# A TEST OF SEVEN POSSIBLE FILLERS AS MOISTURE BARRIERS AND PLATE STIFFENERS

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[From a presentation at the April 1997 MVA meeting in Detroit, Michigan.]

I'm going to talk today about some research in which I have been engaged concerning fillers for violin tops and backs. My interest in this area was whetted by a discussion at the "makers forum" at the Nov. 1996 meeting of the Violin Society of America. In these forums members of the audience are invited to ask questions of a panel of experts. As often as not, no decisive answers result.

This was the case in regard to the questions "Should the interiors of violins receive a coating of some sort?" and, "Did the Italian masters coat the interiors of their instruments?" It was generally agreed, I think, that if a coating were to be applied its purpose was to impede the passage of moisture in and out of the wood due to changes in humidity, and/or to stiffen the plate wood so that it could be graduated to a lesser thickness and thus lower its weight.

Three interesting points were made:

1. Reference was made to an article in Fine Woodworking Magazine, which listed a number of common coatings and rated them according to their effectiveness [as a water vapor barrier]. Only one of the coatings listed, a dip in paraffin wax, proved very effective as a moisture barrier.

2. Rembert Wurlitzer was quoted as saying that if Strad coated the interior of his instruments, the substance he used was so evanescent that it could not today be detected. A man named Bertel Skou reported this (in the Arizona Journal in 1966) as a conversation he had a month before the death of Wurlitzer. Essentially the same statement was reported (STRAD Magazine, Feb. 1962) by an English chemist, Robert Fryxell (whose writings appeared frequently in the Catgut Acoustical Society Journal).

3. Simone F. Sacconi, in his book **The "Secrets" of Stradivari**, states that the master did coat the interior of his instruments. That Wurlitzer and Sacconi disagreed, though they worked practically side by side for many years, appears to be the case. The English translation of Sacconi's book says:

"having glued the back, he used to paint all the inside, the belly, back and ribs included, with two light coats of a sizing compound which had been diluted to a correct density so as not to give too thick a coat; the second coat was applied after the first had dried. This compound is the same as Stradivari would also use on the outside to isolate the substance of preparation of the wood from the colored varnish. In instruments which have not been cleaned up inside following repairs, one can still see it exuding a little after testing with one's finger nail, particularly on the ribs where he used more of it because they are very thin." (end of quote).

It has often been interpreted that Strad used potassium silicate for this inside coating. It should be noted that, according to Sacconi, Strad did not use potassium silicate as the interior coating, but rather the "isolating material which consisted of albumen or white of egg, gum arabic, or cherry gum dissolved in water, a little honey to assure its elasticity and candied sugar." With all due respect to Sacconi it seems ludicrous to me that Strad would have used this concoction. Certainly it would not stiffen the plates; and with the possible exception of albumen in the form of egg white none of these substances will impede moisture.

All this piqued my interest so I decided to try and find a filler that would both impede moisture and also stiffen the plates so that they could be graduated thinner and be less heavy. I make a distinction between "fillers" which serve this purpose and "ground" coats which have to do with enhancing the exterior finish. I have thus far been unable to find an effective moisture barrier, but I think that I have identified a good stiffener.

My testing procedures were based on the research of Charles Gadd which he describes in an article in the Journal of the Violin Society of America titled "Optimising the Acoustic Properties of Violin Plate Wood". Spruce specimens 3mm thick, 4 cm wide, and 14.5cm long are used in these tests. In practically all tests the grain has a transverse orientation (crossgrain). The spruce specimens I used in these tests are of European origin about 25 years old.

The substances one might use for a filler seem endless, Thus far I have tested the following solutions:

Acrylic lacquer -- 50% solution

(Sherwin Williams Sher-Lac TIC 285)
Epoxy varnish -- 50% solution
(Copon Epoxy Resin Varnish)
Polyurethane varnish -- 50% solution
(Acethane Polyurethane Satin Finish
Casein solution -- Ray Doerr's formula
Potassium silicate solution
Egg white
Egg yolk -- thinned with water to a workable solution.

To determine the effectiveness of these fillers as moisture barriers I hung the specimens, each having two coats of filler on all surfaces, in a wide-mouthed gallon jug, in the bottom of which was water 1½ " in depth. The specimens hung on strings on the end of which were small alligator clamps as used for temporary electrical connections. The jug was closed with a threaded cap and the specimens were removed periodically to see how much, if any, they gained in weight; The greater the percentage increase in weight (water uptake) the less effective the filler as a moisture barrier. **Table I** gives a digest of the results.

