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Founding a Family of Fiddles

New measurement techniques combined with recent acoustics research enable us to make violin-type instruments in all frequency ranges with the properties built into the violin itself by the masters of three centuries ago. Thus for the first time we have a whole family of instruments made according to a consistent acoustical theory. Beyond a doubt they are musically successful.

by Carleen Maley Hutchins

FOR THREE OR FOUR centuries string quartets as well as orchestras both large and small, have used violins, violas, cellos and contrabasses of classical design. These wooden instruments were brought to near perfection by violin makers of the 17th and 18th centuries. Only recently, though, has testing equipment been good enough to find out just how they work, and only recently have scientific methods of manufacture been good enough to produce consistently instruments with the qualities one wants to design into them. Now, for the first time, we have eight instruments of the violin family constructed on principles of proper resonance for desired tone quality. They represent the first successful application of a consistent acoustical theory to a whole family of musical instruments.

The idea for such a gamut of violins is not new. It can be found in Michael Praetorius's *Syntagma Musicum* published in 1619. But incomplete understanding and technological obstacles have stood in the way of practical accomplishment. That we can now routinely make fine violins in a variety of frequency ranges is the result of a fortuitous combination: violin acoustics research—showing a resurgence after a lapse of 100 years—and the new testing equipment capable of responding to the sensitivities of wooden instruments.

As is shown in figure 1, our new instruments are tuned in alternate intervals of a musical fourth and fifth over the range of the piano keyboard. Moreover each one has its two main resonances within a semitone of the tuning of its middle strings. The result seems beyond a doubt successful musically. Over and over again we hear the comment, "One must hear the new instruments to believe such sounds are possible from strings."

Catgut Acoustical Society

Groundwork in the scientific investigation of the violin was laid by such men as Marin Mersenne (1636), Ernst Chladni (1802), Felix Savart (1819) and Hermann L. F. Helmholtz (1860). Savart, who can rightly be considered the grandfather of violin research, used many ingenious devices to explore the vibrational characteristics of the violin. But he was unable to gain sufficient knowledge of its complicated resonances to apply his ideas successfully to development and construction of new instruments. Recent research that has led to our new fiddle family is largely the work of Hermann Backhaus, Herman Meinel, Gioacchino Pasqualini, Ernst Rohloff, Werner Lottermoser and Frieder Eggers in Europe and of the late Frederick A. Saunders, John C. Schelleng, William Harvey Fletcher and myself in the United States.

Saunders, widely known for his work on Russell-Saunders coupling, pioneered violin research on this side of the Atlantic. He was a former chairman of the physics department of Harvard University, a fellow of the National Academy of Sciences and president of the Acoustical Society of America. In his work on violin acoustics, Saunders gradually became associated with colleagues who were highly competent in various scientific and musical disciplines. These associates greatly furthered the development of his work and contributed valuable technical knowledge, but they had little time for experimentation. Some were skillful musicians living under the pressure of heavy teaching and concert schedules. Nevertheless some were able to find time for the testing, designing and craftsmanship needed in the development of experimental instruments. In 1963 about 30 persons associated with Saunders in this project labeled themselves the "Catgut Acoustical Society." This informal society now has more than 100 members (see box on page 26), publishes a semiannual newsletter and holds one or two meetings each year. Among its members are acousticians, physicists, chemists, engineers, instrument makers, composers, performing musicians, musicologists, patrons and others who believe that insufficient attention has been paid to the inherent potentialities of bowed string instruments. They are making a coördinated effort to discover and develop these potentialities and are encouraged that many members of the violin fraternity share their aims.

