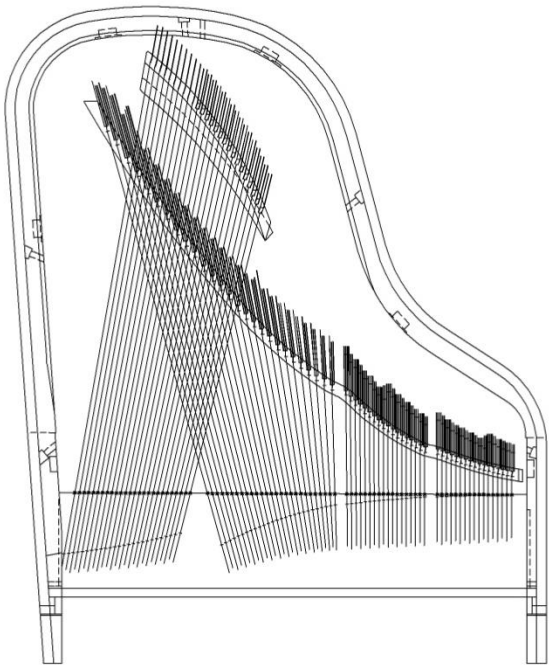
Introduction

Create a Key and Action Scale Stick from the Piano



While rare, there are times you will not be able to create a scale stick for a new keyboard and action from the old action in the piano.

Maybe there is no action. Or, maybe the action parts are angled and the drilling has a murky relationship to the spacing of the strings. Or perhaps the alignment between the action and the piano is so poor that modification is clearly in order.

For any or all of these circumstances, this procedure will show you how to create a Key and Action Scale Stick from the piano itself.

You should understand that starting over in this fashion implies replacement of the keyboard and damper action as well as the top action.

The original keyboard (capstan line) and top action were drilled to the same note spacing or scale stick if the keys were not angled. If you create a new scale stick, both the top action and the keyboard capstan line must

be drilled to the new standard. It is not reasonable to use one scale stick for the action and another for the keyboard. To do so is to invite failure.

Mandatory Minimum Distance Between Notes

WNG requires a minimum of 12.2mm between notes. After you have established the location of the strike line you should determine if a WNG action can be fit into your piano.

Measure the distance between the center of the first and last strings in each section of the piano at the strike line. Divide this distance by the number of notes in the section minus 1 (that is if the number of notes is 26 divide by 25). This calculates the inherent spacing of the notes. If the number you arrive at comes to less than 12.2mm then the WNG action will not work.

It may be possible to stretch a section to achieve the required spacing if you are also replacing the keyboard. If this is the case you will need to contact us to determine feasibility.

Every piano has two scale sticks.

The scale stick for spacing of the note centers at the strike line

&

The scale stick for the key and action

The Key and Action scale stick is derived from the Spacing of the Note Centers at the Strike Line scale stick

Most people think that “The Key and Action Scale Stick” and “The Spacing of the Strings at the Strike Line Scale Stick” are one and the same.

Not true!

All pianos, at the design level, have two scale sticks. "The Spacing of the Strings at the Strike Line" scale stick is the raw data, extracted from the piano, from which a Key and Action scale stick is derived.

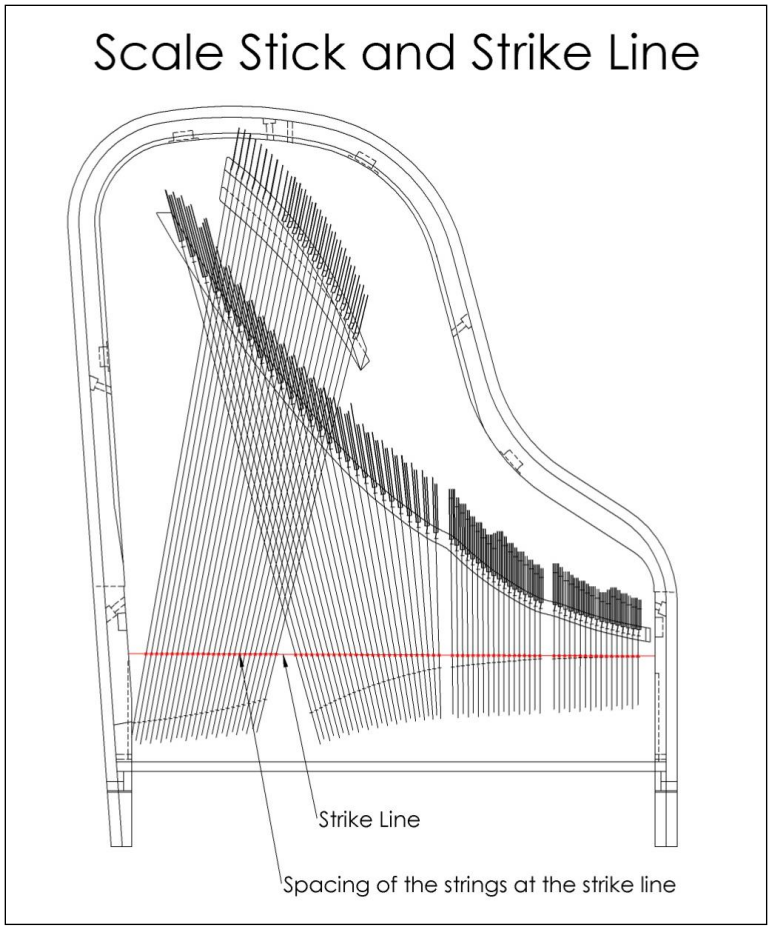
Tools

First you will need some tools to perform the tasks defined in this procedure.

¼" (6mm) tape measure
Slot screwdriver
Masking tape
WNG 72-88 Strike Gauge
Fish line
Center pin vise with collets at both ends
#19 center pin
Mylar strip 150mm or 6" wide and long enough to span the keybed in the piano.
Chisel to remove old dag blocks
Metric 150mm (6") rule
Mylar pencil
Long straight edge
Straight edge (shorter) for inside keybed
24" Decimal machinist rule (preferable metric)
General protractor

Find the Strike Line of the Piano

Our first task is to define the strike line in the piano. You might ask, "What is a strike line?"



A strike line is a theoretical line that runs across the piano. The intersection between this line and the strings (that is, the center line of the note) defines the point where the hammer hits the string. Sometimes, due to poor execution during the making of the plate, the strike line in actual practice is less then straight. You can be assured, however, that the piano was designed with a straight strike line.

Conceptually it is simple to arrive at a strike line in any piano. Find the strike point for note #1, find the strike point for note #88. Connect those two points with a straight line and you have arrived at a strike line.

The term “Strike Distance” is the distance from the agraffe or V-bar to the point the hammer contacts the string.

Prepare the Piano for Strike Line Measurement

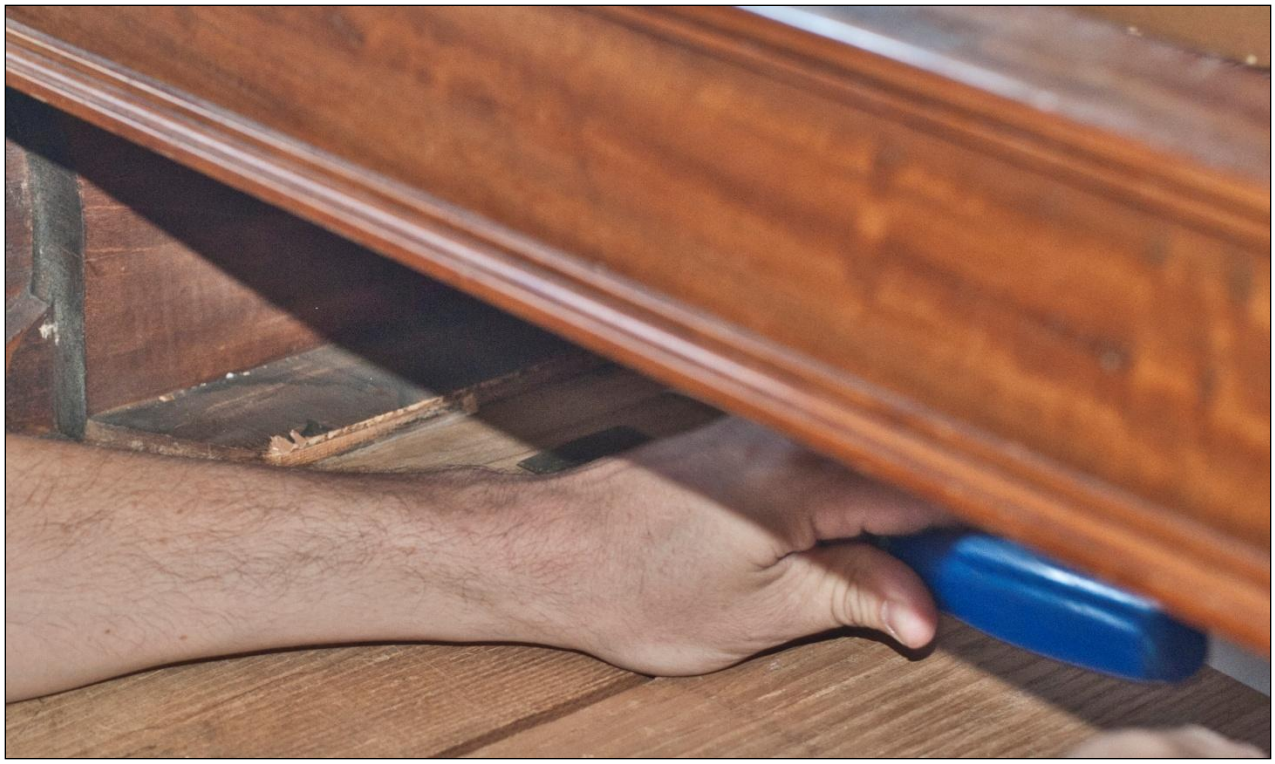
Remove the dampers from the piano. While it should be possible to create this scale stick with the dampers in the piano it will greatly increase the difficulty.

Remove the damper action from the piano. Again, why make life difficult.

Measure the distance from the center of the damper guide rail hole for note #1 to the belly rail. Write down this measurement as you will need it shortly.

Remove the damper guide rails from the piano. With the dampers, damper action and damper guide rails removed from the piano, you are now ready to start creating a scale stick.

The old dag blocks held the old keyboard down against the keybed. Since you are replacing the keyboard, the old dag blocks serve no further purpose. They are however, in the way. Remove the old dag blocks and your life will be much easier.



The bass stop block positioned the old action in the piano. Because it will need to be replaced when you replace the keyboard, remove the old stop block as it is in the way and serves no further purpose.

Now that the dampers, damper action, damper guide rails and the dag blocks have been removed, the piano is now ready for you to proceed.

Cut a piece of Mylar 150mm or 6” wide and just long enough to span the width of the piano inside the action cavity.

Position the Mylar so that the back edge is even with the soundboard and belly rail.

Use masking tape to tape down to the keybed.