The table shows some interesting phenomena. None of these fillers are very effective in impeding poisture. Their effectiveness changes over a period of time; for example, acrylic lacquer ranked third after 48 hours (the same rank as the unfilled control specimen) but dropped down to fifth after 156 hours (again the same rank as the unfilled specimen). Casein, which ranked fifth after 24 hours, moved up to second in effectiveness after 156 hours. Those fillers which show a greater percentage gain in weight from moisture absorption than the unfilled control specimen did are obviously useless as moisture barriers; they are hygroscopic, they actually absorb additional water like a blotter or sponge. It is interesting to note that potassium silicate is the worst in this regard, and its use either as a filler or as a ground coat seems unwise; its caustic character, not unlike a lye solution, likewise makes it undesireable. Since the specimens were a little crowded in the humidity jar and some specimens possibly did not get as free access to moisture as others, the percentage gains and ranking of the various fillers is questionable prior to the 48 hour level of exposure. After 48 hours the exposure should be equalized because the specimens were removed and replaced every 12 hours for weighing.

I conclude that none of the substances tested would be effective moisture barriers. The possibilities for further experimentation seem endless. Some substances to investigate are beeswax, propolis, Liquin®, and Thomson's Water Seal®; and I've read of another silicate, ethyl silicate that is neutral in character that I intend to try. Dale Stevens of Salt Lake City, who has an outstanding reputation as a maker, uses Michelman varnish exclusively and coats the interiors of his instruments with a thinned solution of gelled brown Michelman varnish. It would seem that any chosen substance would be light in weight and certainly should not impede the gluing process.

It is interesting to note that although it took more than seven days for the samples to become fully saturated (no further weight gain with continued exposure to moisture), when returned to normal atmosphere they returned to their original weight in no more than three days.

before describing the procedure I have used for evaluating stiffeners let me explain why I find this subject of interest. Quoting Sacconi, he says, "Strad top plates are around 2.3mm thick. With narrow grained wood and high arching they may be as thin as 1.8mm. Tops with grain inclined to the gluing plane may be as thick as 3mm." Charles Beare says Strad plates are generally 2.4mm to 2.5mm. Joseph Curtin mentions a Strad violin, in their shop for restoration, that had a top thickness of 2.3mm in the center area, 3mm over the sound post patch, and generally about 2mm elsewhere. It weighed a scant 54 grams. Most contemporary makers prescribe a much greater thickness for top plates. Beare prescribes 3.1 to 3.2mm; Peter Paul Prier 2.7 to 2.8mm. In reviewing my records I find that most of my tops, without a bassbar and tuned to a Mode One frequency of 83Hz, are about 3.0mm thick in the center and weigh between 70 and 80 grams.

After reading Joe Curtin's VSA article, "The Trouble with Plate Tuning", I began looking for ways to make thinner and lighter plates. It is generally conceded that lighter plates have less inertia and are thus more responsive. Engelmann spruce varies in density from about .33g/cc to .45 g/cc, and I've read of it going as high as .6 g/cc. European spruce (P. abies), I've read, also varies widely in density.

Most of the spruce I have been using had a density of between .40 and .45gr. Three or four years ago I acquired some Engelmann spruce with a density about .33. A top made of this wood has a weight of 60.2 grams and a maximum thickness of 3.1mm. This is from almost 10 to 20 grams less than my previous

efforts, but thicker and heavier than Strad specifications. I'm therefore searching for a way to stiffen the wood so I can make my plates thinner and thus still lighter.

I shall now explain the procedures I followed in investigating fillers as stiffeners; again I stress they are based on the methods used by Charles Gadd. The objective is to find a filler that will stiffen the plates so that they can be graduated to thinner dimension and lower weight. The best stiffener will be the one that maximizes frequency response with a minimum gain in weight.

[Ed. Note: A related comment made some years ago during an MVA talk by David Burgess was that the criteria for plate treatment materials would be that they add stiffness faster than they add weight to the wood; or better, even lightened the wood by displacing entrained water from the wood cell by with a stable material of lighter density. In either case, the improvement in Young's Modulus would improve the plate frequency and allow a thinner finished graduation.]

To determine the frequency of the specimens they were driven on a Christmas glitter shaker table in the same manner as violin plates are driven to determine their eigenmodes. A supplementary plate with a prot hole 3/4" in diameter is placed over the port used when driving violin plates. This supplementary taple has two strips of flexible foam cemented to it to support the specimens while testing them. These supports are spaced 1/5th of the total length of the specimen from each end. When driven, the specimens act like a xylophone bar with a node line at each support position. Glitter is sprinkled in the center and at each end of the specimen. The frequency of the signal is increased on the egnerator until the first "beam" mode fequency is reached at which time the glitter will bounce vigorously and gather at the node lines directly over the foam supports. The frequency value is then read on the frequency counter.

