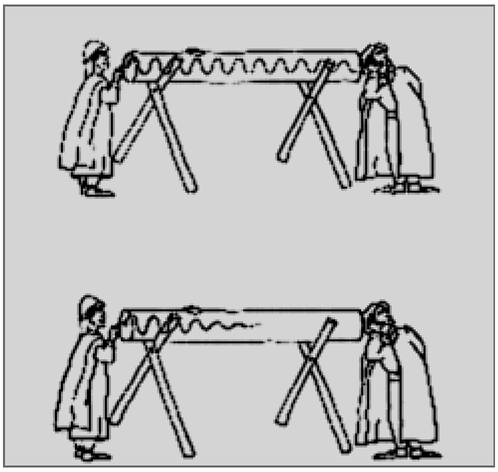
From empiric tests to ultrasonics – Modern development of ancient knowledge

As already mentioned in the preface, many makers have faced the problem of searching the surest and most trustworthy method to optimize the choice of suitable construction materials.

Over the centuries we have followed dozens of theories including some amusing ones. Ultimately, we have concentrated our interest on one in particular.

The method most likely used by Stradivarius, (Photo no.1) even if empiric, was based on an absolutely correct concept. The trunk trunk of a tree that, when stimulated on one side transmits the sound in the most powerful, clear and quick way to the other side, is undoubtedly the best material.



1) Stradivarius empiric test

Our question was how to determine, with scientific precision, the quality of the material. By reflecting on the Stradivarius test, we found our answer.

The sound impulse travels through the fibers and requires a certain amount of time to travel from one end to the other. The shorter the time, the better the quality of the tested sample.

The difference of the time needed for an impulse of the same extent to pass through two samples is to be attributed to the specific elasticity of each one of them.

After having understood that the time is a value determined by the elasticity, Maestro Lucchi began to look for a method that could allow him to measure these variations. A valid aid was supplied to him by the ultrasonic field.

Two probes are set on the same frequency but one transmits an ultrasonic impulse, while the other one works as a receiver. At this point, it was sufficient to connect a timer in order to get the evaluation of the transit time from one probe to the other and, in this way, we succeeded in obtaining the elasticity of the sample under measure.

With a simple math equation, space divided by time (s/t), automatically developed by the new Lucchi Meter “Minipalm” (Photo no. 2), we arrive at the velocity of the sound propagation through the wood.

2) Lucchi ” Minipalm ” Meter

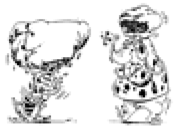
The sound velocity test is the absolute quality parameter that gives valuable assistance to the already skilled craftsman, merging his art with a technologically advanced device.

If you are eager to deepen your knowledge about Maestro Lucchi’s studies in the various fields of bow and violin making, as well as the technology of the materials, you are kindly invited to go on reading.

Sound velocity – Parameter of fundamental quality

The Young modulus, until some years ago, was the only scientific parameter available to luthiers for use to measure sound velocity in materials. Nevertheless, this method does not give any information regarding the acoustic properties. It reveals only the highest weakening degree of the material, that is to say, its strength grade.

The following table will help to demonstrate the failure of this test (figure 3).



MATERIALS	Longitudinal Velocity	Density	Resonance Quality Q	Specific Elasticity	Young E ×cm²
SPRUCE	**6.300**	**0,30**	**210**	**397**	**119**
EBONY	**3.140**	**1,20**	**26**	**98**	**119**

3) Comparison table between Spruce and Ebony

As you can see, both spruce and ebony share exactly the same Young modulus, but no one would be so foolish as to build the harmonic plate of a violin with ebony.
As seen in the analysis, we can note outstanding differences between the two samples.

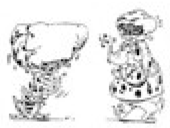
Ebony is obviously much heavier than spruce. It is not a suitable material as it has a much lower sound velocity in comparison with spruce and, consequently, it is unable to transmit vibrations at a satisfactory level.

Due to the repeated pressure from the player's fingertips on the strings, ebony should be used exclusively for the fingerboard of bowed instruments. The fingerboard is not intended to vibrate with the instrument, whereas, the tailpiece needs to. Ebony can offer a very high acoustic resistance; therefore, it does not vibrate.

Below is another example showing how the knowledge of sound velocity can help to select the materials to be used.

The comparisons between two completely different kinds of woods, such as ebony and spruce, are easily understood. However, they become more difficult to determine when two samples of the same material are measured. As you can see, (figure 4) these two samples of Pernambuco share the same Young modulus. Nevertheless, they are completely different.

