CHLADNIAN MOVEMENT IN THE WOOD OF VIOLINS

JOSEPH MICHELMAN,
Michelman Chemicals, Inc., 6316 Wiehe Road, Cincinnati, Ohio

In a program to discover the "lost art" of the old Italian violin-makers Stradivari, the Guarneri, the Amati, etc., the writer (1) recently proposed the use of raw linseed oil for the preliminary treatment of the wood of the violins while the completed instruments are in the condition known as "in the white," that is, before the varnish has been applied. This simple application of linseed oil to the wood produced a number of desirable advantages, which suggest that it might have been used by the old Italian masters. An additional effect has now been found that was not anticipated originally, which may have pronounced influence on the tonal properties of the wood.

THEORETICAL CONSIDERATIONS

It is known (2, 3) that raw linseed oil upon oxidation over a period of years first passes through the rubbery or linoxyn stage and then finally becomes soft, sticky and "balsamic" in character. Although this ultimate degradation or oxidation product is extremely viscous, it will exhibit slow-flow. For this reason it was considered desirable to determine if a liquid could be forced to move ***inside*** wooden plates if the plates impregnated with the liquid were set in vibration. If this movement did occur, it would also be desirable to determine if the liquid appeared in higher concentrations at certain areas of the vibrating plates. This behavior of the liquid particles inside wooden plates would then be analagous to that of the grains of sand on the surface of Chladni plates. The change of position of free particles *in* or *on* vibrating plates to nodal areas may then be called Chladnian movement.

A number of devices were considered to determine if a liquid inside wooden plates would respond to movement to nodal areas when the plates were set in vibration. All were abandoned in favor of actual experiments on a violin "in the white." The top and the back of a violin are vibratable plates and as such should display modes of vibration and nodal areas. Although these plates are very complex systems because of their unique shape, the presence of longitudinal and lateral arches and the varying thicknesses (graduations), they should nevertheless exhibit some Chladnian effects when subjected to vibration. That these effects are produced may be readily demonstrated by placing a suitable small object on the back of a violin and plucking or bowing a string, whereupon the object will dance. But because of the shape and curvature of the plates of a violin, a permanent pattern cannot be obtained on the surface. However, if the wood of a violin were impregnated with a liquid, then a pattern might be obtained as the result of Chladnian movement when the violin is played.

EXPERIMENTAL DATA

As linseed oil is subject to oxidation which would introduce complications especially if the experiments were extended over periods of time, it was decided to use an inert mineral oil; Squibb's medicinal mineral oil was found satisfactory for the purpose. So that any movement of the oil in and on the wood might be observed more readily, the mineral oil was colored red by alizarine-zinc-rosinate (1).

IMPREGNATING OIL

Squibb's Mineral Oil, medicinal grade	50.0 gms.
Alizarine-zinc-rosinate	3.0 gms.

This mixture was applied with a brush to the exterior of a violin "in the white" until further absorption became slow. A large excess of oil was deliberately used so that if movement under vibration (actual playing) did occur, sufficient oil would be re-located to appear on the surface of the wood. At the beginning of each experiment the violin was wiped thoroughly to be certain that all superficial oil was removed; the surface of the wood was "dry." The violin was then played steadily for fifteen minutes each time in the normal manner and using violin music. This method of placing the plates in vibration was considered preferable to that of using only open strings or one tone because it precisely represents actual playing conditions. The following results were observed:

(a) Oil in shiny "wet" patches appeared on the surface of the back of the violin, but not on the top nor on the sides.

(b) The oil-areas on the back, although not well defined, appeared in the same locations after repeated experiments which are illustrated in Figure 1.