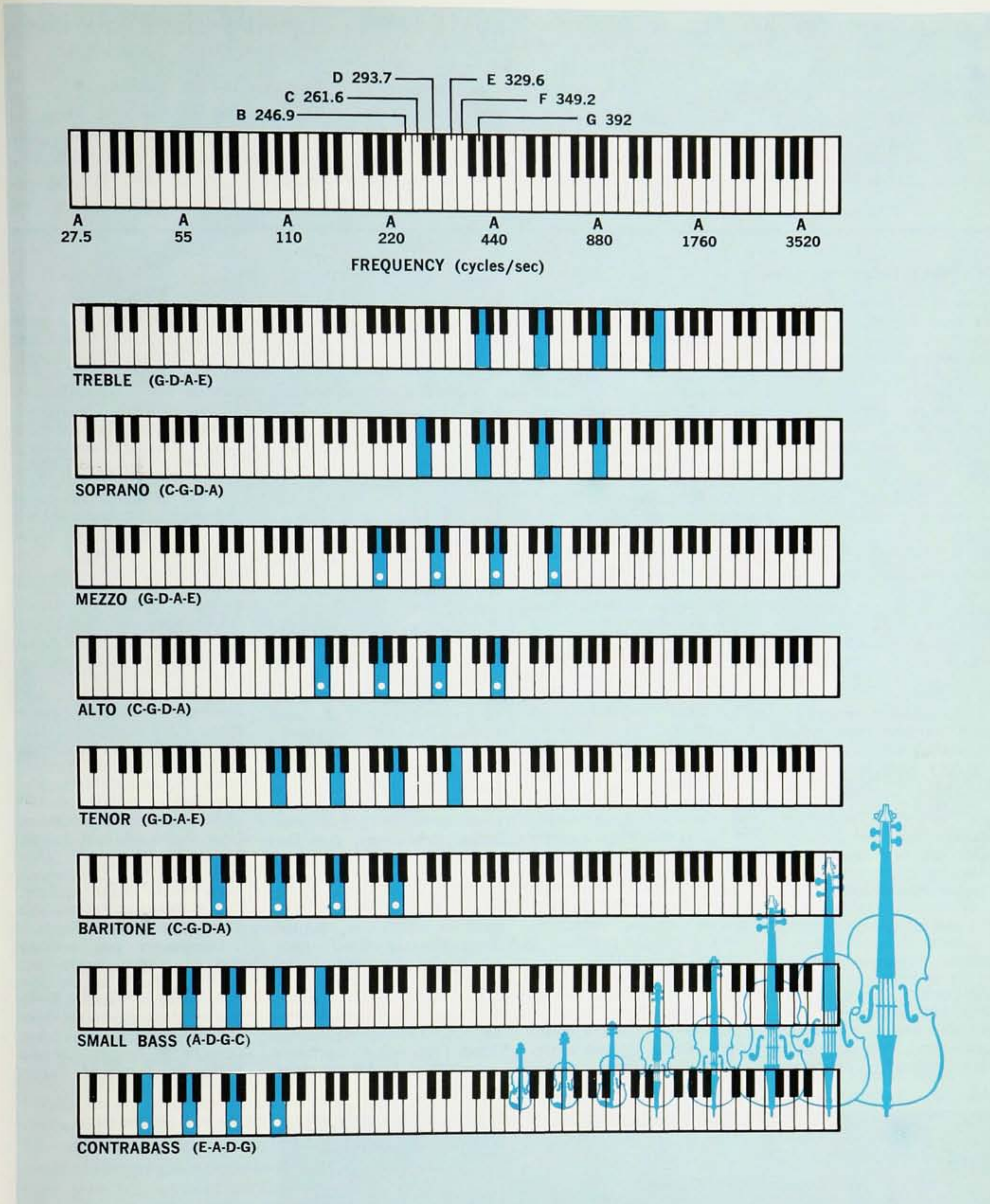
Among other accomplishments of our Catgut Acoustical Society is a concert played at Harvard last summer during the meeting of the Acoustical Society of America. It was dedicated to Saunders and the instruments were our eight new fiddles, which are the outgrowth of research he began. I write about the concert and about the instruments as a member of the society and as one who worked with Saunders from 1948 until his death in 1963. My activities include reconciliation of the wisdom of experienced musicians and violin makers, coördination of much technical information from widely separated sources, and design, construction and testing of experimental instruments. In 1937 Saunders reported[1] in the *Journal of the Acoustical Society of America* what later proved to be basic to the development of the new violin family, namely the position of the main body resonance as well as the main cavity resonance in a series of excellent violins. (The main body resonance is the lowest fundamental resonance of the wood structure; the cavity resonance is that of the air in the instrument cavity.) But the necessary knowledge of how to place these resonances with any degree of predictability in instruments of good tone quality was not evolved and reported until 1960.[2] The tonal effect of this placement of the two main resonances for each instrument and the necessary scaling theory was not reported until 1962.[3]

Between 1950 and 1958 Saunders and I undertook a long series of experiments to test various features of violin construction one at a time. We determined effect of variations in length, shape and placement of the f holes, position of the bass bar and sound post, significance of the inlay of purfling around the edges of top and back plates and frequency of the cavity resonance as a function of rib height and f hole areas (see figure 2). Because many of these experiments needed definitive testing equipment not then available, most of the results are still unpublished in Saunders's notebooks.

