Free Plate Tuning, Part Two: Violins

by Alan Carruth

F rom "The Big Red Book of American Lutherie"
V olume Three, 1991-1993
F rom American Lutherie #25-36.

Before I get into plate tuning I'd like to digress a bit and discuss the rationale behind the process, and a couple of other things I find it useful to keep in mind while I'm working. And I can't think of a better way to begin than by telling you about one of my more elaborate experiments.

Fig. 15 gives the relevant information on my fourth and fifth violins. The idea was to check out the influence of asymmetric back graduations by building a pair of closely matched fiddles with that as the only variable. The one-piece backs were cut from the same plank of birdseye maple and the tops were cut from a red spruce 4x6 that I took out the wall of my house when I put in a new chimney. The molds were routed using a template. Archings were checked for height at over two dozen points on each plate and were held to 0.2MM. Graduation, weight, and frequency data is as shown. The delta f mentioned is the frequency drop obtained when a 5g weight was stuck to the plate in an active area of the given mode. Fittings and so on were matched as closely as possible, and the two bridges were cut back to back from the same piece of maple.

When the instruments were strung up at Carleen's for the first time I had several of the better players try them out without telling them what the experiment was. They sounded very similar, but not exactly alike. When, however, after some discussion, we switched bridges, the sound of the two instruments was also switched around. In short, there was no significant difference between the two fiddles, at least when they were brand new and in the white. Subsequent playing in and refinement of the setup revealed the asymmetric back to be slightly more responsive in the hands of a good player, while the evenly graduated back has a slightly stronger bass response.

I learned some interesting things from all of this. First, birdseye maple is not the most rewarding material to use for a fiddle back, even if it is the hardest to work. Although these are good enough instruments, they are limited, probably because of the weight and the abnormal back graduations forced by the nature of the wood. Second, and more important, I learned that it is possible to duplicate the sound and response of an instrument quite closely *if* you can copy *all* of the relevant static and dynamic characteristic. The trick is to figure out what is relevant and copy it, and a little thought will tell you what a big trick it is. Especially if the only thing that will satisfy you is the Old Master Sound.

Even if you could dismantle a few fine old Strads and Guarneris and test them exhaustively, it might not tell you much. All of them have been rebarred, renecked, restored, repaired, and some have been regraduated. The constant stress of the strings and the insults of age have distorted them in ways that could be hard to factor out. And what about a few hundred years of playing? I should think that would be an effect that would be impossible to mimic without destructive consequences. In short, we probably can't discover the original intent of the makers of these fine old boxes, and even if we could, we would still be building new instruments. The best we can do is to take a stab at it in all humility, and hope that in a hundred years or so we'll be proved right. And if we are, this time the "secret" won't be lost.

I always find it helpful, when tuning plates, to keep in mind that I'm making a violin, not a pair of plates. You have to work them together. The whole is more than the sum of its parts, but it is determined by its parts. The interactions between the assembled parts of the instrument, and between the box and the air it encloses, are complex and not always well understood, and it seems to be the interactions that shape the sound.

A useful analogy is to think about building a radio. You start with a circuit diagram and a parts list of transistors, resistors, inductors, and capacitors. None of these parts is, by itself, a radio. If you get the right parts, and hook them up the right way, you end up with a set that will pick up the stations you want. And, of course, someone who knows what she's doing can switch parts around to compensate if she lacks, say, the specified inductor, and still end up with a pretty good radio. If you keep in mind that a violin or guitar is much more complicated than your average radio because the mass, compliance, and friction (which correspond to the inductance, capacitance, and resistance in the radio) are spread around you will get the picture.

AT LAST

It may seem strange to begin teaching plate tuning with so highly developed an instrument as the violin, but there are several advantages. For one thing, violins are structurally simple and fairly standardized in size and shape, so a lot of variables are eliminated. This standardization also means that you can pick up a lot of good "cannon fodder" cheaply at yard sales and *Junque Shoppes* to practice on. This is an unmitigated Good Thing, because it is difficult to get across more than the basics in print. Even with a lot of expert help, it takes time and experience to really learn these techniques, and it makes more sense to practice on a junker than on something you already have 75 to 100 hours of work in.The other good reason to start with the violin is that a lot of good people have spent a lot of time over the last fifteen years or so figuring out how to tune violin plates, and many of them have published their findings. By comparison, the time devoted to guitars, though productive, has been small. There is still a lot to learn, but we are pretty sure about the numbers we have.

EQUIPMENT

I mentioned the equipment I use in a previous section, but I will go over the requirements here to clarify things.

A signal generator should produce a good sine wave .signal at constant voltage over the range 20-1000HZ for general use; if you are going to work with basses it should go down to 8-10HZ in the low range.

A **digital frequency counter** is a must. You need to be able to know the frequency being produced to an accuracy of Ihz when plate tuning. I don't believe that you can calibrate an oscillator that accurately over the long term, as most of them rely on RC networks which can drift with environmental changes. Most modern frequency counters rely on a quartz timebase and are very accurate.

The **amplifier** is not so critical. Free plate tuning doesn't call for a lot of power; 10-12w should be enough. On the other hand, it can take 25w or more to drive some of the modes on an assembled archtop guitar, so plan ahead and get enough power.

Whatever you do, make sure the amp and speakers match. Trying to drive a 4 ohm speaker with an amp rated at 8 ohms can draw too much current and blow the amp. On the other hand, driving 8ft speakers with a 4ohm amplifier will cut the power output, but is otherwise harmless.

The power handling capacity of the speakers has little to do with their size. I have seen 50w speakers as small as 4" diameter and as large as 15". What counts is the weight and strength of the magnet, and the size of the wire in the coil. On the other hand, no speaker radiates sound efficiently at a wavelength much longer than ten times its diameter. Sound travels at about 1100 ft/sec in air, so a 100 Hz tone has a wavelength of about 11'. Anything smaller than a 12" speaker is not going to radiate very well at that frequency or lower.

The problem is that a small speaker couples more efficiently to the plate than a large one because it is less likely to overlap node lines. Thus we have to live with some inefficiency somewhere, and this is why its hard to specify an exact size for the amp. I prefer to used the smallest practical speaker and a more powerful amp which makes it easy to hand hold the speaker and tends to be quieter, too. A 4" speaker is fine for most violin and viola work with a 15w amp. For 'cellos and basses you will need a 6" or 8" speaker; the huge plates of the bass couple so well that they can be driven to amazing amplitudes by a sound you can barely hear, if the speaker is big enough to radiate at the low frequencies.

Do not try to tune plates without **ear protection.** A sine wave produces much higher pressure levels than a more typical sound at the same power output; 15-20w of pure sine signal may not sound loud, but it can cause permanent hearing damage over a period of time, and you can't afford that. Heed the voice of experience: get a good set of ear protectors, and use them.

Other than that the only special equipment you will need is a set of four or five soft foam pads just big enough to hold the plate off the bench top, and some glitter or sawdust to make the patterns visible.

