This is a three-part discussion about the practice of stringed instrument inlay. Part I covers the principal materials and tools, Part II covers pearl cutting and layout techniques, and Part III covers inlaying technique. The usual disclaimers apply—I recommend specific brands only when either no other will work or I have no experience with others. As far as I know, no manufacturers mentioned here have ever heard of me. Your feedback is solicited and welcome. Feel free to download the text for personal use, but otherwise please do not crosspost, forward, or reproduce the text without permission.

2011 revision: I wrote “Pearl Inlay Technique” in three parts over about two months in late 1995. I posted the parts one by one in plain text and ASCII art in the old USENET newsgroup system (rec.music.makers.builders and alt.banjo), and the series made its way all around the then fledgling “World Wide Web.” The response from established and aspiring luthiers and inlay artisans was unexpected, gratifying, and to my amazement pretty constant over these 16 years—folks still find the series through some dusty link or another and apparently the articles still resonate with those who want to learn how to inlay mother of pearl. But much has changed since 1995 in the world of inlay and in my world too, not to mention in the way we disseminate information online. Particularly because of the latter I’m somewhat reticent to revise and redistribute the articles, and yet some of the information is sufficiently dated to make me think I should either revise the treatise or search it out and pull it down wherever I find it. Since the latter is impossible and since I still have some creative streaks remaining in my aging frame, I decided to revise the text and float it out there once again.

Acknowledgements: I want to thank all who took the time to write to me about the first edition of “Pearl Inlay Technique,” and I also want to thank several individuals who started me down this path so many years ago, either through direct instruction and conversation, or through their first-rate writing. Thanks to Donald Zepp, Roger Siminoff, Frank Ford, Richard Johnson, Hideo Kamimoto, Ervin Somogyi, Don Musser, Mike Longworth, and most of all to my good friend Chuck Erikson, the incomparable Duke of Pearl.

The text that follows describes one person’s method for inlaying mother of pearl and similar materials into wood. There are as many variations on each step and indeed on the entire process as there are people who inlay pearl, so if you run across instructions that deviate from the paragraphs below (or vice versa), please adopt or stay with what works best for you. Practice first, so you know which way that is.
I. Materials and tools

Any number of flat or flattenable materials can be inlaid into the surfaces of instruments, furniture, jewelry boxes, etc., but the most popular for stringed instruments has always been mother of pearl from pearl oysters and a similarly-derived material from abalone shells. Mother of pearl (nacre) is the interior lining of the pearl oyster (*Pinctada* species) shell, and although all shelled mollusks possess a shell lining that resembles mother of pearl, the pearl oyster and abalone shell linings are particularly appealing and the shells are large enough to yield reasonably large flat pearl blanks. Oyster mother of pearl is usually white, gold, or grayish purple (“black”) with red, blue, and green iridescence and often with swirl, “eyes,” a curly pattern like “fiddleback” maple, or other figure that results from proximity to the shell hinge or from imperfections or worm borings in the outer shell.

Pearl oysters are native to the warmer parts of the Pacific and Indian Oceans, from the Gulf of California to the Red Sea, and they are "farmed" in Asia for the cultured pearl industry. I don't know if they are also used for food. I also don't know what, if any, percentage of the pearl oyster shells that are imported for inlay pearl originate in cultured oyster beds, but I hope it's large. Abalone (several *Haliotis* species, of which California red and green abalone are the most popular for inlay) occurs primarily in moderately cold water parts of the Pacific Ocean. California abalone for inlay originates entirely from "wild" specimens harvested for their meat, which is considered an ultimate seafood delicacy. Some abalone is now farmed, and perhaps in the future most of the commercial material for food and shell can originate from such sources. Abalone laminates (“Abalam”) are now widely available and are particularly useful for purfling applications and for large inlays in flat surfaces. (*2011 note:* West coast and Mexican red abalone, formerly the inlay market staple, is now scarce and expensive and it has been largely replaced by western Pacific “paua” abalone and to a lesser extent by green abalone, both of which are also expensive).

Other materials occasionally or commonly used for instrument inlay, at least historically, include bone, ivory, tortoise shell, silver, gold and its imitators, brass, nickel silver, stone and stone composites, and various woods and plastics ("mother of toilet seat"). Each has its own peculiarities, but the process for cutting and inlaying all such materials is basically the same.

To convert an arched shell to flat inlay blanks requires several steps. The first is to mark the shell (on the inside) to take best advantage of the figure and pattern, and to minimize the arch in any particular rough piece (the less arch, the larger and thicker the final blank). The resulting jigsaw puzzle in the shell is then bandsawn into arched individual pieces that are lined with mother of pearl on one side and with the shell exterior on the other. The rough exterior surface is then ground away to reveal the underlying mother of pearl. The resulting piece is anywhere from <1mm to 25mm thick (up to 1” (25.4 mm) for really thick shells at the lip), and it is still arched. Next the arched blank is fed into a special grinder that flattens and finishes each face of the blank, accompanied by production of much dust. The finished blanks are characteristically no
more than 0.06” thick. Many suppliers furnish two thicknesses—thin (about 0.04”) for inlaying flat surfaces, and thick (about 0.05-0.06”) for arched fingerboards. The amount of handwork that goes into planning, marking, bandsawing, and preliminary grinding renders the blanks rather expensive. Blanks may be sold by the piece or by weight—thin blanks when sold by weight are usually more expensive because there are more blanks per unit weight and therefore more labor is involved in producing that unit weight.