One sobering conclusion we reached was that with many alterations in such features as size and shape of f holes, position of the bass bar and sound post, the best tonal qualities resulted when conventional violin-making rules were followed. In other words, the early violin makers, working empirically by slow trial and error, had evolved a system that produced practically optimal relationships in violin construction.

In 1958, during a long series of experiments to test the effect of moving violin and viola resonances up and down scale, the composer in residence at Bennington College, Henry Brant, and the cellist, Sterling Hunkins, proposed development of eight violin-type instruments in a series of tunings

In addition to nurturing her fiddle family, the author shows interest in children. After graduating from Cornell she taught for 15 years in New York schools, acquiring an MA from New York University meanwhile. She also acquired a chemist husband and two children, all of whom live in Montclair, N. J.



NEW INSTRUMENT TUNING spans the piano range with eight fiddles that range in size from 210-cm contrabass to a 27-cm treble. The conventional violin is the mezzo of the new series. Colored keys show tuning of new instruments and white dots that of conventional instruments. —FIG. 1

and sizes to cover substantially the whole pitch range used in written music; these instruments would start with an oversize contrabass and go to a tiny instrument tuned an octave above the violin. Their request was so closely related to our experimental work that after half an hour's discussion Saunders and I agreed that a serious attempt would be made to develop the set. The main problem would be to produce an instrument in each of the eight frequency ranges having the dynamics, the expressive qualities and overall power that are characteristic of the violin itself, in contrast to the conventional viola, cello and string bass.

Research and new fiddles

The problem of applying basic research results to actual design and construction of new instruments now faced us. From the previous ten

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Who's Who in Catgut Acoustics

Without cross fertilization of ideas from experts in many related disciplines our new fiddle family could not have evolved in the short period of nine or ten years. No listing of names and activities can do justice to each one whose thinking and skills have been challenged and who has given time, energy and money. Their only reward is sharing in the project.

The spirit of the group has been likened to the informal coöperation that flourished among scientists in the 18th century. In addition many of the active experimenters are themselves enthusiastic string players so that a technical session is likely to end with chamber-music playing.

In the following list I try to include all those who have helped along the way, listing those who have been most active first even though they are not all members of CAS. Some of the numerous musicians are not actually familiar with the new instruments, but their comments on earlier experimental models of conventional violins, violas and cellos have provided musical insights and information necessary to the new instruments.

Physicists. Basic research and scaling for the new instruments: Frederick A. Saunders, John C. Schelleng and myself. Theory of vibrations, elasticity, shear and damping in the instruments and their parts: Arthur H. Benade, Frieder Eggers, Roger Kerlin, Max V. Mathews, Bernard W. Robinson, Robert H. Scanlan, John C. Schelleng, Eugen J. Skudrzyk, Thomas W. W. Stewart, Sam Zaslavski.

Chemists. Effects of varnish and humidity on the instruments; varnish research: Robert E. Fryxell, Morton A. Hutchins, Louis M. Condax.

Architect. Basic design and development of patterns for the new violin family, and maker of bows for them: Maxwell Kimball.

Electronic engineers. Norman Dooley, Francis L. Fielding, Sterling W. Gorrill, A. Stuart Hegeman, Alvin S. Hopping.

Translators. Mildred Allen, Edith L. R. Corliss, Donald Fletcher.

Editors. Harriet M. Bartlett, Dennis Flanagan, Robert E. Fryxell, Mary L. Harbold, Martha Taylor, Alice Torrey, Howard Van Sickle.

Photographers. Louis M. Condax, Russell B. Kingman, Douglas Ogawa, Peter N. Pruyn, J. Kellum Smith.

Artist. Irving Geis.

Lawyers. Harvey W. Mortimer, J. Kellum Smith, Robert M. Vorsanger.

