The Nature of Coatings and the Care of Historic Varnishes

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A historic varnish is more than just a coating – it is a document. As a furniture conservator with a long-term interest in coatings and varnishes (I am an outsider to the violin-making world) I look at coatings on musical instruments in the same terms as I consider coatings on an ethnographic object, an architectural element, a piece of furniture, or the Wright brothers' aircraft. In order to interpret these materials and design systems for preserving them, it is an asset to have a basic understanding about several subjects. The conservator's study of musical instrument coatings should proceed in small steps, probing and building, considering the instrument in both a general context and in the context of history, preservation, and interpretation. What is this coating How does it behave? What was it intended to do? What did it look like when it was new? These questions seem more fruitful than the query: What is the secret of Stradivari's varnish?

Musical instrument makers, conservators, and technical investigators do not necessarily have a common language but it may be possible and beneficial to bridge this gap by adopting concepts from industry. Trained as an artist and a conservator, I did not share the terms of reference used by the coatings formulation industry, which deals with huge quantities, processed chemistry, and paint and varnish coatings that are meant to be replaced. Yet the language of that industry is descriptive and quite specific. Craftspeople, including violin makers, might consider adopting concepts that are pertinent.

The Three Types of Coating

Formulation chemists distinguish three basic coating types – paint, varnish, and stain – with some grey areas in between. All three types can serve as protection, decoration, or both; it is the end purpose that determines which coating is used and how it is applied. For example, automobile coatings must provide protection against rain, snow, and salt; the primary function of violin coatings, placed only on the substrate wood, is to enhance the appearance of the wood and minimize the effects of fluctuations in humidity.

Paint is an essentially opaque pigmented coating; the substrate will not show through. Paint dries by evaporation of solvent, polymerization, or a combination of mechanisms specific to the end use of the paint. Paint can be applied by hand, using a sponge, rag, or brush, or by dipping; in modern times, rollers and sprays have come into use. Paint can also be applied as a powder that is baked on the surface.

Varnish is essentially unpigmented, although some varieties may include colourants such as dyes. For the formulation chemist, however, varnish is transparent. Like paint, varnish dries by evaporation or chemical reaction, and can be applied in various ways.

Stain is technically neither paint nor varnish. It can be pigmented or transparent to some degree, and depending on the end use, it may be more decorative than protective. Compared to paint, stain has poor hiding power (or good transparency, depending on how you look at it). It can constitute a glaze layer, bound in a medium that is applied very thinly either directly on the wood or between layers of varnish, and then coated, as in graining. Stain can also serve as a decorative layer that must be encapsulated and protected by varnish. Stain mixtures can incorporate dyes as well as mineral or other pigments. The methods of application for paint and varnish are also used for stain.

Colour

What are the precise yellow and red qualities of a violin varnish? Or, as a colour chemist might put it: What colour is red, and how do we define that red in a particular colour space, or colour measurement system? Colour is perceived as a result of both colour components and geometric components. Colour components include hue (the actual colour, such as blue), value (the relative darkness on a scale of black to white), and chroma (saturation). A description of hue, value, and chroma makes it possible to define a colour in a colour space; many definitions or systems exist.[1]

Once the colour effect of a coating is determined the next step is to define it as a physical structure by describing the geometric components that affect reflectivity and light transmission. A surface may have specular reflection or diffuse reflection. Specular reflection occurs on a polished metal surface, where nearly all the light that strikes it bounces off at the same angle. The same metal surface, less polished, would produce a diffuse reflection: although there is some specular reflection, much of the light scatters in different directions. The transmissiveness of a surface determines whether light passes through it in a regular or diffuse manner. With regular transmission, light that strikes the surface does not scatter much, but passes through the medium virtually unaltered. The ideal varnish systems act like glass, with regular transmission. Diffuse transmission occurs when light enters and exits the material at different angles. One example of diffuse transmission is translucent material such as privacy glass: shapes can be seen behind the glass but further details are obscured.

Colour scientists state that when trying to match colours, geometric components are more important than colour components. If the geometry is not correct the product will not match, regardless of what is done with a colour. In retouching work, the surface must be correctly matched on a three-dimensional object; if this is not done, a blotch may appear when the object is viewed from a specific angle.

