The geometric secret of Stradivarius

By Professor Bruno Barosi, director of the acoustical physics laboratory, Cremona Institute of Violin Building.

Professor Barosi delivered this speech to the conference, "Giuseppe Verdi and the Scientific Tuning-Fork," hosted by the Cini Foundation and Levi Foundation and organized by the Schiller Institute and the Italian Harpsichordists Association, on June 20, 1989 in Venice, Italy. An account of the conference and some of the other key speeches appeared in EIR *No. 33, Aug. 18, 1989. The conference pivoted around the theme of the need to return to Verdi's tuning fork of A = 432, which is the highest possible setting for a Concert A based on the "physicist's pitch" of middle C set at 256 Hertz. Already supported by a majority of the leading opera singers, this initiative, prompted by the scientific work of Lyndon LaRouche and the discovery that Verdi had backed a decree to establish A = 432 in Italy in 1884, has won increasing approbation from leading instrumental musicians as well.*

As an expert on the old Cremona violins, the most treasured in the world, physicist Bruno Barosi lent his authoritative voice to the drive to return to the lower tuning, starting with the Schiller Institute's first conference on the subject, in April 1988, and has since actively promoted Italian legislation in that direction.

Our violin building school had already been concerned with this problem of the tuning fork, when the Schiller Institute raised it with us, because the problem of the preservation and utilization of the instruments of the ancient Cremonese school has always been a live problem, both for the instruments belonging to the City of Cremona, and for the instruments belonging to the greatest concert artists.

Parenthetically, what is most often heard or written about the famous Cremona violins is—putting it kindly—fables. "The secret of Stradivarius was in the varnish," or "the secret of Stradivarius was that he went around at night knocking on the trees to find out the fundamental note upon which to build the violins." Stradivarius was a person of great acumen and outstanding sensibility, living in a time, the 18th century, when in Cremona there was a flourishing school of physics and mathematics of Beltrami and Cusanus (not Cusanus the Cardinal), Gardanus, and other persons who gave rise to a hotbed of ideas which Stradivarius probably drew upon a great deal, and to which he added his personal abilities and sensibilities.

The violin—as well as the viola, the violoncello—is an instrument which is extremely contradictory from a physical standpoint. It is a machine which plays two opposite roles at the same time. The first is a static role: The lightweight structure (it weighs 220-225 grams) must hold a tension, a force, in order for the strings to sound, of about 21-22 kilograms, which then presses on the bridge, and hence on the curvature of the soundboard, which at the center, at its greatest thickness, is 3 millimeters of wood, at around 8 kilograms. At the same time, it must be capable of moving, oscillating around a position of equilibrium, and hence of vibrating, maintaining a constant static equilibrium. Such structures in physics are exceptional. The exceptionality is given by the fact that the violin, like most instruments, was born as an imitation of the human voice (people say the violin has a human sound, which is emotionally moving) and not vice versa.

So there is an adaptation, and the secret is that this "box" (which you have probably heard called a resonating box, but this is incorrect), is a coupler between the strings (which are the sound source) and the air of the environment surrounding the instruments, which is the "charge" or utilizer. It's a very simple comparison: From a cybernetic viewpoint, the violin is a "nonstable multivibrator" and is comparable to an electrical transformer, which everyone is acquainted with. The "primary" is the strings, the "secondary" is the surrounding air, and the coupler, the magnetic core, is the box itself.

The discovery of this optimal coefficient of coupling lies in having correlated the internal volume to the external surface. When one talks of raising the frequency (all the instruments of the old Cremonese school having been "tortured," insofar as not one of them still has its original fingerboard), the desire to make them play at a higher frequency involves an adaptation of the system, which cannot help but intervene on fundamental parts of the system.

What happens when you raise the pitch

You cannot go and remake the height of the ribbing to vary the volume, as the surface would remain the same; the coefficient would vary, for which reason the sonority of the instrument would diminish a great deal. So one has to increase the tension of the strings. To stretch the strings means to increase the tension by about 4 kilograms. To increase the tension by 4 kilograms involves an increase in the forces which are distributed on this structure, which can be com-