General consultants. Alice T. Baker, Donald Engle, Cushman Haagensen, Mary W. Hinckley, Ellis Kellert, Henry Allen Moe, Ethel and William R. Scott.

Secretaries. Lorraine Elliott, Belle Magram.

Violin experts and makers. Karl A. Berger, René Morel, Simone F. Sacconi, Rembert Wurlitzer, myself—and Virginia Apgar, Armand Bartos, William W. Bishop, Donald L. Blatter, William Carboni, Louis M. Condax, Fred Dautrich, Jean L. Dautrich, Louis Dunham, Jay C. Freeman, Louis Grand, Jerry Juzek, Otto Kaplan, Gordon McDonald, William E. Slaby.

Violinists. Charles F. Aue, Broadus Erle, William Kroll, Sonya Monosoff, Helen Rice, Louis E. Zerbe—and Samuel Applebaum, Catherine Drinker Bowen, Marjorie Bram, Ernestine Briemeister, Alan Branigan, Nicos Cambourakis, Roy B. Chamberlin Jr., Frank Clough, Louis M. Condax, Yoko Matsuda Erle, Sterling Gorrill, Walter Grueninger, Ann Haworth, H. T. E. Hertzberg, Carol Lieberman, Max Mandel, Max V. Mathews, David Montagu, Max Pollikoff, Bernard W. Robinson, Booker Rowe, Frances Rowell, Robert Rudie, Florence DuVal Smith, Jay C. Rosenfeld.

Violists. Robert Courte, Lilla Kalman, Maxwell Kimball, David Mankovitz, Louise Rood, Frederick A. Saunders —and John A. Abbott, Alice Schradieck Aue, Virginia Apgar, Emil Bloch, Harold Coletta, Helene Dautrich, John D'Janni, Lillian Fuchs, Raphael Hillyer, Henry James, Boris Kroyt, Eugene Lehner, Rustin McIntosh, John Montgomery, Elizabeth Payne, Werner Rose, David Schwartz, Emanuel Vardi, Eunice Wheeler, Bernard Zaslav, Sam Zaslavski, myself.

Cellists. Robert Fryxell, John C. Schelleng, India Zerbe—and Charles F. Aue, Joan Brockway, Roy B. Chamberlin, Frank Church, Elwood Culbreath, Oliver Edel, Maurice Eisenberg, George Finckel, Marie Goldman, Barbara Hendrian, Arnold Kvam, Russell B. Kingman, Charles McCracken, Stephen McGee, George Ricci, Peter Rosenfeld, Mary Lou Rylands, True Sackrison, Mischa Schneider, Sanford Schwartz, Joseph Stein, Mischa Slatkin, Joseph Tekula.

Bassists. Julius Levine, Alan Moore, Ronald Naspo, David Walter—and Alvin Brehm, John Castronovo, Garry Karr, Stuart Sankey, Charel Traeger, Howard Van Sickle, Ellery Lewis Wilson.

Composers and conductors. Henry Brant—and Marjorie Bram, Justin Connolly, Herbert Haslam, Frank Lewin, Marc Mostovoy, Harold Oliver, Quincy Porter, Cornelia P. Rogers, Leopold Stokowski, Arnold M. Walter.