Figure 15: Birdseye Pair

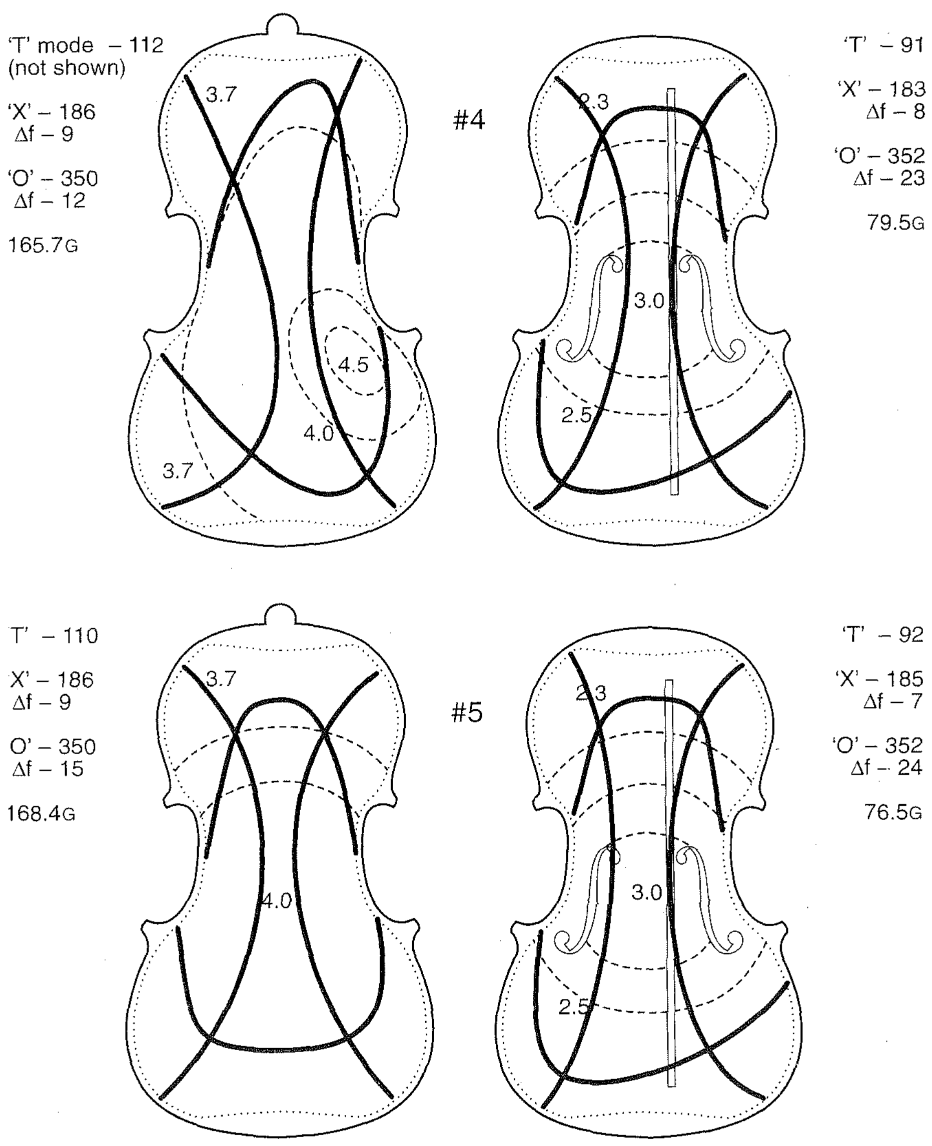
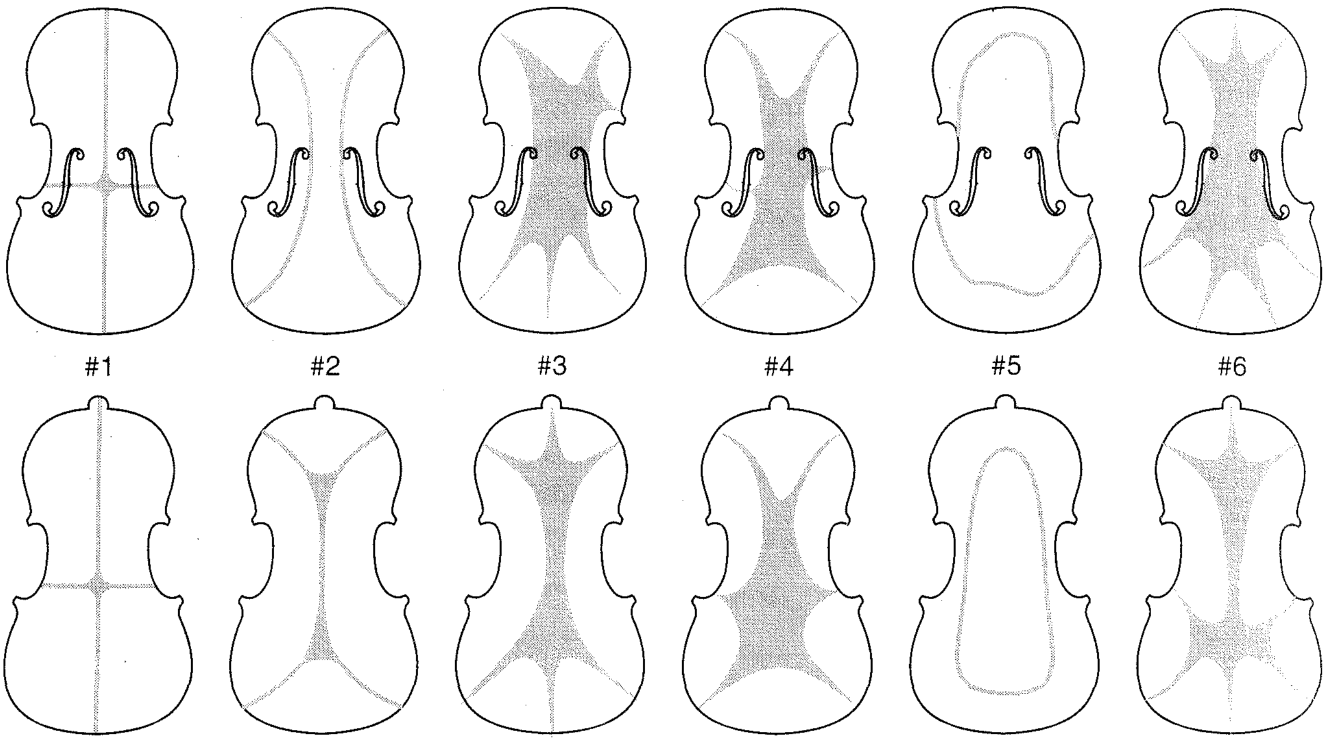


Figure 16: Violin Plate Modes



IN THE MODE

We work mostly with the first six modes when tuning violin plates. Because of the standardized geometry of the family these come in a fixed order, so they are usually referred to in the literature as "mode #1," "mode *#2"* and so forth, starting with the lowest frequency. Fig. 16 shows the shapes of the first six modes on a well-tuned violin top and back. I will stick to convention in this section and refer to the modes by their numbers even though I prefer to give them descriptive names like "T," "X," and "O." I do that because the modes assume different shapes in other instruments or occur in a different order; the "O" mode on a guitar top, for example, is really an "O-and-a-half."

To find a given mode on a plate, support the plate on foam pads where you expect the node lines to intersect the edge, with the inside of the arch facing up like a dish. Sprinkle on a little glitter. Hold the speaker an inch or so away from the plate pointing at a (you hope) ***vibrating area.*** Start with the frequency well below where you would expect the mode's frequency to be. Turn up the volume about half way (don't forget your ear protectors!) and sweep slowly up through the frequency band until you see the glitter start to jump. Find the frequency that is most active and move the supports around to give the best pattern. Then turn down the volume until you can just get the plate to move at one frequency. Once you get the hang of it, it takes less time to do than to describe, sort of like sharpening a scraper.

