Chapter 10

Rebuilding

"The secret of getting ahead is getting started. The secret of getting started is breaking your complex, overwhelming tasks into small manageable tasks, and then starting on the first one."
—Mark Twain

A piano "rebuilding" is a series of procedures performed to restore or improve the instrument's original condition. This includes various repairs, adjustments, and regulation procedures, and sometimes even redesigning or reengineering certain components. Unlike spot repairs, which are performed as needed, a rebuilding entails the careful planning of an entire series of interrelated operations. For this reason, I recommend reading all of this chapter before starting a rebuilding project so that you know what you are getting into.

Figure 481
A rebuilt 1878 Steinway & Sons 8'6" [259 cm] concert grand.

Rebuilding requires a diverse set of skills and experiences. Workers and technicians in piano factories specialize in relatively narrow areas of piano building, but a piano rebuilder must excel in all of them. Those areas include woodworking, some metalwork and machining, finishing, very precise work on action parts, precise regulation of mechanical components, and, of course, tuning and voicing. Most technicians find it difficult to quickly switch from physically demanding work, such as lifting the plate, stringing the piano, or repairing the soundboard, to intricate repairs and adjustments of action parts.

A little knowledge can be worse than no knowledge at all, if it gives you a false feeling of competence. Be *extremely cautious* before doing anything that is irreversible. Whenever you need to cut something or change its dimensions (for example, if modifying action rails), *stop and think*. Measure twice and cut once.

When you need to perform a lot of repetitive procedures, it's easy to lose sight of the "big picture." Take the time to periodically step back and think of the project as a whole.

Many procedures require practice. You can't expect to wind perfect string coils, uniformly notch bridges, or flawlessly spray a finish on the first try. Some work is reversible, but most is not. Procure a scrapped piano or build models of parts so you can practice a procedure. Install key tops and key leads in scrap softwood boards instead of piano keys, for example. You can rout mortises in scrap pieces of pine in order to practice installing cloth bushings. Use materials that are similar to those in the piano.

Controlling the application and quality of glues and finishing products requires testing a particular product in a particular situation. Without thorough testing, you can't be sure of the outcome of any procedure. If you don't have the benefit of learning from a piano technician or in a school of piano technology, try each product in a non-critical project before using it for repairs or in a rebuilding of a good piano. Simulate the conditions of a repair with pieces of scrap wood, metal, and felt. Be sure all the conditions during the testing (temperature, humidity, ventilation, etc.) are the same as they will be during the rebuilding.

Products such as the glues, solvents, and fasteners mentioned in this book are available in the U.S., but you should be able to find substitutes worldwide.

When you open the piano for the first time, look for signs of rodent infestation. If you find any, decontaminate and clean the piano before proceeding (page 136).

Choices and Consequences

In his inspiring book, *Shop Class as Soulcraft*, Matthew B. Crawford points out that a mechanic—or piano rebuilder, in our case—has a "metaphysical responsibility to the machine."[335] This is a concept that every piano rebuilder needs to consider very carefully. Our obligation is not only to the customer (if you are your own customer, soon you will be on the receiving end of your own decisions), but also to the musical and technical heritages handed down to us. We are stewards of this heritage, new participants in a long line of designers, craftsmen, businesspeople, and technicians who have conceived, made, sold, and maintained the instrument you are about to rebuild. We shouldn't gush about this point—the piano is, after all, only a tool—but in today's disposable world one can't but stop and appreciate the passion, thought, and ingenuity with which our forerunners made our pianos.

This doesn't mean you have to blindly adhere to all the original principles, designs, and materials, but stop for a moment to consider the consequences of your choices. In many fine pianos of the late 19th and early 20th centuries, the original materials are irreplaceable, and the level of craftsmanship represents the values of a bygone era. Will your interventions uphold or detract from those values? But, perhaps more important, how will the next rebuilder, and the one after that, feel about your work? Will they be able to rebuild this piano as easily as you can rebuild it now? Will the decisions you are about to make limit their choices in any fundamental way—perhaps in the way the choices of the previous rebuilder are now limiting yours?

The key to a happy future as a piano rebuilder is to keep your options open by making your work:

1. **Reversible**
(avoid doing what cannot be undone)

and

2. **Compatible**
(use techniques and materials that are compatible with the original design)

For example, soundboard cracks can be quickly repaired with a mixture of epoxy and sawdust, but removing this material will be difficult without major damage to the surrounding wood. By contrast, wooden shims glued into the cracks will look and behave like the rest of the board, but are more labor-intensive to install. However, if the soundboard is likely to be replaced in the near future, or the piano isn't of high quality and the current circumstances justify the cheaper repair, the former method is perfectly acceptable.

Using compatible materials prevents unforeseen interactions and stresses that can lead to failure. For example, keys are typically made of a softwood, such as sugar pine or spruce. If you repair them with strips of hardwood, which have a different rate of expansion, the keys may crack or warp. Incompatible finishing products may never harden or may attack each other, causing alligatoring, crazing, or peeling.

The choice of glue is critical to reversibility. In the heyday of piano making, the dominant adhesive was hot hide glue. It created a hard but brittle bond that could be broken apart without damaging the wood whenever disassembly was necessary. Today we use myriad glues that are more convenient but are more difficult to remove, because they are either stronger or more gummy. Epoxy is a

[335] Matthew B. Crawford, *Shop Class as Soulcraft*, p. 120.

special problem in wood applications because it acts as a foreign material, creating a hard barrier that deflects tools and resists sanding. It appeals because of its strength, adhesion, low creepage,[336] and great filling properties, but breaking the joint is impossible without damaging the wood. Used on the soundboard and ribs, epoxy all but guarantees that the assembly cannot be broken up and reassembled in the future. On the other hand, it is an indispensable solution for structural repairs, allowing us to salvage cracked parts, such as bridge caps and pinblocks when replacement is not an option.

In many cases, choosing a material for its performance and practicality rather than its authenticity is justified. Synthetic lubricants, for example, are preferred to graphite and mutton tallow; ivory is routinely replaced with synthetic key tops; shellac is stripped in favor of lacquer and two-component finishes; and a soundboard finish is chosen for its high moisture-excluding effectiveness. Manufacturers like Wessell, Nickel & Gross, Kawai, and Phoenix Pianos are pushing the boundaries with carbon fiber and synthetic materials in action parts, soundboards, even in structural components. When modern alternatives offer a clear advantage, we *want* to improve the original product.

However, when a procedure is challenging and its outcome difficult to anticipate, it's best to adhere to the original methods and materials. A traditional glue or finish will leave your options for future repairs open, whereas hi-tech alternatives will limit them. Sometimes a material that appears to have a clear advantage is just too strong, too rigid, and/or too heavy for the application.

Rebuild or Restore?

Pianos deteriorate mainly due to the wear and aging of their components. Wear is caused by use, but is also affected by the quality of parts and climate conditions. Felts and leathers, for example, wear more quickly in a dry climate. Whether or not a piano is used heavily, most of its components deteriorate simply by aging: felts and leathers become unresilient, wood and certain glues become brittle, and metal parts corrode, fatigue, or deteriorate with time. The core components of the piano, however, remain largely unaffected. A solution, therefore, is to replace the deteriorated components and refurbish those that can be expected to last for several more decades, such as the soundboard, plate, and pinblock. A complete rebuilding, if performed correctly and thoroughly using quality parts, can yield results that surpass the quality of a comparable new piano. The question is not whether rebuilding is a viable alternative to buying a new piano, but whether a piano has a potential that justifies the great effort and expense involved in its complete rebuilding.

Deserving Pianos

Use the following criteria to determine whether a piano deserves to be rebuilt:

- Functional and tonal potential
- Market value after rebuilding
- Quality
- Feasibility of repairs

These conditions are satisfied by most brand-name grands made after ca. 1880, longer than 6′ [183 cm], and not subjected to climate extremes, abuse, improper servicing, or a bad rebuilding. Some of the brand names that are highly valued for their rebuilding potential are Steinway & Sons, Mason & Hamlin, Baldwin, Chickering, Knabe, Bösendorfer, Bechstein, Blüthner, Grotrian, and Ibach. Less-known pianos (grands and verticals), especially those made under generic names, often have poor market value, and replacement parts for them may be difficult or impossible to obtain. Poor design and low quality require extra work. Be cautious with shorter grands because their tonal potential is often limited by their short bass and tenor strings and small soundboard.

