THE NATURE OF VARNISH AND THE CARE OF HISTORIC COATINGS

Mel Wachowiak

Thursday, November 4, 1999, 1:30 pm

Introduction: I'm Gary Sturm, the assistant chair of the Division of Cultural History, the division that houses the Smithsonian's musical instrument collections. On behalf of the secretary and the director of the Smithsonian, welcome to our museum and to this afternoon's presentation.

I have a colleague with me from the Smithsonian's Materials Research and Education Center, Mel Wachowiak, who will begin the afternoon with a discussion of some things we have been exploring here with regard to varnish.

We of course want to share our collection and their holdings with as many people as possible. How is it possible to do this with 150 people? We will try to organize a line of people who will march up on stage, where members of my staff will present the instruments for your inspection. It is unfortunate that our time is so limited, but the good news is that the instruments are out of their exhibition cases and can be seen up close.

Here at the Smithsonian we have been exploring many questions about the history of the violin, and one of the elements of the violin that everybody wants to know about is varnish. By happy circumstance, Mel, who came to the Smithsonian as a furniture conservator, has had a long-term interest in coatings and varnishes on things other than violins. I persuaded Mel to pursue this interest with some other colleagues out at what used to be our conservation analytical lab. So Mel comes to the question of varnish as a non-violin maker.

I have discovered that when we talk about varnish in the violin-making world, we don't know how to talk to each other. Varnish is so subjective. If some say they want a flexible varnish, well, how flexible? Well, you know, it's got to be kind of soft.

What color should it be? Well, it's got to be red. Well, how red? Well, there's no real way of quantifying what we can speak of in describing varnish to each other. So one of the first questions we were concerned with was how to identify what it is people want.

I should caution you that many people who ask about the work we've been doing over the past five years immediately presume we are trying to discover the secret of Stradivari's varnish. Of course, everybody has been trying to do that, but that has not been our concern. We are trying to understand what *is* varnish; we're also trying to understand what is dirt. These seem like pretty obvious questions, but in the painting world a patina of brown varnish on top of a painting might be considered to be integral to the painting, or it might be considered dirt. When we talk about violins, what is varnish and what is dirt? What is it we really care about?

These are the kinds of things we explore. We hope in the end of our investigations that we will have some intelligent suggestions on how to formulate a varnish, what things you might look for, and what you might do. In addition, what has become obvious is that it is not just what you put into your varnish, but how you process it. There are a lot of questions of how a varnish has been processed: How was it cooked? How was it baked? How was it applied to the violin? We don't know as these things are not documented, but these are the things we look at in our efforts to arrive at some bit of intelligence. And now, let me introduce senior furniture conservator Mel Wachowiak.

Mel Wachowiak: Thanks, Gary, and thanks to the Violin Society for inviting me here. I have no specific expertise as a musical instrument maker, which may be my great strength, because I don't have any of the bias or baggage that comes with that. I am an outsider and I'm looking at the coatings on musical instruments in the same terms as I look at coatings on an ethnographic object, an architectural element, a piece of furniture, the Wright Brothers aircraft. I have found that at the Smithsonian Institution it's a great asset to know a little bit about a lot of things. I work at the Smithsonian Center for Materials Research and Education. What we're about is research into materials, designing systems for preserving the materials, interpreting the materials, and disseminating those results. We are always interested in sharing our information. If we learn a lot of stuff and don't share it, then the information doesn't really exist. Furthermore, we describe how the information was collected so our methods can be used by others.

I am going to give you some background information and describe how we're approaching these musical instrument studies. We are just taking baby steps, and we're doing things that we

consider as sort of probing in one way, in another way as building. We're not trying to tackle the Strad varnish because in my mind, Strad equals controversy. We don't want to go there yet. Think about the musical instrument coating in general and in the context of history and preservation and interpretation. What is it? How does it behave? What is it supposed to do? What did it look like when it was new? I think those are better questions to ask now than what's the secret to the Strad. "How can I make historically accurate varnish? If I put it on my instrument, will I have a Strad?" This last is not a real question, and should not guide us.

Describing a Coating

Let's begin with some background on the nature of varnish. Later, I'll give an update on some of the things that we've done in terms of technical studies on varnishes, both creation of new varnish and old varnish. And I'll finish up with a few thoughts about general care, such as cleaning and recoating of historic coatings.

While we don't necessarily share a common language as musical instrument makers, conservators, or technical investigators, I think there is a way to bridge that gap. The bridge is adoption of concepts from industry. I trained as an artist first (sculpture and drawing), and then as a conservator. From these fields I didn't share the language of the coatings formulation industry. They're dealing with huge quantities and processed chemistry and end users who consume paint and varnish that's meant to be replaced. There's a lot of give-and-take and sharing of language that needs to go on in craft, and it's not particular to violin varnish. Since the industry language is descriptive and quite specific, we should think about adopting what is pertinent.