If you're starting with a set of new plates, their outside contours and purfling should be complete. Give varnish at least two months to dry before tuning; it takes that long, really! The varnish does add to the crosswise stiffness, particularly in the top.

I like to rough-tune the top before cutting the holes and installing the bar. Those two things tend to cancel each other out, so I find that if I get the modes around 15HZ higher than I'm going to want them it gives me a bit of leeway. It is easier to do a smooth job of graduating the top without the bass bar in place. The graduations given in Fig. 17 are a good place to start. These are pretty heavy, and once you have some experience you may want to reduce them.

If you're starting with a junker, remove the top plate and lightly glue a piece of cardboard in its place. This will hold the ribs in shape when you remove the back. Cracks and open seams must be repaired, of course, and if it's one of those with a ridge instead of a bass bar, smooth it off and install a real bar. Hopefully you got one with plenty of extra wood everywhere, but a couple of thin spots shouldn't hurt too much.

It is best to tune plates when the temperature and relative humidity have been steady for a while, preferably at 68°f and 50%. Wood gains moisture slowly when the humidity rises and looses it quickly when it falls. Wood with a high moisture content is both heavier and less stiff than drier wood, and so vibrates at a lower frequency. If the relative humidity is falling, the outside layers of the wood are stiffer than the center, and removing wood reduces the stiffness more, and the mass less, than would be the case if the wood were at equilibrium, and also sets up stresses that can distort the modes. Trying to tune plates when there have been large changes in humidity causes the mode frequencies and patterns to change all by themselves after the plates have rested a few hours, usually in ways you won't appreciate.

There are five desiderata in plate tuning:

1: Well formed, active modes. Again, refer to Fig. 16. Note that in most modes there are no large patches of glitter, which indicates that most of the plate is moving. Node lines tend to follow gentle curves, which indicates that the plates are bending over large areas rather than in small spots. Such gentle bending gives lower friction losses. Another way to look at it is that well formed modes indicate a smooth distribution of mass and stiffness.

2: #2 modes matched within 1.4% of frequency. It turns out that there is a bending mode of the completed violin that mirrors the ***#2*** mode shape, with the soundpost on the node line. It seems reasonable that the mass and stiffness distribution that give a well- formed ***#2*** mode would contribute to the formation of the whole-body mode. And, since the soundpost imposes a node, it would seem a good idea to have both ends of the post doing the same thing at a given frequency by choice rather than brute compulsion. The real situation is probably much more complex, but this at least makes some intuitive sense.

3: #5 modes matched infrequency, but only if the #2 ***modes match.*** If the ***#2*** modes don't match the #5 modes should be at least a semitone (20HZ for violins) apart. In no case should the #5 modes be more than three semitones apart.

4: #5 modes one octave above the #2 ***modes.*** Carleen feels that the old boys used the #5 mode as an indicator for the #2 mode as it is easier to hear when the plate is tapped. When the two are an octave apart the plate gives a particularly "clear, full ring," and if you can get the plates both to ring so on the same pitch you will have the two modes in tune even if you can't hear them.

I would also point out that there is only one mass and stiffness distribution that will give this result and it seems likely that the design of the violin evolved in the direction that would give this frequency indicator of that state.

5: #1 mode an octave below the #2 mode in the top, but not in the back. This seems to be a matter more of good luck than good management so far, although it should not be. Again, I think we can look at this as a refinement towards a proper mass and stiffness distribution. Working, as most of us do, with a somewhat random selection of wood, we have to rely on standard proportions and arch heights to get us near our goal, and hope that we are near enough that a little juggling with thicknesses will put us on the money. If you are willing to experiment, and can get a lot of wood from one tree, particularly for backs, you should be able to come much closer to the desired frequency ratios at normal graduations. 1 believe that was part of the "secret" of the old masters.

NUMBERS

Ah yes, numbers. 'Bout time I got to that.

It turns out that there is some latitude in the frequency ranges of these modes, depending on who, or what, you are building for. Since the ***#2*** mode is the one we key from, I'll give the frequencies for that mode.

For standard violins the ***#2*** mode should fall between 170-185HZ in the top and back. In some cases you can go much lower, but I would not leave it any higher.

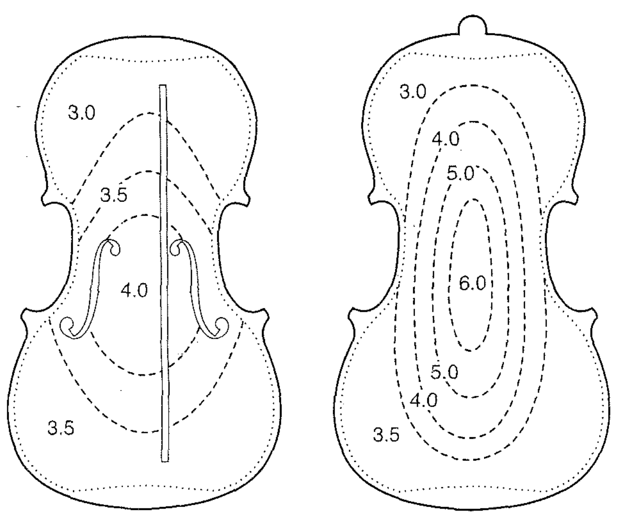
There seem to be two factors in operation here. A higher frequency means a thicker, stiffer, and heavier plate. It has been suggested that this can act like a flywheel, storing vibrational energy without having to reach too high an amplitude. This allows the player to push the instrument harder for more sound. All else being equal, the heavier instrument should take longer to play in, but once played in it should also take longer to wear out.

On the other hand, much of the quality of the sound is due to the coupling of air and wood modes. Many of the air mode frequencies are set by the dimensions of the box and the soundholes, and are only slightly affected by the plate tuning. But the plate tuning is decisive to the wood modes. Hence, to get the right coupling in the finished instrument you have to have the plate modes fall within a certain range.

The upshot of all this is that the higher the modes are the more power and expressive range the instrument tends to have, but it also gets harder to play. It is kind of like a full-race sports car, I think; in the hands of a great driver it can do wonders, but I would wrap the darn thing around a tree within a half mile.

An example of the other extreme is a new top I

Figure 17: Initial Violin Graduations



made a few years ago for the favorite instrument of a local fiddler. The old one was a compendium of repair errors that had pushed it beyond hope of recovery. I started the job with two conditions; that the top had to look old and had to sound the same as the old top. The ***#2*** modes turned out to be at 145HZ! I got an old piece of red spruce, and with some trepidation made the new top to match that frequency, and antiqued it suitably.

When I got done he couldn't believe it was not the old top somehow resurrected. This fiddle has a fine, open sound that projects rather well. It speaks very easily, with only a touch of the bow, which suits it perfectly to the contradance music it is used for. But it can not be pushed. A classically-trained player set it down after a few measures. And I worry to this day about how long it will hold up. Given a choice, I would almost never put out a fiddle with the ***#2*** mode below 160hz.

Okay, so now you've got this extra thick and zesty top with a bass bar that looks like a 2x4. The first thing to do is try to get some good looking modes, and the place to start is the bass bar.