There are terms and instrumental methods to describe and measure colour precisely and reproducibly. However, measuring the colour of a transparent or translucent varnish over a wood substrate is tricky because the wood – which is also translucent – is read as part of the colour system. If only the colour and composition of the varnish are known, we have only part of the picture.

A Brief History of Coatings

To understand coatings it is useful to know a little history. The following brief account demonstrates that the golden age of violin varnish and the varnish made today share a common history that probably dates back more than 3,000 years. Varnish produced in 700 CE was likely very similar to that produced in 1700. I can imagine that cave paintings made 35,000 years ago and still extant today were produced by the original HVLP (high volume/low pressure) system: the painters chewed the pigment with a little animal fat and spat it out, spraying it over the hand to create a hand-shaped silhouette. In Genesis (6:14), we read that Noah was ordered to pitch the ark within and without. Pitch, a historic term for pine resin, is a component in what is possibly the oldest varnish formulation. There are many other ancient references to pitch. The varnish system used by the Egyptians 4,500 years ago was based on linseed oil and plant resins. The Egyptians also synthesized pigments; to create Egyptian blue, glass was formed in a furnace and then ground. By this time the basic varnish system still used today was in place.

Pine resin, or rosin, is clearly the prototype of varnish. Resin can be used as it comes from the tree; the result is not very good but after some evaporation a coating will form. Alternatively, turpentine can be distilled off during heating and used as a solvent. Even in this century pine resin is likely to appear in the analysis of almost every varnish; an organic chemical analysis of a varnish usually reveals rosin ester, ester gum, and pine resin. In furniture making, a historically popular form known as common brown varnish was used on a wide variety of objects because, although it is brittle, dark, and not particularly durable, it is inexpensive.

The earliest examples of lacquer, dating back to 1000 BCE in China, probably represent the finest paint coating ever made. Tung oil and pine resin were also used for coatings. Although artists' manuals often refer to linseed oil as the most suitable medium, it is actually one of the poorest drying oils. Tung oil, which was more expensive, is superior to pure (cold pressed) linseed oil because it is tougher, more durable, and water insoluble. When scientists began to experiment with tung oil in the late 19th century they found that, as an additive, it vastly improves the quality of linseed oil.

The Chinese also developed the most advanced solvents. By 700 CE they had devised a method to produce 90% alcohol by freezing a fermentation product; when the water solidified the alcohol remained. Alcohol produced in this manner was used as a beverage rather than for varnish, but nevertheless, could also have been used as a solvent. In the late 8th century chemists in the Arab world discovered how to produce 90% alcohol by distillation.

In Europe there is no historical record of varnish making from Roman times until the 12th century, when a recipe by the Benedictine monk Theophilus for hot resin oil varnish appears.[2] The formulation he describes – a hot linseed oil and mixed resin system, melted and later thinned with a substance like turpentine – is still in use by many violin makers today. In early times it would have been necessary to heat the resin and add the solvent later. Around the start of the 14th century Europeans developed the technology that made it possible to distill not only beverages but also solvents. With a relatively pure solvent it is possible to make a cold solution of resin, giving a durable spirit varnish.

Once Europeans began to travel the world they gained access to a tremendous variety of new materials. In fact, few natural sources for the raw materials of paint and varnish were native to Europe or, with the exception of rosin, to North America, for that matter. Kauri gum comes from New Zealand, dammar and copal resins from East Asia, and shellac from India. Later, oiticica oil (which is also far superior to linseed oil) was imported from Brazil and linseed oil from Argentina. The Western world was dependent on non-European sources for varnish- and paint-making materials. This situation greatly influenced the creative energy of Western formulation chemists working in commercial enterprises. They sought ways to achieve the best quality at the lowest production cost – and hence the greatest profit – possible. By the 1930s manufacturers were aware of the importance of finding substitutes: agricultural conditions or political changes could at any time reduce or cut off access to raw materials and send prices soaring.

During the great period of Italian violin making and up to the 19th century varnish was produced in much the same way it had been since the time of Theophilus. The process began with small resin running pots (about the size of a coffee pot), made of ceramic, metal, or sometimes copper. The size was restricted because it was not possible to maintain enough heat to melt the resins in larger vessels. Commonly, dammar or copal resin was melted to a liquid varnish state and oil added, creating a sticky mass that, with poor ventilation, was highly flammable; explosions in varnish makers' houses were relatively common. According to some city records, varnish makers were required to locate on the edge of town; when the town grew they had to move even farther out.