Formulation chemists describe three basic coating types: paints, varnishes, and stains. There are some gray areas in between, but these types encompass protective and decorative coatings. Coatings may serve both protective and decorative functions, or they may serve only one function. They may only be placed on the substrate wood, in the case of violins, primarily to enhance the appearance of the wood. They are not meant to protect it against the elements, to hold up under rain and snow and salt, sea spray, and so on, like an automobile coating.

The first type of coating is paint, which is a pigmented coating. It is essentially opaque: it is not something that you see the substrate through. It can dry by evaporation, polymerization, or a combination of these mechanisms. The mechanism really is particular to the end use of the paint. Paint can be applied by hand, sponge, rag, brush, and in modern times by roller, dip, spray, and baked powder. This holds true for varnish and stain as well. Again, it's the end purpose which defines what the coating is and

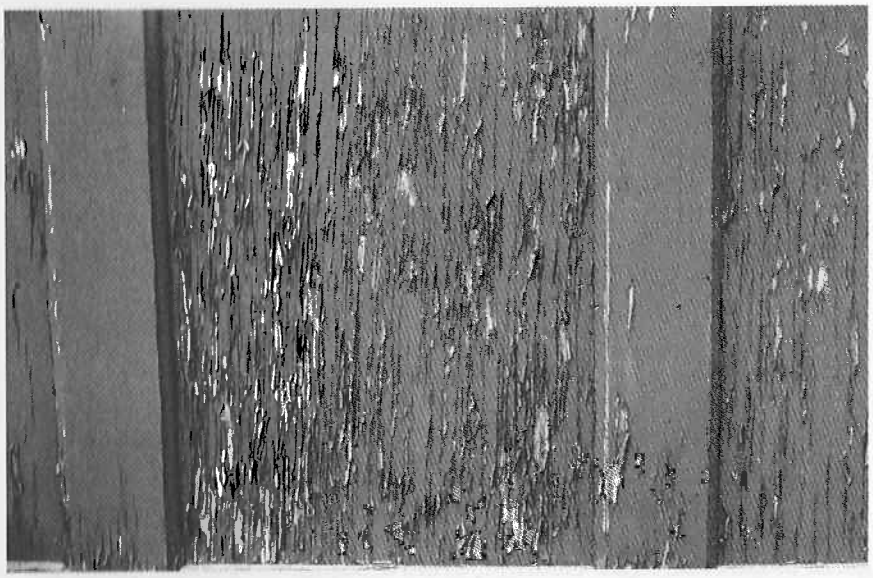

Figure 1. Failing architectural paint

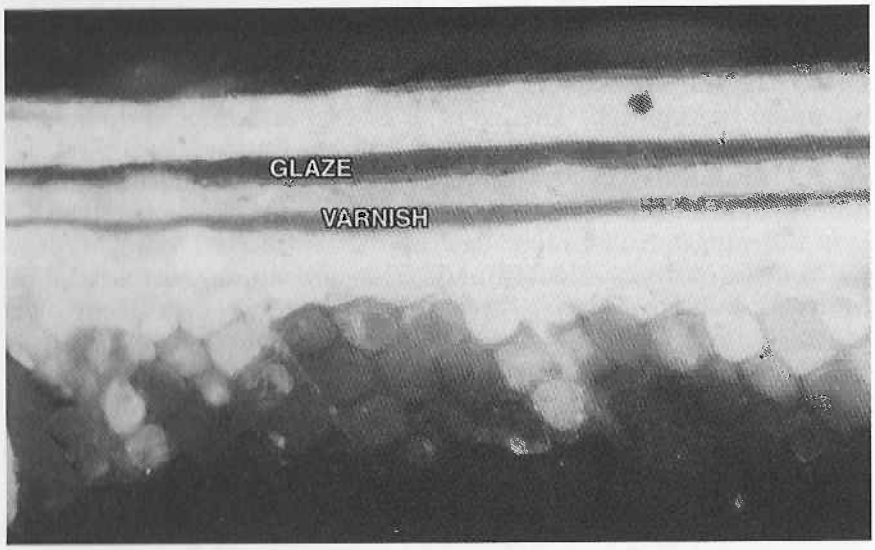

Figure 2. Architectural graining magnified 200X

how it is applied.