As long as the design is fully modern, the age of the piano is not as important for rebuilding as its condition. Pianos that were previously rebuilt (especially with high-tech glues and finishes) tend to be more difficult to rebuild than those still in their original condition.

Avoid rebuilding cheap, low-grade pianos, whether old or new. You may find yourself correcting problems that result from the use of poorly seasoned, low-quality wood, inconsistent workmanship, inaccurate scaling, incorrectly set plate and downbearing, low-quality finish, poorly fitted pinblock, etc. To the owner, such a piano may have great sentimental value, and he or she may be willing to pay a lot of money to have it restored or rebuilt. Be careful, and be honest with yourself: are you setting yourself up for failure? Is one job worth risking your reputation and losing ten other jobs? Try to understand the owner's motivation and expectations. If the piano doesn't promise good return on investment and you nonetheless decide to go ahead, at the very least protect yourself by stating this in your proposal and having the owner sign it.

Pianos of Historical Value

If the piano was made prior to ca. 1870, consider its historical value, and how the restoration or rebuilding will affect its authenticity. Is the piano more valuable as a historical "document" or as a working instrument? Conservators are split between preserving the original condition of the instrument and making it playable.[337] Even keeping the strings under tension may damage the structure over time.[338] If your goal is to make the piano fully functional, should you strive to restore its assumed original condition or modernize it? Should you repair worn and brittle parts or replace them? What should you do about "inherent vice," such as unstable structure, corrosion, or woodworm infestation?[339] Be sure to discuss these points with

[336] Creepage is a property of a glue joint to allow bonded parts subjected to continuous opposing forces to slowly slide along the joint.

• • •

clamps on long rods are versatile because they can be used on long objects and are easy to work with, though they lack the width and clamping strength of conventional C clamps. Other types of clamps may be necessary for particular woodworking projects.

Materials

Materials that are used frequently in various repairs and rebuilding should be acquired ahead of time. Determine how much you need until the product's expiration date, and buy greater quantities from wholesale distributors and through mail-order channels. You may need to pay an extra fee for the delivery of hazardous materials.

Test Every Batch

Never follow recommendations regarding materials blindly—test every batch, especially the glues and finishes. The batch you purchase may have been exposed to **temperature** extremes. Piano-supply houses are more likely to handle and store their chemicals with care because their own service departments use them, but you don't know whether the product was exposed to temperature extremes during shipping. That's why some supply houses don't ship glues during winter months. Although some products may not be marked with an **expiration** date, their freshness may still affect your results. The **formulation** itself may change. Finally, **your conditions** may be different.

The only way to ensure success is to test every batch before using it for the first time, and after it's been stored for an extended period of time. Reproduce the conditions of the final application as closely as possible, from temperature and humidity to type of wood, metal, primer, and finish.

Material Safety Data Sheet (MSDS)

The properties of all adhesives, solvents, lubricants, finishing materials, and other chemicals are published by their manufacturers in the form of Material Safety Data Sheets (MSDS), which are available directly from manufacturers (and on their websites), or from MSDS search sites on the Web.[348] An MSDS reveals everything from a substance's physical properties to its composition, toxicity, health effects, first aid, and much more.

Glues

Various glues must be available at all times. To ensure freshness, buy glues in stores with high sales volume. Be sure all your glues are well sealed and stored indoors.

This discussion is limited to common types of glues that have been proven in piano repair and rebuilding. The technology of adhesives is advancing rapidly, and I encourage you to experiment with new products. When you test a product, test it on the same materials and in the conditions in which it will be applied, but also subject it to the same conditions you expect the piano to be exposed to. Resistance to freezing or high temperatures may seem unimportant until you consider that the piano may be caught in a snowstorm during transportation, or may be subjected to a heat treatment for insect infestation.

The glues mentioned here are available in the U.S., but their substitutes are available worldwide. If you use different glues, follow the manufacturer's directions closely. *Always* test a new glue thoroughly before using it in an important project.

Hot Hide Glue

Hot hide glue is the glue traditionally used by the piano industry for all porous materials. It creates a strong bond that sets within minutes and reaches full strength overnight. It resists creep, but is very brittle and doesn't tolerate variations in rates of expansion and contraction between the bonded pieces. It is not waterproof, and can be weakened by very high levels of humidity. It is supplied in flakes or granules that are diluted in water, then heated and kept at a constant temperature of 140–150°F [60–65°C] in a thermostatically controlled glue pot (Figure 493). Once diluted, the glue has a relatively short pot life. The shelf life of the granules is also limited to about one year. Freshness is very important, both for the granules and the mixed product.

Cured hot hide glue can last for centuries. It can be reactivated with heat and moisture, and by applying more glue to it. The bonded joints can be separated and the glue cleaned easily. All of this makes it particularly suitable for instrument repair.

For successful bonding, the pieces must be kept warm; otherwise, the glue may "skin" on contact and not penetrate into the pores of the material. Avoid cold drafts. You can extend the glue's work time by increasing the temperature of the pieces being bonded (which makes working with it uncomfortable in warm climates), or by adding urea powder, a fertilizer. Unfortunately, urea can be lethal to pets, and pets are attracted to hide glue.

Hot hide glue is time tested and excels in longevity and reversibility,[349] but a liquid hide glue (which can be used at room temperature, see below) and PVA glues are easier to work with. Conventional PVA glues are more resilient and more forgiving of dimensional changes, and have better moisture resistance. Low-creep PVA glues may be the closest to hide glue in their properties, but offer even greater strength and moisture resistance.

[348] A comprehensive list of such sites is at `http://www.ilpi.com/msds/`.

[349] See Stephen Shepherd, *Hide Glue*.

Figure 493 *Hot hide glue and a thermostatically controlled pot.*

Figure 494 *Two popular PVA glues: Carpenter's Wood Glue, a yellow wood glue (left); and Franklin's Titebond® Molding and Trim Glue (right).*

Figure 495 *PC-7 epoxy paste (top), slow-drying epoxy (bottom left), and superglue (bottom right).*

Urea

Urea is added to hot hide glue to extend its working time and improve its penetration into wood. It is used by piano manufacturers for building laminated rims, soundboards, bridges, pinblocks, and case parts. If you use this glue, give it plenty of ventilation and *keep it away from children and pets*.

Liquid Hide Glue

Hot hide glue gels at temperatures below ca. 100°F [38°C], but with the addition of an anti-geling agent it can be applied at temperatures as low as 50°F [10°C]. The result is a liquid hide glue that doesn't require a glue pot, has a longer shelf life in liquid form, and still offers most of the benefits of hot hide glue. It is not as strong, though, and, like PVA glue, introduces more moisture to the glued pieces. In all other respects it behaves like hot hide glue: it resists creep, creates a strong but brittle bond (this makes it easy to crack the bond without damaging the wood), is neutral to stains and finishes, and is easy to clean up.

Franklin's Titebond® Liquid Hide Glue is widely available in the U.S. The Old Brown Glue[350] by Antique Finishers offers an extended "open" time (up to half an hour) at temperatures above 80°F [27°C]. When heated sufficiently, this glue can reactivate a cured hide glue.

PVA Glues

Polyvinyl acetate (PVA) glues are widely used for bonding porous materials. They are strong, resilient, easy to work with, have a long shelf life, and are not toxic. All PVAs are *thermoplastic* to some extent—they soften and ultimately melt when heated. As a consequence, they become gummy and ball up when sanded, clogging the sandpaper. Thermoplasticity permits realigning parts by simply heating the glue joint(s), but it also precludes using conventional PVAs for bonds exposed to high temperatures (but read about low-creep PVA glues below).

The main limitation of conventional PVA glues is that they do not resist creepage of bonded parts, and are not suited for high-stress structural joints, for laminated boards, such as pinblocks, bridge roots, and for gluing the soundboard to the ribs and rim. Certain formulations, however, fare well enough in this respect to be rated as "low creep" glues (explained below).

High creep is an advantage when gluing parts with different rates of expansion and contraction, such as hammer heads with tropical-wood moldings, porous key tops, etc. Despite their limitations, conventional PVA glues are quite versatile and are widely used for simple joints on wood, felt, cloth, and leather.