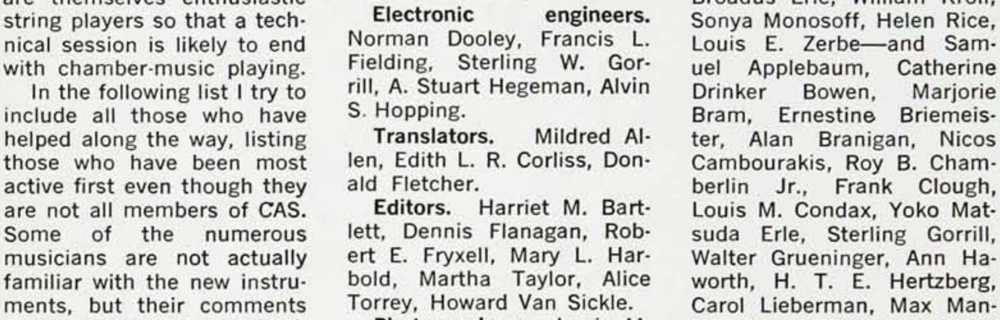
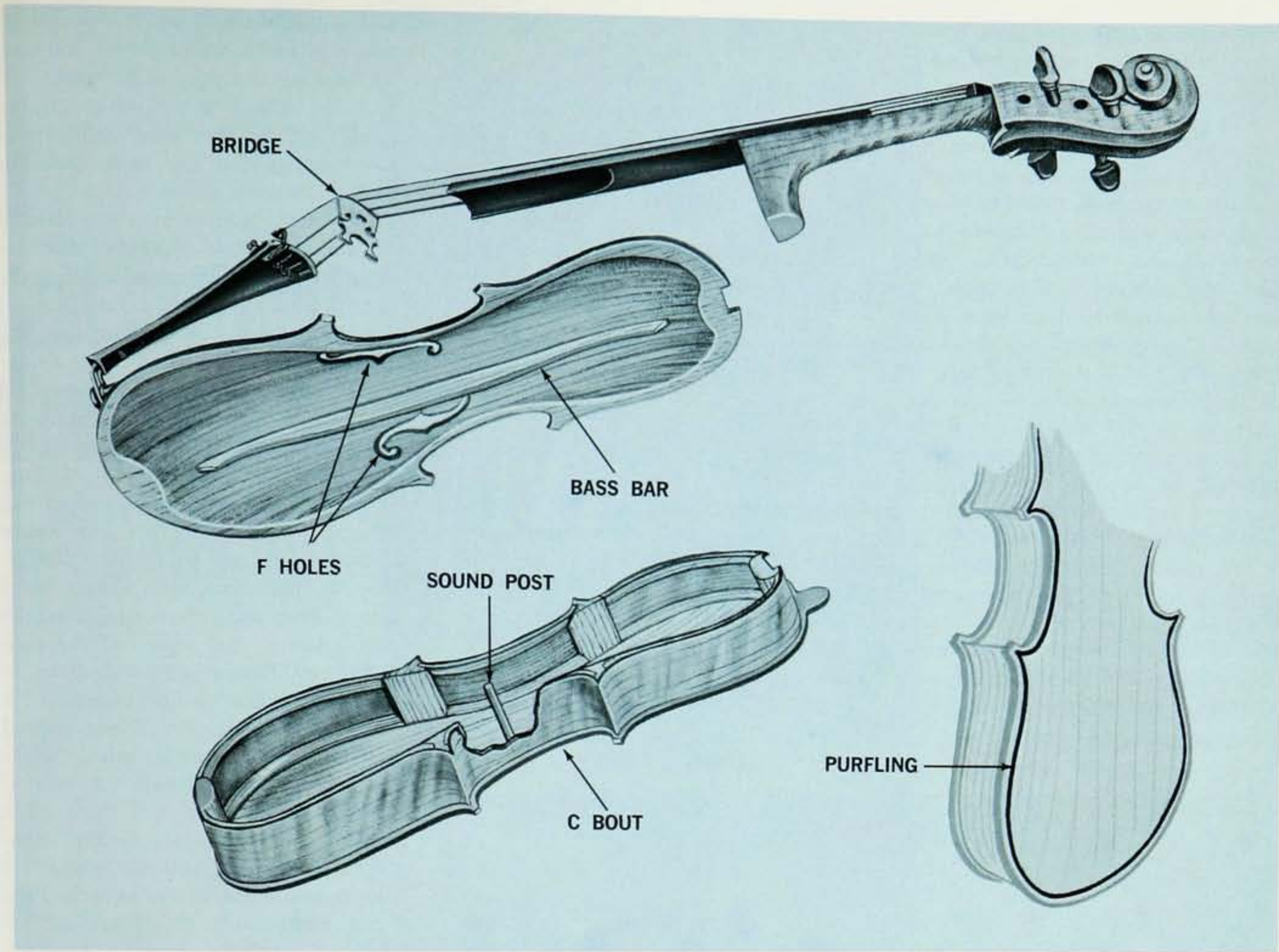


PHOTO BY J. KELLUM SMITH

REHEARSAL for a concert with Henry Brant conducting an octet of fiddles.