But, we may see evidence of the process of application in the material itself. During microscopy of coatings we may see by the nature of layers or by the presence of abrasives that something has been rubbed out. We may see little hairs stuck in varnish and infer that it may have been applied by brush. It could be that hair was falling out of somebody's head, but at least we can account for some of the process by traces left in the material. The historic varnish is a document; it's more than just a coating.

Let's look at an example of paint that has failed (Figure 1). You can't really tell what the substrate is, what the wood is underneath, although you probably have a pretty good idea that there is wood under this because of the way this has shrunken and swelled and the paint is falling off.

Figure 2 shows a paint coating on wood, greatly magnified. This is graining, and it's a multiple-layer creation. There are several reasons why you can have many layers of paint. One is that the object had been re-coated over and over and over again. Another is that multiple layers are part of the creative process, as in graining. You need to be cautious: in looking at a small sample of something under the microscope, you shouldn't lose sight of what the whole effect is. In other words, if somebody brings me something and says, "Look at it under the microscope," I say, "Well, give me a hint: is this animal, vegetable, or mineral? What was this on? What does the whole object look like?" I could make assumptions (even unintentionally) or none at all, and simply say it's paint on wood.

Varnish, by comparison, is an unpigmented composition. Some varnishes may have colorants in them, such as dyes. For the formulation chemist, varnish has essentially no pigment and is transparent material. It may dry by evaporation of solvent or by chemical reaction, as described for paint. Likewise, it can be applied by the same methods.

Of course, you know what varnish looks like (Figure 3). This example of varnish, to my way of looking, is very interesting, but it has failed. We have begun to describe historic violin varnish as "an elegant failure," and that seems to be what a lot of new makers are looking for. Something that perhaps cracks, something that's not consistent. They are flaws, and other inconsistencies which a chemist would call failure. But these are considered by makers and their consumers as very desirable qualities.

The last of the groups, stain (Figure 4), is neither paint nor varnish. It may be pigmented; it may be transparent to a certain degree. Compared to paint which has excellent hiding power, stain has poor hiding quality (or good transparency, depending on how you look at it). It may constitute a glaze layer where very thinly applied stain is bound up in some medium which is

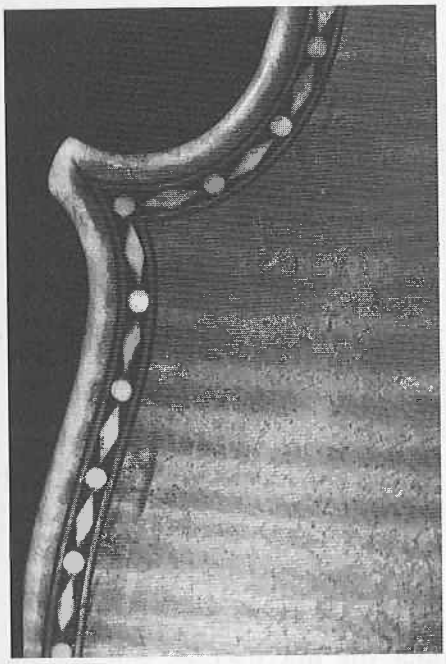

Figure 3. Varnish (the Greffuhle, Smithsonian Institution)

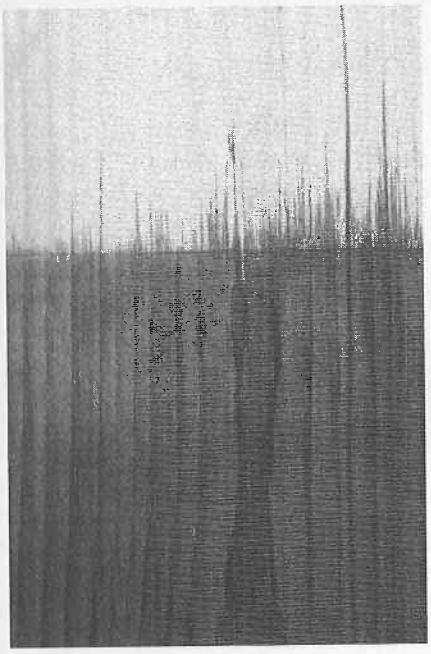

Figure 4. Stain

applied either on top of the wood or in between layers and then coated (as in graining, Figure 2). It may just be sort of a decorative layer that has to be encapsulated and protected by subsequent varnish. And this may also incorporate dyes as well as mineral, or other pigment.

Again, there are many ways to apply varnish, and it may be a factor dictated by the coating itself or it may literally be in the hands of the artist. The artist may be more comfortable with rubbing a varnish by hand than brushing it out. Or they may be dealing with a varnish that is so viscous that it pulls the hairs out of a brush and would never smooth out by another method. In many cases, we see traces of the method of application in the final product.