Chances are that when you checked the modes on the top they didn't look much like the ones in Fig. 16.
In particular, the ***#2*** and #5 modes in the top probably looked like Fig. 18, with the ***#2*** mode around 225HZ and the #***5*** close to 400HZ. What this tells you is that the bar is too heavy for the top.

It took me a long time to learn to tune bars. The final shape of the bar in any given case depends on so many variables it is hard to give any fast rules. I tend to look at the bar as composed of five sections of approximately equal length; call them the center (at the bridge line), the outer sections, and the ends. The procedure is to trim a little wood off one section and see what happens. If the frequency of the #5 mode drops or the pattern gets better, trim off a little more until it stops working. Note that when the ***#2*** mode is well formed the tips of the bar are secondary stiffness contributors. If you are trying to drop the #5 mode and
keep the #2 mode frequency up it is best to leave the ends of the bar alone.

One generalization I can make is that the bar often seems to reflect the arch of the top. If the lengthwise arch of the top comes to a noticeable peak at the bridge line, the bar tends to as well, while a top that is flatter in the center often has a bar that is high through the whole center section. On the other hand, some unexpected things can happen when you tune a bar.
For example, it often happens that removing wood from the center raises the #5 mode frequency. This indicates that the outer sections are responsible for most of the stiffness that is holding the mode up, and the center is a load area. This can also happen when you take the bar from a rectangular to a triangular cross section, which is more efficient. Sometimes trimming one of the outer sections will cause the mode in the other end of the plate to come in more clearly.

At any rate, the thing here is to work slowly and check the plate often, at least for the #2 and #5 modes. At some point the ***#2*** mode lines will start to curve and the #5 mode will start to rotate into a more normal position. You should be able to get a #5 mode that looks something like the one in Fig. 16. For some reason the top seems to work better if the modes don't quite close; they should look as if the plate is a bit too short (see Fig. 9). Don't take too much off the bar, and see that the node lines come off the edges as shown.

What you've done here is to get the bass bar balanced to the plate. The plate is still much too heavy; I suspect that your #5 mode is still around 380-390h_z. Henceforth removing wood from the plate will lower the mode some, and the bar will have to be retuned at every step. I find it best to work in a balanced fashion like this. It cuts down on surprises.

Fig. 19 shows the primary and secondary bending and load areas in the top and back for the ***#2*** and #5 modes. Removing wood from a bending area lowers the frequency of that mode with primary areas having a greater effect, while removing wood from a load area

Figure 18: Rough Violin Top Modes #2 and #5

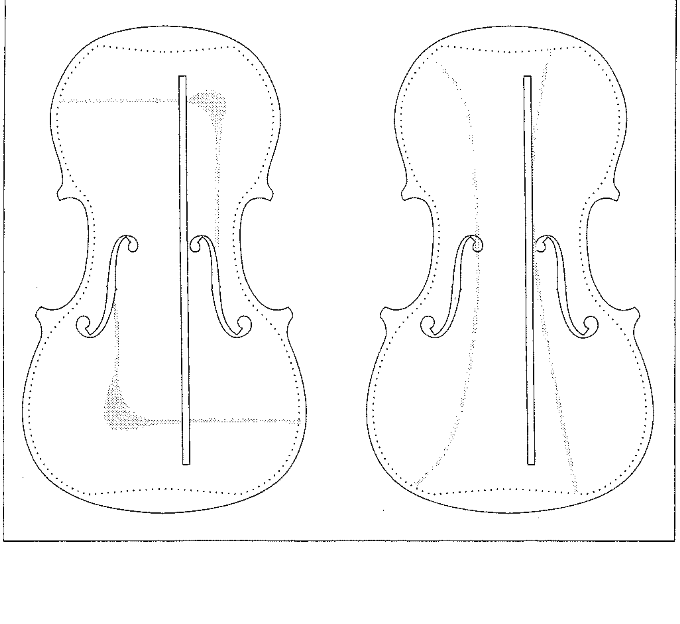
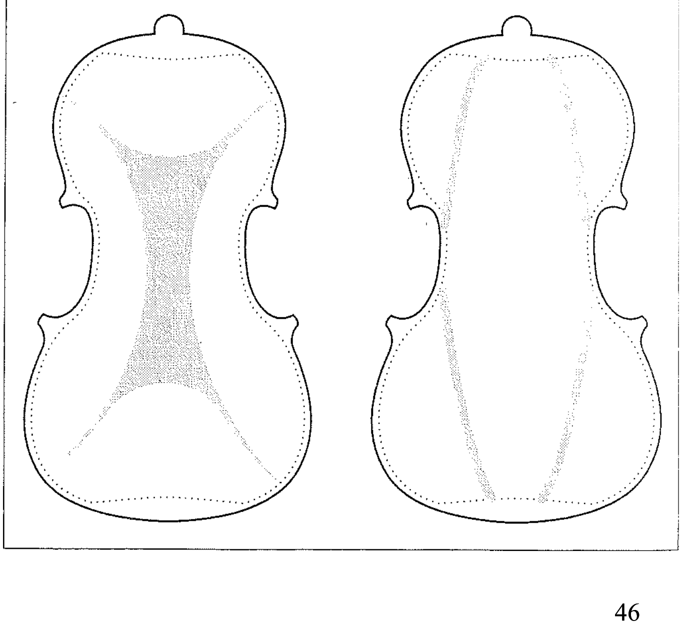