INSTRUMENT PARTS, except for scaling, have remained the same since master makers brought the violin to near perfection about three centuries ago. —FIG. 2

years' experimentation, the following four working guides were at hand:

1. location of the main body and main cavity resonances of several hundred conventional violins, violas and cellos tested by Saunders and others,[1, 4–9]

2. the desirable relation between main resonances of free top and back plates of a given instrument, developed from 400 tests on 35 violins and violas during their construction, [2,10,11]

3. knowledge of how to change frequencies of main body and cavity resonances within certain limits (learned not only from many experiments of altering plate thicknesses, relative plate tunings and enclosed air volume but also from construction of experimental instruments with varying body lengths, plate archings and rib heights) and of resultant resonance placements and effects on tone quality in the finished instruments,[2,4,11]

4. observation that the main body resonance of a completed violin or viola is approximately seven semitones (quarter notes) above the average of the main free-plate resonances, usually one in the top and one in the back plate of a given instrument.[2] This observation came from electronic plate testing of free top and back plates of 45 violins and violas under construction. It should not be inferred that the relation implies a *shift* of free-plate resonances to those of the finished instrument. The change from two free plates to a pair of plates coupled at their edges through intricately constructed ribs and through an off-center soundpost, the whole under varying stresses and loading from fittings and string tension, is far too complicated to test directly or calculate.[12]

What is good?

In developing the new instruments our main problem was finding a measurable physical characteristic of the violin itself that would set it apart from its cousins, the viola, cello and contrabass. The search for this controlling characteristic, unique to the violin, led us through several hundred response and loudness curves of violins, violas and cellos. The picture was at first confusing because many variations were found in the placement of the two main resonances. However, Saunders's tests on Jasha Heifetz's Guarnerius violin[13] showed the main-body resonance was near the frequency of the unstopped A 440-cycles-per-second string and the main cavity resonance at the unstopped D 294 string. Thus the two main resonances of this instrument were near the frequencies of its *two unstopped middle strings.*

Ten violins, selected on the basis that their two main resonances were within a whole tone of their two open middle strings, were found to be some of the most musically desirable instruments—Amatis, Stradivaris, Guarneris and several modern ones. In marked contrast to these were all violas and cellos tested, which characteristically had their main body and cavity resonances three to four semitones *above* the frequencies of their two open middle strings although they still had the same separation, approximately a musical fifth, between these two main resonances.

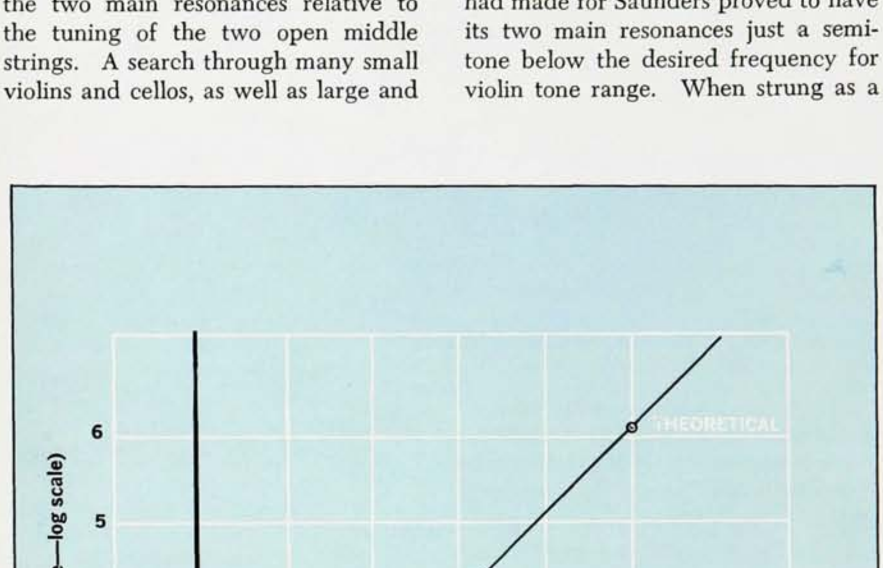
We reasoned that the clue to our problem might be this placement of the two main resonances relative to the tuning of the two open middle strings. A search through many small violins and cellos, as well as large and small violas, showed enormous variation in the placement of these two resonances. We hoped to find some instrument in which even one of these resonances would approximate what we wanted for the new instruments.