The tools necessary for cutting and inlaying pearl include good lighting, a jeweler's saw, a homemade cutting jig, a scribe with a sharp metal point that is hard and stiff enough to scribe very hard wood, a few needle and small mill files, a hand held high speed drill (aka high speed rotary tool) with a router attachment, various bits and appropriate collets for the drill, a jig or vise to hold the object to be inlaid, and a 2.5” x 5” or similar rubber sanding block. For lighting, use a swing-arm lamp to give best control of angle and intensity. The jeweler's saw resembles a coping saw with a very slender blade, and the saw and the blades are available from luthier, jewelers, and lapidary suppliers. Blades are typically retailed as "fine," "medium," and "coarse," but the actual thicknesses vary among retailers because dozens of thicknesses are available from the manufacturers. I use "medium" blades for most of my work because they are less subject to breakage than fine blades and less likely to bind and break the inlay sheet than coarse blades. Fine blades are usually recommended for scrollwork and other intricate inlays, but as your skill increases you will have less need for them. Beginners should purchase at least 2-3 dozen blades. Many inlay artisans use a jeweler's saw with an adjustable throat to accommodate variations in supplied blade length. Such an adjustment feature also permits the use of broken blades, but in my experience this is a waste of time unless the blade was broken before it was ever used. The homemade cutting jig is a piece of hardwood such as maple, birch, or oak about 12" long x 2-3" wide x 3/4" thick. Two common shapes of the business end of the jig include a slot with a small hole a few inches from the end of the jig, or a triangular cutout:

![Diagram of a cutting jig](image)

The jig is clamped flat to a table so that the slot and hole or V-notch extends beyond the edge, the pearl sheet is positioned over the opening, and the wood supports the sheet.
while the saw cuts downward. The scribe is used to inscribe the exact shape of the inlay into the wood that will be routed for the inlay. Many hardware stores sell utility scribes—the one I use is a knurled steel shaft with a fairly fine hardened steel point that is removable with pliers. Spare points are stored at the opposite end of the scribe, which is sealed with a hexagonal plastic cap. A small mill or needle file may be handy for removing the small spur that sometimes remains at the end of the blade path and for fitting individual inlays together in larger motifs such as the “vine of life.”

The high speed drill is used to delineate and rout the inlay mortises in the wood. The most commonly used drill for inlay work is probably the Dremel Moto-Tool, which has been in production in one version or another since the 1930s and has a well-deserved reputation as one of the most useful of luthier’s tools. Be sure to check out other high speed drill options such as the Proxxon or the Black and Decker, but do not economize on the high speed drill: purchase a variable speed, ball-bearing model, and if you can afford it, purchase two. Three is not too many. You’ll also need a router attachment for the high speed drill. The choices for this important attachment have changed quite a bit in the past 16 years. I believe that most current Dremels work with the current Dremel “plunge router attachment,” but the base on that device is huge, much too large for inlay work in tight corners. Another option is the Stewart Macdonald “precision router base” (standard disclaimers), which is threaded to fit many post-1995 Dremels. It is a compact well-designed, reasonably precision accessory that is also a bit tricky to learn to adjust and use effectively. Research the alternatives, decide which you like better, and make sure that your chosen drill is compatible with your chosen base before you purchase. I have a couple of old-style Dremel router bases that fit the classic, discontinued Dremel 380, and I confess that I use that old but useful combination for the stages of my inlay work that require the router base. Ebay, as though you were wondering. I modified the router base by replacing the bottom plate with piece of 1/8” plastic 1 1/8” front to back and the same width as the original base so that the bit is not surrounded by plastic and I can see the operation clearly. With this modified router base I can also access just about any tight corner with the bit. The narrow base setup is prone to tipping but the tradeoff in access and visibility is worth that minor inconvenience.

Numerous bits, sanders, cutting wheels, buffers, etc. are available for high speed drills, but I have found that just three bits are necessary for inlay. These include a fine-pointed bit, a bit with a plain shaft that ends in a tiny cutting ball that is slightly larger in diameter than the shaft, and a couple of fairly large (1/16" and 1/8" are good sizes) router or downcut bits. The pointed bit is used in the tool freehand to delineate and cut down the edge of the inlay mortise, the router bit is used in the router base to hog out waste wood in the middle of the mortise and to even up the mortise depth, and the ball-end bit is used on the tool also in a router base to undercut the edge after the mortise is mostly completed. Because most “hobbyist” pointed and ball-end bits are generally too large for small inlay work, I use dental bits that I obtained for free from my dentist—used bits are entirely sharp enough for inlay, and will remain sharp for a long time. Quite a variety of dental bits is available, from exceptionally finely-pointed carbide bits to tiny ball- and cone-shaped carbides and various straight and pointed diamond bits. One request to
my dentist and a 30-day wait yielded a lifetime supply, even if I live a really long time. Since the bits were at one time exposed to human cells and tissues ask your dentist to steam-sterilize the bits in an autoclave. If for some reason this is not possible, you could sterilize them yourself in a pressure cooker. Don’t immerse the bits in water in the cooker--sterilization comes from prolonged contact with pressurized steam, which can’t happen if the bits are immersed in water. Instead, place them in a clean tuna can with some marbles for ballast, and place the can in about one inch of water in the cooker. Process for at least 30 minutes on high heat after the cooker seals (the autoclave standard for sterilization is 30 minutes at 250°F (121°C) and 15 psi).

You will still need the router bits, and you will need one or more collets for your drill system to match the dental bit shanks which are smaller than most standard Dremel bit shanks (1/8”). Very hard (ebony) or very hard and resinous (rosewood) woods are notoriously hard on router bits unless the bits are made of durable materials like tungsten carbide. Most hobbyist 1/8” shank router bits are not carbide, and the carbide coated general cutting bits that Dremel offers are too large for small inlay routing and they do not cut hard woods very well. For routing work I use carbide spiral downcut bits (aka miniature end mills) with 1/8” shanks that fit the standard 1/8” collet, available from various lutherie and machine tool suppliers such as MSC. These cut ebony reasonably well, are available in sizes that range from tiny (1/64”) to substantial (1/8”) and except in the smallest sizes they are not expensive which is good because they will probably burn after a couple of hours of use on ebony and probably sooner on rosewood. If you find miniature straight router bits with carbide inserts like their larger siblings have, by all means try them out and also let me know where you found them.

Foredom and similar flex-shaft tools are an alternative to hand-held high speed drills. I am now using a Foredom motor with a Foredom H8 handpiece for the freehand work (see Part III) because the Foredom seems easier to control than Dremels. If you want to use a Foredom for all steps of your inlay work you'll need to fashion your own complete router attachment to hold a Foredom handpiece (not easy) or to purchase the “precision router base” and corresponding specially threaded Foredom handpiece from Stewart Macdonald.

You can use a padded bench vise or even sandbags to hold the object that you are inlaying (usually a fingerboard or peghead already attached to a neck), or you can build a jig to hold it on a tabletop. Purchase a standard rubber sanding block from the hardware store, along with lots of 80, 100-120, 220, 320, 400, and 600 grit open coat and wet or dry sandpaper. A large mill file and a flat cabinet scraper are useful for leveling the inlays and filler with the wood in the final stages of an inlay project. Other tools you might need include a very small chisel for cleaning inlay pocket corners, gravers and Laskin’s filler if you intend to engrave the inlay, and other bits for the high speed drill as the need arises.