Figure 20: Rough Violin Back Modes #2 and #5

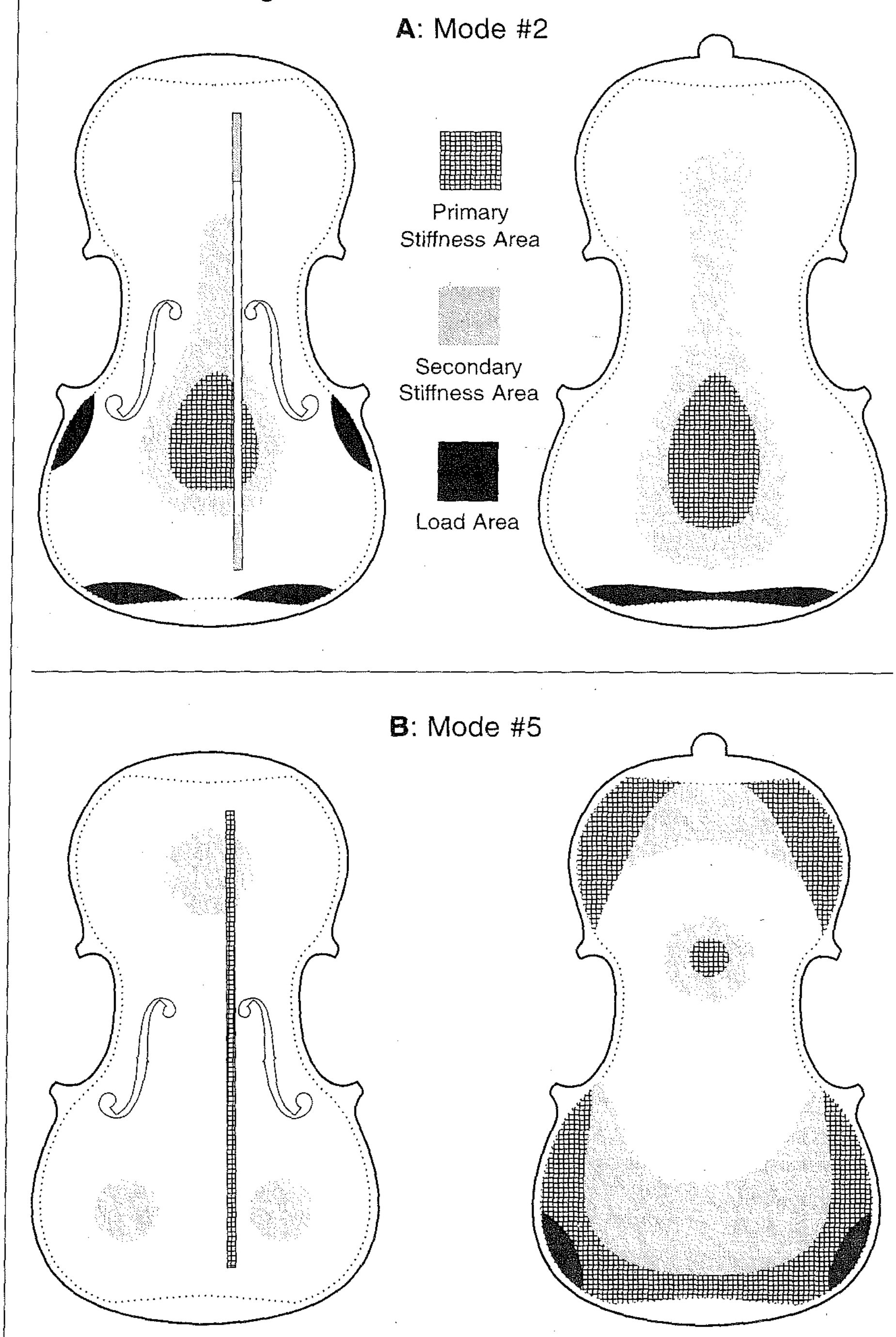


can raise the frequency. Remember that stiffness falls a lot faster than weight. In practice it is hard to raise the frequency of a mode, particularly the *#2* mode. You must realize also that this is more of a general indicator of what you should expect than a hard and fast rule.
The bending areas of any given plate will vary with the grain density and runout, as well as the thickness distribution and arch shape. As with the bar the best thing is to go slowly and check often to see what is happening as you remove wood. One good rule of thumb is that a sharp curve in a node line or a spot where the glitter puddles indicates a stiff area.

You will notice that the initial graduations as shown in Fig. 19 left a lot of wood in the #2 mode bending areas. This was deliberate. For one thing it is always possible that the wood you've got has an abnormally low crossgrain stiffness, and it-is better to protect yourself against such a possibility than to lament it. More importantly though, the ***#5*** mode frequency is held up by the arching, and this makes it hard to lower mode #5 without also lowering mode ***#2,*** particularly in the back. On the other hand, it is relatively easy to lower the mode *#2* frequency without lowering mode #5 because the mode *#2* bending areas are load areas for mode #5. Thus we generally try to hold mode *#2* up as long as possible in hopes of achieving the ideal octave relationship between the two.

Once the bass bar has been brought into balance with the top it is easier to tune the top than the back. The best procedure, then, is to do a little work on the back and then tune the top to match it. Working slowly in a stepwise fashion allows you to stop when you reach the best combination of traits that you can get for that particular set of plates.

Figure 19: Stiffness and Load areas



The *#2* and #5 modes on the back probably look something like Fig. 20. The #2 mode node lines are broad, with little activity in the middle of the plate, and the #5 mode lines run off the plate at one or both ends. If you go back to Fig. 9, this is much the same pattern the rectangular plate showed when it was too long for the modes to close. Another way of looking at it is that the crosswise stiffness is too high, and the culprit is that long, thick area down the middle. Shortening the constant thickness ovals by 1cm or so at each end should clear up the mode shapes some, and drop the *#2* and #5 mode frequencies a bit. If the #5 mode only runs off at one end, do that end first, and when the mode looks the same at both ends, proceed symmetrically.

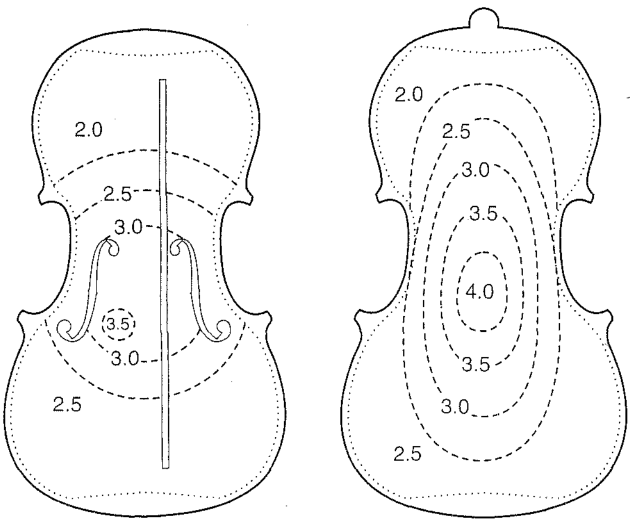
If the *#2* mode node lines are thick but the *#5* mode is not elongated, the plate is probably too stiff above and below the comers. Scraping a few tenths of a millimeter off each end starting at the corners should prove whether this is so or not. If the #5 mode runs off the end but the *#2* mode looks good then the centerline between the corners is most likely too thick. Try thinning the whole central oval a little.

Whatever you do, take your time. Once you've made a spot too thin it is hard to recover. Neatness counts too. The thickness around the edges of the upper and lower bouts should be held constant to a 0.1mm tolerance right out to the gluing ledge. The thickness should not change through the corners; note the tops of my fourth and fifth violins as bad examples. Take no more than 0.5mm off any one spot at a time and keep the graduations smooth with no bumps or hollows. Again, the area in the corners is particularly critical and thus, of course, difficult to get right because of the contour changes. When you have the ***#2*** and #5 modes in the back well formed, note all the mode shapes and frequencies as well as the thickness data for future reference and compare to the top.

With any luck the back frequencies are just a little lower than the top. You can thin out the top a tad, taking more off the ends than the center to help keep the ***#2*** mode up, and rebalance the bar. And by now you have the idea. Slowly juggle your way down, trying to keep the modes well-formed and the ***#2*** modes close in frequency. As the plates get thinner they should approach the octave relationship, with any luck at about the same frequencies. If you were good boys and girls and ate all your vegetables, the graduations will be close to those in Fig. 21, and the ***#2*** mode around 175-180hz. The #5 mode node line in the lower bout of the top should intersect the edge about 2-3cm below the corner on the bass bar side.

Plate tuning on violas and 'cellos is much the same, but at lower frequencies. Violas come in such a wide range of sizes and shapes it is difficult to give any firm numbers. I've had good luck on instruments between 16" and 16%" with the ***#2*** modes coming in between 115-125hz. Most violas are wider in proportion than violins, so it is difficult to get an octave between the ***#2*** and #5 modes, especially in the back. Carleen says the best results for violas are obtained when the ***#2*** modes are matched at about 125hz, the #5 modes are an octave higher, and the #1 mode an octave lower in the top, but not the back. The back #1 mode should be higher than that of the top.