Describing Color

Where does color come from? For a violin varnish, what is the yellowness, what is the red quality? A color chemist would say, "What color is red and how do we define that in a particular color space?" There are different components, and they are not all based on a pigment or a dye. They may be a factor of the physical nature of the coating.

Color is perceived as a result of two attributes: the color and geometric components of the object. Color components are the hue (the actual color, for example, blue), and then the value, which is the relative darkness on a scale of black to white. The last color component is chroma, the saturation. With a description of hue, value, and chroma, you can define a color in a color space. You haven't defined it as a physical structure, but you've defined its color effect. You need next to describe geometric components of the coating. For instance, does the surface have a specular reflection or a diffuse reflection? An example of a specular reflection would be something like a polished metal surface. Nearly all the light that strikes the surface bounces off at the same angle. An example of diffuse reflection would be the same surface, but not quite so polished. In this case, there is only some specular reflection, while a lot is being scattered in different directions.

The above definition fits when the material is opaque. By comparison, a definition of the geometric component of a transmissive surface, like glass, should consider whether there is regular transmission or diffuse transmission. That is, does light strike the surface and not scatter very much, or pass through that medium virtually unaltered? The ideal of a varnish system acts like glass, with regular transmission. The second case, diffuse transmission, is defined as light entering and exiting the material at different angles. This condition is found in translu-

cent material, such as a "privacy glass." You can make out the shape of someone behind the glass, but you can't tell who it is.

Color scientists have told us that, especially when you're trying to match colors, the geometric components are actually much more important than the color components. This is because if you can't get the geometry right, then the product will not match no matter what you do with a color. You will recognize this from re-touching work. If you don't match the surface correctly on a three-dimensional object and then move it on an angle, all of a sudden you've got a blotch.

To summarize, there are terms and instrumental methods which can measure color quite precisely and reproducibly. You may ask, "What color is this varnish? What is its composition?" and get answers. But there is a down-side. Measurement of color, in a transparent/translucent varnish over a wood substrate, is very tricky. This is because the wood is also translucent and is "read" as part of the color system. How much do you want to invest in that sort of partially conclusive definition?

History of Coatings

If you know a little bit of coatings history, you will understand your coatings better. I hope the following brief history will show that the Golden Age of violin varnish, and the varnish made today, have a common history probably more than 3000 years old. There was probably a varnish very similar to what was done in 1700 produced in 700 AD. This will be a short history, but it has a bearing on a historic instrument, even though interest in the history basically ends in the 18th century for most of us.

From 35,000 years before the present, there are examples of cave paintings. I can imagine that they were produced by the first HVLP (high volume/low pressure system). One of the theories is that the painters took the pigment and a little bit of animal fat and chewed it up and spit it out, spraying over the hand, thereby giving a silhouette of the hand. In the Book of Genesis, Noah was ordered to "pitch the ark within and without." Pitch is the historic term for pine resin, a component in possibly the oldest varnish. There are many other old references to this. The Egyptians, 4,500 years ago, had varnish systems based on linseed oil and plant resins, and they had also synthesized pigments (Egyptian blue, a glass which was ground after it was formed in a furnace). By the time of the Egyptians, the basic varnish system that's still being used today was in place.

A little more should be said about pine resin because it is absolutely the prototype. This resin, also known as rosin, can be used as it comes from the tree. This will not give a good result, but a coating is formed after some evaporation. The turpentine

can be distilled off during heating and used as a solvent. I assume that pine resin is going to appear in analysis of virtually every varnish, because it is that ubiquitous. I suspect that it's in every object that I look at, including the ones in this century. Usually when the organic chemists do their analysis, they tell us, "Well, there's rosin ester in here; there's ester gum; there's pine resin in there." In furniture making, a historically popular form is called common brown varnish. It's a brittle, dark, not particularly durable varnish, and therefore of poor quality. However, it's inexpensive, so it's very popular and found on all kinds of objects.

In China, 1,000 B.C., the earliest examples of lacquer, probably the finest coating that's ever been made, can be found. In addition to lacquer, tung oil and pine resin were used. Regardless of the fact that linseed oil is often referred to in artists' manuals as the finest artist medium, it is one of the poorest drying oils that can be selected. Tung oil is far superior: more durable, water insoluble, and tougher than linseed oil. When scientists started to experiment with tung oil in the late 19th century, they found that they could adulterate linseed oil and vastly improve its quality. When you select something like pure linseed oil, or cold pressed linseed oil, it's a poor material compared to tung oil.