PERNAMBUCO



MATERIALS	Longitudinal Velocity	Density	Resonance Quality Q	Specific Elasticity	Young E ×cm²
PERNAMBUCO 1	**6.070**	**0,90**	**67**	**368**	**331**
PERNAMBUCO 2	**5.145**	**1,25**	**41**	**264**	**331**

4) Comparison table between two different pernambuco samples

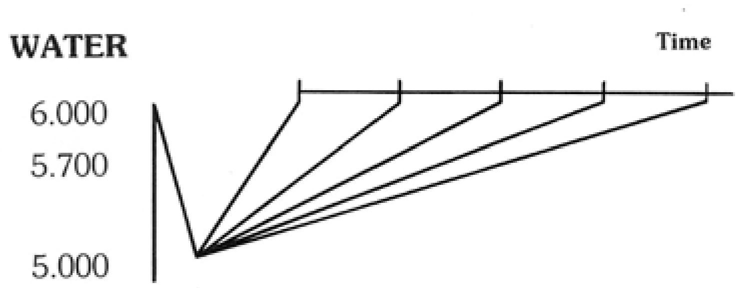
The first sample has a very high sound velocity reaching almost the highest possible level for pernambuco. This measurement, in conjunction with good density, renders it well-suited for the making of bows. The second sample has, in fact, a higher density but has a very low sound velocity. This means that the fibers do not transmit sound and, in spite of its weight, this wood will never play or sound well. It is advisable not to use it at all, or use it only for low-grade bows.

From this point on, we will show how it is possible to strictly follow every working phase with our instrument, the Lucchi Minipalm Meter. Every working step, from raw wood until the finished product, may be checked enabling us to understand how the different working techniques may negatively affect our finished instrument and, consequently, how to improve them.

Check of various treaments with ultrasonics

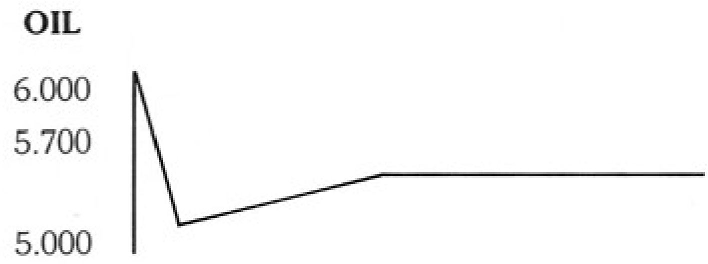
The ultrasonics may be used also to check how varnishes, oils, artificial oxidation etc. may affect the wood.

For instance, if a wood has a velocity of 6000 m/s when completely wet, it may decrease to 5000 m/s. As time passes and it dries out completely, it will come back to its original values. (Figure 29)



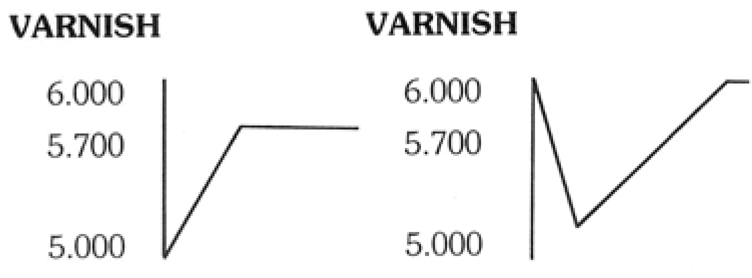
29) Time needed for a wood to return to its original velocity when completely wet

If the same wood became wet with oil, it would be permanently damaged and the manufactured instrument would be destroyed forever. (Figure 30)



30) Permanent damage to an oil-treated wood

The varnishes applied are very important because only some of them do not damage the wood. Others that contain oil may destroy the fiber. The wood may also be destroyed by applying layers of varnish before the solvent has evaporated. (Figure 31)



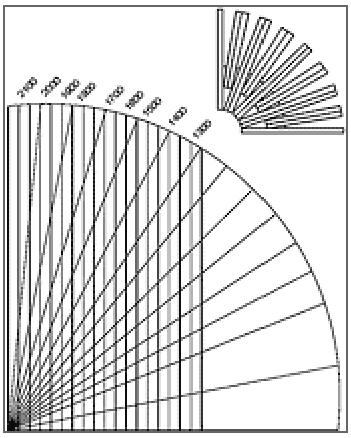
31) Difference in the effect of drying and the damage caused by different varnishes

Through the use of ultrasonics, information can be gained that will reveal any chemical treatments. Their long-term effects will determine working techniques for all instrument and bow makers.