In one quarter-size cello the body resonance was right for viola tuning, D 294, but the cavity resonance was too low at D 147. We bought this chubby little cello and reduced the rib height nearly 4 in. (10 cm), thereby raising the frequency of the cavity resonance to the desired G 196. When it was put back together, it looked very thin and strange with ribs only 1.5 in. (3.8 cm) high and a body length of over 20 in. (51 cm), but strung as a viola it had tone quality satisfactory beyond expectations!

An experimental small viola that I had made for Saunders proved to have its two main resonances just a semitone below the desired frequency for violin tone range. When strung as a violin, this shallow, heavy-wooded instrument had amazing power and clarity of tone throughout its range. It sounded like a violin although the quality on the two lower strings was somewhat deeper and more viola-like that the normal violin.

The next good fortune was discovery and acquisition of a set of three instruments made by the late Fred L. Dautrich of Torrington, Conn., during the 1920's and '30's. He had described them in a booklet called *Bridging the Gaps in the Violin Family.*[14] His *vilonia,* with a body length of 20 in. (51 cm) was tuned as a viola and played cello-fashion on a peg. The *vilon,* or tenor, which looked like a half-size cello, was tuned an octave below the violin, G-D-A-E. His *vilono,* or small bass, with strings tuned two octaves below the violin, filled the gap between the cello and the contrabass. These represented three of the tone ranges we had projected for the new violin family. Tests showed that their resonances lay within working range of our theory. A year of work, adjusting top and back plate wood thicknesses for desired resonance frequencies and rib heights for proper cavity resonances in each of the three instruments gave excellent results. The vilono proved to have exactly the resonance frequencies projected for the enlarged cello, or baritone. So it was moved up a notch in the series and tuned as a cello with extra long strings.

Dautrich's pioneering work had saved years of cut and try. We now had four of the new instruments in playing condition; mezzo, alto (verti-



BODY LENGTHS for new instruments were determined by plotting lengths of known instruments against wavelength, then extending data in a smooth curve to include treble at one end and contrabass at the other. Identified points show where old and new instruments fall. —FIG. 3

cal viola), tenor and baritone. I was able to add a fifth by making a soprano, using information gained from many tests on three-quarter- and half-size violins.

With five of the new instruments developed experimentally and in playing condition, we decided to explore their musical possibilities and evaluate the overall results of our hypothesis of resonance placement. In October 1961 the working group gathered at the home of Helen Rice in Stockbridge, Mass., where Saunders and his associates had, for some years, met frequently to discuss violin acoustics and play chamber music. Short pieces of music were composed for the five instruments, and the musicians gave the new family of fiddles its first workout. The consensus was that our hypothesis was working even better than we had dared to hope! Apparently the violin-type placement of the two main resonances on the two open middle strings of each instrument was enabling us to project the desirable qualities of the violin into higher and lower tone ranges.

The next step was to explore the resonances of various size basses to help in developing the small bass and the contrabass. A small three-quarter-size bass with arched top and back proved to have just about proper resonances for the small bass. With removal of its low E 41 string and the addition of a high C 131 string to bring the tuning to A-D-G-C (basses are tuned in musical fourths for ease of fingering) it fitted quite well into the series as the small bass. But as yet no prototype for the contrabass could be located. This final addition to the series was to come later.