PVA glues suitable for most woodworking are "yellow wood glues," such as Carpenter's Wood Glue (Figure 494) made by Elmer's, and Franklin Titebond® Wood Glue (Titebond III Ultimate Wood Glue approaches the properties of low-creep PVA glues). These glues require clamping because they dry relatively slowly, but they penetrate the

[350] `http://www.oldbrownglue.com/`.

• • •

. . .

Key Top Replacement Challenges

Figure 525 *The person who removed ivories from these keys inadvertently pulled off wood strips from the front mortises. If the strips are not restored, the tops will click in those spots.*

Figure 527 *Overtrimmed keys can be widened by gluing a softwood veneer to their sides.*

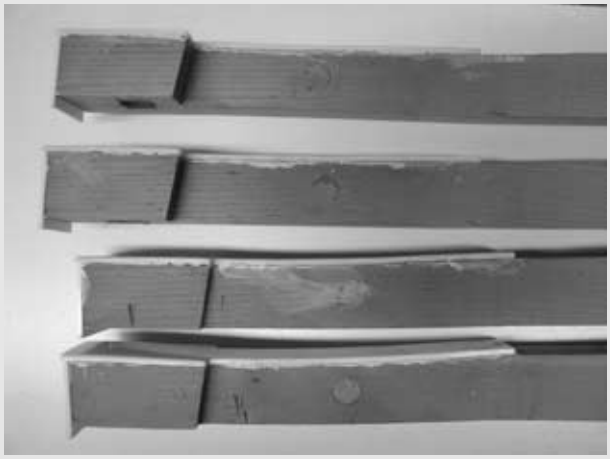


Figure 526 *A poor key top replacement job like this one makes recovering the keys a challenge.*

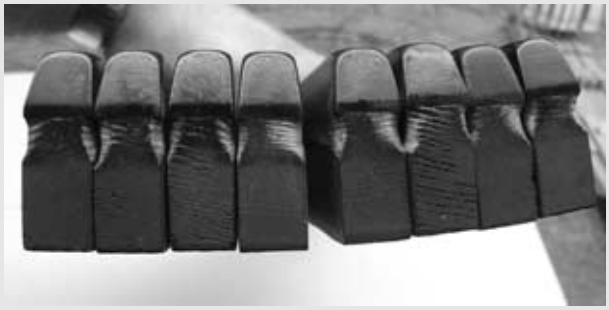


Figure 528 *Eroded wood under black key tops: what to do?*

Photos by Mike Morvan of Blackstone Valley Piano

Natural materials and mineral plastic tops are more challenging to install, but provide a better feel to the pianist. If you plan to use ivory removed from another keyboard, buy at least two full sets.

Glue

All white key tops are best glued with **PVC-E** or similar adhesive (see sidebar, "Gluing Porous Key Tops: Tools and Materials," on page 358). Acrylic tops can be glued with a PVC-E glue or a contact adhesive. The advantage of a contact adhesive is that it doesn't require clamping, but it may not match the longevity of PVC-E, especially if exposed to temperature extremes. Thick PVC-E formulations need minimal clamping.

If you decide to use **contact cement**, use a fresh, uncontaminated, solvent-based cement. The cement will etch the plastic. If it contacts the surface of the key top, wipe it off *immediately* with alcohol. Acrylic key tops reflect light in a way that makes even the slightest surface dents or bumps easily visible. This is why it's so important to keep the cement free of all contamination. To do so, dispense just the amount you will use into a smaller container, and brush it from that.

Procedure

For replacement white key tops to look straight and square, the keys themselves must be straight and square. After removing the old key tops, you need to repair *all* sur-

. . .

• • •

the differences in length between the old and new hammers, and install the backchecks correspondingly higher or lower.

2 **Remove action from key frame. Put key frame with keys on bench** with the backchecks in front of you. Note any backchecks that are too high or too low, and do not use these for comparisons.

3 **Test whether backcheck wires are long enough:** Take a key off the key frame and place a new backcheck next to the old one. Align their tops, adjusting the new backcheck's height if it must be installed higher than the old, and make sure the new wire will extend at least a few millimeters below the hardwood block. Shallowly installed wires may lead to hardwood blocks cracking or breaking off during a regulation of the backchecking.

4 **Record height of original backchecks** (step 4 on page 370).

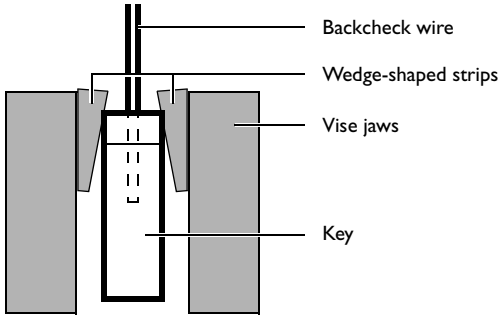
5 **Extract old backchecks with their wires:** Temporarily affix a wedge-shaped strip of wood (such as a soundboard shim) to each jaw of a vise, as depicted in Figure 565. This will prevent splitting or breaking off the hardwood blocks. Clamp each key into the vise, tilting it down slightly toward the front. Using the jaws of the vise for leverage, extract the wire with larger end-cutting nippers (Figure 565). Pull the wire in short strokes, to avoid elongating the hole.

6 **Size holes:** If the new wires are much **thicker** than the originals, drill the holes wider (Figure 566), or you will split the backcheck blocks and the keys. Use a drill bit slightly thinner than the wire itself. On Renner backchecks for Steinways, for example, the wires are ca. 0.112″ [2.825 mm] in diameter and their fluted end is ca. 0.118″ [3 mm] wide; use a #35 (0.110″ [2.794 mm]) or 7⁄64″ [2.778 mm] bit for laminated backcheck blocks, or a #36 (0.1065″ [2.705 mm]) bit for conventional blocks. If the new wires are the **same size**, glue-size the holes with wood glue (Figure 567) and let them dry. If the new wires are **narrower**, plug and redrill the holes (see "Repairing Stripped Screw Holes and Action Rails" on page 240) or replace the backcheck blocks, then drill them. Be sure to accurately reproduce the angle of the original holes.

Installing Backchecks

7 **Install new backchecks** by hammering them in with a backcheck installation block (see note below), press them in with a drill press (Figure 569), or hammer them in with a small felt-lined hammer (Figure 568). Compare their heights to the outlines of the original backcheck(s) (Figure 558 on page 370). Position the backcheck in line with the key and hammer or press it in. If the new wires are slightly loose, glue-size the holes; if tight, repeat step 6 with a wider drill bit. Forcing the wire may split the key.

Note: *A backcheck installation block, available from Steinway, is a hardware block routed to support a backcheck on three sides. The block is adjusted in length with strips of leather or felt on the bottom. Lined with leather, the notch absorbs the hammer impact and protects the backcheck from damage.*



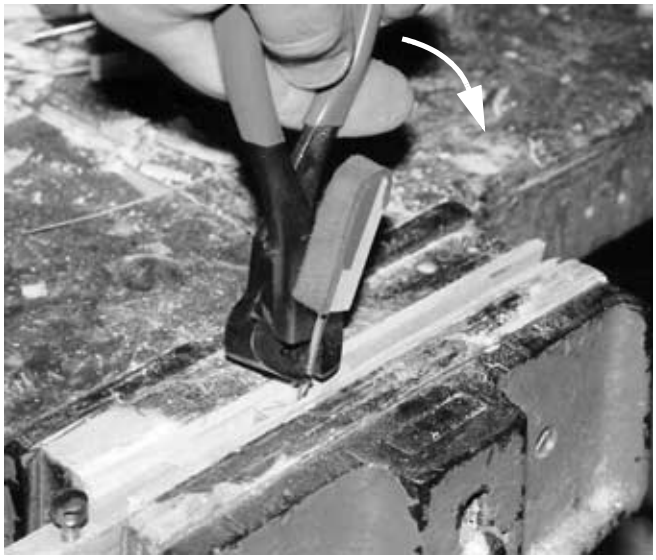


Figure 565 *Extracting a backcheck. Wedge-shaped wooden strips between the vise jaws prevent the backcheck block from cracking off the key.*

8 **Regulate backchecking**, note the backcheck-to-tail distance throughout the scale, and adjust the backchecks' height as necessary. See steps 10 and 11 on page 371.