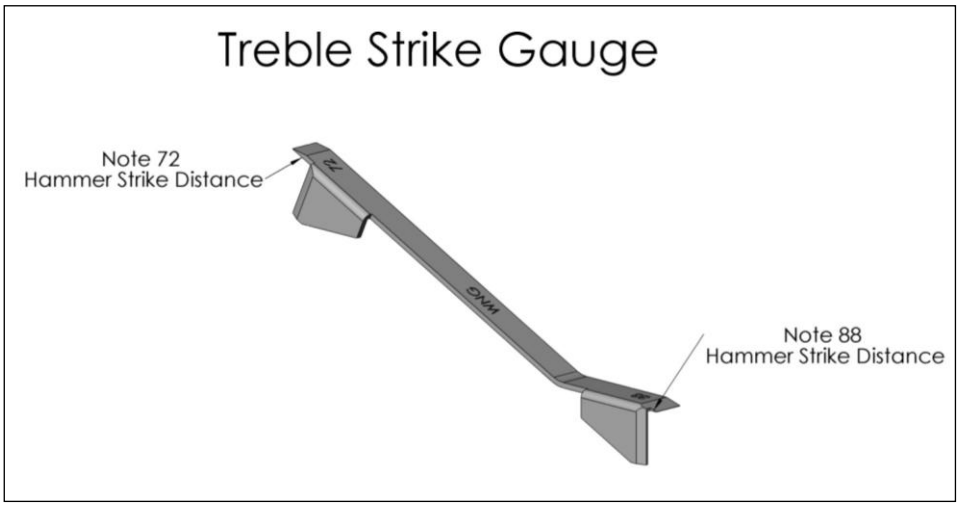
Use a level on the keybed to make sure that the piano is sitting level. It is necessary to level the keybed bass to treble and front to back.

Place blocks of wood or cardboard under legs until the piano is level. With luck you will not need to do anything here however, it is necessary to check. After all, even if the piano was accurately made, your floor might not be.

Another way to level a piano is using the hydraulic jacks in a Grand Transporter.

Find the strike point for note 88

At note #88 finding the strike line is easy. The strike line is about 2.4mm or 3/32” from the center of the v-bar. Because the distance from the v-bar where the note sounds good is so narrow, there is little wiggle room here.



The Treble Strike gauge is a WNG tool that facilitates finding the proper strike point for notes 72 and 88.

As we stated earlier, it is simple to arrive at a strike line in any piano. Find the strike point for note #1. Find the strike point for note #88. Connect those two points with a straight line and you have a strike line.

The Treble Strike Gauge will make it easy to find the strike location for note 88.

Conceptually, this method is quite easy.

- Measure strike point from the V-bar using the WNG 72-88 Strike Gauge.
    - Obviously you want to use the end of the tool marked “88”.
- Use the plumb bob to transfer the measurement to the Mylar in the keybed.

Pass the string on the plumb bob up through the strings of the piano at note #88. The string should ride on the bass side of note #88. Raise the plumb bob until the center pin end is just off the keybed. Tape the string to a plate bar so the pin vise is supported off the keybed.

Use the 88 Gauge to position the string at the strike point.

This is the piano technician's plumb bob. It is just a pin vise that every piano technician has in his or her tool kit. Put a center pin in one end, use a small size. In the other end clamp to a fairly thin fishing line.

If the piano is not level then the measurements you obtain using the plumb bob will not be valid.

Stop the motion of the plumb bob so it hangs motionless over the Mylar.

Mark the Mylar where the center pin points. This transfers the location of the strike point for note 88 to the Mylar taped to the keybed.

Find the strike location for note 1

The strike location at note 1 us much more interesting problem. At note 88 the location of the strike point is very narrowly defined because the area on the string where the piano sounds good is very small.

At note 1 the problem is different. The area on the string where the piano sounds good is much larger. Because of this, several other considerations come into play. These considerations must be resolved because one way or another, you will need to generate a strike distance specification for note 1.

Ask the manufacturer if you can

The world of piano making is a slow motion universe. Piano companies that were in business a century ago sometimes still exist. On an obsolete model they may or may not know the strike distance for note #1. A quick call to determine if they can supply this specification is worth your while. It is even possible that the model in question is still in production.

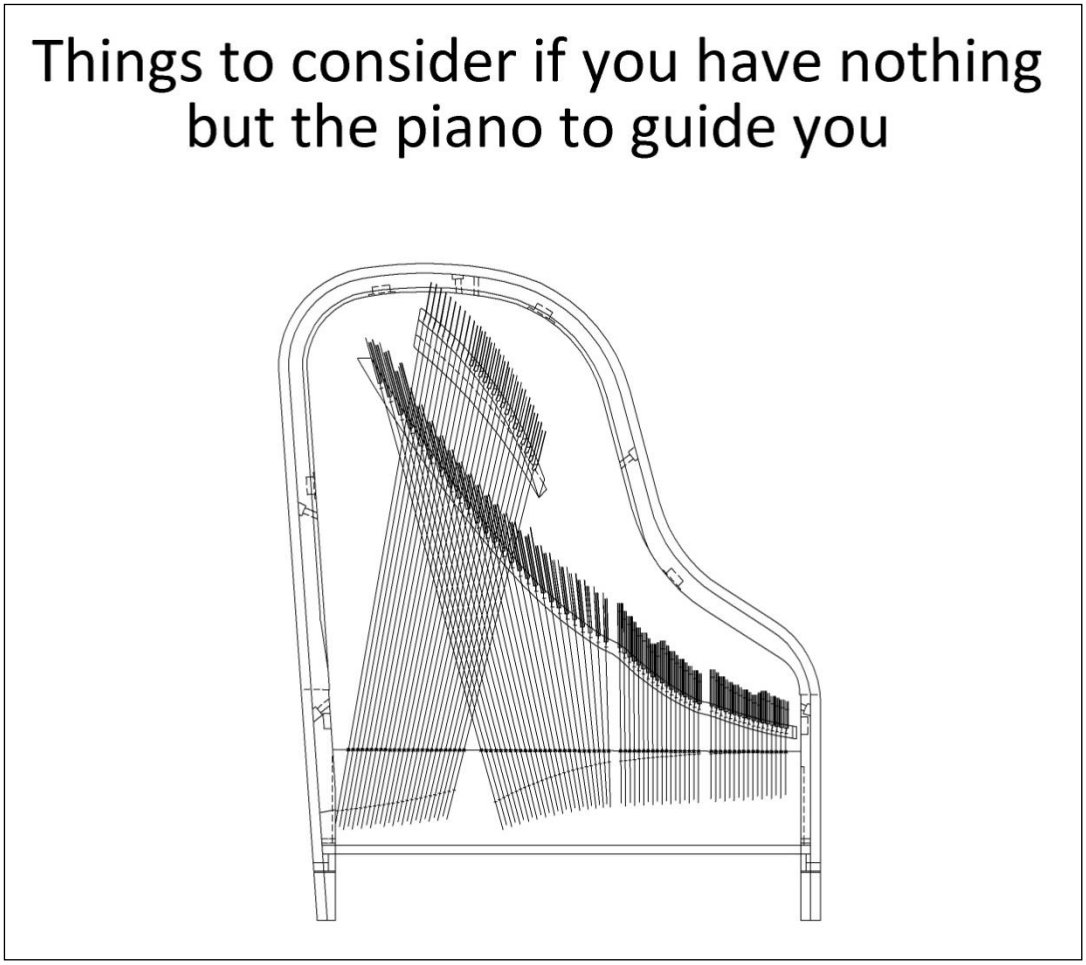
If the manufacturer can provide this specification, by all means, use it.

If the manufacturer is no longer able to provide a specification for strike distance you will need to create it.

Use the old action

If the original action still exists, it is relatively easy to establish the strike point for note #1.

- Position the action correctly in the piano as it was manufactured.
- Place a piece of masking tape on the string in the general area where the hammer will hit.
- Rotate the hammer against the string using a hook.
- Mark on the tape with a pencil where the center of the hammer contacts the string.



Several criteria need to be balanced in order to arrive at a strike point for note #1.

1. Unlike note #88, the piano will sound good over a much wider distance on the string.
2. Most pianos are designed, in the lower half of the instrument, with a strike proportion between 1/7th and 1/9th of the speaking length.
    a. In the bass, typically, pianos are designed so the distance from the agraffe to the strike point is proportional to the speaking length.
    b. The speaking length is the distance from the center of the agraffe to the center of the closest bridge pin.
    c. If you were to divide the speaking length by both 7 and 9 this would define the range in which the hammer can strike the string at note #1.
    d. If you were to divide the speaking length by 8 this would be the most common strike distance for grand pianos.
    e. These distances, of course, would be measured from the center of the agraffe.
3. Smaller pianos are typically designed with a strike line parallel to the front of the piano.
    a. Above 180cm, or about 6', pianos can have a strike line that is angled away from the front of the piano.

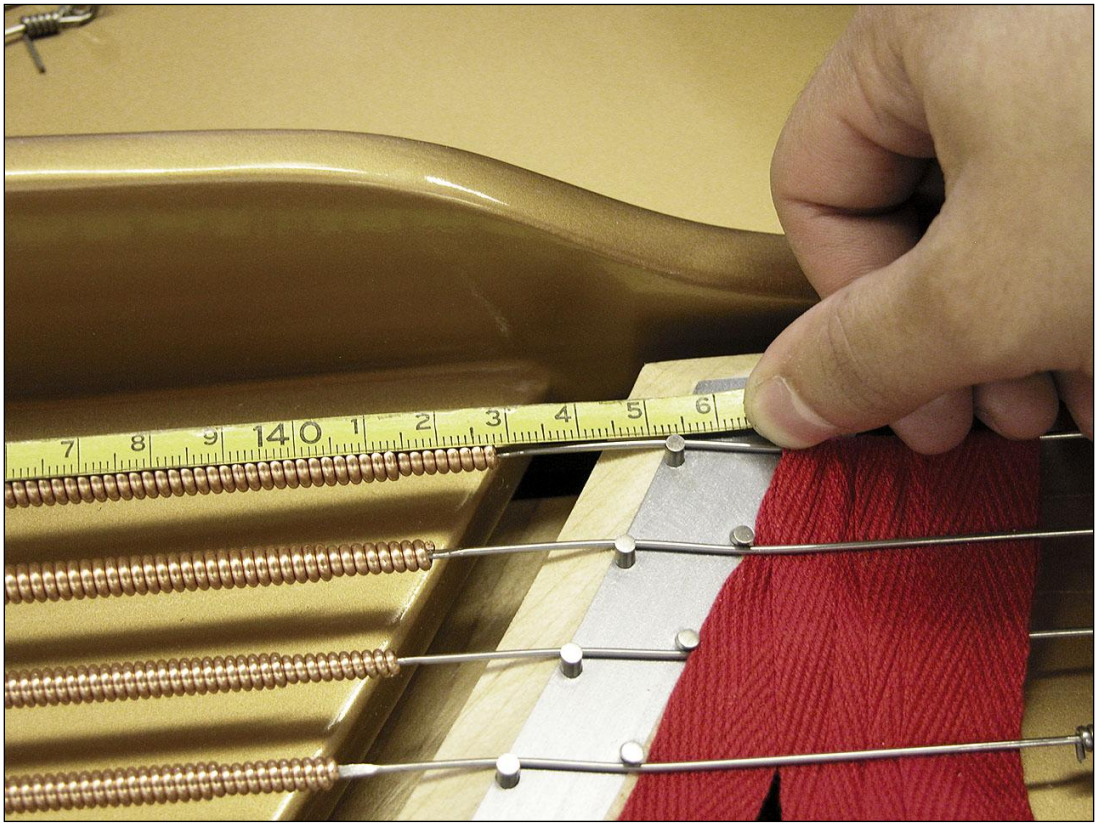
b. 212cm or about 7’ in size and larger will typically have angled strike lines.
c. On a small piano, you can use this fact to help you find a strike point in the bass.
    i. If you can have a parallel strike line in the piano, do so.
    ii. It is easier, and cheaper, to make a keyboard with a parallel strike line. An angled strike line adds complexity and difficulty to the keyboard.