FIGURE 1

Parts of a violin

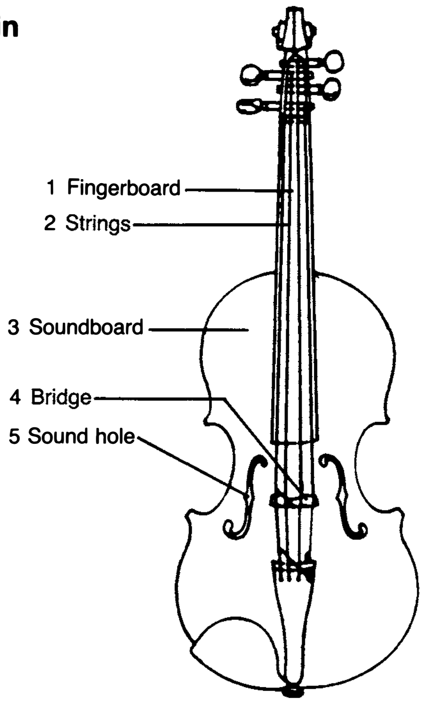
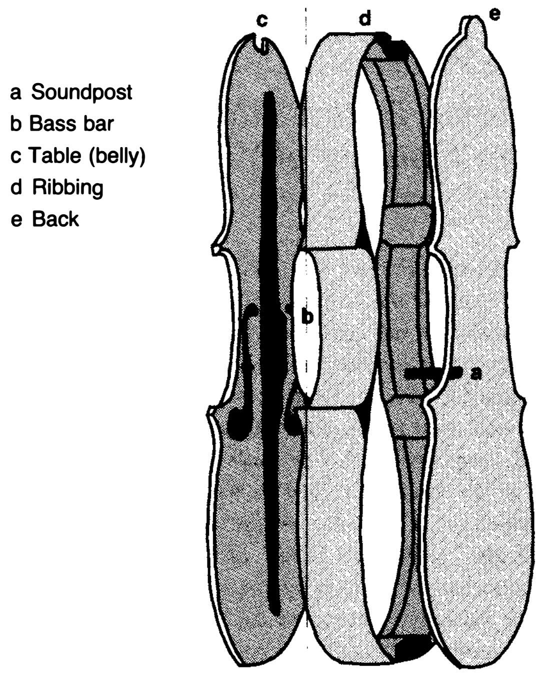


FIGURE 2

Interior of a violin



The soundpost (a) set under the right foot of the bridge, transmits vibrations to the back of the violin (e). The bass bar (b), glued to the back of the table (c), stiffens the body and distributes the vibrations.

pared to an egg: If you grab an egg in the middle of its points you cannot break it, because the sum of forces is equal to zero, so it is in perfect equilibrium. If you analyze well the form of the violin, the sum of all the forces equals zero.

If I increase the tension, even though going from 21 to 25 kilos is not exceptional, the overstress on the instrument is not just the result of the amount, but above all of the duration. A structure of this type, stressed for extremely long periods, will give way, because the discovery, the "novelty" introduced by Stradivarius with respect to the previous school, that of the Amati, was precisely that of slightly varying the curvature, of not attaching the table by means of a joint, but of gluing the table; and hence statically speaking, a table which *rests* at its two extremes, has a greater rise than a slab which is *joined* at its two extremes.

This is the reason why the Stradivarius violins have more sound, and the perfection of the form is the reason why they sound better. It relates to having a loud sound and a pleasing sound—the color of the sound, we call it timbre—the psychological response which the human brain gives to a vibration between 16 and 16,000 Hertz, although now that we have become deafer, and the norm goes from 20 to 20,000 Hz. The hearing threshold has increased in intensity, and the psychological response is proportional to the logarithm of the stimulus, i.e., it is not linear, it is a logarithmic spiral which goes back to the theory of sound, of the harmony of the universe developed by Jonathan Tennenbaum [see *EIR* Vol. 16, No. 33, page 30].

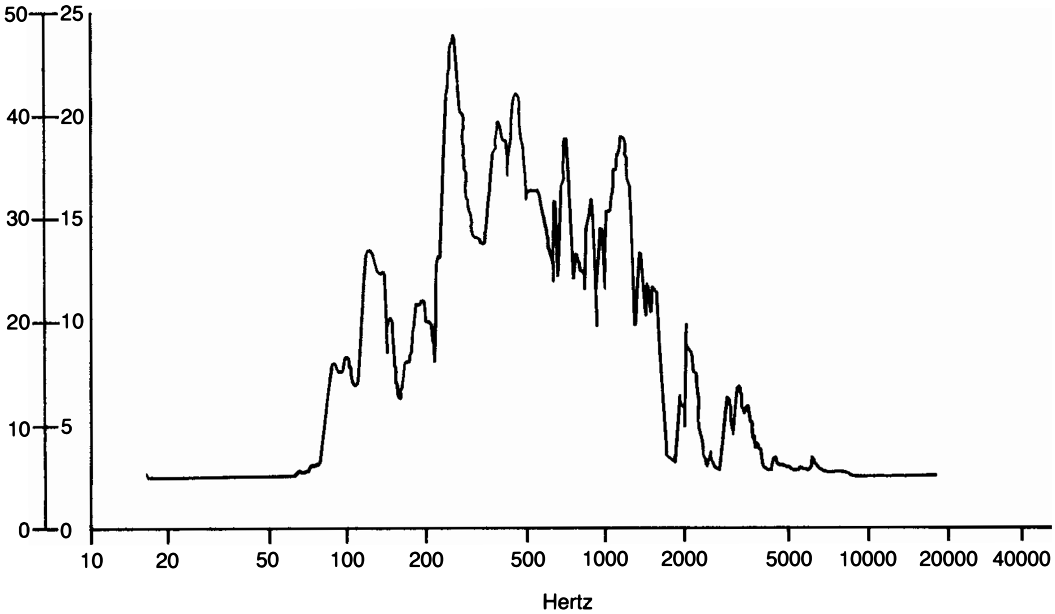
To increase tension means to shorten the average life of the instrument. When I said these things for the first time, Uto Ughi blew up, even though he is a friend, and said it was not true. I told him that within five or six months his Stradivarius would have to be rebuilt. The Amatis in the collection of the City of Cremona are not fit for concert use, except in a hall half the size of this one, because since they are earlier than the Stradivarius structure, they no longer hold the tension and they are instruments on their way down—museum pieces.