Aligning Backchecks

See "Aligning Backchecks" on page 371.

Rebuilding Grand Action

The action rebuilding is at the very center of any piano reconditioning project. Typically, the action is rebuilt together with the keyboard, damper system, and pedals. You can rebuild all four systems in parallel, or start with the keyboard, then follow with the action, dampers, and pedals. The rest of the piano can be rebuilt separately. I suggest reading all of this chapter before proceeding.

• • •

. . .

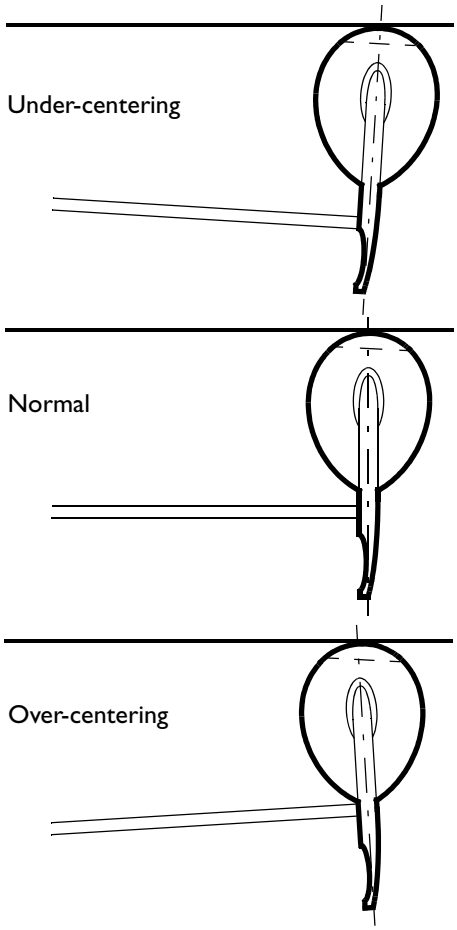


Figure 581 *Under-centering and over-centering. The dashed line indicates the loss of felt through wear and the angle at which the grooves will form.*

that will affect the action regulation, especially the back-checking (backchecks may need to be raised).

Marking Hammers

1 **Lay hammers on strong sheet of paper** (on which you'll be able to lift them) in three rows, with the inside of the molding facing up on all hammers. Make sure not to disturb the order; in some sets, hammers are not numbered.

2 **Mark drilling positions on end-hammer moldings in each row** using old hammers (Figure 582), measurements, or boring specifications (always good to have for comparison). When the original hammers are worn (grooved and/or reshaped), increase their boring distance appropriately (usually ca. ⅛″ [3 mm] for the hammers in the middle section).

3 **Mark boring positions on remaining hammers' moldings:** Place a large plane (I use a 4′ [1.22 m] plane) behind each row of hammers (on the felt side), and clamp the plane in place (see Figure 583). Push all hammers against the plane and place a ruler on top of the moldings,

Figure 582 *Comparing the drilling mark with the old hammer.*

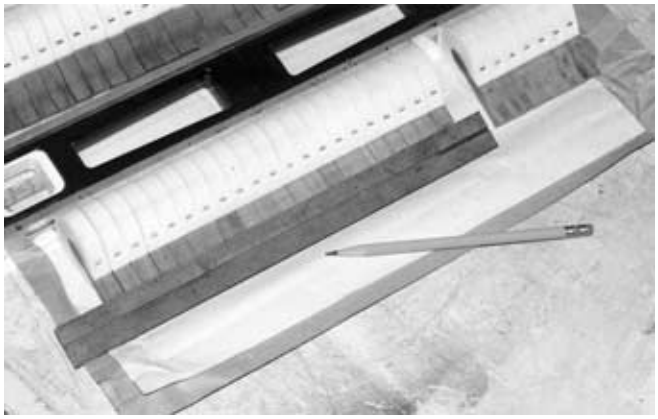


Figure 583 *Marking the drilling positions on hammer moldings.*

aligning it with the markings on the end hammers. Draw a straight line on the moldings, making sure that it aligns *perfectly* with the end hammers' markings. Compare the marked hammers with old hammers, or remeasure them and correct the line, if necessary.

Drill Press and Angle Vise

To be installed properly, hammers must be drilled with precision. Various jigs are available specifically for this purpose; for example, the Renner Deluxe Hammer Boring Jig, available through Renner USA.[362] Here I describe how to use a conventional angle vise (Figure 584) with a drill press.

Adjust the drill press to a speed of 800–1100 rpm. Loosen the drill-press table bolt and, using a true square, set the table at 90° to the drill bit (mark this position so you can repeat it later), then secure the vise to the table with bolts and nuts, or clamps. Set the vise dial to 0°. Measure the angle between the drill bit and the top surface of the vise jaws (as observed from the front and from the side) with a square. If it's not 90°, readjust the table angle and/or shim the underside of the vise with strips of veneer, as needed.

Create a support block on which you will lay the hammer molding: cut a straight wooden or plastic block ap-

[362] `http://www.lloydmeyer.com/productcart/pc/viewPrd.asp?idcategory=8&idproduct=26#details`.

Figure 584 *Angle vise set up on a drill-press table (shown with a bass hammer).*

proximately 1″ [25 mm] long, ½–¾″ [12–19 mm] thick, and slightly narrower than the narrowest hammer you will drill (5/16″ [8 mm]). Using a PVC-E or thick CA glue, affix the block to the inside of the stationary jaw. The block should be centered on the jaw, and set parallel to and approximately 7/32" [5 mm] below the top surface of the jaw.[363] When you place a new hammer on the block, the inside surface of the hammer's molding should be parallel to the jaws, as shown in Figure 585.

Drilling Hammers

1 **Install drill bit in drill-press chuck:** Choose a drill bit that will allow you to insert the shank in the hole so that it protrudes on the other side only up to ⅛″ [3 mm]—you will widen the holes with a tapered reamer when you install the hammers. Insert the drill bit in the chuck as far as it will go, so that it is as stiff as possible, and tighten the chuck.

Note: *Hammer shanks from different manufacturers vary in diameter—match the bit to the shanks on which you will install the hammers. WNG composite shanks are significantly thinner than wooden shanks.*

2 **Adjust table of drill press** up or down, so that the tip of the bit is just slightly above the top of the jaws. Put a hammer on the block and tighten the jaws. Adjust the in/out position of the angle vise, or turn the table around the column, until the drill bit is centered on the hammer molding. Recheck the angle—it should be 90°.

3 **Adjust vise to desired pitch:** The most accurate way to duplicate the pitch (the angle between the hammer and shank when viewed from the side—see Figure 586a) of the original hammers is to clamp an original hammer (with its shank) in the vise slightly in front of the drill bit (move the vise forward), and tilt the table or shim the vise until the shank is perfectly parallel with the bit.

4 **Adjust drilling angle:** Looking at the original hammers and shanks from above (Figure 586b), compare the angle of the string grooves with the angle of the hammer itself. If there is a discrepancy, drill the new hammers at angles that match the grooves, unless the manufacturer's specifications call for a smaller angle or the angle exceeds 16°, which can cause the hammers to rub and click against each other. Readjust the angle of the vise for each group you will drill at the same angle. All bass hammers are typically drilled at the same angle, whereas tenor hammers are graduated, the angle changing by 1° every 3 to 6 hammers. Note that you will insert the tenor and treble hammers and the bass hammers in opposite directions (a bass hammer is shown in Figure 584). Remove the original hammer from the vise.

For each hammer you put in the vise, do the following before tightening the jaws (Figure 585):

- Position the hammer fore/aft so the drilling mark is aligned to the drill bit (when viewed from the side). Regular bits look deceptively off-center—brad-point bits are easier to align.
- If the back of the molding is already shaped, you won't be able to rely on your jaw block for the pitch angle—adjust the angle visually. The molding should be parallel to the top edges of the jaws.

When a hammer is drilled at an angle, the hole must be off-center on one side so that it will exit the molding offset for the same amount on the other side. Adjust the offset by rotating the drill-press table a small amount whenever you change the vise angle.

As you drill the hammers, compare every other new hammer with the original (Figure 586).