4. As a very important practical matter, you need to leave room for dampers in the bass. Leave a minimum of 35mm or about 1-7/16” from the strike point at note #1 to the center of the damper guide rail hole.

Room for dampers is important!!!!!

If you fail to take this into account, you will discover the mistake after you have paid for a custom keyboard. This is a very expensive mistake. Do not make this mistake.

A method to arrive at note 1 strike in any piano



Start by measuring the speaking length for note #1. Use a millimeter tape measure for this task. Since you want to calculate using these numbers, use a measuring device that is decimal to begin with. While you can use fractional English measurements and then convert them to decimal, unneeded work is involved and not very sensible.

The easiest way to make this measurement is to hook the end of the tape over the agraffe, stretch the tape down the string so you can read the distance to the center of the bridge pin.

Since you want to measure to the center of the agraffe, subtract half the thickness of the agraffe from the measurement and this is your speaking length. Usually this is about 2mm.

Calculate tentative strike distances

Divide the speaking length you measured by 7. This is the longest reasonable strike distance.
Divide the speaking length you measured by 8. This is the most common strike distance.
Divide the speaking length you measured by 9. This is the shortest reasonable strike distance.

Place a piece of masking tape on the string that spans these strike distances. Mark both the longest, most common and shortest strike distances calculated on the masking tape. These two outside marks define the range within which strike distance will likely fall. The center mark is the most common strike distance.

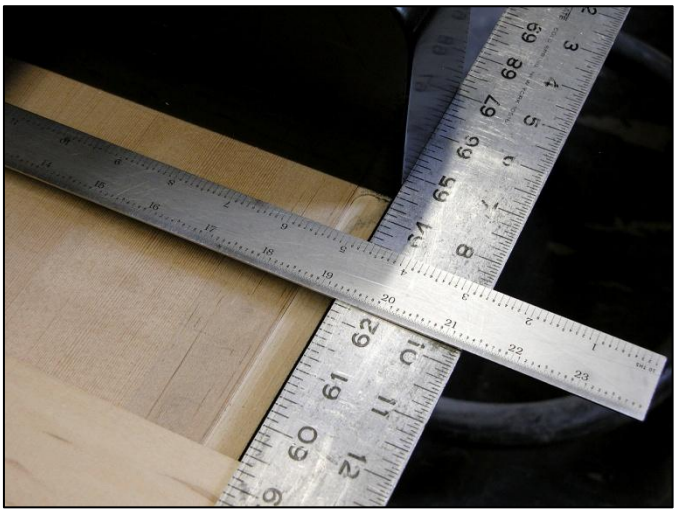
Mark the belly rail location

In the area where the string for note 1 crosses the belly rail, use a square to transfer the location of the belly rail down to the Mylar in the keybed. You will need to measure from the belly rail to the damper guide rail hole. Mark this measurement on the Mylar in the keybed. Transfer this to the Mylar in the keybed.

Mark minimum clearance to dampers

Measure forward in the piano the distance from the damper guide rail hole 35mm or about 1-7/16” and mark on the Mylar. This mark is the closest the strike point can come to the belly rail and damper system without parts fouling on each other.

Evaluate if you can use a parallel strike line



Measure, from the arms of the piano to the strike location at note 88, and mark this on the Mylar at note 1.

Decide on the location of note 1 strike

Recommendations

- If a parallel strike distance is close to a 1/8 strike distance and has sufficient clearance to the dampers, this piano was likely designed with a parallel strike line. Ignore the 1/8 strike distance and instead, make the strike location the same distance from the arm as in the treble. That is, make the strike line location from the arms the same for both note #1 and note #88. Thus the term, “parallel strike line”. This will make designing and building the key set much easier.

- On a larger piano, if a 1/8 strike distance is significantly further back in the piano than the strike point in the treble and has sufficient clearance to the dampers, this piano was likely designed with an angled strike line. In this case use a 1/8 strike distance.

- On a smaller piano, if a parallel strike distance would yield about a 1/9 strike distance and there is sufficient but not excessive clearance to the dampers, make the strike distance so there is a parallel strike line.

Mark note 1 strike location on Mylar

Use the piano technician's plumb bob to transfer the mark on #1 bass string down to the Mylar in the keybed.

Make a mark on the Mylar where the plumb bob points to mark the strike location for note #1.

Draw the strike line

Use a straight edge and a Mylar pencil to draw a line between the note #1 and note #88 strike points on the Mylar.

This is the strike line of your piano.

Mark the strike at the end of each section

Place tape on the end of section notes in the area of the strike line. Use the plumb bob to transfer the strike location to the tape.

Slide the string on the plumb bob up through the strings until the center pin is just off the Mylar. Move the string front to back until the pointer is directly over the strike line.

Mark on the tape on the end of section notes the location of the strike line.

Mark the side to side location of the end of section notes on the strike line

Use the plumb bob to mark the opposite sides of the strings for each end of section note. The procedure is the same for unichord, bichord and trichord notes. This will produce two marks for each end of section note.

Mark the note center half way between the two marks.

Now you have the end of section note centers marked on the strike line.

Prepare section Mylar strips

Cut pieces of Mylar about 50mm or 2” wide that will fit into each section of the piano. Draw a line down the Mylar to represent the strike line.

Cut the ends of these pieces of Mylar so that they fit into each section.

Position each piece of Mylar in its section so that the line drawn on the Mylar is aligned with the strike marks on the end notes of each section.

In the low treble section, trim the Mylar on the V-bar side so you can position the line over the strike marks.

In the high treble, there is not enough room between the v-bar and the strike to position the Mylar as in the lower sections. Use the edge of the Mylar itself as your strike line mark.

Tape the Mylar into place so it cannot move.

Mark the note centers on the section Mylar’s

In the high treble there is not enough room to use a piece of Mylar with a line drawn on it as in the lower sections of the piano. Instead cut an edge on a piece of Mylar that is straight. That will serve as your line. Cut the ends as before and tape the Mylar onto the strings so the edge is on the strike line marks on the end of section notes.

Mark treble trichord note centers with the mark centered on the center string.

Sometimes it is easier to see if you place a mild light in the keybed.

Write the note numbers on the end of section notes so you will be able to know which Mylar represents which section.

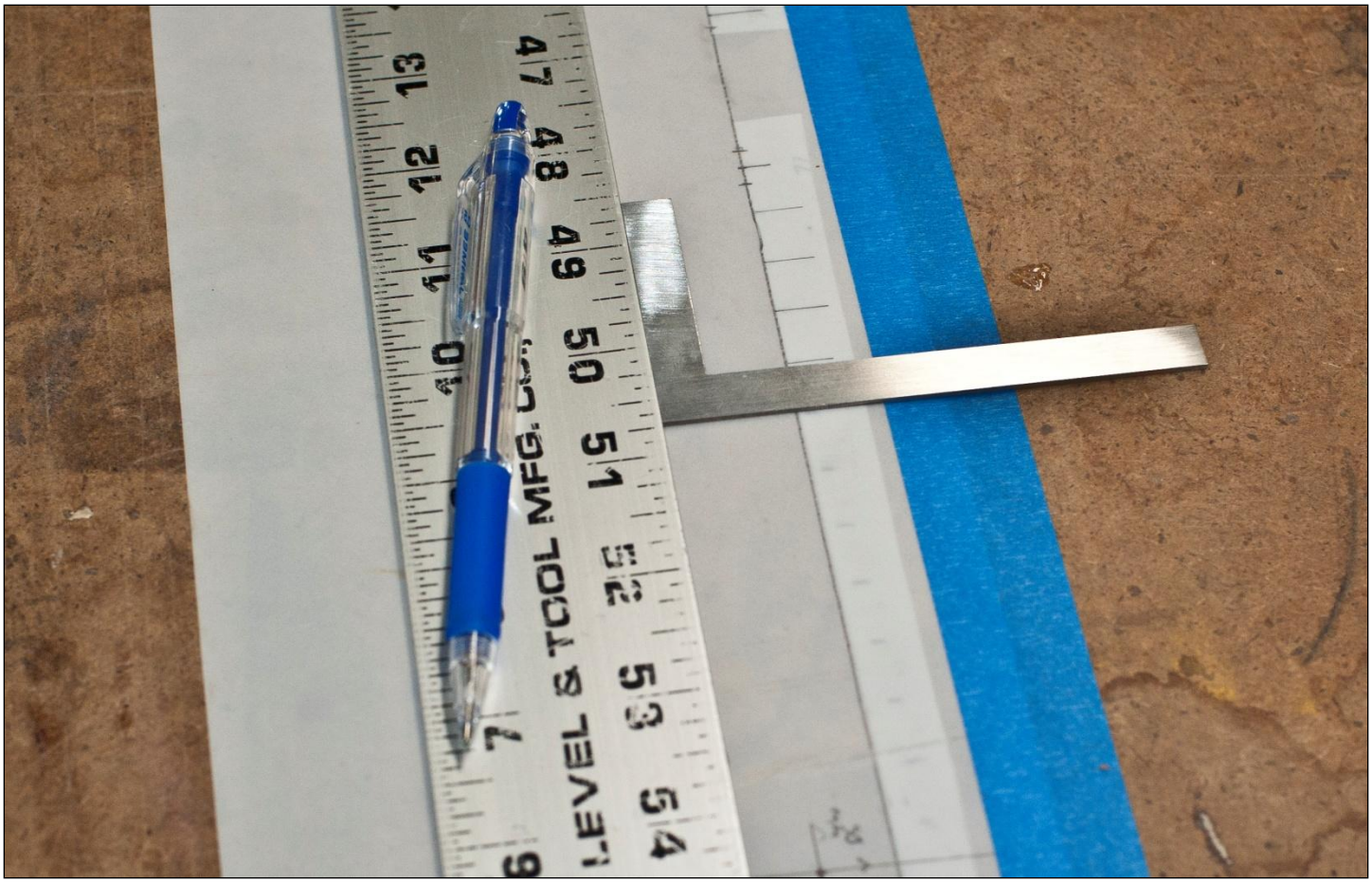
Mark on the keybed at each end of the piano the location of the strike line. One easy way to do this is to use a stick pin on the strike line at the bass and treble ends. This will allow you to reposition the keybed Mylar at a later date if needed.