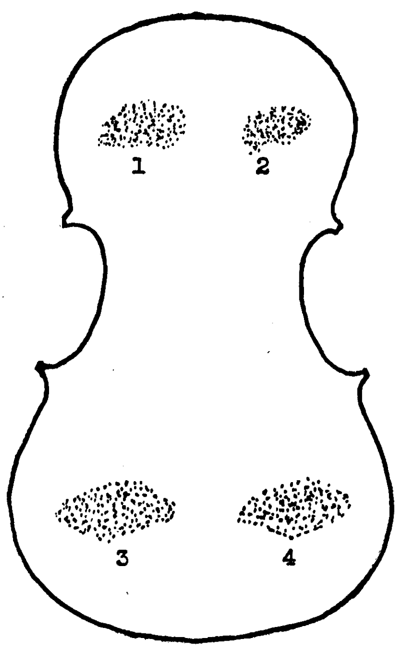

FIG. 1. Location of oil areas on back of violin.

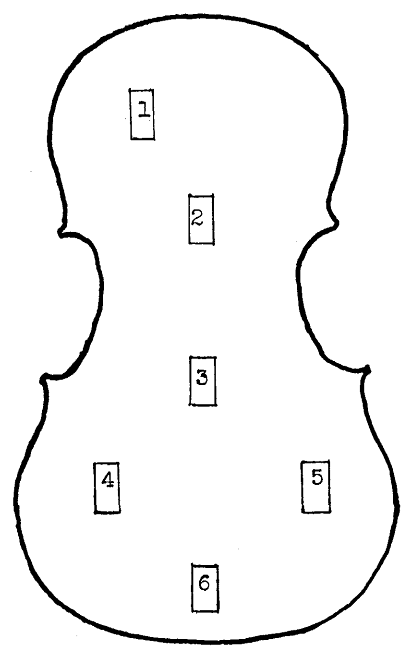

FIG. 2. Location of specimens taken for oil analyses.

(c) The oil patches disappeared from the surface of the back and were reabsorbed by the wood within several hours after the first experimental playings.

(d) The oil-areas gradually failed to appear on the surface of the back upon playing the violin, and after about five days, the oil patches did not appear. Additional applications of oil caused the oil-areas to appear again; but these too gradually failed to appear after four or five days. A total of four applications of oil were made extending over a period of eighteen months, and in each instance oil areas appeared upon playing the violin, to a decreasing extent, for a few days and then failed to appear after four or five days.

ANALYTICAL DETERMINATIONS

In order to investigate this behavior of the oil further, analyses were made of specimens of the wood cut from various locations on the top and on the back. The specimens were one inch by two inches in size, and the locations are indicated on Fig. 2. Specimens No. 1 and No. 2 were cut from the back immediately after playing the violin for the last time with the thought that the oil would not have an opportunity to return to a more uniform distribution in the wood. The other specimens were cut thirty-six hours later with the thought that the oil would have had an opportunity to redistribute itself after the wood was subjected to vibration.

When the violin was opened, preparatory to sawing test specimens from various sections, "reddish areas" were visible on the inside of the back corresponding to the oil patches on the outside. The colored area corresponding to back Specimen No. 5 was well pronounced. This would indicate that the oil patches appeared on the inside of the plate also, but to a lesser extent than on the outside. The center portion of the back on the inside was yellowish. The inside of the front of the violin was deeply colored around the ff holes, the colored area extending several inches above and below the openings. The inside center of the top was light yellow. The side bouts were generally reddish.

The specimens were extracted with benzene in a Soxhlet extraction apparatus, air dried to remove residual solvent, and then dried in an oven for eight hours at 105° C. The weighings were made at once, and the percentage of benzene soluble matter was referred to the oven dried weight. The results are summarized in Table I.