5 **Drill test hole** first in a scrap hammer or a piece of wood of the same thickness as the hammer molding. Temporarily insert a hammer shank in the hole and observe the angles. Is the hole off center the same amount on both sides of the molding? Rotate the table or readjust the vise if necessary.

6 **Drill all bass hammers** and adjust the angle in the middle of the section, if necessary.

7 **Drill tenor and treble hammers,** readjusting the angle of the vise every few hammers, as needed. Don't forget to put each hammer in the vise in the direction opposite of the bass hammers.

Shaping and Tapering Hammer Tails

After drilling the hammers, but before installing them, you will need to shape their tails and taper the sides of their moldings. Although the two procedures are described

[363] If you don't want to glue the block, create a block that rides loosely on the threaded shafts of the vise, and that you can slip in and out, as needed. Alternatively, don't use a block at all—align the hammer to the jaws visually.

• • •

. . .

Modernizing Old Steinway Pitman Linkage

If the pitman dowel's hole in the key bed is bushed (Figure 620), with time the dowel wears it out and starts binding on the bushing. Rebushing the hole and keeping it lubricated is a good remedy, but won't last as long as modifying the system to a modern pitman linkage.

Dowel with pins: Lower the trapwork lever, and drill the hole in the key bed with a 1″ [25 mm] Forstner drill bit. Create a new pitman dowel out of a ½″ [12 mm] wooden dowel slightly longer than the original. Install a metal pin, such as a bridge pin #8 or #9, in the center of each end, and place one or two round, firm, felt or cloth balance punchings on each end of the dowel. Remove the old leathers from the tray and lever, and clean off the old glue. Drill a hole for the bridge pin in the trapwork lever and on the bottom of the tray, making sure the dowel pin fits, and can rock a little fore-and-aft, without binding. The rocking is necessary because the centers of the arcs that the tray and trapwork lever describe are in different spots. From under the key bed, insert the new dowel into the hole you drilled in the bottom of the tray and, while holding the dowel, bring the trapwork lever up, insert the dowel's bottom pin into the hole you drilled in the lever, and lift the tray with the lever. Turn the L-shaped lever stop back in place and lower the lever. Reattach the lyre with its braces and adjust the pedal rods. If the dowel is too long, remove a pin from one of its ends, shorten the dowel, and reinsert the pin.

Figure 620 *Bushed pitman dowel in a 1923 Steinway A III.*

Dowel with felt wafers: This is an alternative to bridge pins in the ends of the dowel. Follow the instructions above, but instead of inserting bridge pins in the ends of the dowel, route two shallow round mortises, ca. ¾″ [18 mm] wide, with a Forstner drill bit: one in the bottom of the underlever tray, the other in the top of the trapwork lever (make these as shallow as possible, not to weaken the lever more than necessary). Cut two round, ¾″-wide wafers out of a sheet of firm felt or cloth, and glue them on each end of the dowel. The wafers will center the dowel instead of the pins, making the interface less likely to develop noises over time. Lubricate the wafers with a powder lubricant.

6 **Install tray in piano:** Lubricate the tray-end pins with a thin coating of dry-film lubricant, then rub and burnish powder lubricant into the cloth punchings. Swab a little dry film lubricant on the end blocks where the punchings will touch them. Plug and redrill the screw holes for tray end blocks in the belly rail if necessary, then fasten the blocks, making sure they remain in the positions in which you tested them. When you push the tray to the right or left, you should feel very slight free play—the blocks must not squeeze the punchings excessively or the tray will move sluggishly.

Prepare the tray or rail for the pitman dowel: if the dowel has pins at each end, glue a piece of leather and/or felt on the bottom of the tray and the top of the trapwork lever, and drill holes through those pieces of leather into the wood for the dowel pins. If the dowel has wide cloth or felt wafers on ends, drill shallow round mortises with a Forstner drill instead. If the pitman hole in the key bed is bushed, as in older Steinway grands, replace the bushing if worn, or consider modifying the system (see sidebar, "Modernizing Old Steinway Pitman Linkage").

If a leaf spring is used for the tray, glue a piece of leather on the tray at the spot where the spring will contact it, then lubricate the leather with a thin coating of grease lubricant.

7 **Install damper stop rail.**

8 **Install and regulate dampers**, as explained on page 182.

Rebuilding Vertical Action

Before rebuilding a vertical piano action, you should diagnose it thoroughly as explained in "Regulating Vertical Action, Pedals, and Dampers" on page 189. The following instructions assume that you are repairing or replacing *all* action parts. If performing a partial rebuilding, omit procedures that do not pertain. For example, to replace the hammers only, there is no need to remove the wippens or damper levers from their rails.

It's best to have the whole piano in the shop when rebuilding its action. If that's not possible, measure the distance between hammers and strings and observe, looking from the side, whether the hammers hit the strings at a right angle (90°). If this is not the case, consider altering the boring distance of new hammers and/or changing the angle between them and the shanks (pitch) so that they strike the strings at a right angle. Before removing the action from the piano, regulate guide notes so that you can later test the fit and regulation of new action parts against those notes.

1 **Remove action from piano** as explained on page 137. Tighten the nuts back onto the action support bolts. Transport the action to the shop on an action cradle, or on its back (the side with backchecks). Be careful not to tip the action onto the dampers.

2 **Mark numbering on all action parts to be removed from action rack:** hammers, wippens, and damper levers.

If you intend to rebush the flanges, mark the parts *and* their flanges separately.

3 **Spinet with plastic elbows only: Replace the elbows.** Plastic elbows link stickers—metal rods attached to the rear end of each key—with wippens, which are below the keyboard. The elbows become brittle with time and begin to break (Figure 621). It's best to replace them. To do so, measure a few sample elbows to see how far the stickers extend from an imaginary horizontal line passing through the elbow bushing. Then, cut and crush the remnants of the old elbows with wire nippers and a pair of needle-nose pliers (Figure 622). Buy Vagias snap-on elbows. Wind the new elbows onto the stickers (Figure 623) so that the stickers extend as far from them as they did originally. You will install the elbows and stickers after you reinstall the action in step 17.

4 **Unhook all bridle straps** with the action positioned upright.

5 **Remove wippens:** If repairing or replacing the wippens, remove all wippen flange screws. Keep the screws in order in a pre-punched piece of cardboard. Remove the wippens and lay them on the bench in order.

6 **Rebuild or replace wippens:** Perform all the necessary repairs on old wippens, including replacing the backcheck felt, the wippen heel felt, and possibly rebushing and repinning the flanges. For instructions on replacing felts, see page 340. If installing new parts, be sure they are true replacements for old ones. Even the smallest discrepancies will affect their functioning and regulation.

- **Wippen heel felt:** Remove old cloths and felts with a razor blade and remove the old glue. Glue the new felt and cloth (in some designs there is only cloth) with a hot hide or fast-drying PVA glue applied to both ends of the cloth. The middle of the cloth should not be glued.
- **Replacing whole backchecks:** Backcheck wires in vertical pianos are usually fluted on the bottom and threaded at the backcheck end. For removal and installation, see the instructions for grands in "Replacing Backchecks without Wires (Retaining Existing Wires)" on page 370. Vertical wippens are more fragile than grand keys—handle them gently.
- **Replacing backcheck felts:** Remove the old felts by soaking them with acetic acid, steaming them, or by cutting them off with a sharp cutter (careful!). Scrape off the old glue. Buy pre-cut strips of felt or cut individual felts yourself. Glue the felts with a hot hide, PVC-E, or wood glue. If the glue dries slowly, gently clamp the felts in the middle with tie wraps (to avoid distorting the felt, mold the tie wraps into the shape of a staple).
- **Rebush and/or repin wippen flanges** if necessary, as explained in "Repinning Action Parts" and "Rebushing Action Parts," starting on page 244. Beware: this work is tedious and requires a lot of patience. Replacing parts may be more cost-efficient than rebushing and repinning old parts.