Figure 21: "Ideal" Violin Graduations



'Cellos seem to like matched octaves when you can get them, with the ***#2*** modes at 55-65hz. Also, with 'cellos and large violas it is wise to keep an eye on the #6 mode. Because of the proportionally broader plates and lower arch of the larger instruments, the #6 mode can come in very close to the #5 mode frequency. If j_t is within a couple of semitones and very active, the assembled instrument will probably have a strong wolf

Speaking of the #6 mode, sometimes a plate will show hybrid patterns with the top half of a #6 mode and the bottom half of a #5 mode. The halves switch at a slightly higher frequency. This generally indicates one of two things: either the archings of the two halves of the plate are different, or the upper bout is a little too stiff in the crosswise direction. You can usually fee] the mismatch in stiffness with a bit of practice. If this is due to a hard spot in the grain, the area should be thinned. Here is one case where the Chladni method really shows to advantage over the traditional tap tones. This condition is very hard to spot unless you can actually see the modes, and a fiddle with this problem can be disappointing.

Plate tuning seems to work best when it just happens. The harder you have to work, and the further you end up from ideal graduations, the less good the results. There is no substitute for the best wood and the finest workmanship, but when you can't get the best wood, or you want to try something different, this will help you get the best out of what you have.

SIG GEN II - BEYOND PLATE TUNING

I have mentioned several times that there are vibrational modes of the completed instrument that can interact usefully with air modes of the body. At least one is fairly easy to find and tune on the finished fiddle and well worth the effort.

One of the lower frequency modes of the instrurnenl is called the B_0 (B-zero), or sometimes the neck mode. It is a bar mode with three node lines, roughly at the nut, the base of the neck, and straight across the widest part of the lower bout. It tends to fall very close in frequency to the Aq air mode, alias the Helmholtz mode. This is the mode you hear when you blow across the mouth of a soda bottle, or in this case, across a soundhole. In the classic formulation, the air in the neck of the bottle, or the soundhole of the violin, is treated as a rigid piston of a certain mass, which can be determined by finding the area and height of the piston and the density of the air. This air piston bounces on an air spring, consisting of the air in the body. Since it does not involve standing pressure waves like other resonance modes of the air in the body do, it is outside the normal sequence, which presumably accounts for its being given the lowly "zero" subscript. On the violin it comes in at around 260-270hz. When the A_0 and B_0 modes are at the same frequency they can couple because the vibration of the neck pushes on the top and causes it to pump air through the soundholes, and vice versa. In this way the neck vibration "steals" some energy from the air mode at its peak and gives it back at higher and lower frequencies. Instead of having two tall narrow output peaks you get one broad peak at a somewhat lower level. The total power output is greater and more evenly distributed. In musicians' terms, the instrument "wakes up," becoming easier to play and having more projection.

It is not usually practical to tune the Ao mode on the violin. Even if you could enlarge the soundholes it would take a lot of opening them up to effect the frequency much. But it is fairly easy to tune the B_0 mode within limits. You don't even need a signal generator, although it is always easier to work when you have the right tools.

To find the Ao mode, simply blow lightly across the soundhole. The pitch may not be clear at first. Or, sing the pitch into the soundhole if you can sing that high. I use my oscillator to sing for me.

To find the B_0 mode, hold the violin lightly with your thumb and finger near the nut, so as to damp the strings. Listen to the back in the center of the upper bout as you tap on the top of the scroll with your fingertip. Sometimes it is easier to hear this pitch than the air mode, and one will lead you toward the other.

To find the neck mode with a signal generator, I support the violin under the nut and the lower bout high enough off the bench so that the speaker will sit under the upper bout without touching it. Touching the top of the scroll lightly with a fingertip will tell you when it is vibrating, and the timbre will often change noticeably at resonance when the fingertip is removed. To be certain you are looking at the right mode, add some weight to the end of the fingerboard; a small clamp or a lump of clay. If the frequency of the mode does not drop, you are looking at the wrong mode.

There are two easy ways to change the neck mode frequency. One is to change the stiffness of the neck. This is generally done by planing off the fingerboard at the nut end if the mode is high and the board is thick enough. Some fiddles have quite chunky necks, and wood can be removed there too. If the mode is low to begin with, a thicker fingerboard will raise it.

The other way to change the neck mode frequency is to remove wood from under the fingerboard where it overhangs the top. This long cantilever really flops around in this mode, and a small change here can make a big frequency change. Removing wood under the end of the fingerboard raises the neck mode frequency, as does cutting it shorter. Just be aware that the fingerboard of a classical violin is supposed to be 5/6 as long as the strings. If it is cut too short the player may not be able to get all the high notes. The fingerboard can also be hollowed out at the neck end of the overhang, which lowers the mode frequency by reducing the stiffness of the cantilever, if you can figure out a way to get in there.

Replacing a light chinrest with a heavy one can also lower the mode, but not much. Even heavy pegs can make a difference. These can be useful seasonal adjustments, as both the wood and air modes change frequency with changes in the humidity.

REALITY CHECK

Regraduating a Cheap 'Cello

One of the best ways to practice plate tuning is to get an old, cheap, heavy fiddle and regraduate it. Production instruments can often be had for less than the cost of a set of wood, and you avoid all the labor of carving arches. True, at best you end up with just a good sounding student instrument, but you can generally turn it over at a decent profit, and the student who buys it will remember you with gratitude.

I got a modern, machine carved German 'cello for $75. It showed no signs of wear, not even on the pegs, but the top was in three pieces. The finish was an ugly red, shiny, shaded lacquer, but the wood under it looked good, and the archings were right. Above all, it was heavy, so I figured I'd have some wood to remove.

Since the top was already off the first step was to glue on a piece of 1/8" plywood in its place as a keeper, and then remove the back. Although it was assembled with white glue this one came off fairly well. I have used hot vinegar, or even 28% acetic acid (available from photo supply stores) to dissolve white and yellow glue. If you try it, remember to use a stainless steel knife to avoid staining the wood, and neutralize the surface afterward with baking soda.

One of the splits in the top ran along the outside of the bass bar in the upper bout, so I removed the bar and put a patch in the top in that area, as well as a soundpost patch. Once the top was whole again I put in a bar to match the original and checked the graduations and frequencies of the plates, as shown in Fig. 22.

This is pretty typical of machine carved plates; irregular and far from ideal. The poor carving is reflected in the mode shapes, which are badly formed and not very active. Note also the near match in the *#5* mode frequencies, while the *#2* modes are more than three semitones apart; a major problem. Instruments in that condition are often harsh and hard to play, so it is no wonder this one was not played much. On the plus side the plates certainly are heavy, except for a couple of thin spots on the back in the lower bout.

Reducing the plates to more normal graduations and evening them out as much as possible gave the results shown in Fig. 23. The centers were left heavy to help hold up the *#2* mode frequency, in case the wood was not as good as it looked. I'd like to get the *#2* modes to match at about 55HZ, and the back was close to that already. Unfortunately, the thin spots had thrown it a bit out of balance and the upper bout was not as active as I would like, but there did not appear to be much I could do about it at that moment.

The top was another matter. The *#2* mode node line was very nearly straight on the bar side, and the ends of the *#5* mode node lines were skewed around clockwise from where they should have been, both of which indicated a too-high bar.