Remove the Mylar with the strike line from the keybed of the piano.

Create the “Spacing of the note centers at the strike line” scale stick

Tape the Mylar to a flat bench on one edge only. This will allow you to lift the Mylar up to put a section Mylar underneath the keybed Mylar. Make sure that you have not distorted the Mylar by checking the straightness of the strike line.

Place a section Mylar underneath the keybed Mylar and align the strike line and note marks. Make sure that the section is oriented correctly bass to treble. When the strike line and note center marks for the end of section notes are aligned, tape the section Mylar to the bench so it will not move.



With the section Mylar under the keybed Mylar, you will be able to see the locations of each note. Mark these locations on the keybed Mylar.

When you have done all the sections in the piano, you will have created a “String Spacing at the Strike Line” scale stick.

This is a necessary step and the foundation that the key and action scale stick will be based upon however, there is still more work to do.

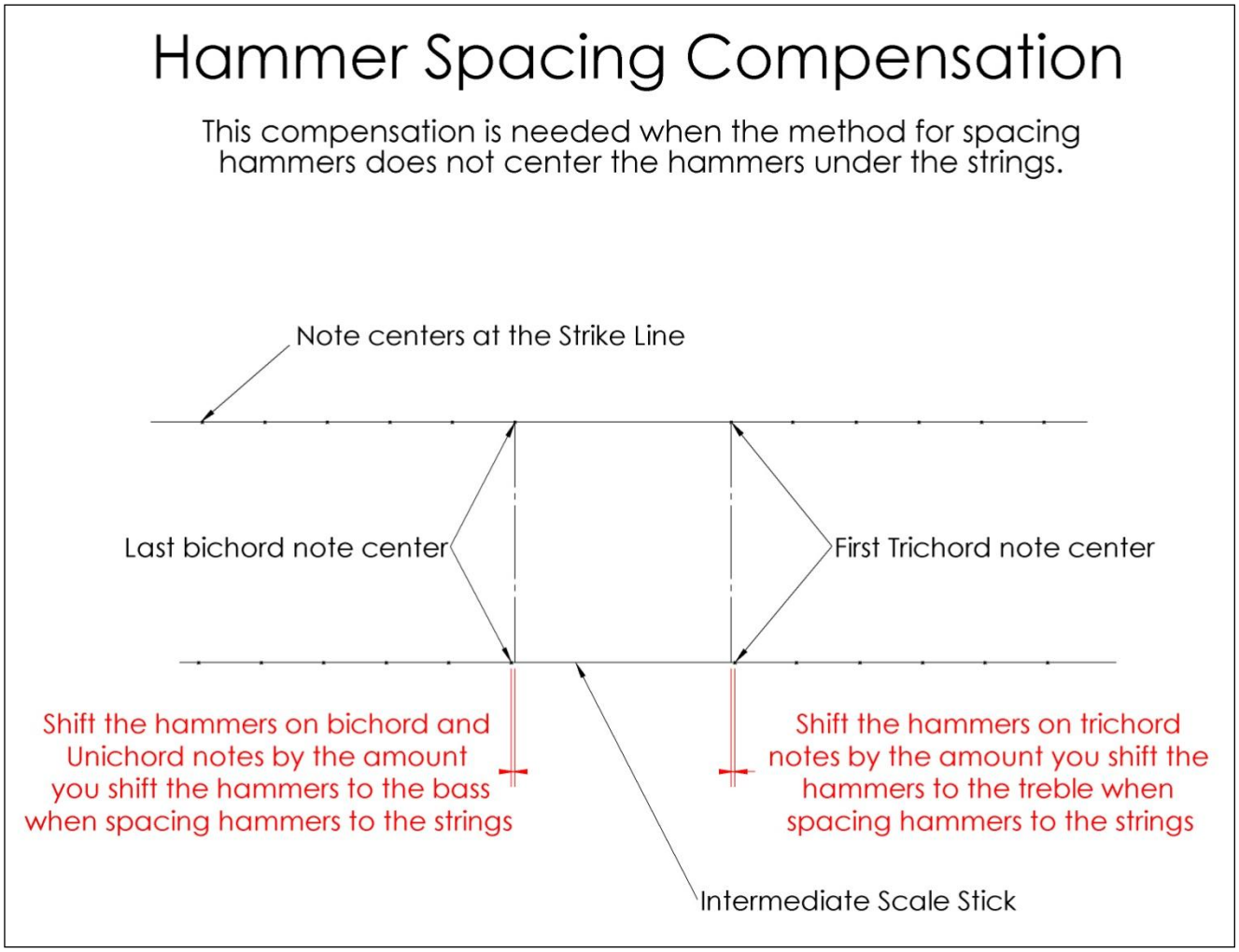
Compensations

Now you must add two important compensations in order to create a scale stick for the key and action.

The hammer spacing compensation

The hammer tilt compensation

Ideally, after all regulation is complete, the hammer shanks will fall centered above the repetition flange, directly over the cushion. The following compensations are required to meet this criteria.



On the overwhelming majority of pianos, the Soft Pedal shifts the action towards the treble so that trichord hammers will miss one string. Because of this there are at least two ways to space hammers to the strings.

If the piano you are working on shifts to the bass, given the extensive nature of this job, WNG suggests you convert the piano to a treble shifting Una Corda as part of this project. To do this you would need to purchase an Una Corda pedal and probably a shift spring. The task is relatively straight forward to cut the required holes in the keybed and mount the shift lever. Since you are making a new keyboard as part of this job, in both cases, cutting the keyframe for the shift lever is the same.

The simplest method is to space the hammer so it is centered below the string/s for each given note. Those who like this method feel that the best power transfer between the hammer and the string occurs when centered.

Those who do not like this method feel the shift on the Soft Pedal is excessive. When trichord hammers shift off a string so do bichord hammers. While desirable for a trichord, it is most definitely not acceptable for a bichord to shift off one string.

A mildly more complicated method requires the regulator to space the hammers so that, on the trichord notes, the hammer is spaced to the treble reducing the distance that the Soft Pedal must shift the action. On bichord hammers, the hammer is shifted in the opposite direction. Thus, in the bass, instead of shifting off a string, the Soft Pedal moves the action so softer felt on the hammer hits the string.

As far as compensations go, if you space hammers so they are centered on the string/s no compensations are needed.

If you space the trichord hammers to the treble and the unichord and bichord hammers to the bass, this needs to be taken into account in the "Key and Action" scale stick.

Create the intermediate scale stick that includes hammer spacing technique

Take a new piece of Mylar. Draw a new strike line down the Mylar. Lay the Mylar over the "String Spacing at the Strike Line" scale stick. Align the strike lines. Tape the new Mylar into place so the it cannot move.

On all trichord notes transfer the marks onto the new Mylar.

When you shift the hammers, allow about .75mm or about 1/32" for the trichord hammers. For the unichord and bichord hammers allow about the same in the opposite direction. Since the trichord and non trichord hammers shift in the opposite directions, you can add the compensations so as to increase the distance between the trichord and non trichord hammers.

You have already marked the notes that correspond to the trichord hammers. From the first bichord hammer mark measure this combined dimension, in this case 1.5mm or about 1/16". This increases the distance between the last bichord and first trichord hammer by the total compensation.

Lift the new Mylar and re-position so that the last bichord note center reflects the added compensation. When positioned, tape the new Mylar to the bench so it cannot move.

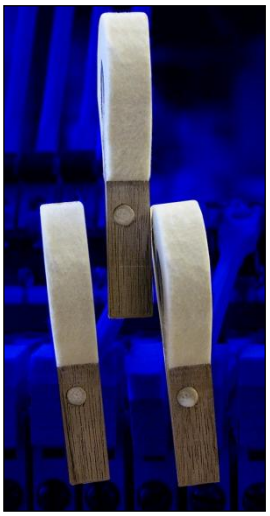
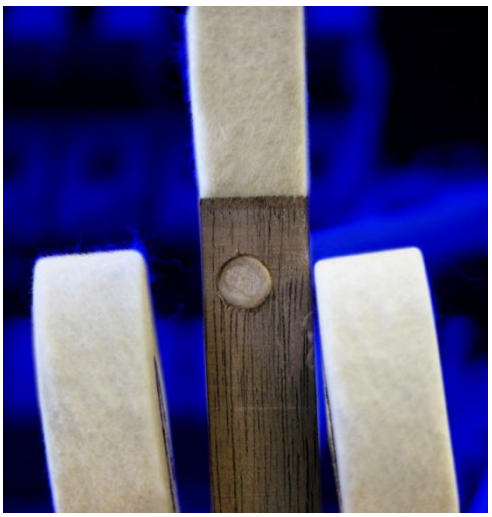
Mark the bichord and unichord note centers.

You have now created an intermediate scale stick that reflects compensations for hammer spacing.

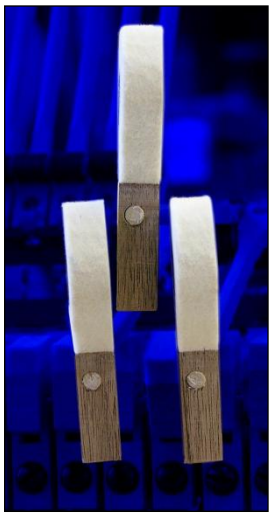
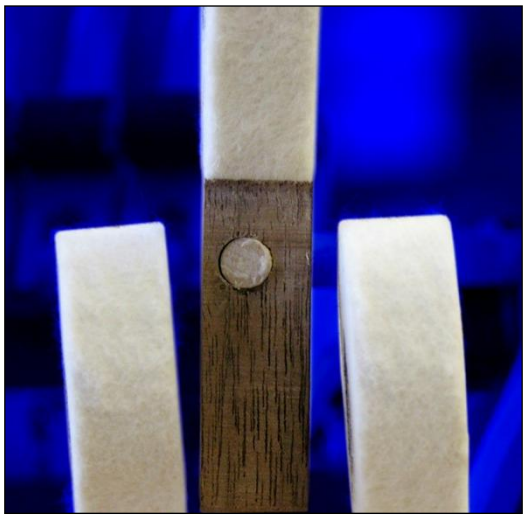
You really do need to tilt the angled hammers when gluing

Many believe that this is hooey. "I don't tilt hammers, I glue them on straight. Afterwards I heat and bend the shanks for clearance."

Whether or not they are aware of it, when they bend the shanks they are tilting hammers. See the pictures below.