**Staying healthy:** Contrary to frequent assertion, neither mother of pearl nor abalone dust is toxic. However, the ultrafine but sharp-edged particles that result from grinding or sawing shell can enter the operator’s lungs and do all sorts of mischief at the cellular
level, never ever to be expelled no matter how hard you cough. If you grind shell or saw lots of inlay and thus generate lots of these particles, lots of them can lodge deep in your lungs and could eventually cause serious, even fatal, respiratory disease. The trouble is that the threshold between minor and significant exposures undoubtedly varies with the individual, and no one knows where that threshold may lie for anyone. To avoid inhaling pearl dust you can use a NIOSH-approved respirator, but first consult an occupational health physician for information on medical clearance for respirator use, and ask an industrial hygienist for advice on respirator selection and fit-testing to ensure that the respirator actually protects you.

Hardware store respirators may or may not work, depending on the type of protection the specific respirator offers and on the seal the respirator makes with the operator’s face under a variety of conditions. Only an expert at fit-testing can verify correct respirator fit, but I recognize that many will still opt for the hardware store approach. Half-face hardware store elastomeric respirators should indicate HEPA (high efficiency particulate air) or P-100 filtration and they should also indicate NIOSH approval. If possible try the fit first by donning the mask with filters in place, breathing normally for a few seconds, then placing your palms tightly over the filter cartridges to block inflowing air. If you can still breathe the respirator is not making a good seal. Try adjusting the straps before rejecting the unit and also try a different size of the same model if available, but if you don’t obtain a good seal the respirator won’t protect you. Also try each unit while looking in various directions, talking, bending over, and changing to other body positions like you would realistically expect to do when working with inlay. If you opt for the lesser “mask” instead of a respirator, purchase (usually disposable) N95 masks that bear the NIOSH stamp. Do not use “dust masks” which offer no protection at all from the ultrafine particles. When you don the mask be sure to squeeze the metal band around the bridge of your nose so that it makes a snug fit. Use the mask even if you cut only a little inlay. If you have facial hair beyond a moustache and no desire to shave you really should consult an industrial hygienist because it can be difficult to achieve a good respirator fit for the hirsute among us and an industrial hygienist can offer the best counsel on this problem.

Using compressed air to blow the pearl dust away from the inlay during the cutting is potentially a bad idea because even a slow and gentle air stream can aerosolize the dust right under your nose, and could transform a minor dust exposure (dust particles released by the sawing) to a significant exposure (invisible clouds of dust). I have the same concerns about vacuum systems, unless they are HEPA filtered at the exhaust (with an efficient prefilter to avoid clogging the HEPA filter). If the pearl dust from sawing actually does obscure the work (it rarely has for me) I recommend that you use a small artist’s paintbrush to sweep away (gently) the accumulating dust.

**Getting older:** Sixteen years ago I wouldn’t have dreamed of using an optical magnifier to help me see the pearl I was cutting—magnifiers typically have critical focus that means that being just a bit too near or far from the work results in a blurry picture. Nowadays at my slightly advanced age the choice seems to be between doing sloppy work or using a magnifier so I now use a standard binocular magnifier and have
adapted to the critical focus without too much difficulty. These devices range a bit in quality and price—try reading fine print with several different units at various distances and see which gives you the least critical focus combined with the sharpest image.

Next: cutting pearl

Pearl Inlay Technique
Sean J. Barry
Davis, California

This is the second of the three-part series on instrument inlay. I’m grateful for all of the positive feedback on Part I, and again I solicit and welcome your comments. Disclaimers and copyright rules are still in place.

II. Inlay patterns, layout, and pearl cutting

When last we met I spoke of tools and materials, and I left you staring at an array of scribes, jeweler’s saws, thin blades, and noisy high speed drills. Now, you must choose an instrument or other object to be inlaid, purchase some inlay material, and either purchase or design a pattern to cut. For your first effort, I suggest that you stay with mother of pearl from the pearl oyster, and save abalone for a later endeavor. The reasons are simple: abalone tends to be somewhat more brittle than pearl and most abalone is almost twice as costly as mother of pearl (or more). Mother of pearl and abalone blanks and laminates and other inlay materials are available from luthier supply companies and from specialty suppliers. I have my favorites among both types of merchants but I’ll leave it to you to develop your own. Many suppliers also sell machine cut inlays and some sell inlaid fingerboards and peghead overlays but that’s not why you’re here.

I have seen pearl advertised in thicknesses that range from 0.02 to 0.06 inches. Inlays less than 0.04” are usually pretty translucent and may not contrast well with wood. Use 0.04” blanks for flat surfaces, and thicker material for curved surfaces, such as arched guitar fingerboards. Thick blanks are also less likely to break as they are cut. Thick blanks do increase the rate of blade breakage, so be sure to have an ample stock of medium blades available. Mother of pearl is sold by the piece or by unit weight, typically by the ounce. Many suppliers claim that one ounce is sufficient to cut a Gibson-style banjo neck, but I have found that although an ounce of thinner blanks will cut all of the fingerboard pieces it will not usually cut the peghead pieces (even though there are more thin than thick slabs to the ounce). Further, many peghead patterns require oversize blanks (e.g. Gibson Flying Eagle and Bella Voce), so if you have such special requirements be sure to discuss them with the supplier. Most suppliers do not “grade” mother of pearl (except to separate the "gold" pieces, which have a specialized market), because highly figured pieces are scarce enough so that the cost of sorting by hand would multiply the final cost of the pearl manyfold. The end-user should pick out the
best blanks from any given batch and stash them away for some future ultimate inlay job. Look carefully at each blank and wet it to reveal unsuspected figure and color. Check both sides. Use as plain and routine a selection of pearl as possible for your first cutting efforts.