For solvents, the Chinese were ahead of the game once again. By about the year 700, they had 90% alcohol, which they made by freezing a fermentation product. When the water went solid, they were left with pure alcohol. Now, they were going to drink it, they weren't going to use it in varnish. But the technology existed, and they could have used it as a solvent.

In the Arab world in the later eighth century, early chemists discovered how to distill 90% alcohol. They had figured out how to construct a still, obviously, because there weren't too many places where they could freeze alcohol on a regular basis.

The next period is "a brief intermission," because there's a huge gap in the historic record in the West. We don't have any record of varnish making from Roman times to the 11th century.

In the 11th century there is a record from the monk Theophilus in the form of a recipe of hot resin oil varnish. Again, this is what's still being used by a lot of violin makers who make their own varnishes. They are using a hot linseed oil and mixed resin system, melting it together, and then maybe later thinning it with something like turpentine.

In Europe by around 1300, they finally caught on to distilling good beverages. This could also be used as a solvent. Until you get a more pure solvent, you cannot do a cold solution of resin, giving a durable spirit varnish. Prior to this, heat would have been necessary, with solvent added later.

When Europeans travel the world, a tremendous number of

new materials come on the scene. If you were to examine the sources for paint and varnish raw materials, you would notice that hardly anything in quantity comes from the United States or Europe. Rosin from America is an exception. Kauri gum is from New Zealand; dammar and copal resins from East Asia; shellac from India. Later, oils such as oiticica (another oil far superior to linseed oil) is coming from Brazil, and flax seed from Argentina. The Western world was basically beholden to non-Western sources for varnish and paint-making materials. And this really becomes a factor in the creative energy of formulation chemists. They know by the 1930s with all the uproar going on in the world that they need substitutes. Their access to materials was inconsistent due to growing conditions, or may have been cut off at any time due to politics, and the prices therefore soared depending on what was going on.

Prior to the late 19th century, varnish was produced in much the same way as it had been since the time of Theophilus. This includes the time of the Italian master violin makers. The process began with small resin running pots. These are generally metal or ceramic, and sometimes copper. The size (about that of a coffee pot) was restricted because sufficient heat to melt the resins could not be maintained in large pots. Commonly dammar or copal resin was melted to a liquid varnish state, and oil was added. The problem with this sort of system is that it had a nasty habit of blowing up and taking out the house in which the production was going on, killing the people involved. They were making a highly flammable, sticky mass, with poor ventilation. I'm sure the varnish makers would be instantly recognized because they had no eyebrows. In some city records, the varnish maker was required to locate on the edge of town, and when the town grew, the varnish maker had to move still farther out.

What I call the modern age of varnish making really doesn't occur until the middle of the 18th century. This is when you start to see records of turpentine being used as a solvent, which means they had sufficiently perfected the distilling of pine resin so they could get the fraction that acted as a solvent. Factories are not seen until late in the 18th century, 1790 being the earliest one in England, 1820 in France, 1830 in Germany, 1843 in Austria. In 1773 the first edition of Wautin's book comes out, but nothing really changes in paint manufacture for some time. That book goes through 14 editions, and the last one is published in 1916. If you can get somebody to buy the book, you're probably dealing with someone who is buying into the technology.

The United States was a latecomer: it was much cheaper to import varnish and raw materials from Europe. In 1804 the first lead white production begins in Philadelphia. Basically that factory supplied the entire United States' consumption of lead white,

including lead-based paint and lead white putty for driers in varnish systems.

It wasn't until 1815 that the first varnish production begins in the U.S., and not until the 1850s that the big kettle production begins. Only at the end of the century did an industrialized varnish process grow. But there was only a small difference: the scale of production changed, not the technique.

And what's really driving the industry is not violins, I'm sorry to report. What's driving the industry is custom coach building, architectural work (and later on automobile bodies, which are basically the same system as coach building from 100 years before). They're using a lead-based paint and it takes them weeks and weeks to paint a car body. Henry Ford had a dream: he wanted a paint system which could keep pace with assembly line production. They were building cars like crazy on a daily basis, but the car bodies stacked up out in the yard drying for weeks and weeks and weeks. That was the choke point. The search was for a faster drying, less labor intensive system. Even industrial furniture production suffered from this slow process, and there was far more consumption of varnish for this sort of product than for violins. Eventually, technologists could trumpet the fact that they had a four-hour varnish. It was something that would dry enough at the end of about four hours that you could recoat it, so you could get two coats down in a day. If you're doing floor varnish, this is important if you want to make any money. By comparison, labor cost is not necessarily driving the production and use of violin varnish. Today, there is still by far more labor cost in violin varnishing than the material cost.

