, but hammer line becomes uneven again when piano is played.
    a. Jack too low in relation to repetition lever.
    b. Always lost motion
9. Pianist feels a thump in the key immediately after the key is depressed.
    a. Damper up-stop rail too high
    b. Regulate the pedal stop on the trap lever first, then adjust the up-stop rail.
10. Pianist feels a bump as the key is released.
    a. Repetition spring too strong.