The inlay design is dictated by the nature of your project, and for this, you must choose carefully. I think that the best instrumental candidates for practice material are instruments you have built yourself or instrument necks you have built or purchased. You might consider a medium-priced commercial instrument, one that is unlikely ever to be collectable, but you will have to strip and refinish the peghead, de-fret and refret the fingerboard, etc, none of which is simple and all of which increases the likelihood of project failure on the heels of a successful first inlay job. I don't recommend altering even these instruments, and please do not tamper with a fine or collectable instrument (don't laugh—too many great instruments have been “customized” with misbegotten pearl inlays). Like many other aspiring inlay artisans, I started by inlaying a reproduction Gibson banjo neck. This is one of the best ways to learn because most of the “prewar” Gibson Mastertone patterns are relatively easy to cut, and there are enough pieces in most of the patterns to give you lots of practice in layout, cutting, and inlaying. Banjos are generally very amenable to such decoration—in my opinion too much pearl on a guitar or mandolin is too much pearl, but banjos rarely have this problem. The various Gibson, Vega, Paramount, and other inlay patterns are available from suppliers, and for your first effort you should probably stick to one of those (assuming you have a project that would use such a pattern). Select a pattern in keeping with the instrument—a 1920's Gibson tenor banjo pattern would look pretty strange on a guitar neck. The best time to inlay a new fingerboard and peghead overlay on a new neck is after both are glued in place and the neck and peghead are profiled and bound and the binding has been leveled with the playing surface of the fingerboard, but before the peghead is reduced to final thickness and the neck is shaped. The squared unshaped neck back surface is much easier to control and any dings that happen during the inlay work will be removed when the neck is shaped. If a banjo neck is not part of your present or future world, you could also just inlay a box, a cribbage board, or something similar. The important thing is to get to work.

If you are more adventurous and want to design your own pattern, by all means do so. Get ideas from extant inlay patterns, Grecian urns and columns, $100 bills, TV test patterns, classic museum architecture, kitchen fixtures, chandelier displays, or deep within yourself, and draw them on a piece of translucent graph paper (I use Clearprint 100% rag vellum, 10 squares to the inch, which is available from art and graphics suppliers—megabucks but worth it). You can work within a delineated area the exact size of the surface to be inlayed, or you can draw much larger patterns to be reduced photographically or Xerographically to actual size. I work up script patterns (like my brand name) by writing with a medium-wide calligraphy pen until I have the pattern I like and that fits in the assigned space. Then I overlay a second sheet of translucent paper on the design and trace carefully around the edge of the script with a size-0 technical pen or “crowquill” pen and India ink. Other types of patterns can be drawn in pencil, and then traced with the technical pen. If you design your first pattern, you will
undoubtedly discover later as you are attempting to cut the pearl that not all designs can be cut. Try to remember as you design to keep straight lines straight, and curves as segments of a circle, rather than as ovals. Remember that you will not appreciate your design fully until it is embedded in the wood, after it is much too late to change it, so try to keep it simple and elegant, especially the first time out.

Lay out the pearl slabs on a table and examine each one to determine the best side. Take your purchased or drawn pattern, make sure you have lots of accurate photocopies, and with scissors cut out the individual designs. I number each piece of the pattern so that all can be accounted for when the layout is complete. Glue each paper pattern piece to a piece of pearl with a very thin layer of Titebond or white glue, and let the glue dry completely. Be sure to glue edges and corners adequately, because these are likely to lift during the subsequent cutting if not glued well. I have tried rubber cement and contact glue and both have failed to hold the design in place along thin areas and at corners. These days many people design or scan inlay patterns on the computer and print them on adhesive labels and I can’t think of a single disadvantage to that approach except that you have to own a computer and printer. Otherwise, as noted use a very thin coat of Titebond or white glue (thin to avoid gumming up the saw blade), and after the glue has dried, it is time to cut the inlays. Clamp your cutting jig to a table and set up the work light. Mount a blade in the jeweler’s saw, and make certain that the teeth will cut on the downward stroke—the teeth should point toward the saw handle, which you can ascertain by running a fingertip gently along the blade in each direction. The rough, snaggy direction is opposite the one where the teeth point. Use the tensioning mechanism to tighten the blade so that it yields very little when plucked like a string (or flex the saw frame to tension the blade if you have that type of saw). When you mount the blade, be careful to avoid bending or twisting the ends, and make certain that the blade is as straight as possible. Put on your respirator or N95 and fire up the MP3 player. There are peaceful but meticulous times ahead.

To cut inlay well requires only that you be able to follow a line with the jeweler’s saw. This was easy to write, but if you are like most it will take many inlay-feet of cutting before you achieve the consistently smooth, graceful line that characterizes expert work. If you’re not already the patient sort you’ll need to learn how to be. Many artisans like to cut along the outside edge of the line, which they endeavor to keep to the left of the blade as it lays on the jig. The left hand steadies, moves, advances, indexes, and turns the pearl slab over the opening or hole in the jig and the right hand holds the saw handle beneath the jig, and saws up and down (remember, set the teeth so down is the cutting stroke) and cuts the pattern. The saw should advance, turn or otherwise move very little (except up and down)—that’s why the hole or other opening in the jig can be so small. Examine the pattern thoughtfully before you start to cut. Look for inherently weak areas, and plan the best route for the initial cut. Cut into the slab near the end of a point or corner—if you are cutting out a star, try to intersect the pattern at the apex of a point rather than somewhere along a side. When you hit a tight corner, back up the blade, cut a bit into the outside to widen the kerf, repeat if necessary, and use the widened kerf to turn the blade around the corner. When possible cut from weaker parts of the pattern into stronger sections, but learn to cut from any point in any inlay. Endeavor to cut long
straight lines and curves without stopping, because a small bump or ridge often results where the cut is interrupted. Try to use the entire blade for each cutting stroke, except when you are approaching a stopping point, but even here keep you sawing movements as smooth as possible. To cut out "blind" interior sections, drill a hole into the blind pocket with a pointed bit in the Dremel high-speed drill, and then thread the saw blade through the hole and install it into the saw--this is tricky and a threaded blade is difficult to tighten, but you will improve with experience. Cut the blind sections first, and for that matter, if you have delicate sections that are not blind, try to cut them first as well. As your skill improves your pace will quicken, but be careful not to cut too fast because the blade will heat up and break. The other principal reason blades break is that they bind in tight corners or from being forced to turn too tightly to follow a tight curve. Blades also break when the metal fatigues from use, or simply because they get dull. Again, be sure you have lots of blades on hand. Blades usually just break without causing problems, but now and again a partially-cut inlay will break when the blade breaks. Likewise, once in a while a blade piece will fly when it breaks, so you might consider including goggles in your personal protective equipment arsenal. The blade can also loosen somewhat during the cutting, which actually makes it easier to cut but it wanders aimlessly. Be alert for this and tighten as necessary. If this is a chronic problem, clean the blade attachment points or buy a better jeweler's saw frame. When the inlay is completely cut, carefully examine it for problems and then put it in the safe deposit box along with your figured pearl blanks and other irreplaceable items.