Other than spirit varnish, the major traditional varnish type is oil resin, or oleoresin varnish. Both require a solvent for dilution and application, but the difference in properties can be substantial. Spirit varnish was never as durable, so its use was limited to interior application. Early oil varnish processing is a craft and an art. Large wheeled kettles were used to put raw materials over the burner and pull finished varnish off the flame (Figure 5). If the temperature started to run away, they could roll it out; upon completion, they could let it age and put on another pot. The first step entailed "running" the resin, or a melt which may have required decomposition of the resin. Next, the operators would begin incorporation of the hot oil (almost always linseed). At several points the temperature would be held, and in the end, driers and other additives added. Often the varnish was "chilled back" with oil, diluted with solvent, and then aged before shipping.

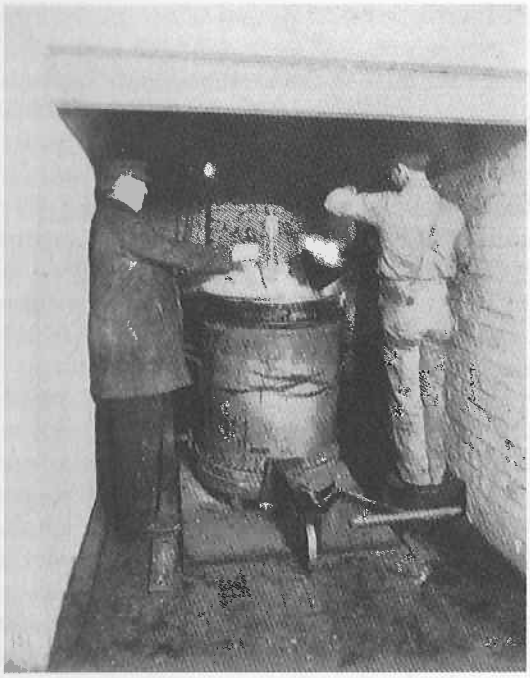

Figure 5. Early 20th-century oil-resin varnish production

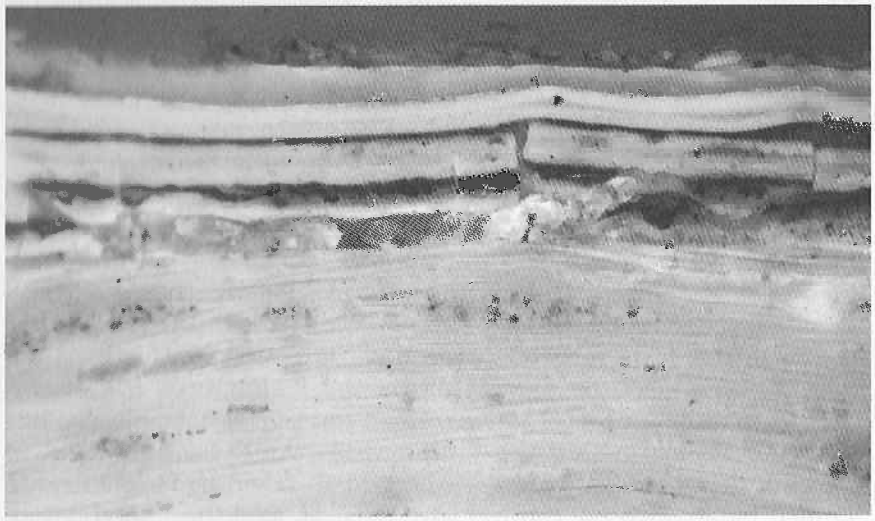

Figure 6. Section of Vuillaume cello rib magnified 200X

Varnish Studies

The Smithsonian (Gary Sturm at the National Museum of American History and my lab) and the Federation of Violin and Bow Makers have conducted two workshops. We are looking at new varnish and old varnish at the same time. We need to do both to interpret each of them.

One of the most important things we do is to look at the varnish and discuss it. Then we use the microscope and other analytical instrumentation. Now, if we did gas chromatography and tell a chemist on the West Coast the method, they can reproduce exactly what we did. There is a caveat when looking at tiny samples from objects. The danger is not only do you learn something along the way, you may learn more and more about less and less, until you know everything about nothing. A sample may be representative, but most likely it is so small that it isn't. This is a biased sample. You have to be careful about conclusions drawn from such small samples. When you read the articles about chemists getting these tiny little snippets and we only need picograms, be conservative. For the product of an artistic endeavor, it probably won't be enough sample. And we should be appropriately reluctant to take samples from important objects.