The modern age of varnish making began in the mid-18th century. Records from that time indicate that turpentine was used as a solvent; this means the distilling of pine resin was sufficiently perfected to collect the fraction that acts as a solvent. The first factories began operation in the late 18th century: 1790 in England, 1820 in France, 1830 in Germany, and 1843 in Austria.

The first edition of Jean Félix Watin's *L'Art du peintre, doreur et vernisseur* appeared in 1773 but there was little change in paint manufacture for some time. Watin's book went through fourteen editions, the last of which was published in 1916. People who bought and used all those editions probably made the same formulas for paint.

Varnish manufacture in the United States began relatively late since varnish and raw materials could be cheaply imported from Europe; any production was on a small scale, probably for individual use. In 1804 a factory in Philadelphia began production of the first lead white, supplying the entire country with lead-based paint and lead white putty for driers in varnish systems. It was not until 1815 that varnish was first produced in the United States and big kettle production did not begin until the 1850s. When an industrialized varnish process did develop at the end of the century, it was the scale of production, and not the technique, that changed.

The demand driving the paint and varnish industry was not violin making, of course, but custom coach building, architectural work, and a hundred years later, automobile bodies, which received the same treatment as wooden coaches. Factories turned out plenty of cars on a daily basis but the lead-based paint required weeks to dry. Stacks of car bodies drying in factory yards created a bottleneck in production. Henry Ford dreamed of a faster-drying, less labour-intensive paint system that could keep pace with the assembly line. Industrial furniture manufacturing was also bottlenecked by this slow process. Technologists eventually met the demand with a varnish that was dry enough to recoat in four hours, an important speed for anyone wanting to make money at floor varnishing. However, drying time and labour cost are not a factor in violin varnish. Today, the cost of labour involved in violin varnishing still far outweighs the cost of materials.

Other than spirit varnishes, the major traditional varnish type is oil resin (oleoresin). Both spirit and oil varnishes require a solvent for dilution and application but their difference in properties is substantial. Spirit varnish, never as durable, was limited to interior applications.

Early oil varnish processing was an exacting craft: the first step entailed running (melting) the resin and may have required decomposition of the resin. Hot oil, usually linseed oil, was incorporated in large kettles on wheels that could be placed over a burner and easily rolled away if the temperature rose out of control. The temperature was held at several points in the process; driers and other ingredients were added at the end. The finished varnish was pulled off the flame, moved to another pot, and often chilled back with oil, diluted with solvent, and then aged before shipping.

Studying and Analyzing Varnishes

Both old and new varnishes must be studied in order to interpret them. In studying varnish, the first step is to look it and discuss observations before proceeding to microscopes and other analytical instrumentation. Standard analytical methods are applied in the interpretation of varnish formulations. For example, gas chromatography techniques make it possible for another chemist to reproduce the exact formulation.

It is extremely difficult to precisely determine the starting materials from the degraded remains of 300-year-old varnish. Another problem is that it is not appropriate to remove samples from important objects, and the samples that are available to work with are unlikely to be representative, because they are generally tiny. The examination of such small samples under the microscope entails a risk of learning more and more about less and less. Conclusions drawn from such studies should be viewed conservatively. It is important not to lose sight of the overall picture: What does the whole object look like? Is it animal, vegetable, or mineral? Assumptions could be made (even unintentionally) or it could be simply described as paint on wood. A microscopic cross-section examination will provide a lot of information about what a sample looks like, but even the most scientific examination cannot be used to identify the varnish. Even a scientist skilled in microscopy cannot state: "This is a spirit varnish."

With experience it is sometimes possible to recognize the method of application from the general appearance of an object. An artist may be more comfortable rubbing a varnish with a bare hand than brushing it out; a varnish may be so viscous that it pulls the bristles out of a brush and could never be smooth unless applied by hand. During a microscopic examination it may be possible to detect something that has been rubbed out by the nature of layers or the presence of abrasives. Evidence of the method of application may also appear in the coating material itself: little hairs stuck in varnish could imply application by brush but there is also the possibility that the hair fell from someone's head.