If you need to file the inlay edge(s), hold the inlay on the cutting jig and carefully file downward, slowly. A small sanding wheel in a high speed drill can be useful for some smoothing, but try to cut smooth lines with the jeweler's saw so that you don't have to try to improve the inlay by filing or sanding after the cutting is finished. Also, do not attempt to inlay broken pieces, glued or not. Throw them away, save them for practice with engraving, whatever, but don't include them in a fine inlay job. If you proceed slowly, carefully, and thoughtfully your skill will improve dramatically between the time you start and finish your first elaborate pattern, so much so that you will probably want to recut some early inlays that are not as nice as later efforts. This skill will always improve, no matter how much experience you have, and you will become more critical of your own work as experience accumulates.

When you have cut all of the inlays, scrutinize them carefully. Compare and match paired patterns (such as opposite petals in the hearts and flowers pattern) so that the final product reflects care and attention to detail. Reject any inlays that are really clunky, but for a first attempt don't be too hard on yourself. However, the really meticulous (and irreversible) work is soon to begin. Don't use substandard inlays, for once their shapes are inscribed in wood, you're committed to them.

Fitting or “piecing” inlays together such as in a vine or more elaborate patterns is pretty straightforward but requires experience and mega-patience to do well. First cut the inlays carefully so that minimal further work will be needed to achieve a gap-free fit. If further work is needed, use the small mill or needle file. Hold the inlay on the wooden jig or any small wooden board so that the “fitting” region barely protrudes and file
carefully, horizontally, vertically, and slowly. Start at one end or corner of the design and work through it as unidirectionally as possible. Work on just one inlay in a fitted pair, not both—filing both will compound your errors (not to be confused with smoothing—you might have to do that to the joining surfaces of both inlays before attempting to file-fit them together). Try the fit frequently until the inlays fit together without gaps, in the correct orientation so that one inlay “flows” smoothly into the next as designed. If you neglect to maintain the flow between component inlays, unforeseen gaps or a cockeyed pattern will likely result when the motif is inlayed. Assemble the completed fitted motif on the table and study each joint carefully to detect gaps and places where the flow isn’t quite right, then correct the problem areas as carefully as you can to ensure that new problems don’t emerge.

**Afterword:** The above applies as well to other materials commonly used for inlay. These differ physically from pearl quite substantially, but none is especially difficult to cut. Wood veneer should be glued to a paper backing before it is cut. Bone for inlay should be at least .06" thick, because thinner bone is translucent and does not contrast well with wood. Sheet brass, nickel silver, and gold lookalikes are fairly easy to cut, although somewhat harder on jeweler's blades than is pearl. I have no experience with stone or “reconstituted” stone composites but I expect that each has its own surmountable problems, just as pearl does. The use of ivory is rightly controversial and raw ivory is very rightly almost impossible to obtain any more. Should you wish to inlay some old ivory, old piano key tops are the most common source these days. These tend to be quite fragile and translucent and they do not make the most satisfactory inlay material. Ivory became obsolete as a decorative material in about 1862 when celluloid was invented and as a structural material it became obsolete when bone first came along (a really long time ago). In my opinion the only valid reason to use ivory is for repair of original ivory fittings or inlays on old instruments.

Next: Routing and inlaying

---

**Pearl Inlay, Part III**

Sean Barry

Davis, California

This is Part III of the III-Part series on instrument inlay. Part I, a discussion of tools and materials, appeared in October 1995, and Part II, an explanation of pearl-cutting technique, appeared at Thanksgiving 1995.

As before, all standard disclaimers apply--to my knowledge, no company mentioned here has ever heard of me, and tools and materials are mentioned by brand name only when my experience indicates that few or no other alternatives exist, or I have insufficient experience with alternatives. Copyright rules remain in place: feel free to download the text for your own use, but please do not forward, crosspost, or otherwise distribute the text without permission.
Part III--Routing and inlaying

By now you should be finished cutting your chosen pearl pattern, and you are probably tired of repeated trips to the safe deposit box to safeguard the products of your efforts. Undoubtedly you have been staring at the high speed rotary tool and the router base that you purchased after you read Part I and are wondering what they do. Now you shall find out.

Go one last time to your safe deposit box and retrieve your entire inlay set, and arrange it on the table in the proper orientation. Perhaps place all of the inlays on black construction paper so you’ll have a preview of your finished product. With a pencil, number each inlay, and draw a small arrow that points toward the end of the peghead. The arrow is only necessary for radially or bilaterally symmetrical inlays or for identical components of such an arrangement with several identical pieces, such as petals of a flower. Once you have scribed and begun to cut the mortises, you must avoid confusion regarding the precise location and orientation of each piece. From this point forward, you must not change your assigned positions--to do so will result in confusion, broken inlays, and problems during the final inlaying process. This is your last opportunity to recut any inlays that are not up the level of quality of the others, and to rearrange and rematch pieces to best advantage.

The next two steps are really the most critical in the entire inlay process. Up to now, if you broke an inlay or your pattern was uneven in quality, the problems were fixed easily by cutting new pieces. After you (temporarily) glue your inlays in place and scribe their shapes into wood, it will be tricky at best to replace any, so take special care not to break any or to change your mind about placement or replacement.

Glue your inlays in place on the surface to be inlaid. In my experience, this is best done with DUCO cement, because this glue can be dissolved away with acetone. "Spot" the glue lightly in several places on the bottom of the inlay, and press the pearl firmly in place on the surface. Check and double check the inlay position and remember that it may move by itself before the glue sets up. If any do, run a few drops of acetone around the inlay edge, let it soak in for a few seconds, lift the inlay, remove the glue with more acetone, and try again. Script inlays (written text) are especially tricky and obviously fragile, and should be glued thoroughly on the bottom. Endeavor to clean up as much of the glue squeeze-out as possible while it is still soft. Double-check that all inlays are properly positioned (remember: guitars are inlaid on the 9th fret, banjos and mandolins on the 10th), and set the object aside for at least 24 hours. I used to use white glue instead of DUCO, but had problems removing the inlays when the scribing step was done. The only options are to pry up the glued inlays or to soften the glue with water. The former can result too easily in broken inlays, and the latter tends to obscure the scribe lines, so I went to DUCO (which is not perfect but works well enough). Again, once your inlay shapes are inscribed it is essential to use the same inlay that was
inscribed, because it is impossible to cut another piece exactly like the original. So don’t break any by being careless or rushed.