Cutting the Trunks of the Tree

The importance of the measurment of sound velocity is that it gives the possibility to know when to cut the tree and which part of the wood will reveal the best sound properties.

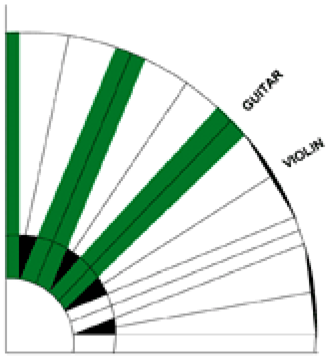
After having selected the best trunk in relation to its longitudinal velocity, we can optimize the cut of the trunk by also measuring the radial velocity. This represents the main criteria for making bowed instruments. (Figure 6)



6) Wrong cut of the spruce

In the graph, representing a trunk, an improper cut which doesn't take into account the different transversal velocities, may damage an excellent material. After having completed measurements with the Lucchi Minipalm Meter, it is possible to decide the best use of the material. A decision may be made (Figure 7), from the beginning, to determine the outcome of the level (student to professional) of the finished instrument.

Approximately twenty years ago, "Fazioli Pianoforti" showed interest in Giovanni Lucchi's research by using the first version of the ultrasonic meter. Fazioli Pianos began to choose and classify in quality levels the construction materials they used in building their concert grand pianos.

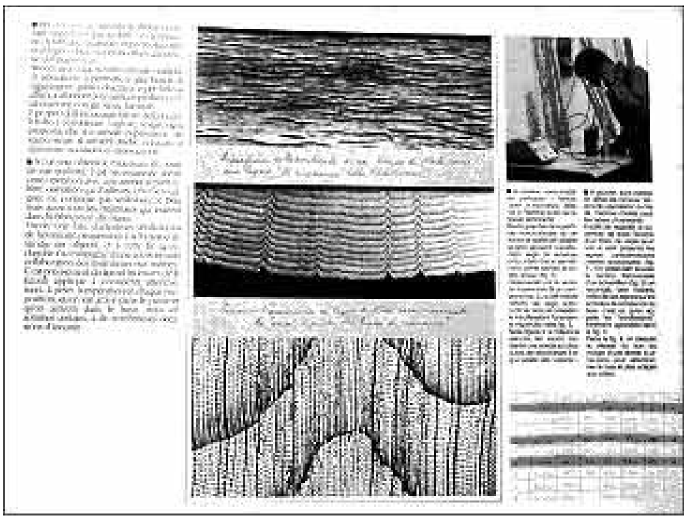


7) Correct cut of the spruce

The Lucchi Meter, in fact, enabled Fazioli Pianos to select and purchase the highest quality wood in order to acquire the best suitable material for high-grade concert pianos, leaving the inferior quality materials behind.

The quality of an instrument or bow may be decided before starting to work. Time is saved and the value of the finished product is increased. (Figure 8).

8) Publication of Fazioli's study

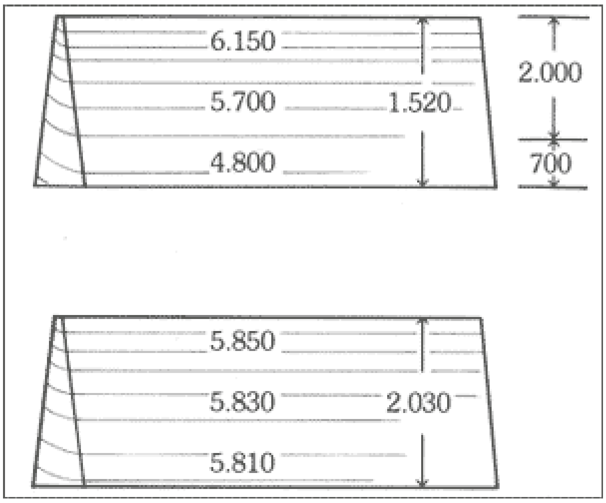


Violin making and ultrasonics

The luthiers had very few parameters to judge the material to be selected and much was left to their own personal touch. (Photo 20) You can see a luthier trying to determine the force of the harmonic plate.