TABLE I

Distribution of Oil in the Wood

Specimen	*Location*	*Benzene Extractable*
No. 1	Back	11.7%
2	Back	12.2%
3	Back	10.3%
3	Top	12.3%
4	Back	10.6%
4	Top	13.4%
5	Back	9.8%
6	Back	11.7%
6	Top	13.7%

INTERPRETATION OF RESULTS

Those areas on the back of the violin initially showing increased oil concentration, as the result of vibration, would at first thought be presumed to be nodal areas. It would be reasonable to assume that the oil particles, like particles of sand on a vibrating Chladni plate, had been moved by vibration of the violin plate to these areas. However, these portions of a violin back are the freest to vibrate being away from the node at the sound-post and from the sides of the violin to which the plate is attached. These areas would normally be considered antinodes. Moreover, the oil patches appeared upon playing the violin only for a short time after an application of the oil. Since the plate as a whole has not apparently lost its property to vibrate, then some other component, which loses some of its property to vibrate relatively quickly, is responsible for the movement of the oil for a short time.

This anomalous behavior may be explained by the concept that in a vibrating wooden plate, there may be two components in motion: the plate as a whole and the internal cellular structure of the wood. Vibration of the cell walls would then be more intense in areas where the vibration of the whole plate is constrained, and vice versa. For example, the node of the back plate at the foot of the sound post would then be an area of maximum vibration of the cell walls of the wood. The four areas indicated on Fig. 1 where the violin plate is freest to vibrate would then be areas of minimum excitation of the cellular structure. The oil patches observed were accordingly areas of least internal vibration ("nodal areas" with reference to the cell walls) and the oil concentrated in these areas in consequence. After the oil had thoroughly permeated the cellular structure of the wood, its ability to respond to vibration was reduced (damping effect) and the movement of the oil when the violin was played no longer occurred.

This theory would also account for the pronounced red areas on the inside of the top plate around the ff holes. This portion of the top is freest to vibrate bodily resulting in less internal motion in the cell walls, which would cause a movement of the oil to these areas. The absence of oil patches on the top plate may be due to the fact that the character of the wood (soft wood, spruce) and the manner in which it is cut for violin making are not conducive to the migration of the oil when the plate is vibrated.

The analytical data reveal that the oil eventually becomes distributed relatively uniformly in the wood irrespective of the original appearance of concentrated oil patches. These analyses also indicate that any gravitational flow of oil will not account for the presence of oil patches on the back and the absence of oil spots on the top and the sides. The experimental violin with its average content of over 11% oil was hung by its scroll in an *upright* position for a year and one-half, which included two summers (hot weather). If any gravitational flow of oil had occurred it would have been observed; and the difference in the oil contents of Specimen No. 1 cut from the upper portion of the back and of Specimen No. 6 cut from the lower portion of the back would have been appreciable. The percentage content of oil in both specimens was the same. Apparently the wood is capable of "holding" the oil so that vibration (after a preliminary period) and gravity cannot dislodge it.

The effect of vibration on the wood of violins, especially on its internal structure, has received very little attention from previous investigators. Moreover, the realization is growing that the old Italian masters subjected the wood of their instruments to some preliminary treatment which could account for the consistent superiority of their instruments. Wood is a natural product the growth of which cannot be controlled or influenced; moreover, wood is far from being a homogeneous material. This fact would also suggest the need of some processing of the wood to render it more uniform and more suitable for a use in which its ability to vibrate properly is of prime importance.

Nicholas (4) as the result of X-ray studies of the wood of an old Italian violin has stated that the only possible explanation of the difference between the diffraction rings obtained from a new violin and those from a Guarneri fiddle is that the wood in the latter has been subjected to some special treatment which tends to alter the cellulose structure. Fry (5) has reported that the violin finished and not varnished has more power and mellowness in its tone but if it remains in this virgin state, it becomes modified little by little, and after a somewhat short time, the tone becomes poor and feeble. A better understanding of the effect of vibration on wood and variously treated wood will supply much needed information on this aspect of the Science of Violin-Making. For example, a preliminary treatment that dampens secondary vibrations inside the wood and permits the primary bodily vibrations of the violin plates to prevail to an increasing extent should improve the acoustical properties of the wood.

SUMMARY

The Chladnian movement initially observed in an oil-impregnated violin plate may be due to the vibrations inside the wood, that is, in its cellular structure. The distribution of the oil in the wood eventually becomes relatively uniform and is not affected by gravity or vibration.

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