The next step, the most critically important in the entire process, is to inscribe the inlay outline into the wood. Use the scribe that we discussed in Part I, and trace around the inlay as close to the edge of the inlay as possible (which should be flush with the edge). Avoid undercutting the inlay, and most of all avoid pushing on the inlay itself with the side of the scribe. At best you could dislodge the pearl (this only happens, according to Mr. Murphy, to complex inlays and then only after the outline is about 50% but less than 75% inscribed), and at worst you could break the inlay. This is a calamity if you have already inscribed any of the outline. If your scribe encounters a mound of glue, scribe carefully over it several times until it separates from the inlay, then scribe the wood. The wood grain will tend to divert the scribe point, so be aware of grain direction changes (relative to the inlay). Ebony is so hard that it is best inscribed by making repeated passes. Be slow, be cautious, be meticulous, be a perfectionist. This is your only chance to do this step correctly, and the quality of your final product depends on the scribed line (and your ability to follow it with the high speed drill). I have tried to deepen the scribed lines later, after the inlay is removed, but with very limited success. Even though the pearl is not supposed to be a "fence," its presence offers a much better visual limit than does the scribed line alone. Inspect each scribed line carefully and make certain that all are complete and deeply inscribed.

With a glass eyedropper, dribble some acetone carefully around each inlay, but just do one or two at a time. Be extremely careful not to allow acetone to contact finish or plastic bindings, as it will corrode them. Also, heed the fire hazard. After the acetone has contacted the inlay for a few minutes, gentle side pressure will usually dislodge it. Allow very delicate inlays to soak up the acetone for at least 30 minutes, and then use the gentlest side pressure distributed over the entire inlay to dislodge it. Be very careful—it will be almost the ultimate in disheartening feelings to break the inlay now, exceeded only by breaking it later. After each inlay is dislodged, take a moment to clean the residual glue from the inlay bottom and crevices, and renew the label and arrow (the acetone may tend to disperse the pencil marks, and it will dissolve away virtually any ink). Arrange the pieces carefully because you don’t want to make any fitting mistakes during the routing process attributable to trying to fit the wrong piece or orienting an inlay incorrectly.

**Frequent variation:** Some artisans transfer inlay shapes to the wood surface by coating the wood with a spray adhesive such as 3M, holding the inlay in place by pressing on it with a toothpick or some other slender implement, and coating the entire wood surface with blown or shaken fine white powder such as talcum or corn starch. No scribing is involved, and the inlay shape stands out on the dark wood in stark contrast to the white powder which is bound to the adhesive. This method is easier and less involved than scribing and its adherents maintain that it makes the inlay shape more distinct and easier to follow than scribed lines. Drawbacks are that the powder may not cover evenly which you won’t know until the inlay is lifted, and that when you start your mortise work you may have problems seeing the boundary between black and
white clearly, especially if you inadvertently cross into the “no cut” zone. Another concern is that you are potentially aerosolizing fine powders that have unknown potential when inhaled so if you use this technique remember your respiratory protection. Talcum’s purported hazards are controversial and unconfirmed but the material is likely pretty innocuous if not inhaled. Some people are sensitive to talcum so if you start itching when you try this technique you should probably abandon it.

Now comes the three-step routing process, the most difficult part of inlay technique. You must wear goggles and a respirator or N95 mask, you must keep a steady hand, you must STOP if you can’t see clearly where you are cutting, you must cut very slowly, and you must keep the faith in your scribed lines, even though many times they don’t seem to be correct. The first step is to cut the inlay outline deeply with the pointed dental bit (again, the pointed bits offered by Dremel tend to be too large, but they will work for many larger inlays as long as there aren’t tight corners). Use the drill freehand, not in the router base, and cut downward and sideways with the point of the bit from the line into the wood. Hold the drill like a pencil and use the lowest speed, but vary this to suit the hardness of the wood and the part of the outline you are cutting. This is actually the most difficult of the three steps, and it must be done slowly. BE SURE TO CUT INSIDE THE LINE!! Only experience will help you improve, but this step will establish how "close" your inlays are, that is, how much filler space results. Try to cut 2-3 millimeters down into the wood. If you can’t see your scribed line clearly, stop and rearrange the workpiece until you can. Formerly, I used two or three 25-pound bags of #7 lead shot (available from shotgun reloading suppliers) to pad and support a typical finished neck but I suspect that too much lead dust emanated from those bags so I now use sand bags instead. These give great flexibility on repositioning and do not dent or nick the wood. For unshaped necks as described earlier positioning is less important but the bags still help for positioning. Cut completely around the inside of each scribed line, and examine each very critically to make sure the initial mortise is of uniform depth and that the corners and tight curves are cut vertically and cleanly. When you are satisfied that all is well, examine the workpiece once again. I have never failed to find spots that needed work, even after two or three examinations.

Next, chuck the router bit or miniature end mill (not the ball-end bit) into the high speed drill, and mount the drill in the router base. Leave enough bit exposed so that it will cut a mortise to about 95% of the thickness of your inlays. To check, use scrap wood and adjust the bit depth so that one of your inlays protrudes just slightly above the mortise. If you are inlaying large pieces in a curved surface (D-45 hexagons in a guitar, for example), your mortises will be curved as well unless you shim the bottom of the router base with tape and wood veneer so that it rides perpendicular to the peak of the fingerboard. For these inlays, set the cutting depth to 95-98% of the pearl thickness. If you are inlaying a laminate such as Abalam, you must cut your mortises so that the inlay is flush or very nearly so—the outer laminate is very thin and easy to sand through during the leveling process (described later). Laminates obviously won’t usually work across curved surfaces. Straight router bits function best at very high speed, so use the highest speed setting. Use the router bit to remove as much of the inlay mortise wood as possible, but do not encroach the edge too closely because if you slip this bit will cut
really fast and do terrible, irreparable damage. For that reason do not try to take large “bites” of the wood in the middle of the mortise either. Work slowly and methodically, and be careful. If you can't see very clearly, STOP and rearrange the workpiece so that you can. Cut out all of the mortises and then examine them critically. Do not yet attempt to fit the inlays, because the mortises are not quite ready, and you may break an inlay if it binds in a mortise.