**Table II** tabulates the weight and frequency increase of cross-grain specimens coated with seven possible fillers. One might immediately question the difference in frequency of the unfilled specimens (column 1). Except for the silicate specimen the samples all came from the same board; but those with frequencies around 150 came from the edge of the board having a medium grain width throughout whereas those with frequencies of 183 and above came from the opposite edge of the same board and this edge had a band about 4cm wide of very narrow grain. I would have preferred to have all specimens with the same grain pattern but in cutting my specimens I had to work around imperfections, knots, etc. in the board.

The samples are arranged in descending order by the percentage increase in frequency [from original untreated state] a month after the coatings were dry (column 14) compared with the frequency of the initial unfilled state (column 2). This, incidentially, also arranges the results in descending order by actual frequency increase (column 12). My weighing scale is accurate to .025gr., ± .005gr. temperature at the time measurements were made varied from 65 to 68° farenheit, most often 66°. Humidity varied from 41 to 46%, most often 44%. I have a bare-wood graduated violin top hanging permanently in my shop, which I call "par". Every time I weighed specimens, I also weighed "par". "Par" varied in weight from 76 to 76.375 grams, a variance of one-half percent. One-half of an 8gr. specimen amounts to .04gr. so the variance in weight due to atmospheric changes is very small.

Generally speaking there was little change in weight and frequency between the time the specimens first seemed dry (colums 3 and 4) and a month thereafter (columns 9 and 10). The frequency of the urethane specimen increased in this interim from 177Hz to 195Hz, about a 12% difference when compared with the initial unfilled frequency of 153Hz. This I presume is the result of the slow drying nature of the urethane varnish. The casein coated specimen for some reason dropped in both weight and frequency over the month long interim. Weight and frequency of the silicate and egg yolk specimens did not change significantly over this period.

Most of my tests were repeated with no significate changes in the results; in all twenty-six specimens were used. Long-grain specimens were tested, but no significant frequency change was noted.

To determine the effectiveness of the fillers as stiffeners, my procedure consisted of reducing [by sanding] the thickness of a filled specimen until its frequency dropped to that which it had in its original unfilled state. Each specimen was run through the thickness sander and the frequency and thickness checked after each pass. When the initial frequency was reached, the weight and thickness were recorded -- **Table III.** The reduction in thickness in every case was small -- varying from about .2mm to .3mm. The specimens are listed in ascending order of maximum weight

Table I. **Water Vapor Absorption of Seven Fillers**

| Filler | Initial Weight (Grams) | After 12 Hours | % Gain |
|---|---|---|---|
| Epoxy | 8.1 | 8.15 | 0.6 |
| Urethane | 7.4 | 7.55 | 2.0 |
| Acrylic | 7.75 | 7.925 | 2.3 |
| Casein | 7.25 | 7.45 | 2.8 |
| Unfilled | 7.75 | 8.0 | 3.2 |
| Egg Yolk | 7.725 | 8.1 | 4.9 |
| Egg White | 7.125 | 7.5 | 5.3 |
| Pot. Sil. | 8.25 | 8.775 | 6.4 |

| Filler | After 24 Hours | % Gain |
|---|---|---|
| Epoxy | 8.225 | 1.54 |
| Urethane | 7.725 | 4.39 |
| Acrylic | 8.175 | 5.48 |
| Unfilled | 8.175 | 5.48 |
| Casein | 7.675 | 5.86 |
| Egg Yolk | 8.20 | 6.15 |
| Egg White | 7.625 | 7.02 |
| Pot. Sil. | *.950 | 8.48 |

| Filler | After 48 Hours | % Gain |
|---|---|---|
| Epoxy | 8.575 | 5.86 |
| Casein | 7.85 | 8.28 |
| Acrylic | 8.475 | 9.35 |
| Unfilled | 8.475 | 9.35 |
| Urethane | 8.10 | 9.46 |
| Egg Yolk | 8.55 | 10.68 |
| Egg White | 7.90 | 10.88 |
| Pot. Silicate | 9.475 | 14.85 |

| Filler | Saturated | % Gain |
|---|---|---|
| Epoxy | 8.975 | 10.80 |
| Casein | 8.05 | 11.03 |
| Urethane | 8.275 | 11.82 |
| Egg Yolk | 8.70 | 12.62 |
| Acrylic | 8.75 | 12.90 |
| Unfilled | 8.75 | 12.90 |
| Egg White | 8.15 | 14.39 |
| Pot. Sil. | 10.00 | 21.21 |

* All specimens were left in the humidity jar until they no longer gianed weight. Except for those filled with epoxy, urethane, and potassium silicate this stable condition was reached in 156 hours (6 ½ days). For epoxy and urethane it took 7 days. The specimen filled with potassium silicate never reached a stable condition; it was still gaining 0.05 grams per day after 11 days.