Figure 621 *Broken plastic elbows.*

All photos on this page by Chuck Behm

Figure 622 *Crushing the remnants of old elbows.*

Figure 623 *Winding a new elbow onto a sticker.*

• • •

• • •

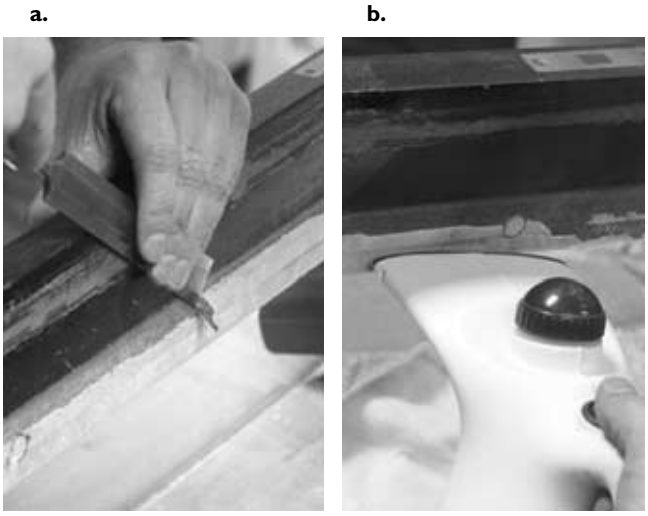


Figure 680 *Cleaning the remaining wood from the stretcher with a chisel (a). Steaming the wood first (b) may reduce damage to the stretcher (courtesy Pianos Bolduc).*

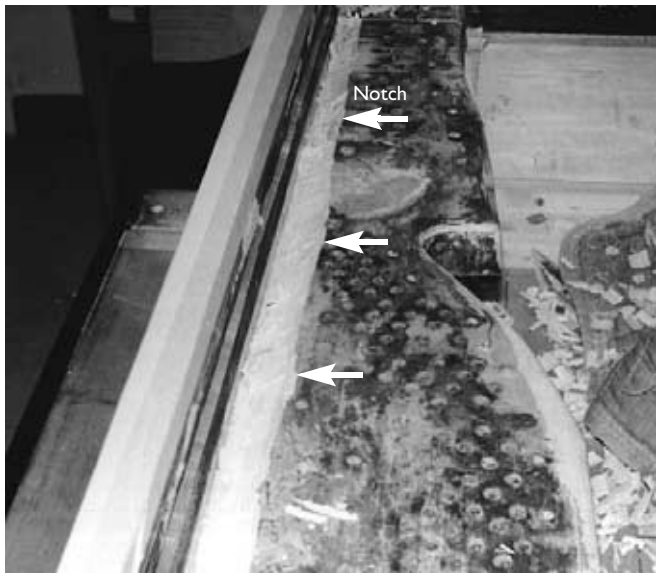


Figure 681 *Alternative to routing: chiseling a bevel in the back of a full pinblock to free it from the stretcher.*

If you *do* have a large, sturdy band saw, you will be able not only to cut the ends and the flange, but also to resaw the whole plank to the desired thickness. This allows you to purchase thick planks and reduce their width without overtaxing your planer. Read Lonnie Bird, "Resawing on the Bandsaw," for information about how to set up and use a band saw for this task. Remember that pinblock planks are made of some of the densest and hardest woods available. Multi-laminated planks are extremely abrasive and should be cut with patience, being careful not to overheat the blade.

If you have a band saw with a tilting table (or a stationary table but a tilting head), I recommend cutting the pinblock yourself. To be adequate for this work, a band saw must be able to cut through the very dense pinblock material without ripple or wander. A saw blade should be relatively narrow (viewed from the side) to allow guiding the block precisely by hand. Feed the block slowly to prevent the blade from overheating. Have an assistant hold up the back of the block as it exits the saw's table. Be careful with your fingers, and wear eye protection.

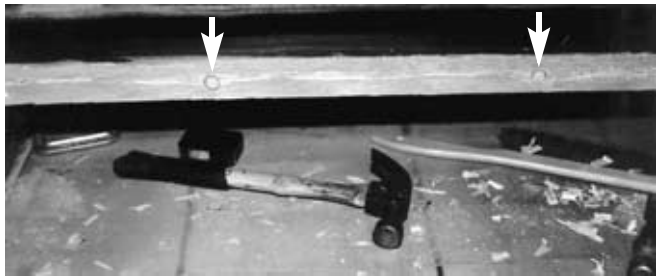


Figure 682 *The stretcher after removing the pinblock. Note the blind dowels marked with arrows.*

7 **Prepare new plank:** Obtain a pinblock plank that is wider and thicker than the original pinblock's widest/thickest spot. Pinblock panels are just under 60″ [1.5 m] long and between 1¼″ and 1⅝″ thick. A double panel is 17–18½″ [43 to 47 cm] wide and allows cutting two pinblocks (except for some concert grands, which have extra-wide blocks). Single panels are also available, often with a diagonal cut that predetermines which side goes up and which down (which can make fitting the block harder if it is warped the wrong way). Measure the thickness of the old block with a caliper in various spots and plane the new plank to match. In conventional pinblocks with few plies, remove the same amount of material on both sides

Figure 683 *Chiseling out the treble end of the original pinblock. Chisel the top layer in one piece to facilitate duplicating the width of the pinblock.*

Figure 684 *New plank ready for marking the outline of the original pinblock.*

Figure 685 *Aligning the old block (top) to the new plank (bottom) with a ruler. Note the small horizontal gap between the old block and the ruler.*

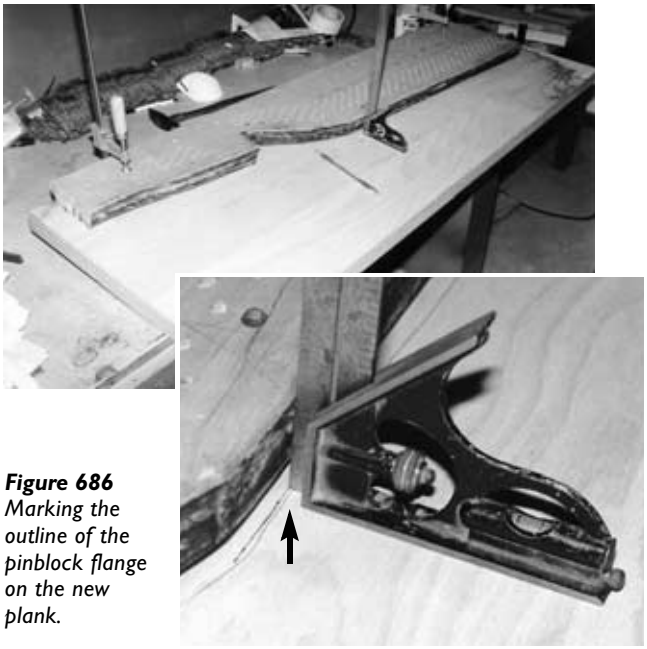


Figure 686 *Marking the outline of the pinblock flange on the new plank.*

to prevent the plank from warping. This is not a concern in multi-laminated planks. If the plank is already warped, turn the concave side (which is bowed in) up, toward the plate. This will make it easier to fit the block to the plate flange as you will have to push it down only in the middle. Flexing it down at both ends requires clamping, which is much less convenient. Use a stationary planer if you have one, or a hand-operated power planer in several passes (see Figure 490 on page 332).[397] If the plank is much thicker than the original pinblock, first *resaw* it on an industrial band saw equipped with a wide blade and a high fence, or on a large radial saw. Some pinblocks taper in thickness from one end to the other. Duplicate the taper with a handheld planer.

8 **Align back edges of new and old blocks:** Place the plank on a workbench (if you planed only one side, place the unplaned side up; if the plank is warped, turn it so it bows up in the middle). Put the old pinblock onto it *upside down*, as depicted in Figure 684 (bass to the right, flange away from you). Align the old pinblock with its straight edge flush with the side of the new plank (Figure 685). Plane/shape the edge of the new plank to perfectly match the old block (especially important for full-fit blocks). Push the old block inward just a little (1⁄32″ [0.7 mm] or less), and clamp the blocks together and to the workbench.

9 **Trace flange of old block on new plank:** Place a true square on the new plank and push it against the flange of the old block. Mark the position of the vertical arm on the new plank with a pencil and repeat that along the whole flange (Figure 686), creating a line that traces the old block's flange on the new plank. Also trace the ends of the pinblock. If the old block is not as long as it should be because you were not able to retrieve its end portions in one piece and glue them to the block, use measurements to mark the edges on each end. Check the outline of the pinblock and correct it if necessary. Remove the clamps.