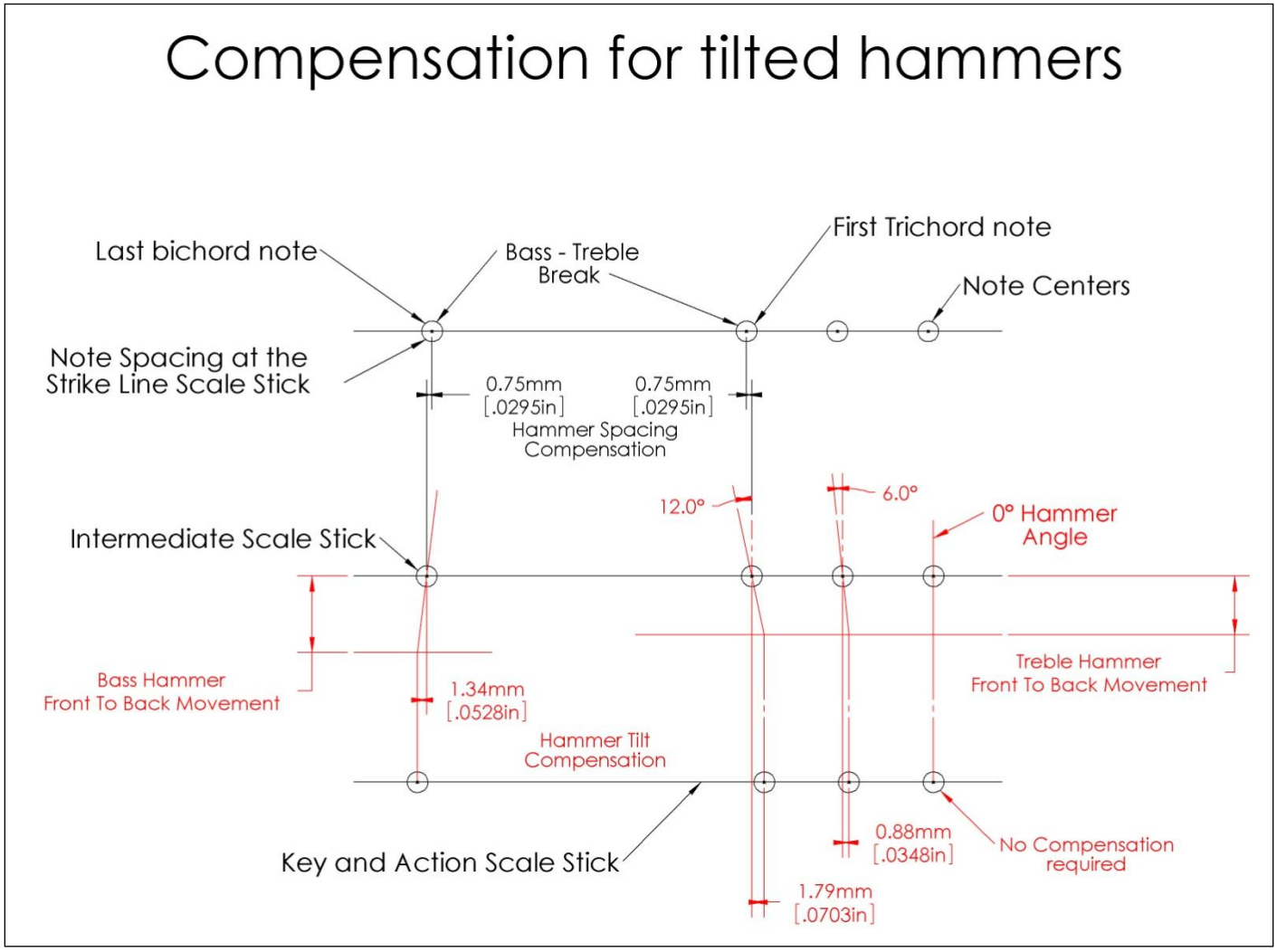




When glued on square, because of hammer front to back movement, clearance will always be a problem. Above you can see what happens when angled hammers are glued on square.

Traditionally, piano makers have tilted the hammers during gluing so as to create clearance. The pictures show clearly how effective the technique is in creating clearance for the hammers.

This tilt, however, creates a problem for the key and action scale stick. Because the hammer is tilted, the shank is not directly under the note center. It is instead offset to the side. This offset needs to be taken into account in the key and action scale stick so that, when the action job is complete, the hammer shanks fall directly over the repetition cushions.



Hammers are bored with angles to match up with the string angles. Because of this, when glued on to shanks, hammers need to be tilted sideways so they will clear the adjacent hammers when played. An alternate method used in Europe is to tilt the travelling instead of the hammer gluing. Either way, the scale stick compensation is the same.

The amount of tilt for a hammer is directly dependant on the amount of angle and the amount of hammer front to back motion when played. If there is no angle, as is usually the case in the high treble, no tilt and thus no compensation is required. The more the angle, the more tilt is required and thus more scale stick compensation required.

When a hammer is tilted, the location of the shank over the repetition is changed. This change needs to be taken into account in the “Key and Action “ scale stick.

Create hammer boring specs for the piano

While you can use the old hammers, the best way is to create an entirely new set of boring specs by measuring the piano.

Your first step is to decide if you wish to have a common angle in the bass or if you wish the bass boring to follow the strings. Pianos such as Steinway and Mason & Hamlin use a common boring angle throughout the bass section. Steinway uses 5.5°. Mason & Hamlin uses 9.0°. WNG prefers a common angle in the bass.

Ultimately it is your decision. If you use a common boring angle throughout the bass you will not need measure the bass string angles. If you wish the bass boring to follow the strings you will need to measure the string angles in the bass.

To measure the string angles, you need a straight edge aligned to the strike line to measure from. Place a straight edge on top of the plate bars. Using two small squares align the straight edge to the strike line marks you placed on tape on the strings earlier. Tape the straight edge into place with masking tape so it cannot move while you are measuring the string angles.

Use a protractor to measure the string angles. Measure as best you can the lowest tenor note to get a sense of the angle. Reset the protractor to nearest whole number angle as close to the angle of the lowest tenor note. For instance we would set the protractor to 12.0° or 13.0° or 14.0° as needed.

Move the protractor until you find a note that is exactly the angle set on the protractor. Write down the note number of that note along with the angle.

Set the protractor to the next lower whole number angle. Again, move the protractor until you find a note that is the exact angle on the protractor.

Repeat this process until you reach 0° and / or note 88. It is possible, though unlikely, that the highest notes could go past 0°.

Define Hammer Boring Angles

Note Number	Measured string angle	Hammer boring angle
21	12°	12°
22		11°
23	11°	11°
24		11°
25		10°
26	10°	10°
27		10°
28		10°
29		9°
30	9°	9°
31		9°
32		8°
33	8°	8°
34		8°

Define the hammer angle sections so they start and stop half way between the even angles you have measured. For instance, say note 30 happened to be 10° and note 35 happened to be 9°. The section for 10° hammers should end on note #32. The section for 9° hammers should start on note #33.

Hammer Boring Specifications

Molding Material Walnut

Boring Distance:

Bass	57.4mm (2.26in)
Treble	49.3mm (1.94in)

Rake Angle: 0 °

Drill Size: .4.9mm (.191in)

Boring Angles

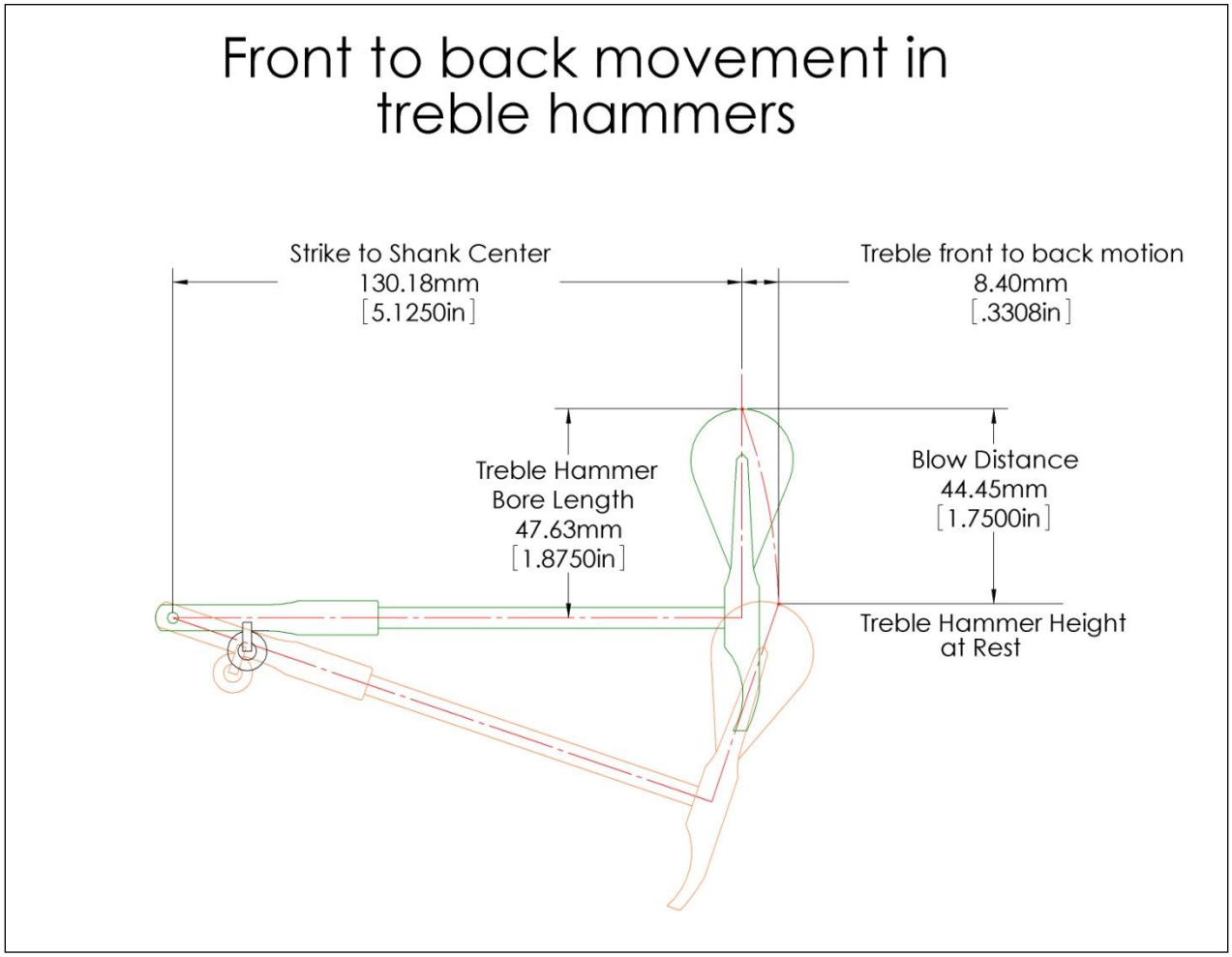
Bass	Note No.	Angle	No. Of Hammers
	1-26	9°	26