Now chuck the tiny ball-end bit into the drill (leave it in the router base) and set the bit depth so that the ball cuts flush with the bottom of the routed mortise, not into it because you don’t want to deepen the mortise anywhere. However, if with this setup the top of the ball is flush or within 1mm of the wood surface, the bit must be set deeper because otherwise it will greatly enlarge your mortises along the edges. You are going to undercut the edges of the mortises, and if the ball is too close to or at the surface it will overcut them too. The ball diameter of this bit should slightly exceed the shank diameter, and should never be smaller than the shank—the shank rubs against the wood "fence" (the edge that you established with the pointed bit) and thus keeps the ball from undercutting too deeply, but it must undercut a little or the inlay may bind when it is inserted. Use low or medium-low speed and go around the edges of your mortises very slowly and carefully with the ball. Be very aware of the previously established mortise limits, and do not exert any pressure against the wall of the mortise with the bit shank. Otherwise the spinning shank will tend to erode the wood and enlarge the mortise, and unfortunately you will be unable to see this because your scribed lines are now obscured. Tight corners and narrow curves may not admit the bit shank, and so these will be unreachable with the ball. Use the pointed bit freehand again to undercut these. When this job is complete inspect each mortise carefully and recut any questionable spots. It is not unusual to spend hours with each large mortise (and sometimes with small ones as well). Be prepared to devote lots of time to a large inlay project.

Now remove the drill from the router base and chuck the pointed bit again, and begin fitting the pearl inlays in their mortises. Once again examine each mortise for any rough edges or uneven lines, and smooth them carefully with the pointed bit. Gently press the inlay into place. If it won't go in easily, stop and find out why. Some inlays go a short distance and bind, and then yield to slightly greater pressure and slip in to full depth. This is undesirable—remove the inlay, find out where it is binding, and smooth the edge. If you don't, even slight expansion of the wood during seasonal changes may crack the inlay. Tight spots are usually visible after the inlay is removed because the pearl leaves a white mark. Examine such spots carefully and decide how deeply to cut into the wall of the mortise. This is where all of your careful early work can be compromised by impatience, so use good judgment about enlarging the mortise. If you stayed within the scribed line any binding has to be the result of little ridges and bumps on the mortise edge between the top of the ball-cut and the top surface of the wood. Look carefully for these and smooth them a little, then try to fit the inlay again. I have modified a discarded dental "elevator" into a tiny chisel for cleaning out areas that will not admit even the tiniest of dental bits. I don't need it very often, but when I do nothing else seems to work. It is relatively rare for any inlay to fit perfectly on the first try, but it will become more common as your skill and experience accumulates. Now and again a delicate inlay
(especially script) will become wedged in the mortise so that it is very difficult to remove. You must resist the temptation to 1) pry it out other than extremely gently; 2) leave it in place and attempt to pack filler around it. Work very carefully with toothpicks around the edges, and lift it out. It will come, but if you don't work carefully it will break. Then find out where it is binding and smooth the edge.

Once all of the inlays are fitted they can be glued into place, and any gaps between the pearl and the mortise edge filled at the same time. The process is simple: fill the mortise with a glue/filler, press the inlay into place, level it, allow the filler to set up, and file, scrape, and sand the inlay flush. The standard glue/filler has been epoxy with dust from the same type of wood mixed in for color and texture. This works well with ebony, but far less so with rosewood—finely-divided rosewood dust mixed with epoxy is usually much darker and greener than solid rosewood. Some artisans use tinting colors, such as are used to tint house paint, with some success for rosewood, but I have yet to see a perfect match for rosewood with any coloring system. I just use rosewood dust and try to keep the mortises as close as possible.

Not all epoxies work well as inlay filler. My pearl inlay mentor experimented during the 1960's with various epoxy brands to find those that set up hard (without a tacky surface) and that crept minimally. Epoxies are technically fluids even when set, and tend to flow just like water, except much slower. Really creepy epoxies soon leave gaps and pits in the fill space, and a superior inlay job can end up looking very inferior. My mentor selected Wilhold epoxy, and I followed his advice with good results for years. Wilhold epoxy is no longer with us and I now use Epoxy 220, a long-cure two part preparation available from jewelers suppliers and other sources and I'm about as satisfied with its performance as I was with Wilhold's. I know that many are using five-minute epoxy, and I guess this is all right except that one must mix several batches in the course of an inlay job, and many of these preparations never lose a slight tack. I think the best choice is the light-colored long-set/long cure material, and the appropriate goal is to develop your skills enough so that you need very little or no filler at all. Whatever epoxy you use, be sure to mix dead-equal quantities of resin and catalyst, because a mixture of unequal quantities, particularly an excess of resin, tends to creep forever. I make up the mixture, stir carefully to ensure uniformity, and mix with just enough wood dust to yield a fluid mixture of the correct color. In my experience, the best dust is produced by filing wood with a metal file, as other dust may be too coarse or may be mixed with "impurities" (sandpaper abrasives, etc). Some artisans insert the inlay, pack wood dust into the crevices, and then saturate the dust with cyanoacrylate glue which sets up in seconds. The work I've seen that used this method looked good, but time will tell whether the glue remains stable enough to keep the inlays in place down through the decades. I have my doubts.

If you are using long-set epoxy, you can fill all of the inlay mortises to about 3/4 depth with the epoxy filler. If you are using five-minute material, only fill one or two large mortises at a time. I emphasize this—if your epoxy sets up before you embed the inlay, you will have to re-rout the mortise. After the requisite number of mortises is filled, press each inlay into place, and level it by rocking gently with a couple of toothpicks or thin
dowels. Another advantage of long-set epoxy is that there is time to self-level prior to embedding the inlay. Be very careful not to let epoxy flow into the fret slots! Embed all of the inlays and double-check each to make certain that they are seated to full depth and that the filler has oozed out all around. Make sure that no inlay is tilted. In the past I have applied heat from a high-intensity reading lamp to each inlay-filler to increase fluidity and allow bubbles to escape, but this practice is now discouraged because it has been shown that most epoxies liberate toxic gases such as phosgene when heated. This practice also accelerates the cure, so that long-set epoxy when heated may harden in just a few minutes. In any case, allow the epoxy to harden completely before proceeding.