10 **Saw relief cuts** in the new plank perpendicular to the flange wherever the flange curves sharply and at the bass/tenor corner (Figure 687). Stop sawing just at the flange line you marked earlier.

11 **Tilt band saw table:** The pinblock flange is tilted and its angle must be reproduced precisely. Place the old pinblock on the band saw and tilt the table until the flange surface is parallel to the saw blade (Figure 688), then clamp the table securely in place.

12 **Saw flange on new plank**, starting at the bass end, make a gentle curve over the relief cuts in the bass/tenor corner, then cut the corner. Saw slowly, with an assistant

[397] Ideally, you should put blocks of wood against each end of the block to support the planer as it exists the plank. These blocks should be of exactly the same thickness as each the plank, or the planer will gouge the surface as its front drops (or create a ridge if the front kicks up). Instead, learn to lift the planer gently as it exits the plank—practice on scrap pieces of wood.

• • •

• • •

this repair to succeed, the stretcher and the entire pinblock layer under it would need to be replaced but, as mentioned earlier, you couldn't mortise them into the case on both ends (at least not fully). The larger question, however, is whether or not you should even attempt such a repair. A treatment as invasive as this would greatly reduce the piano's authenticity and devastate its historical value. A more fitting repair, if restoring the piano to playing condition is a must, might be to treat the existing pinblock with epoxy (page 256) and tune the piano to lower pitch.

Rebuilding the Soundboard

To most laymen, a piano soundboard is a wooden panel behind the strings. And just as any other wooden panel is "good" if unblemished, this one, too, must be faultless, and certainly *without cracks*. This is not surprising—cracks normally tell us that something is broken, that it has failed. Why should it be any different in the most elaborate piece of furniture one can own, a piano? The truth is that all the other aspects of soundboard condition—its impedance, downbearing, crowning, and glue joints—are more important than cracks. Still, cracks signal illness, and must be addressed. Before we look at how to repair them or how to improve the soundboard's performance, let's look at why cracks appear.

Compression Set and Cracks

The planks that comprise the soundboard are glued to the ribs. During periods of high humidity, the planks swell across the grain but the ribs don't allow them to expand. The soundboard responds by arching upward and forming the crown. Because the soundboard is constrained by the strings, additional compression builds up in it, eventually causing wood fibers to collapse. As humidity drops during the subsequent dry season, the wood shrinks and the crown drops, but the wood fibers now take up less room than they originally did. This effect, called *compression set*, would make the planks increasingly narrower after each season of damaging compression, but because they are glued to the ribs, the planks can't shrink. As a result, the wood fibers are pulled apart and cracks appear in the soundboard.[399]

Wood cracks *in* low humidity, but it cracks *because of* high humidity. If there were no compression set, which is caused by high humidity, the soundboard would continue oscillating between high-crown and low-crown periods indefinitely and, theoretically, would crack only if the humidity during dry seasons was lower than the humidity during its manufacture. Surprisingly, when humidity is consistently lower than during manufacture, such as in a desert climate, a quality piano may *never* develop cracks.[400]

The important point is that the cracks are not a problem per se. They are merely a symptom of the compression-set–induced deterioration of the soundboard. They indicate a loss of compression, crown, and downbearing, and an accompanying drop in impedance, which shortens sustain and makes tone boomy. However, many pianos with cracked soundboards sound good and don't necessarily need to have their soundboards replaced. See the sidebar, "Repairing vs. Replacing the Soundboard."

Repair Options

The critical test for a soundboard—more important than the downbearing or the crown—is this: does the piano sound good? Use the checklist in "Evaluating a Piano" on page 321 to learn how to ignore the effects of deteriorated components while evaluating the sound.

If only the **melody octave** is deficient, you can improve it as explained below. Make those modifications after performing all other soundboard repairs.

If the sound is good and the sustain acceptable, there is a strong case for repairing the old soundboard even if it has **lost some crowning** and downbearing. You will need to dry the soundboard, reglue the separations between it and the ribs, rim, and belly rail (provided the beams allow access to *all* separations), shim the cracks, and refinish the soundboard. Most customers don't mind that the shims are lighter in color (Figure 715), but for some this is a consideration. The shims can be stained to match each other's color, but the repairs still will be visible. Also consider that traces of the old finish may show as dark streaks or patches after the soundboard is refinished. Blemishes in the color of the wood itself are likely to remain (Figure 716).

If the board has **lost most of its crowning** and there is little measurable downbearing in the middle and tenor sections, the decision is less straightforward. Your choices are:

- Treat the soundboard with epoxy
- Attempt to restore compression by breaking up and reassembling the soundboard
- Shim the long bridge with wedges (page 467)

None of these options is without serious drawbacks: epoxy is irreversible, breaking and reassembling the board is risky and time-consuming, and the wedges require irreversibly compromising the bridge root. Restorations like the one depicted in Figure 735 on page 468 can yield very good results, but raise issues of practicality and profitability. Some would question whether the crushed wood cells could ever provide the same level of performance as a new soundboard. Considering that one can buy a pre-crowned soundboard, installing a new soundboard may be less risky and less time-consuming than repairing it.

[399] Compression set is explained and illustrated in Bruce Hoadley, *Understanding Wood*, pp. 82–83 and pp. 129–130.

[400] Thanks to Fred Sturm, RPT, for this insight.

Repairing vs. Replacing the Soundboard

Many cracked soundboards perform well and have many more years of service in them. The question is *how* many? Some technicians believe that a concert grand is at its peak around its fifth year, and should be removed from concert service after 10 years. Yet some 30-, 40-, and even 50-year-old concert grands, maintained in top condition and rebuilt as needed, are routinely chosen by discerning pianists, and are rented to concert venues and recording studios. Even some 100-year-old soundboards sound lively and musical, and have plenty of sustain. Of course, many don't.

Perhaps the determining factor is the extent to which the soundboard was subjected to compression set during its life. String instruments such as violins and cellos, which aren't subject to significant compression set, don't seem to deteriorate with age. The fact that 300-year-old violins are in high demand, and are played in concerts and on recordings by most discerning violinists (a 1697 Stradivarius violin known as "The Molitor" was sold for $3,600,000 in 2010[a]), must be proof that a moderately loaded spruce board doesn't deteriorate and can perform for well over 100 years. That may not be applicable to many, perhaps even most pianos, but may explain why some pianos perform so well tonally despite their age.

For most rebuilders, the decision to repair or replace is based on practicality and cost. If you are not set up to replace a soundboard, repairs will be the more appealing option. Yet for someone who has mastered replacement, the risks involved in keeping the old soundboard, in terms of both its ultimate sound quality and the amount of effort needed to repair it, are simply too great. The other constraining factor is cost. In the market in which a new Asian grand piano can be purchased for less than the cost of a serious rebuilding, only the best pianos warrant the added cost of replacement.

[a] `http://www.answers.com/topic/antonio-stradivari#cite_ref-28`.

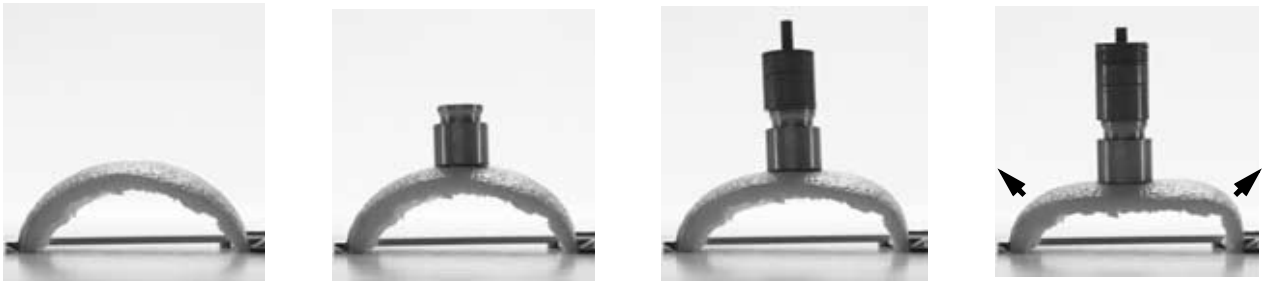


Figure 714 *This piece of orange peel demonstrates how the soundboard distorts under the downbearing force of strings: the middle caves in, but the ends pull away from the rim (see arrows).*

An overloaded soundboard tends to become distorted with time (Figure 714), and can have **zero or negative crown** and downbearing. Such a board should be replaced. The soundboard also should be replaced when the piano has been in a fire or a flood, damaged by wood-boring insects, deeply gouged, or damaged otherwise.