The preservation of this patrimony is a preservation which forces us, as a moral obligation, to hand on to those who will come after us the masterworks of human genius, of Mankind's creativity. They are unrepeatable instruments. Our violin building school makes very fine instruments, but they are not Stradivarius violins, which are unrepeatable, because like all the works of the human genius, just as Man is unrepeatable, each of us is unrepeatable, and so the works of human genius are unrepeatable.

The increase in tension involves a significant shortening of the average life of the instrument. The great concert artists who stretch their strings to 445-450 will soon realize the damage they are doing to their instruments—damage they try to fix, as some have already tried to do, with a very bad

FIGURE 3

The spectrographic profile of the 'Omobono' violin



The logarithmic graph shows the point of maximum sonority of the "Omobono" Stradivarius violin, which occurs around C = Hertz.

restoration, i.e. by replacing the bass bar, reinforcing the table, above all under the soundpost, because increasing the tension on the strings means increasing the reaction, which tends to flatten the back and arch the table. This means a distinct upward reaction which compresses and flattens the instrument, with the damages that are provoked, not so much by the increase as by the *length of time* of this increase. This is what really brings on the illness of these instruments.

The crucial experiment

It was also necessary to demonstrate that by returning to A = 432, without changing anything of the interventions already carried out on the instruments, that not only was the instrument better off from the static standpoint, but—what really counts—that the instrument was better from the sound standpoint, both in terms of emission, that is, quantity of sound, and in quality of sound. So we took a great violinist, Norbert Brainin, and a great instrument, a Stradivarius. We took the Stradivarius to be analyzed, monitored, we gave it a "check-up." The "check-up" gave these results: With the Verdi A, not only does the instrument sound louder, but it sounds better, it satisfies the listeners better, and it has an exceptionally pleasing timbre. The resistances are significant, above all from the modern string instrument makers, because the devil is always making pots, but not lids. So the violin builders, even those of the same school, who had started to waver, have had to become become aware.

Now I will show you the graph of the Omobonus Stradivarius of Brainin, but also the Cremonese 1715 du Cremona (**Figure 3**). They have a typical Stradivarius profile like an I.D. card. You can see right away if an instrument is a Stradivarius or not from the spectogram. The greatest response in breadth and hence in sonority, and as a result in timbre, is given by the instrument at 256 Hz, that famous 256 Hz which is the C natural invoked again this morning, this C that reflects the harmony of the universe and so forth. The envelope of Figure 3 is characteristic. This point which is around 80 Hz is the resonance of the box, which is why the construction of the instrument is such that according to Helmholtz's rules it sounds only at integral multiples of 80 Hz. I will now show you the spectrographic analysis, that is the characteristic makeup of the sound, i.e. the formants which define the timbre, of the Brainin Stradivarius tuned at A = 432 and A = 440. You will see that in comparison to the 440 tuning, with the 432 tuning the Stradivarius violin has a much richer sound, a much more "pleasing" timbre. This test was not conducted on some crummy violin, with some poor fiddler. You will hear the difference between the same Bach piece executed with the tuning at 432 and at 440. The person playing is Brainin, on a 1736 Stradivarius.

In closing, I would say that we have to thank the Schiller Institute and above all the inventor and promoter who gave the first spark to this initiative, Lyndon LaRouche, with an ingenious intuition, which has since been backed up by the facts. I think that the scientific demonstrations reported are obvious, and that they show that the return to A = 432 not only will prolong the average life of these instruments, but will also cause them to be more appreciated.