Since the *#5* mode was also open in the lower bout I started by thinning that end of the bar first. When that stopped having an effect I worked on the middle and the upper portion of the bar until I got the patterns

Figure 22: "Made In Germany" Cello – Initial

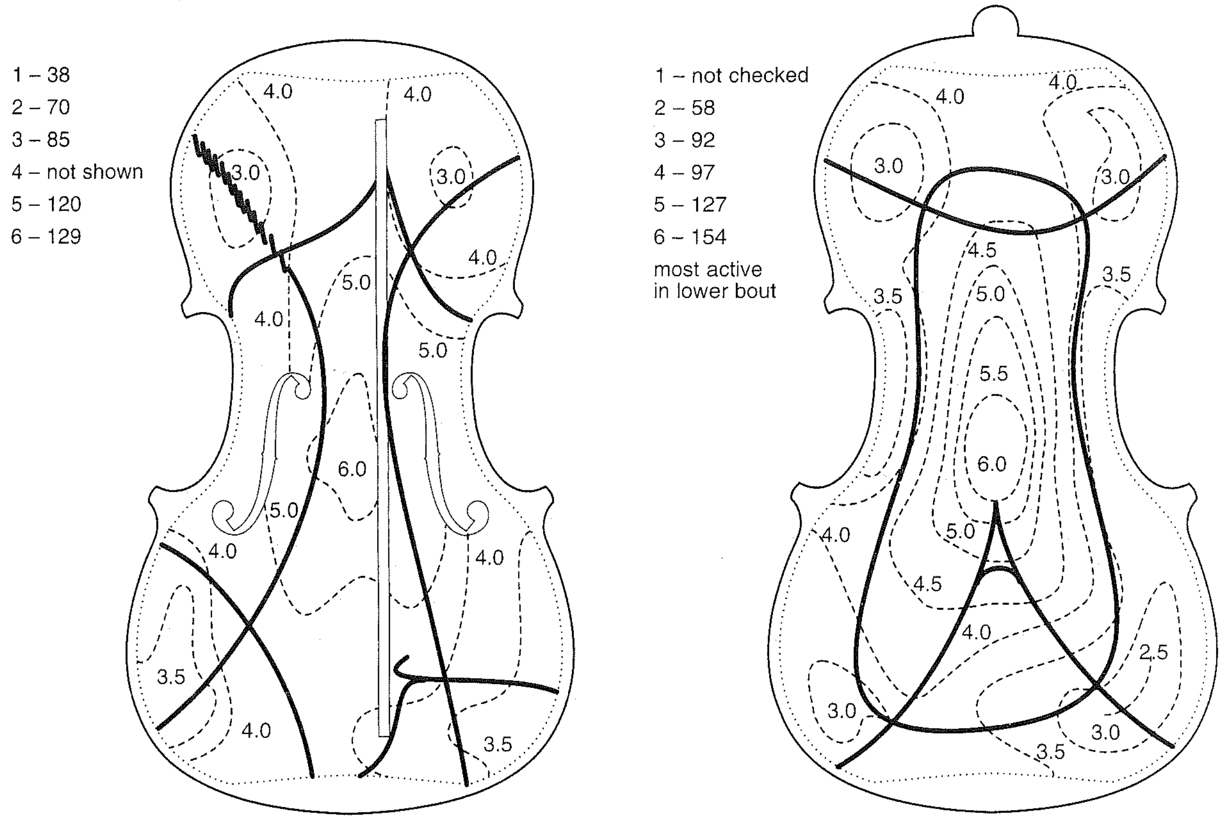
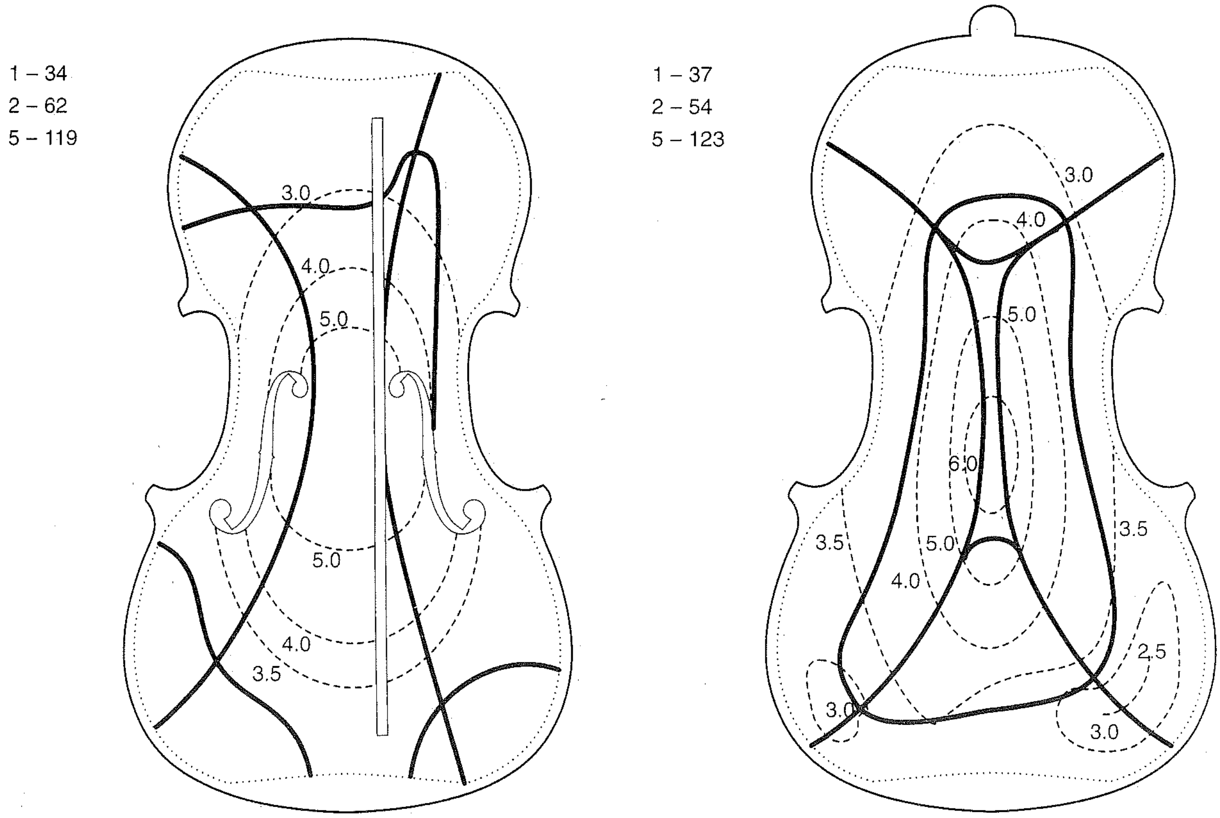