Table II. **Weight and Frequency Gain Using Seven Different Fillers**
* Weights are in grams.

| | Weight* & No Filler | | Two Coats -- All Over (February 17, 1997) | | | | | | Re-Weighed March 16, 1997 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Increase | | Percent Increase | | | | Increase | | Percent Increase | |
| Filler | Wt | Hz | Wt | Hz | Wt | Hz | Wt | Hz | Wt | Hz | Wt | Hz | Wt | Hz |
| Epoxy | 6.6 | 183 | 8.17 | 277 | 1.57 | 94 | 23.9 | 51.4 | 8.1 | 279 | 1.5 | 96 | 22.7 | 52.5 |
| Urethane | 6.8 | 153 | 7.5 | 177 | 0.7 | 24 | 10.3 | 15.7 | 7.5 | 195 | 0.7 | 42 | 10.3 | 27.5 |
| Acrylic | 6.8 | 194 | 7.25 | 231 | 0.45 | 37 | 6.6 | 19.1 | 7.3 | 232 | 0.5 | 38 | 7.4 | 19.6 |
| Egg White | 6.75 | 152 | 7.0 | 173 | 0.25 | 21 | 3.7 | 13.8 | 7.02 | 175 | 0.27 | 23 | 4.0 | 15.1 |
| Casein | 6.7 | 190 | 7.05 | 211 | 0.35 | 21 | 5.2 | 11.1 | 7.0 | 206 | 0.3 | 16 | 4.5 | 8.4 |
| Pot. Sil. | 7.1 | 155 | 8.3 | 161 | 1.2 | 6 | 16.9 | 3.9 | 8.3 | 161 | 1.2 | 6 | 16.9 | 3.9 |
| Egg Yolk | 6.75 | 150 | 7.62 | 150 | 0.87 | 0 | 13.0 | 0.0 | 7.65 | 152 | 0.9 | 2 | 13.3 | 1.3 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

Table III. **Synopsis of Stiffness Tests.** (Arranged in ascending order of coating effectiveness)

1. Sample W3. Epoxy. Coated all sides -- two coats. Sanded both surfaces.

| | | |
|---|---|---|
| Initially (uncoated) | 6.6g | 183Hz |
| After two coats | 8.25 | 278 |
| After sanding | 6.625 | 180 |
| Weight gain | +0.4% | (6.625/6.6 = 1.0038) |

2. Sample W4. Urethane. Coated all sides -- two coats. Sanded both surfaces.

| | | |
|---|---|---|
| Initially (uncoated) | 6.6g | 184Hz |
| After two coats | 7.425 | 221 |
| After sanding | 6.425 | 184 |
| Weight reduction | 2.7% | (6.425/6.6 = .9735) |

3. Sample W2. Casein. Coated all sides -- two coats. Sanded both surfaces.

| | | |
|---|---|---|
| Initially (uncoated) | 6.7g | 190Hz |
| After two coats | 6.975 | 206 |
| After sanding | 6.475 | 190 |
| Weight reduction | 3.4% | (6,475/6.7 = .9664) |

4. Sample ZF. Acrylic. Coated one surface -- two coats. Sanded coated surface.

| | | |
|---|---|---|
| Initially (uncoated) | 6.875g | 168Hz |
| After two coats | 7.05 | 190 |
| After sanding | 6.8 | 168Hz |
| Weight reduction (%) | 1.1% | (6.8/6.875 = .989) |
| **Recoat** (1 coat) | 6.875g | 175Hz |
| After sanding | 6.8 | 165 |
| Weight reduction | 1.1% | **no change** |

5. Sample W5. Acrylic. Coated all sides -- two coats. Sanded both surfaces.

| | | |
|---|---|---|
| Initially (uncoated) | 6.7g | 155Hz |
| After two coats | 7.125 | 202 |
| After sanding | 6.05 | 156 |
| Weight reduction | 9.7% | (6.05/6.7 = .9029) |

6. Sample R2. Acrylic. Coated one surface -- two coats. Sanded **uncoated** surface.

| | | |
|---|---|---|
| Initially (uncoated) | 7.45g | 185Hz |
| After two coats | 7.7 | 202 |
| After sanding | 6.95 | 185 |
| Weight reduction | 9.74% | (6.95/7.7 = .9026) |

7. Sample XC. Acrylic. Coated all sides -- two coats. Sanded one surface.

| | | |
|---|---|---|
| Initially (uncoated) | 7.525g | 179Hz |
| After two coats | 7.75 | 199 |
| After sanding | 6.75 | 169 |
| Weight reduction | 10.3% | (6.75/7.525 = .897) |
| **Recoat** (1 side) | 6.9 | 178 |
| After sanding | 6.75 | 170 |
| Weight reduction | 10.3% | **no change** |

loss when returned to their original unfilled frequency.