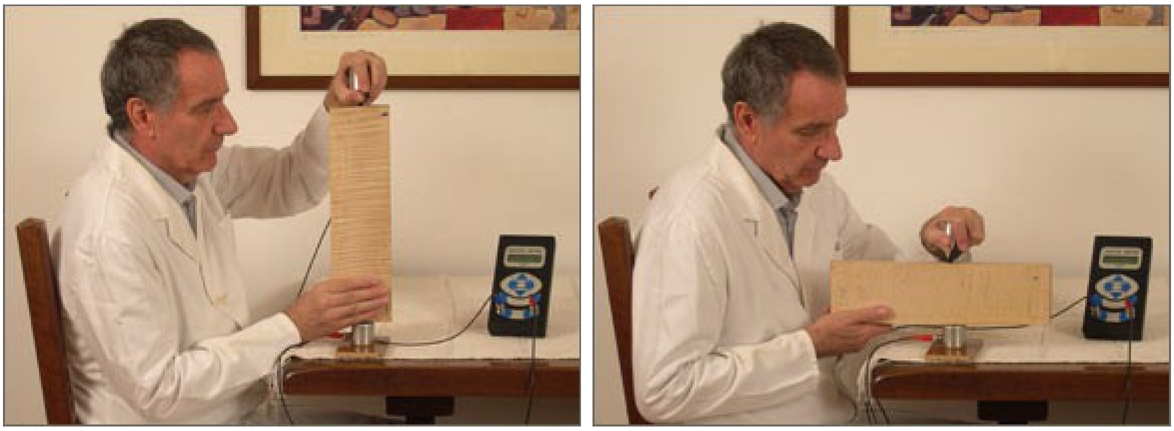
20) Tests of resistance to torsion and flexion

The aid of ultrasonics is very useful in the lutherie world and determines, surely and reliably, which is the best material to be used. (Figure 21)



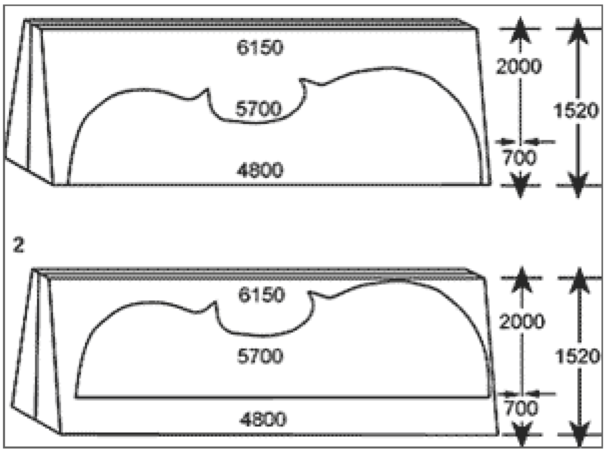
21) Analyzing two spruce tables

With a quick and simple check, the Lucchi Minipalm Meter can determine, in a sure and trustworthy way, all selection data among the woods to be worked with. (Photo 22)



22) Maestro Lucchi measures a table

The use of the wood can be optimally chosen because the quality can be excellent in one portion but very poor in the other. (Figure 23)

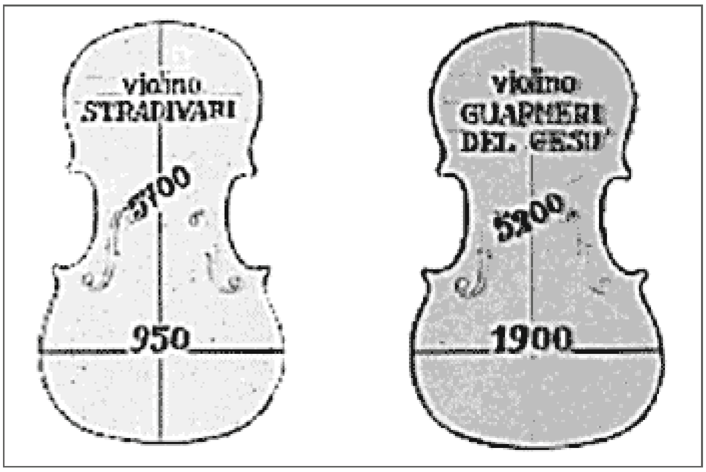


23) The same spruce table correctly cut

By analyzing the ancient instruments and bows with the Lucchi Minipalm Meter, we can understand the materials originally used. Ancient bows tend to become weaker with long use and lose many of their original qualities. However, instruments suffer a loss of quality only in the soundpost, bassbar, bridge and strings, while the rest of the instrument retains its original qualities. By measuring it, (Photo 24) we can understand thoroughly how the instrument was conceived by its original maker and, consequently, we can make copies that only slightly differ from the original one.