Old varnish is examined in order to compare it with or differentiate it from something that is known. Since the purpose of identification is often not simply to discover the components of a varnish but to reproduce the varnish using old methods, in practice, only a general characterization may be needed. New varnish is examined in order to build a new "old" varnish. Varnishers in the crafts want to know how to get a better product with a consistent outcome, but most remain reverently devoted to the idea of doing things the old way. If they want a more durable varnish – a beautiful varnish that is hard but flexible with a good colour – the old-time resin and running pot is certainly the hard way. But many makers will not buy alkyd varnish off the shelf at the paint store, even though it is far superior to anything they can formulate. Tradition plays an important role in modern violin making.

Unlike the terminology used by scientists and the coatings industry, descriptions by conservators and craftspeople are reminiscent of wine-tasting language: "dull," "glossy," "cracked," "transparent." In fact, historic violin varnish is perhaps better described as an "elegant failure." This varnish shows flaws and inconsistencies that a chemist would simply call failure. Present-day violin makers and their customers, on the other hand, consider these inconsistencies highly desirable.

I observed a varnish making in the San Francisco area and collected samples from every step for chemical analysis. The process started with known materials and intermediate stages were compared to the end product. What began as a clear liquid ended up as a hard, tarry mass that is considered beautiful. Examination under a 100-power microscope of a sample that had been cooked for only an hour revealed a transparent, glassy material. After almost 25 hours of cooking, the material was a little yellower but still transparent. The chemical profiles of the starting material and the end product were virtually identical. Something other than polymerization – perhaps a physical rearrangement on a molecular level, not necessarily a chemical change – had occurred. Apparently, the cooking has a cumulative effect. The thickness of the varnish is of major aesthetic importance; the final product shows some transparency and a reddish colour. Desirable properties were created, but the chemistry and process that occurred to create this colour are difficult to identify.

Care of Historic Coatings

How and when is an active intervention justified in order to make an instrument look better, improve its preservation, and protect it while in use? Each case is different; the answer depends to some extent on the nature of the coating and what is expected of the musical instrument. Is it on display or is it used? Is the building climate controlled? Will the instrument travel all over the world? Will it be exposed to light for a significant amount of time? How much intervention will be needed to accomplish the specified goals?

Cleaning and recoating are both forms of intervention. Cleaning is a subtractive process that, by definition, involves removing unwanted matter; one portion is intentionally removed and discarded while the other is retained. Cleaning is both a chemical and a physical action. Agents used for cleaning – including water, detergents, solvents, and abrasives– can be used in combination, which aids in the selectivity of cleaning.

Recoating a surface with a protective layer is an additive process. In order for an additional coating to adhere there must be chemical and physical interaction. The layers must bond physically or the underlying layer must swell to incorporate the new varnish. All coatings change the varnish underneath in order to adhere. Protective coatings are designed to be removed with minimal disturbance of the layer underneath. In some cases, a historic coating is so fragile that it must be consolidated. The fully protective consolidation coating then applied cannot be completely removed. The decision to apply such a coating can be one of the most difficult choices for conservators and restorers to make.

Conclusions

Violin varnishes are made from simple materials but are complex in their effect on us. Small amounts of specific ingredients are added to impart an artistic quality, but I have not yet encountered anything that makes these formulations drastically different from furniture varnish. We continue to learn from historic musical instruments, but we cannot know their history completely. If properties of a coating, such as colour and transparency, can be defined, they may be replicated in a coating with similar properties and appearance, but the resulting formulation is not necessarily an exact copy that reproduces the original coating. Similarly, a new replica reproducing all the attributes of an old violin can be made without using the identical original materials. In fact, the appearance of original materials might well be surprising. It is possible to re-create a good model of an original instrument by reverse engineering using traditional materials and recipes, but in the end, the value of such an effort – the most important features and the cost to reach this goal – must be realistically calculated.

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NOTES

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1 Examples include HSI, RGB, CIELab, Munsell, and Pantone. See also Stewart Pollens, "Cleaning and Retouching Violin Varnish, with a Discussion of Colour Theory," 1:664–94. *Ed.*

2 Presbyter Theophilus, *De diversis Artibus*. 12th century; English translation, *On Divers Arts: The Foremost Medieval Treatise on Painting, Glassmaking, and Metalwork*, trans. John G. Hawthorne and Cyril Stanley Smith (Chicago: University of Chicago Press, 1963; reprint, New York: Dover, 1979).

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