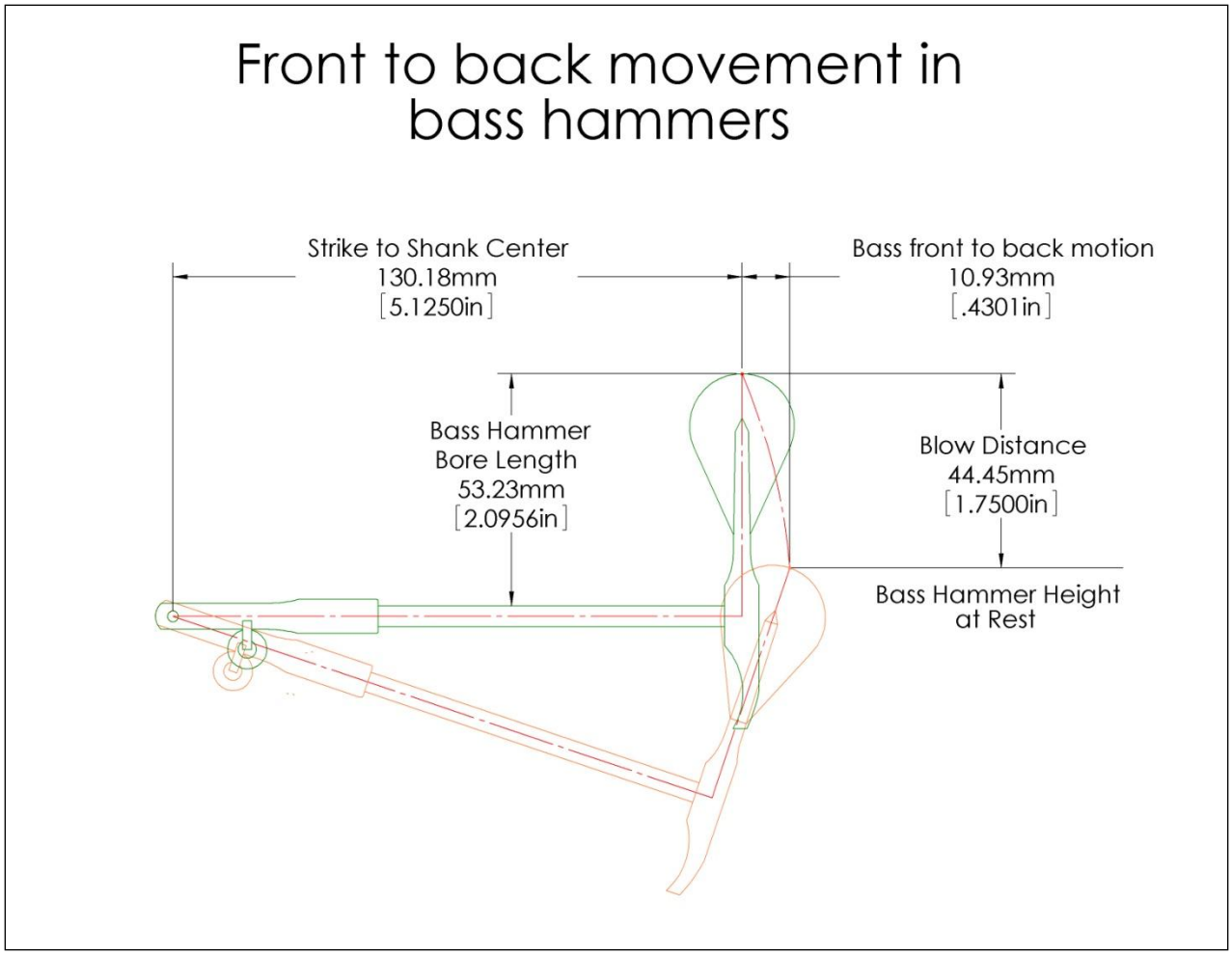
Treble	Note No.	Angle	No. Of Hammers
	27-28	16°	2
	29-30	15°	2
	31-32	14°	2
	33-34	13°	2
	35-36	12°	2
	37-38	11°	2
	39-40	10°	2
	41-42	9°	2
	43-44	8°	2
	45-46	7°	2
	47-49	6°	3
	50-53	5°	4
	54-57	4°	4
	58-59	3°	2
	60-61	2°	2
	62-63	1°	2
	64-88	0°	25

When you are through you should have specifications that look something like this. While you need this for the scale stick you will also need these specs for prepping the hammers when you get to that point.

Hammer Front to Back Motion

As the hammer rotates from the rest position to the string it also travels front to back in the piano. The distance it travels is the crux of why you need to tilt hammers. A combination of the front to back movement and the angle of the hammer dictates how much tilt is needed when installing hammers.

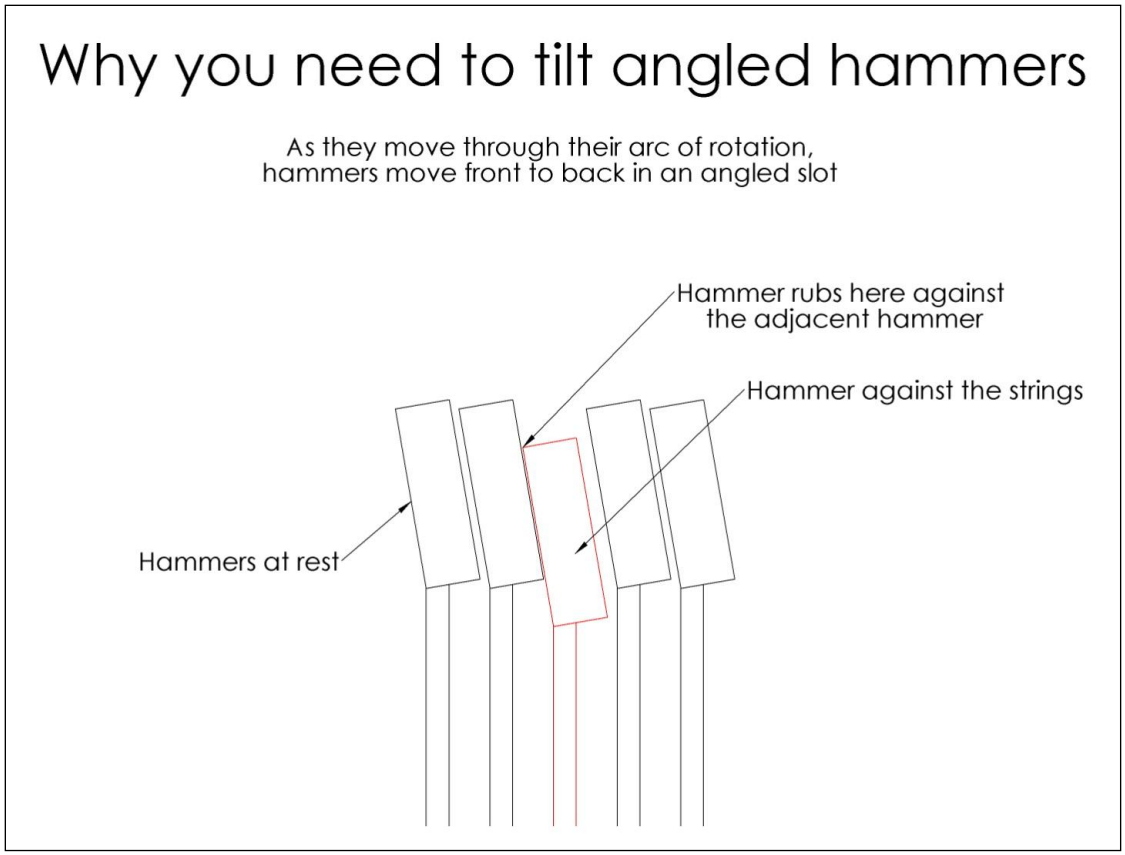




From the above drawings, you see that, as the hammer rotates from its rest position to the string, the tip of the hammer moves forward in the piano.

Notice that there is more front to back motion in the bass than in the treble. This is because the hammer is longer in the bass than in the treble.

So let us ask the obvious question, why is this a problem?



Calculate Hammer Front To Back Motion

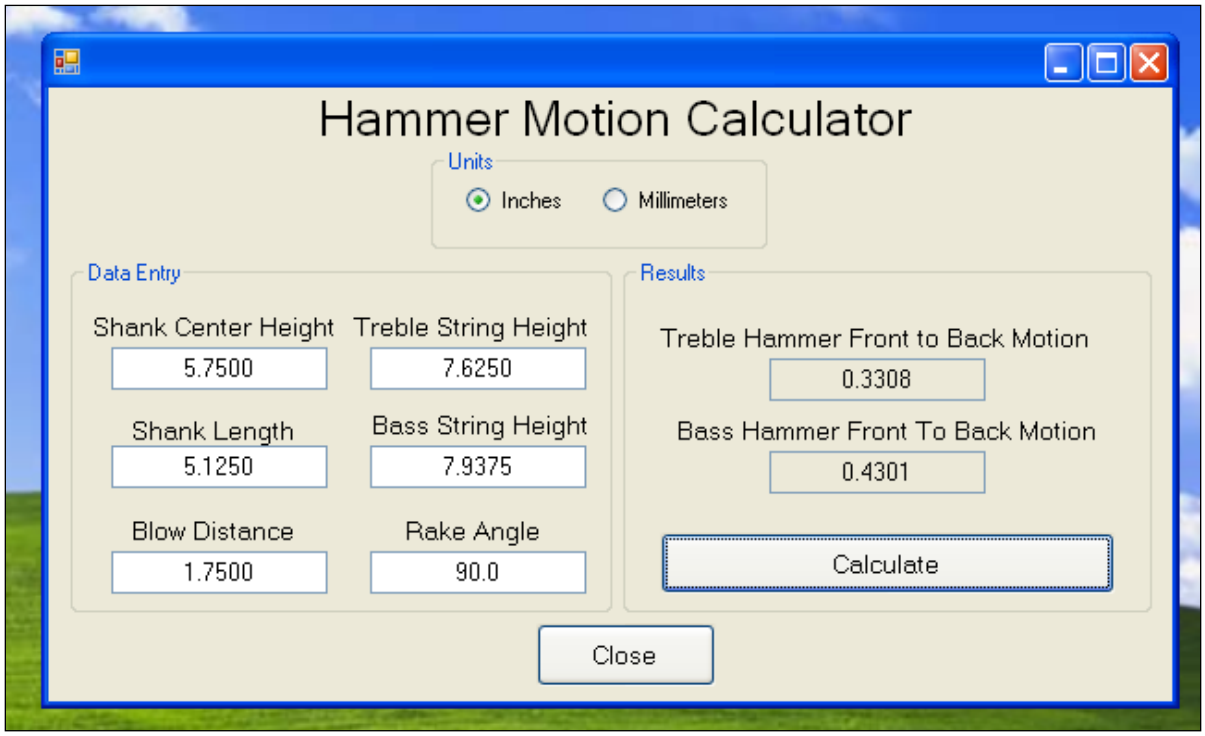
You do not need to make these drawings to arrive at these numbers. WNG has created a simple little calculator for this purpose. The math is not difficult however we have made it really easy. Just download the calculator from the web site.