To illustrate, Figure 6 shows a microscopic section of Vuillaume cello rib fragment in ultraviolet light, 200 times magnified. It's very thin, made of as many as six layers, during perhaps three campaigns of recoating. We can see the wood substrate and the wood cells in the maple. And we can see discontinuous coating, where the coatings have fractured and separated, and there is a flow of subsequent varnish down into the cracks. A solvent effect is visible where varnish is swollen. There are more continuous layers on the top. You can say a lot about how something appears, but by this sort of examination you cannot say what the varnish is. You cannot say, "Well, that is a spirit varnish." Sometimes you can say by the general appearance the method of application based on experience. However, you never want to go out on a limb just by the visual examination, no matter how scientific your use of the microscope.

Varnish Analysis

We look at new varnish to build a new "old" varnish, the elegant failure. Something that's cracked; something that's transparent; something that's dull; something that's glossy. You know, it's a lot like wine-tasting language. Varnishers want to know how they can get a better product and how to get a consistent product, a predictable outcome, again without losing their eyebrows. But I also see a reverence for doing things the old way,

because if you want to get a more durable varnish, a beautiful varnish, a hard but flexible varnish with a good color, using that old-time resin and running pot may be the hard way. But somehow, many makers can't separate from that. They are not going to buy alkyd varnish off the shelf of the paint store, even though it's far superior to anything that they can cook up. Tradition plays a big part in this, and I have no quarrel with it.

I went out to the San Francisco area recently and watched a varnish making. I collected samples regularly, and later they were chemically analyzed. The process started with known materials, and we compared the interim materials to the end product. We started off with something that was quite clear and liquid, and ended up with a hard, tarry mass, which is considered beautiful (Figure 7). Examination of a sample which has only been cooked an hour, magnified 100 times in the microscope, reveals a transparent, glassy material. After almost 25 hours of cooking, it's a little more yellow, but still transparent (Figure 8). The chemical profile of the starting material and the end product are virtually identical. Something other than polymerization is happening: perhaps a physical rearrangement on a molecular level, not necessarily a chemical change. Perhaps the process is similar to caramelizing the varnish. I looked in *Joy of Cooking* to see how caramelizing of sugars is done. Caramel is used to color gravy, etc, and the sugar loses taste, but the process produces color. The hope that *Joy of Cooking* was going to explain it all was not fruitful. Apparently, there is a cumulative effect here. The thickness of the varnish is very important. The final product has some transparency and a nice reddish color. Some desirable properties were being created, but what were we looking at in terms of the chemistry, what is the process which created this color?

When we examine old varnish, what we're doing is comparing or differentiating it from something we know. Identification, on the other hand, is very difficult. And again, I think a lot of times the question is being asked not just because someone wants to know what it is, but because they want to make it "the old way." So perhaps we may only need general characterization, not identification.

Care of Historic Coatings

How and when do you intervene in a positive way to make the instrument look better, to improve its preservation and protect it as it's being used? Some of the questions encompass the nature of the coating, and what is expected of the musical instrument. Is it on display, is it being used? What's the whole context? Is the building climate controlled, or does the instrument travel all over the world? Is it exposed to a tremendous amount of light?

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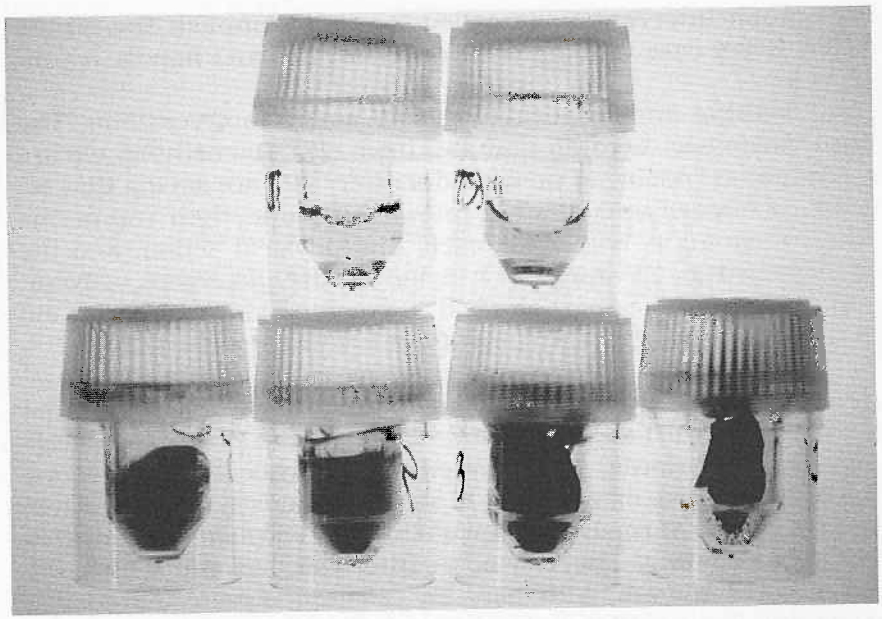