24) Measuring a violin with the Lucchi Minipalm Meter

We personally executed some tests and our studies led to interesting results. Master Lucchi had the opportunity to measure these two instruments (Figure 25)

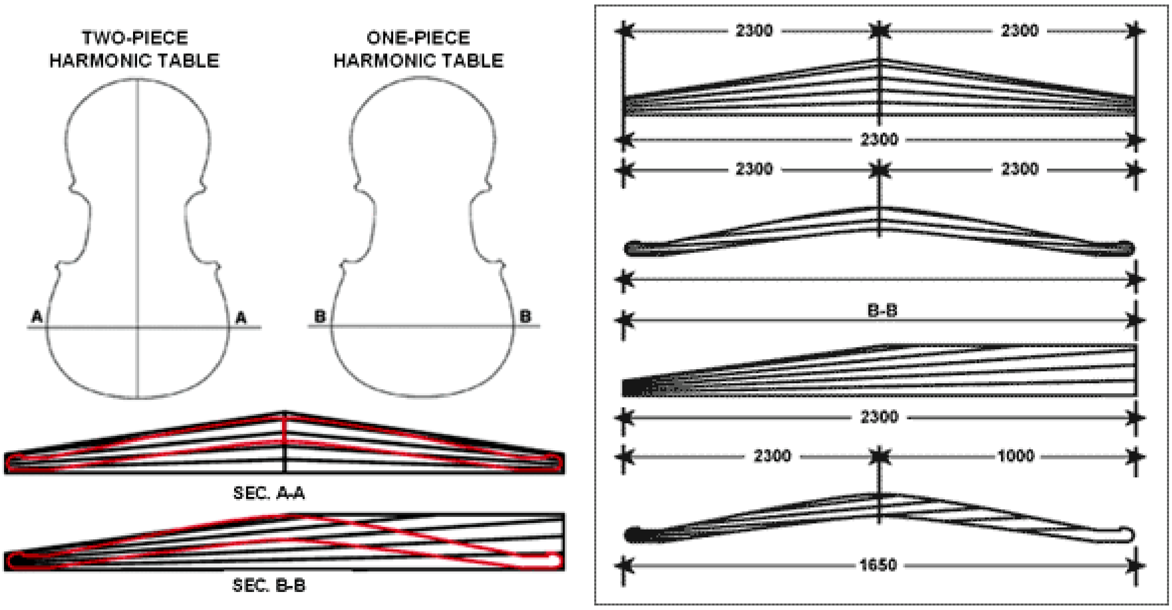


25) Two measured instruments

In spite of the higher longitudinal velocity of the first, the second instrument was determined to be more powerful when submitted to a listening test.

By measuring the transversal velocity the secret was revealed. The second instrument was extremely high and emitted a large sound volume because the sum of the two velocities measured was higher.

This has enabled us to understand how important the radial velocity could be in the lutherie field. With further trials, we have discovered why the one-piece harmonic table exhibits less velocity than the two-piece harmonic table. On the one-piece plate shown in the picture (Figure 26) the left side of the fiber is very long and well used, but the right side is obviously too short as a result of the working process.



26) Distribution of the medullar rays on one-piece and two-piece harmonic plates

The shortening of the medullar rays greatly decreases the sound velocity and, consequently, reduces the vibrational capabilities of the instrument. By using a two-piece harmonic plate, we can optimize the cut of the wood and reach the maximum transmission level.

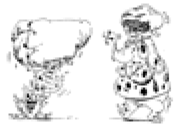
Carrying out a continuous check during every working phase, (Photo 27) we will be able to optimise not only the choice of the material but also avoid incorrect processes, thus improving the obtained results.

27) Check of working phases

By knowing the parameters of the sound velocity, it is possible to receive indispensible information for both bow makers and instrument makers. With a simple math equation, velocity divided by density (v/d), we arrive at what, in mechanical engineering, is the so called “coefficient of resonance”. This parameter, known in lutherie as “quality factor”, permits us to determine, between two pieces of wood owning the same velocity, which one has the better vibration. The lightness of wood is, in fact, of basic importance for the construction of musical instruments but, if the weight is not related to velocity, we risk making a light violin that doesn't play or sound well.

As you can see in the table below, (Figure 28) these two spruce trunks present a very different density, apart from the outstanding differences in the velocity values. The extremely high density of the second sample, when related to the poor longitudinal sound velocity, causes a very low coefficient of resonance. In other words, this makes the second example of no use for a skilled maker.

28) Comparison of spruce tables



MATERIALS	Longitudinal Velocity	Density	Resonance Quality Q	Specific Elasticity	Young E ×cm²
SPRUCE 1	**6.300**	**0,30**	**210**	**397**	**119**
SPRUCE 2	**4.280**	**0,65**	**65**	**183**	**119**

Longitudinal Spruce