To use this calculator you will need to establish the following dimensions. These are "design" dimensions in that they are what the piano was designed to be, not an actual measurement that will always deviate from the ideal to some degree.

Below we have an example of a typical action setup. In actuality these dimensions vary somewhat, usually plus or minus about 1/16" or about 1.5mm. For this calculation we will use design not actual dimensions.

For the piano you are working on, you will need to establish design dimensions for the following.

Dimension	Example	Your Piano
String Height – Treble	7.625"	_____
String Height – Bass	7.9375"	_____
Shank Height	5.75"	_____
Shank Length	5.125"	_____
Blow Distance	1.75"	_____



Download the calculator and save to a directory of your choosing. Here is the link.

https://www.wessellnickelandgross.com/media/programs/HammerMotionCalculator.exe

This calculator runs on Windows XP service pack 2, Vista and Windows 7. You will need Microsoft .Net framework 4.0 installed on your computer. Dot Net software can be acquired from Microsoft for free.

Double click the .exe file to invoke.

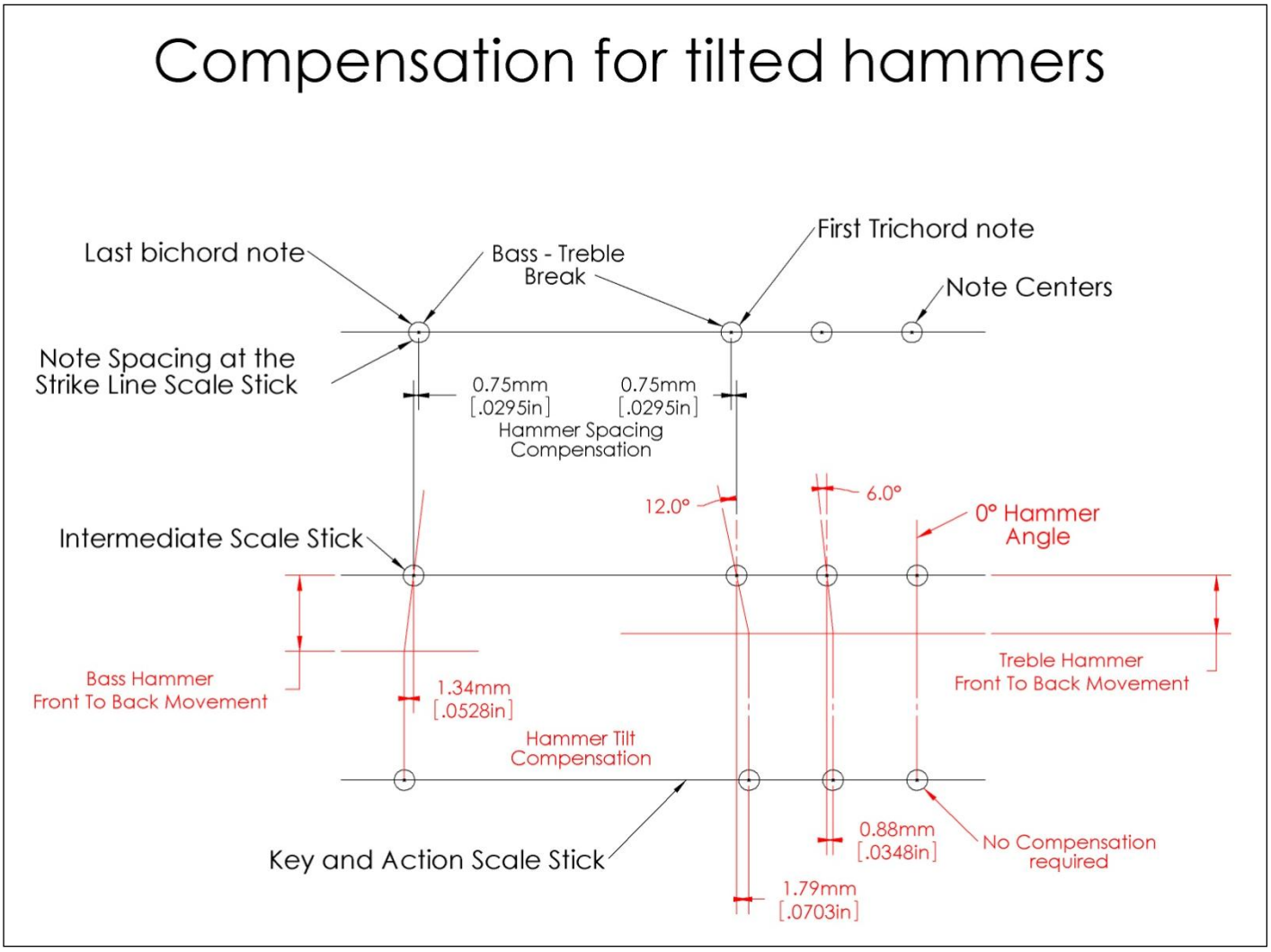
Enter the above info into the appropriate text boxes.

After all the dimensions are entered into the calculator, click calculate.

For the example above, using Mason & Hamlin data we get a treble front to back motion of 8.4mm or .3308in. For the bass front to back motion we get 10.9mm or .4301in.

For your piano, of course, the data will likely be different. However, the principles are the same.

In fact the data will not be terribly different. Most likely if you used the data shown above you would be fine. We prefer precision. You can do as you please.

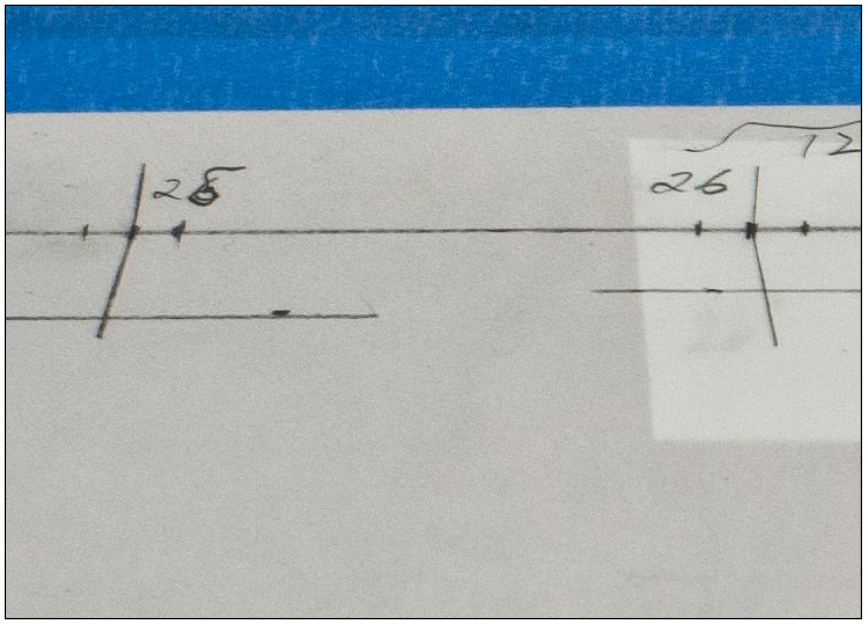


Using the scale stick you created earlier that includes the compensation for soft pedal shift, we will now add the compensation for hammer tilt.

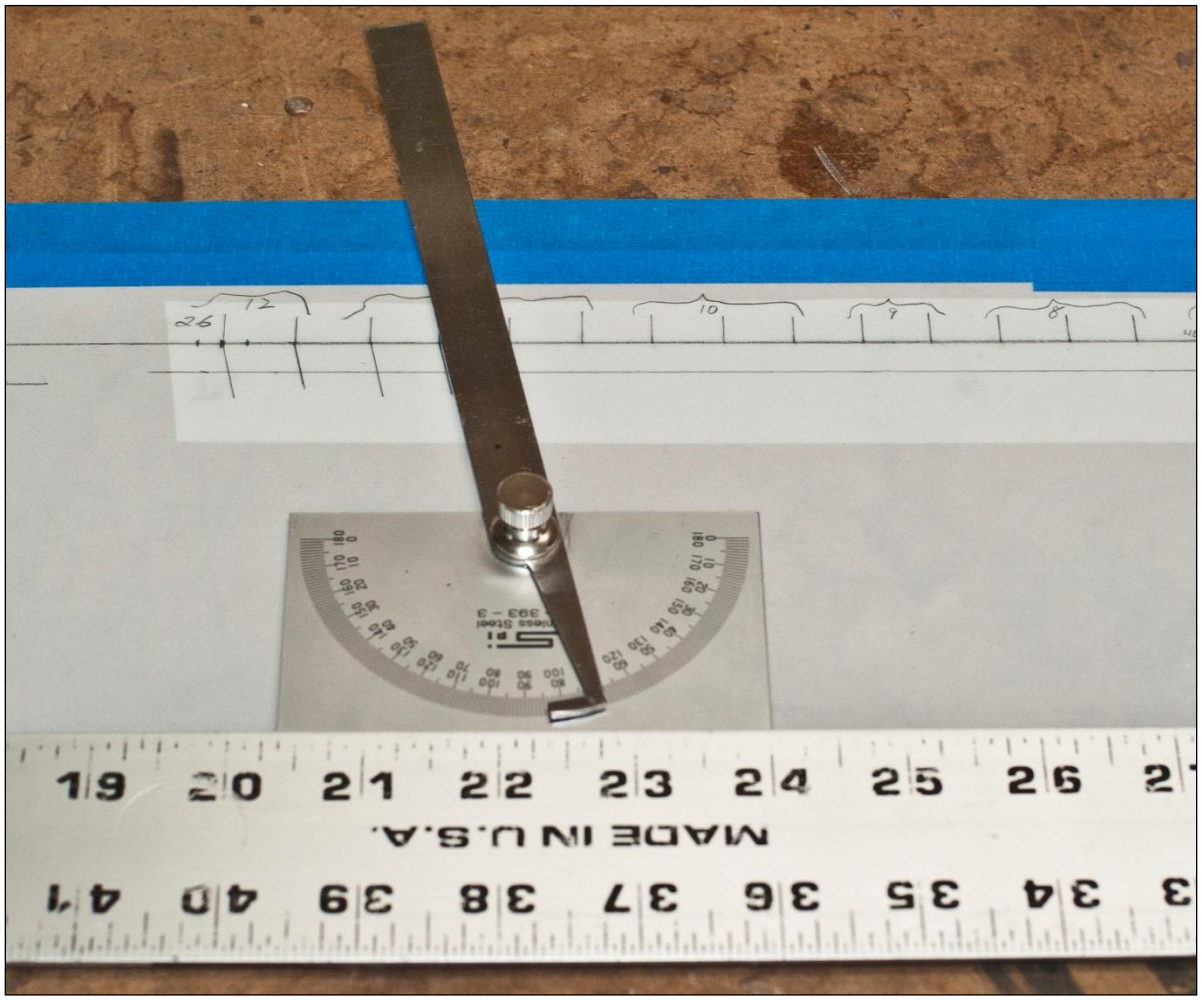
Orient the Mylar on the bench with the bass to your left. Tape down making sure that the note line is straight.