Figure 7. Modern varnish in one cc vials. Top row: starting materials; bottom row, 5, 9, 13, 25 hours

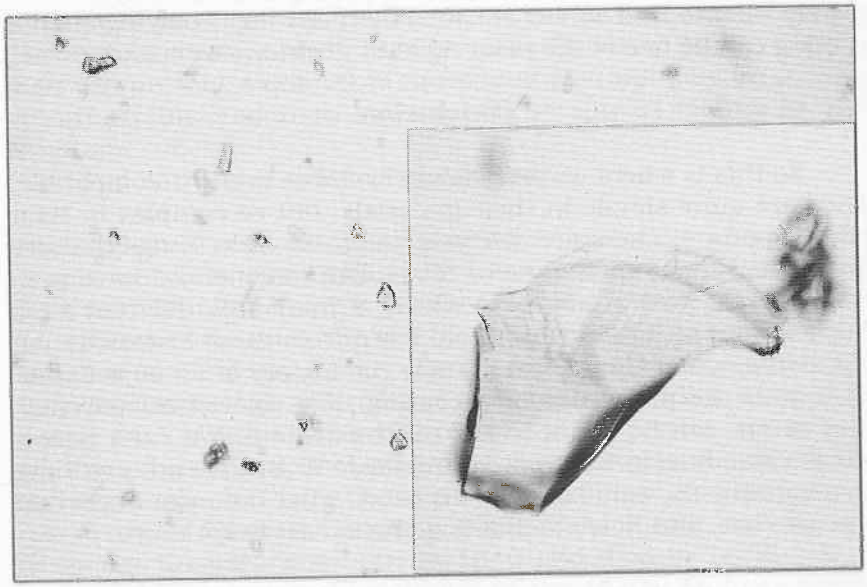


Figure 8. Varnish particles magnified 100X, transmitted light; inset: after one hour of cooking; background, after 25 hours of cooking

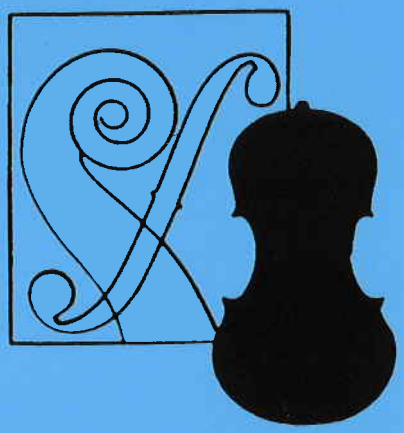
How much intervention is called for to accomplish the stated goals? Every case is going to be different; we can't impose a simple rule.

Cleaning and recoating are two active interventions. The third, obviously, is to do nothing. If we clean something, we are by definition "removing unwanted matter." We are saying that we want to remove and discard one portion and then retain the other. Cleaning is both a chemical and physical action, and the agents used for cleaning may include water, detergent, solvent, and abrasives. They can be used in combination, which can aid in the selectivity of cleaning; not for every instrument, though.

Recoating with protective coatings is an additive process. However, if you put an additional coating on an object, in order for it to adhere there must be a chemical and physical interaction. In other words, you have either to physically bond something, like Velcro, or you have to swell the underlying layer when you put on the varnish. You are changing a varnish underneath a protective coating. There is no coating you can add which will not, otherwise it will not adhere. By design, the protective coating is neutral, removable, and sacrificial. In other words, it can be removed with minimal disturbance of what is underneath. This may be a fully protective coating, and may be non-removable in that sense. In some cases the historic coating is so friable that it must be consolidated. As a practical matter, you cannot completely remove that sort of consolidation coating. Applying such a coating can be one of the most difficult decisions we make.

Conclusion

So this is where we are: violin varnishes are Y1K compatible. They are quite simple in their materials, but so complex in their effect upon us. There are always going to be little things that are added that make them a piece of art. But in general, I have seen nothing nor read of anything which is incredibly different from furniture varnish. We continue to learn from these historic musical instruments. But we can't know the history of an object completely. If the properties of a coating, like color, transparency, and so on, can be defined, you can replicate it. We can't necessarily reproduce it, but you can replicate it. In the end, you have to determine the value of such an effort, what the most important features are, and how much it is going to cost to get there.



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