The final steps are to clean up the excess filler and level the inlays with the surrounding wood. I use a cabinet scraper, a double-cut mill file, and a hard rubber sanding block with various grits from 80 (pretty coarse) through 600 (pretty fine). Start with the (dull) scraper and shave away the epoxy from around and on top of the inlay. Be very careful in this and the following steps not to gouge or otherwise damage the surrounding wood. Continue to shave until most of the epoxy is gone. A coarse mill file can take the process a step further and begin to level the inlays with the wood, but again please be careful not to dig into the wood. Finally, use the sanding block alternately with the scraper on each inlay (avoid the surrounding wood, because it is much softer than the inlay and will erode at a much higher rate--this will result in high and low spots). Change to 120 grit after the inlays are completely leveled and flush with the wood, and sand carefully to remove the 80-grit scratches. I emphasize--use a sanding block, or at least use sandpaper folded over a thick piece of cork. Do not use your fingers as a sanding pad for this or any other operation in lutherie. If large bubble holes show up in the filler, take an extra day to fill them and to cure the new epoxy, then level with the sanding block and scraper. After the 80-grit scratches are gone, move on in turn through 220, 320, 400, and 600 grits (all used dry). Sand the entire fingerboard with all of the grits from 220 and finer. By the time you get to 600, the inlays should be free of visible scratches and they should look pretty good against the dark wood. You should be beaming with pride....

Carefully clean out the fret slots with an X-Acto knife and #11 blades, and with a vacuum cleaner hose before you attempt to install frets.

I don't oil fingerboards, other than to allow skin oils to put the characteristic patina in the board with time and playing. I have found that a final vigorous polish with a cloth diaper or dish towel does at least as nice a job as oil on the board and inlays, and doesn't add any chemicals to the wood, so I recommend that approach over any oil, plant-derived or not. Oils also soften fingerboard wood, may cause finish to peel away from the wood along the edges of the fingerboard, may loosen frets and inlays, and do not actually prevent moisture movement across fingerboards (proper seasoning does that). Avoid them—they're up to no good.

**Engraving:** If your pattern involves engraving, now is the time. Engraving is an advanced technique that requires much practice and study to master, and the technique
itself when done well has subtlety that defies simple instruction. The basics of engraving are simple enough—purchase some gravers, draw some lines on the inlays, etch, deepen, and widen the lines as appropriate with the graver(s), and use Laskin’s black filler, the epoxy-ebony dust mixture, or perhaps colored inks to darken and color the engraved lines. If you’re just copying an established pattern all you really need is practice—glue some scrap pieces of pearl to a piece of wood and practice your engraving on them until you have the confidence you need to do a creditable engraving job.

To become a master engraver you need to develop your graphics skills as much as your engraving technique. If you want to inlay a “real” object (human, animal, etc) to be engraved, start with photographs and detailed sketches of the object, and a sketch of the inlay. Use the photographs and other visual aids liberally to help you envision the accents needed to lend dimension and realism (assuming that’s the artistic goal). Pencil the lines on the sketch, verify that each line is needed, and then when the inlay is completed execute each line on the inlay with style and confidence. Strive to achieve smooth curves, correctly tapered and deepened cuts, appropriate accents and shading, anatomical accuracy, good perspective, and dimensional resolution, all of which characterize expert engraving. As with everything else that we have discussed, start simple, build methodically from there, and don’t rush. Inexpert engraving can detract from otherwise good inlay, so be sure of your skills before you commit to an inlay job that requires engraving. Hint: try to devote some time watching an expert inlay engraver at work.

**Dot inlays:** Purchase the correct dots, purchase a matching brad-point drill bit, purchase a drill press. Do not attempt this with a hand drill. Drill the holes to nearly full depth, press each dot into place, put a drop of cyanoacrylate glue (Crazy-Glue or similar) around the edge of the inlay, let it set up, sand off the glue and protruding pearl and polish as above. I’m not so concerned about the longevity of cyanoacrylate for this application because the dots usually fit tightly and the glue may just create a vacuum under the inlay so the dots won’t move even if not technically “stuck” in place. Some of the old Gibson Mastertone patterns use small dots in floral array—purchase the appropriate size dots, don't try to cut them with the jeweler's saw because such hand-cut dots will usually make an otherwise glorious inlay job look clunky.

**Resources:** There are websites galore devoted to inlay—take time to visit as many as you can. Most steel string guitar construction books include sections on inlay technique, as do Roger Siminoff’s books on mandolin and banjo construction. All of these references have much to offer and some have rather different approaches than what I have described. An older but very useful print reference on inlay technique is James Patterson’s “Pearl Inlay,” (revised in 1988) which covers lots of territory including how to produce your own blanks and strips from raw shell. A somewhat newer reference also now in its second edition is Larry Robinson’s “The Art of Inlay,” which includes instructions on the inlay process and has many great photographs of Larry’s phenomenal pieced inlay work. Larry “works large” and has developed an elaborate technique for filler-free inlaid motifs with multitudes of amazingly well-fitted component
pieces. His work is stunning, his book is superb, and you should be able to get lots of ideas on using various inlay materials to best advantage. Larry has also produced a series of DVDs on inlay which I haven't seen but I can't imagine would be anything less than great. My other favorite book on inlay is William “Grit” Laskin’s "A Guitarmaker's Canvas." Grit also does phenomenal pieced work with numerous inlay materials, and like Larry he is a master engraver. I never tire of gazing at Grit’s astonishing and evocative inlaid scenes and it is tempting to think that he and Larry have taken instrument inlay as far as it can be taken. But Grit, Larry, Renee Karnes, and others are proof that at about the time we think we’ve seen the apex, along comes someone whose design talents and inlay technique surpass that apex by a mile. New hands will bring further accomplishments, more inspiration, new pinnacles. Practice, think, use your imagination, continuously improve your drawing, layout, and inlaying skills, think some more, devote the learning time, practice some more, and try to make your hands the new hands.

Sean Barry
Davis, California
October 2011