If you're not equipped to replace the soundboard, you will have to ship the piano, which entails risks with which the owner must be comfortable.

If you're considering replacing a soundboard on your own, I suggest watching the video *Installation of the Grand Pre-crowned Soundboard* by Pianos Bolduc,[401] attending a soundboard-installation class at a PTG conference, and reading all piano-design–related books in the "Selected Bibliography" on page 509. Search the *Piano Technicians Journal* archives, and online forums, such as pianotech at `my.ptg.org`, for pertinent topics.

Improving the Melody Octave

Many pianos suffer from poor sustain in the melody octave due to the loss of compression in that area of the soundboard and/or due to inadequate stiffness of the belly rail. Typically, this affects pianos that don't have a beam on the treble side of the belly rail.

Treble Tone Resonator

One approach is to stiffen the belly rail with a device, such as Robert Grijalva's Treble Tone Resonator, available from Pianotek (Figure 717). The device pulls in the belly rail, stiffening it and adding some compression to the soundboard.[402]

Riblets

Darrell Fandrich addresses this problem with his "riblets"—small wooden ribs installed between the main ribs. The riblets increase the stiffness of the board and improve sustain.[403]

[401] Available from Pianotek.

[402] See Robert Grijalva, RPT, "Introduction to the Treble Resonator."

[403] See Barbara Richmond, RPT, et al., "Voicing the Soundboard with Weights and Riblets"; see also Darrell Fandrich, RPT, "Riblet Update."

• • •

• • •

Preparing the Surface

1 **Scrape** the old finish from the top surface of the soundboard and the bridges with a smooth, sharp scraper 1–2″ [25–50 mm] wide. Be careful not to scratch or gouge the soft wood.

2 **Sand** the whole board with a belt sander (Figure 737) equipped with a coarse belt (60- to 80-grit), then sand by hand with 60-grit sandpaper supported by a hard, flat block. Sand *along the grain*, and without digging into the board with the edges of the belt or paper. Sand the board and bridges by hand with increasingly finer sandpaper (100-, 150-, 220-grit) backed by a semihard block. Brush and vacuum the board and bridges after each grade *thoroughly*. Hold the opening of a nozzle with a closed palm of your hand and move the nozzle around the board by sliding the hand on it. This way, you create stronger suction and feel the grit on the board.

Figure 737 *Sanding the soundboard with a belt sander.*

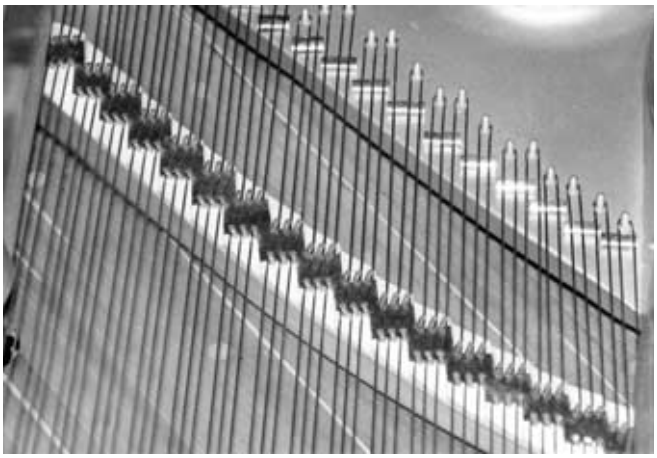


Figure 738 *After the soundboard has been refinished, the shims are lighter than the rest of the wood.*

3 **Apply finish** in a dust-free room. If you're spraying the finish, cover the case, pinblock, key bed, and legs. Moisten a "tack rag" or microfiber tack sponge with paint thinner (*not* water), wring it out fully, and thoroughly wipe the board with it. This will pull the dust from the pores of the wood. Let the board dry.

Concealing the Shims

Regardless of how well you sand the soundboard, traces of old finish in the pores of the wood will make it darker than the new wood. This makes spruce shims much lighter (Figure 738), even when cut from an old soundboard. The difference is accentuated by the finish—don't base your judgment on the appearance of an *un*finished board. If you want the repairs to be less conspicuous, you have two choices: darken the shims, or lighten the color of the entire soundboard.

Shims can be **darkened** using a diluted wood stain compatible with your top-coating finish. Considerable experimentation may be necessary because the color of the board changes when a finish, even a "water white" finish, is applied to it. Even the number of coats you apply affects the final hue. You can apply the stain with an artist's brush but you risk staining the board. Some technicians use an air brush.[411] Experiment with spare shims and in areas of the soundboard that will be covered by the plate.

The latter option, to **lighten** the color of the entire board, is not recommended because bleaches introduce moisture, which may cause surface cracking, and neutralizing the caustic chemicals in the wood requires even more water. The best solution is to use the least-yellowing finish, such as a "water-white" lacquer or even a spar urethane varnish, which contains UV filters that prevent it from yellowing. A clear sanding sealer or primer will reduce the penetration of the top-coating finish into the wood and keep the wood light colored. A water-based lacquer, which is "water white," would be a good option, but, because it is thinned with water, it introduces moisture into the board.

Selecting a Finish

The following characteristics are desirable for a soundboard finish.

- **Protection from water vapor:** Different finishes have different Moisture Excluding Effectiveness (MEE) values.[412] The higher the MEE, the slower the exchange of water vapor between the air and what the finish protects. A slow exchange is desirable because the wood has more time to dimensionally adjust to the change, it is less likely to crack or develop pressure ridges, and is exposed to less stress. Because the compression and crowning of the soundboard change more slowly, the total amount of change also is reduced.[413] As a result, tuning holds much better with a high-MEE finish during

[411] See Bill Spurlock, "Router Repair of Soundboard Cracks," *Europiano*, Issue 1, 2011, p. 48.

[412] MEE is expressed as a percentage of vapor exchange. An MEE of 100% indicates zero vapor exchange. See "Control of Water and Water Vapor" in *Wood Handbook*, p. 16-13.

[413] Ibid., Figure 16-13, p. 16-14. See also Bruce Hoadley, *Understanding Wood*, Figure 7.3, p. 135.

• • •

. . .

Figure 757 *Using temporary tape markers to align the decal.*

Figure 759 *Cutting away lint caught under a letter.*

Figure 758 *Pressing down the decal with a rolling pin.*

Figure 760 *Rosewood-veneered fallboard refinished with a new, modern-style brass decal.*

2 **Measure and mark fallboard with tape** to install the decal centered with, and an appropriate distance from the bottom of, the fallboard (Figure 757). A modern Steinway decal should be installed so that the bottoms of the letters are about 3″ [75 mm] above the bottom of the fallboard. Carefully remove the backing that exposes the backs of the letters, without removing the letters from the clear sticky sheet on which they were assembled. Hold the sticky sheet so that the letters form a straight line, align the letters above the tape markers you affixed earlier, and press down the sheet.

3 **Press letters** onto the fallboard with a smooth, straight rolling pin (Figure 758). Press each letter with a small block of wood *from edge to edge*, to prevent the finish you will later spray from getting under the letters and ruining the job.

4 **Clean edges of letters:** Look carefully around each letter for any lint or hairs that might be protruding and cut them away (Figure 759). The edges of the letters must be absolutely clean, or you may end up with unsightly pin holes in the finish around the letters.

5 **Spray clear finish** (compatible with previous coats) in as many coats as necessary to build it up to a *dry* thickness[426] that equals or exceeds the thickness of the decal (Figure 761). Typically, that means you will need to apply more than 10 coats of lacquer. If unsure, spray the finish on a foil, peel it off after it dries, and measure its thickness with a caliper.

6 **Sand surface and satinize or buff:** After the finish is fully cured (up to seven days recommended for most conventional finishes), wet-sand the *entire* surface equally

[426] The thickness of finish after it has cured.

. . .