Figure 23: "Made In Germany" Cello – Interim



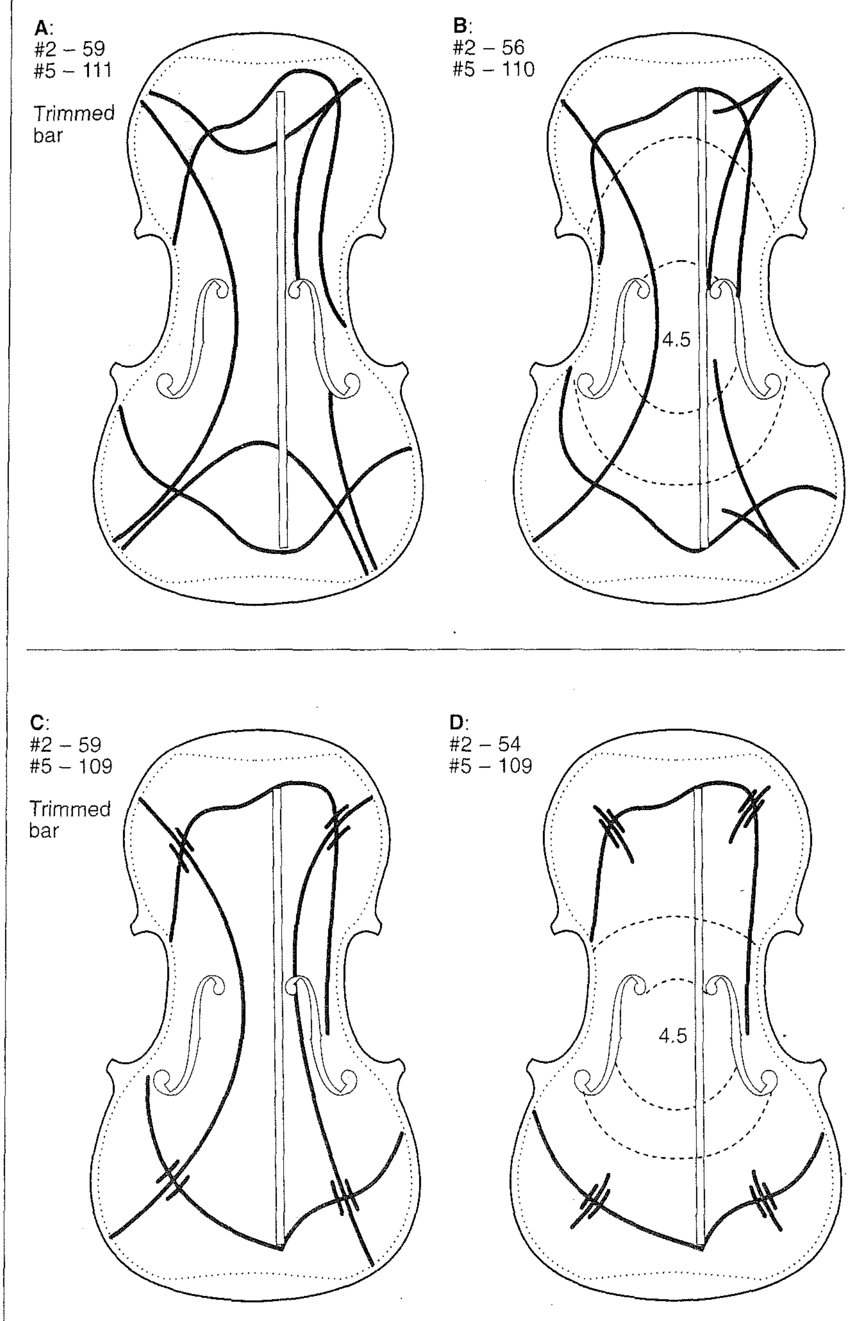
50

shown in Fig. **24a.** The node lines ended up where they should, which indicated that the bar was in balance with the plate, but the *#2* mode was not as active as it should have been, and the *#5* mode was still poorly formed. Also, the frequencies were too high, so I thinned out the center area from **5MM** to **4.5MM,** and moved in the outer contour lines a little. This gaves the results shown in Fig. 24b.

The modes were better formed and more active, but the bar was too high again, so I trimmed it, giving the results shown in Fig. 24c.

On the last two frequency checks there had been a tendency for the glitter to puddle at the *#2* mode and #5 mode crossing points at the *#2* mode frequency. Although the signal generator puts out a reasonably clean sine wave the plate responds to it non-linearly.

Figure 24: Tuning the Cello Top



This introduces harmonics in the plate motion; in this case the plate was trying to vibrate at 112hz as well as 56hz. This was evidently within the half-power bandwidth of the **#5** mode at **109h$_z$,** so that mode was getting activated as well. This was a good sign, as it indicated that the modes were quite close to an octave apart, which is a desirable condition. A little thinning in the center, making the **4.5mm** area smaller, and pulling in the end contours, dropped the #2 mode frequency to exactly an octave below the *#5* mode without materially effecting the balance of the bar, as shown in Fig. 24d. The last time I had looked at the back its *#2* mode was at 54hz as well, so the match should be right on, right? A quick check showed it to have moved to 57hz. This was not surprising. Removing the surface layer of wood sometimes seems to set up stresses that change the mode shapes and frequencies. Giving the plate a few hours to relax allows them to settle in to their true values. In this case I didn't mind; now I could get a little more activity into the upper bout.

If it were just a matter of dropping the *#2* mode frequency it would be easy; moving in the **4.0MM** and **5.0MM** contour lines in the upper center would drop it like a rock. But I would really like to lower the #5 mode more than *#2* and that is hard. Thinning the central area of the upper bout can do it, but if you go too far down you get into the *#2* mode stiffness area, so you have to go slowly, as shown in Fig. 25.

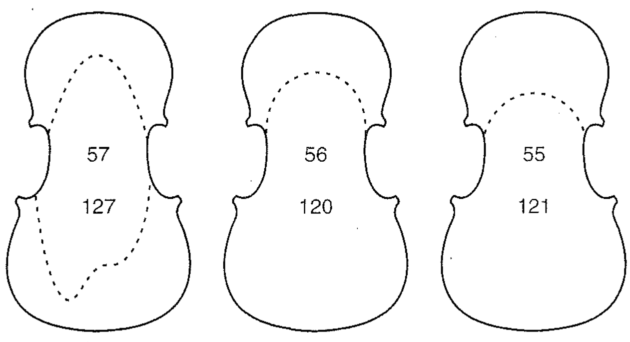
All this was a long day's work, so I left the plates to rest overnight, and checked them out the next morning (Fig. 26). This is not perfect, but certainly close enough for a student 'cello. The *#2* modes matched, the top #1, *#2,* and *#5* modes were close to being on octaves, and the #6 modes were weak on both plates and more than a semitone away from the **#5** modes, which should help avoid a wolf. I would have liked to have dropped the back #5 mode some more, but this will do.

After gluing the back on (with hide glue!) and removing the keeper, I thinned the ribs down from **2.5MM** to **1.5MM,** using a tooth plane and scrapers. Since this is intended as a student instrument I took the precaution of reinforcing the ribs with linen tapes soaked in glue. A number of small studs were glued to both the top and back to reinforce glue lines and questionable areas, and the top was mounted.

With the soundpost in I checked the Ao and B_0 modes, which were at 88 Hz and 97 Hz respectively. Removing some wood from the underside of the fingerboard at the neck end lowered the B_0 mode the requisite 9hz. Don't forget to extend the endpin when checking the B_0 mode on 'cellos! Then it only remained to do the touch-ups, cut a bridge, and string it up.

The regraduated 'cello turned out to have a strong, open, even sound, with just a hint of a wolf between A and B^b on the G string; it should be no trouble. Not a world-class instrument perhaps, but a very good student 'cello for less than $150 and 30 hours labor.

Figure 25: Cello Back Changes and Frequencies



See Mr. Carruth and his amazing glitter dancer at the 13th National Convention / Exhibition. See a listing of errors that appeared in Part One on page 61. See the whole lowdown on classic, flattop, and archtop guitars in Part Three, coming up in our next action-packed issue.

Figure 26: "Made In Germany" Cello – Final