In the bass, measure towards yourself the dimension of the ”Bass Front to Back Motion” (10.9mm or .4301in) at each end of the bass section and mark on the Mylar. Draw a line parallel to the note line through these marks.

In the treble, measure towards yourself the dimension of the ”Treble Front to Back Motion” (8.4mm or .3308in) at each end of the bass section and mark on the Mylar. Draw a line parallel to the note line through these marks.

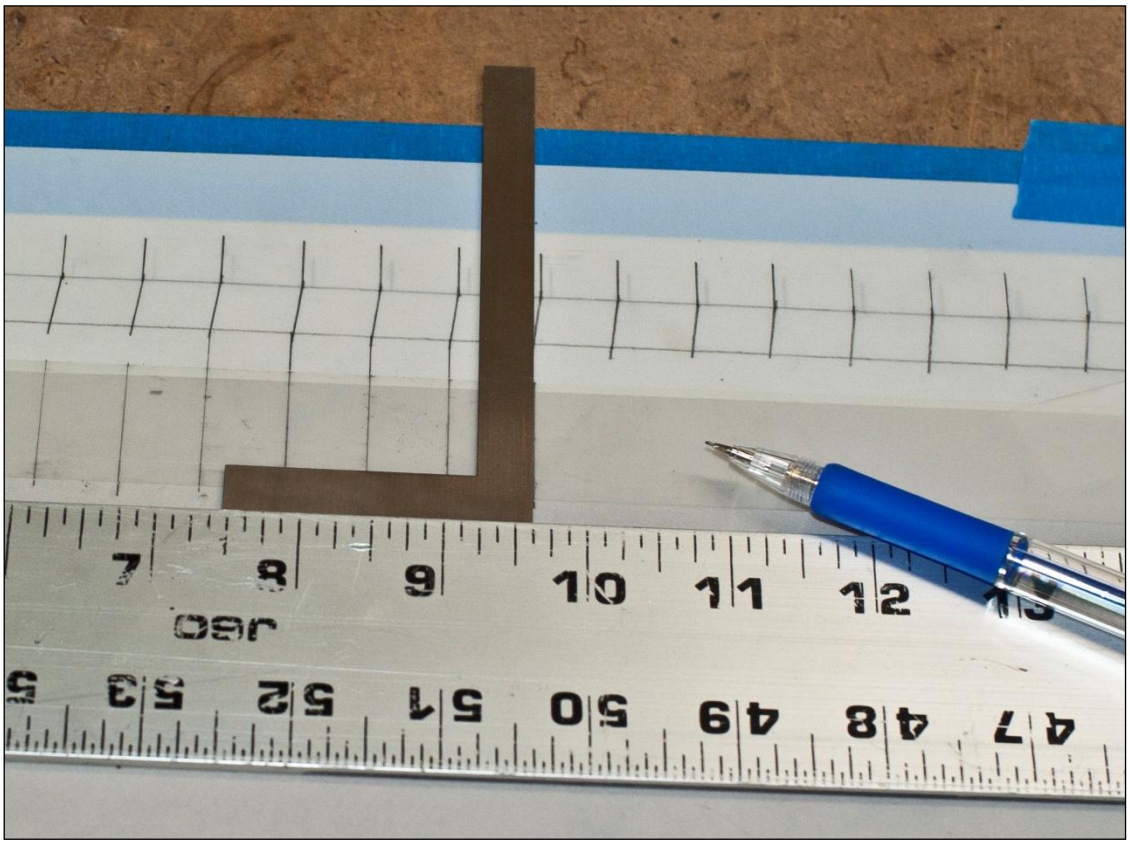


Here we have drawn the hammer front to back motion line for the bass and the treble.



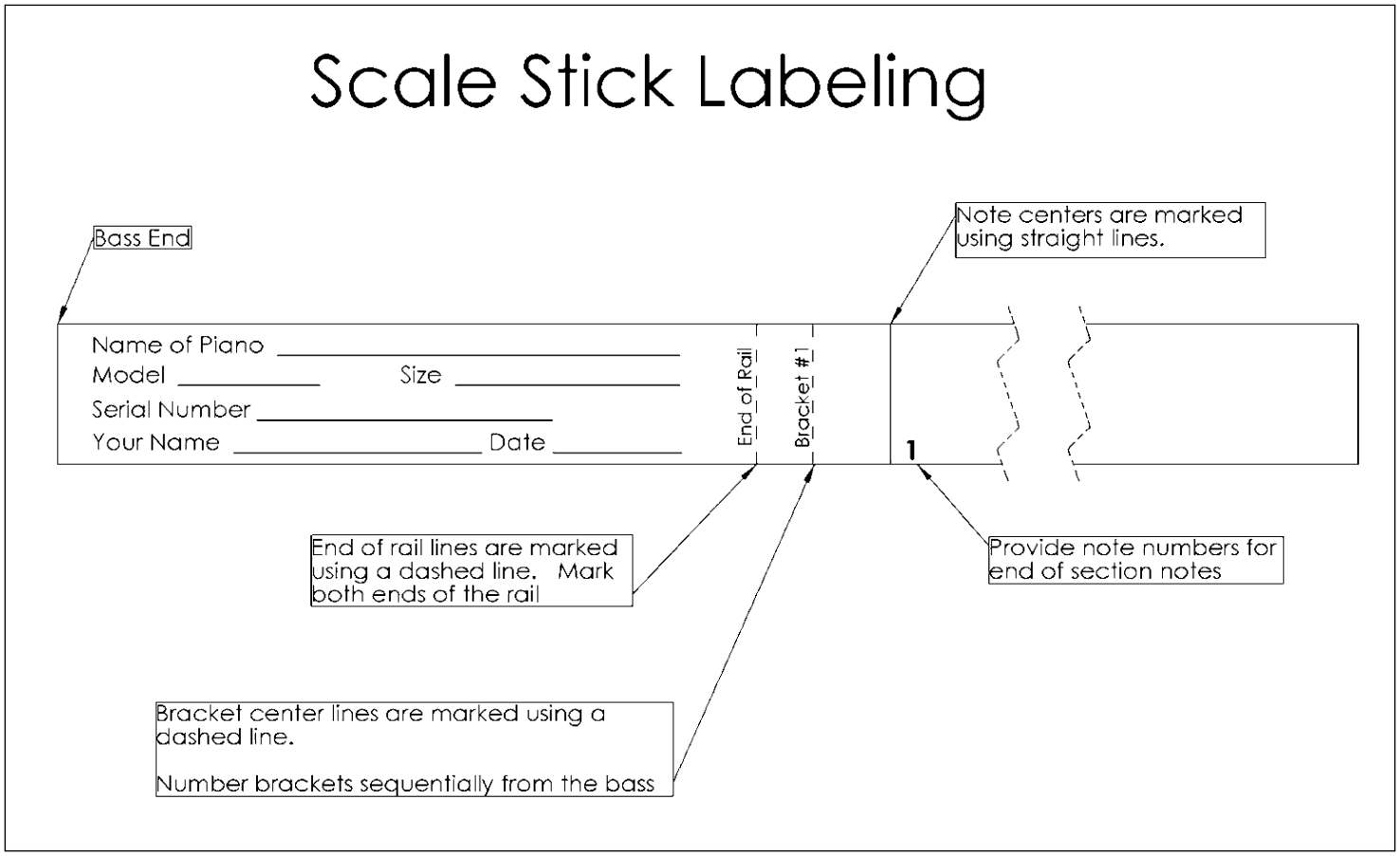
Set up a straight edge parallel to the note line on the Mylar. Mark out the sections of hammer boring by angle.

For each section that hammers will be bored to a given angle, set up that angle on the protractor. Slide the protractor along the straight edge and draw a line through the mark for the note and extend it down to the front to back motion line. This is the compensation for that note. Do this for all the notes in the piano changing the angle on the protractor for each section of hammers.



Lay a 25mm or 1" wide strip of Mylar on top of the Mylar you have been working on. Tape down so that the strip is parallel to the note line. WNG supplies a scale stick kit with a Mylar pencil, square and 25mm wide strips of Mylar for your convenience.

Using a square or draftsman's triangle, place one edge against the straight edge and slide the vertical to the intersection between the "Front to Back Motion Line" and the hammer angle line. Draw a vertical line on the strip of Mylar. Do all 88 notes of the piano. This is the note spacing for your Key and Action Scale Stick.



Scale Stick Labeling

WNG has established a scale stick protocol that ensures we understand your information.

- Note centers are marked with straight lines.
- Bracket centers are marked with dashed lines.
- Brackets should be numbered sequentially from the bass.
- Each end of the rail is marked with a dashed line.
- At the bass end of the scale stick mark the following information as shown above.
    - Name of Piano.
    - Model and size of piano.
    - Serial number of piano.
    - Your name and the date this scale stick was taken.

The purpose of the WNG scale stick protocol is to reduce confusion. It helps us to avoid mistakes when we are looking at your scale stick. Avoiding mistakes helps us all.

Design Bracket Locations

- At note #1 measure to the bass 14mm or about .55in and mark a line for the #1 bracket.
- At note #88 measure to the treble 14mm or about .55in and mark a line for the treble bracket.

- At the bass – tenor break measure half way between the notes and mark a line for the tenor bracket.
- Do the same for each break in the piano.
- Draw a dashed line through the bracket marks.
- Write on each bracket line the bracket number (Bracket #1 etc).

End of rail lines.

- From the first and last bracket lines measure out 10mm or about .394in and mark. This is where the hammer and repetition rails will end.
- Draw a dashed line through the "End of Rail" marks.
- Write on the "End of Rail" lines "End of Rail".

Send this Scale Stick to WNG

Send the scale stick to WNG so we can drill the action rails for your new top action. The best way to do this is to roll the scale stick up with a rubber band around it. You will also need to fill out the WNG Action Build Sheet. This build sheet specifies the feature set you wish for the WNG top action.

Send the scale stick to:

WNG
Attn: Jamie Marks or Bruce Clark
35 Duncan Street
Haverhill, MA 01830

Even Spacing

When your piano was designed it is possible, even likely, that some of the sections were evenly spaced. During the manufacture of the plate and your subsequent extraction of a scale stick, small errors have likely occurred. Consequently, on the scale stick you send us, the note spacing might not be as originally designed. On a tight scale, because of the random nature of these deviations, the distance from one note to the next could easily fall below WNG mandatory minimums.

For this reason, when we receive a scale stick from you, we will evaluate the various sections of the piano to see if even spacing is reasonable. Of course, if even spacing is not reasonable we will go 100% from your scale stick.

If, in our judgment, equal spacing is sensible for a particular section, WNG will use the first and last notes from that section on your scale stick and evenly space the notes between. If you plan to replace the keyboard, you will need the action scale stick from WNG to provide to your key maker. WNG will gladly provide a copy of the final scale stick if requested.