Specimens 1, 2, 3, 5, and 7 were coated on all surfaces.

Specimens 1, 2, 3, and 5 were sanded on both top and bottom. Each surface was run alternately through the thickness sander. Specimen 7, with the acrylic coating had the greatest weight reduction of all the specimens. Of those specimens coated on only one surface, 4 and 6, (both acrylic) number 6 had the highest percentage weight loss. Number 4 was sanded on the coated surface and number 6 on the uncoated surface.

To see if a further reduction in weight could be effected, specimens 4 and 7 were recoated after the initial sanding and again resanded to their original unfilled frequency. No significant change in weight reduction was noted.

It was interesting to note that when I had finished sanding the acrylic-coated specimens, the fact that they were impregnated with acrylic lacquer was visually not apparent. Even though Strad would have used none of the modern filler products, had Strad used a filler with a similar attribute, then scraped or sanded, Rembert Wurlitzer's observation that no filler could now be detected would be appropriate.

I intend to try filling a top using the method applied to number 7, Sample XC -- two coats inside and out, and sand the inside surface. I am going to tune an unfilled top to Eigenmode One -- 82z. I shall then apply the filler, inside and out, and regraduate by scraping the inside until Mode One is again 82Hz. If I were to reduce my top weight by 10.3%, as in Sample XC, from the 61 grams obtained by using spruce with a density .33g/cc I would get a top weighing 54.7 grams. Actually I won't get this dramatic result because in order to keep Mode Five at a reasonable high frequency, I shall have to leave the center area thicker throughout the length of the plate (closer to my usual thicknesses). Recall that I stated the filler had no significant effect on the long grain samples.

One thought bothers me, and I am sure you will think of others: How effective will the stiffener be in the long run? After years of playing will it suffer fatigue from the constant vibration of the plate?

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## PLATE GRADUATION THICKNESSES OF SOME HISTORICAL VIOLINS

by David Brownell

At the April 1996 CAS-MVA96 joint conference in Dearborn, Carleen Hutchins during one of her talks put up on the screen the well-known Sacconi diagram of plate graduation showing the "platform" square across at the line of the blocks, and apparently including a zone prox. 10mm inside the line of the purfling. She commented that within that outer zone the plate was actually worked out thinner in a transition from the formal graduations to the thinner outer boundary created by the channeling -- that a thin outer boundary, as well as the acoustic separation formed by the purfling groove is one necessary element of a good instrument.

This set me to thinking about actual measured thicknesses in some historical violins, ones which I felt reasonably sure had not been regraduated. A Stradivari ca. 1720-21, with max. top thickness 2.3 - 2.4mm ran from a scant 1.8mm near the edges to prox 2.2mm just inside the C bout purfling. A Brothers Amati ca. 1600 (on the smaller 352mm model) with max. top thickness 2.3mm, min. 1.7mm towards the edge, with 2.0 - 2.1mm just inside the C bout. A Pietro Guarneri 1739 of Venice had max. top thickness 2.5mm with boundary zone 1.9-2.0, 2.1 near the C edges. A 1729 D. Montagnana was 2.4mm with boundary zones prox. 1.9mm, 2.2mm inside the C. A London 1796 Vincenzo Panormo had max. top thickness prox. 2.7-2.9 mm, but edge zones prox 2.0-2.2mm. As a comparison, I looked at a Leandro Bisiach (I) 1920, with max. top thicknesses of 2.8-3.05mm, with edge zones prox. 2.1-2.4mm, except that the lower root of the F hole wing was kept rather full in thickness. An 1897 Eugenio Degani ran 2.8-3.0mm, with the edge zone quite thin at 1.5-1.8mm (the inside was actually hollowed out some 1.5mm to leave the actual gluing edge coming down like a box lid to the rib!)

These are all instruments considered quite "good", of soloist grade. Looking at in part rather fragmentary notes, my impression in each case is that the outer boundary zone (as the inside graduation had approached the outside channel) tapered out in thickness to a minimum thickness prox. 2-2.5mm inside the purfling, with the C bout reduced less.