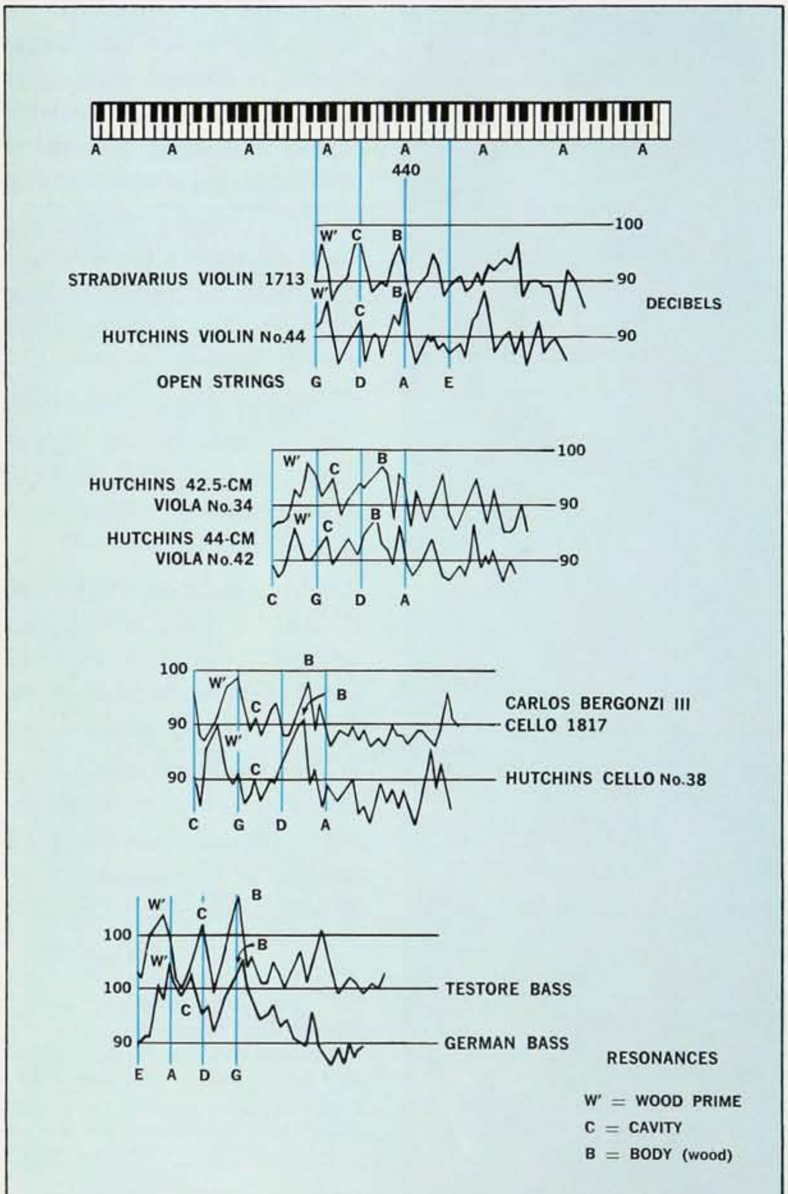
First musical success

By January 1962 we were ready for a real test in which experts could hear our six new instruments and compare them with good conventional violins, violas and cellos. Composers arranged special music, and professional players had a chance to practice on the new instruments.

Ensemble results exceeded all our expectations. We had violin-like quality and brilliance through the entire range of tones. Our soprano produced a high clear quality that carried well over the other instruments although the high positions on its two lower strings were weak. The mezzo tone was powerful and clear although somewhat viola-like on the two lower strings. The alto (vertical viola) was judged a fine instrument even with inadequate strings. The unique tone of the tenor excited all who heard it. The baritone produced such powerful and clear tones throughout its range that the cellist playing it in a Brahms sonata commented, "This is the first time I have been able to hold my own with the piano!" The small bass was adequate but needed more work. General comments told us that the new instruments were ready to stand on their own, musically, although much more work was to be done on adjustments, strings and proper bows.

End-of-scale problems

With the helpful criticisms and suggestions that came from the first musical test we were encouraged to



LOUDNESS CURVES are useful evaluations of instrument characteristics. Each is made by bowing an instrument to maximal loudness at 14 semitones on each string and plotting the resulting loudness ceiling against frequency of sound. —FIG. 4

tackle the problems of the largest and smallest instruments. No existing instruments could be adapted experimentally. We had to design and build them.

The largest bass available for testing was a huge Abraham Prescott, with a 48-in. (122-cm) body length, made in Concord, N.H., in the early 1800's but even that was not big enough! A tiny pochette, or pocket fiddle, from the Wurlitzer collection, with a body length of 7 in. (18 cm) had the right cavity resonance, but its body resonance was much too low.

The body length of each of the new instruments has been one of the controlling factors in all of our experiments. Thus it was decided that the best way to arrive at the dimensions for the largest and smallest would be to plot a curve of body lengths of known instruments, to check against their resonance placement and string tuning. This working chart is shown in figure 3 in which linear body length is plotted against the logarithm of wavelength. The curve for the new instruments was extended in a smooth arc to include the contrabass frequency at the low end and the treble frequency at the upper end, an octave above the normal violin. This procedure gave a projected body length of 51 in. (130 cm) for the contrabass and 10.5 in. (26.5 cm) for the treble. Of course rib height and enclosed air volume were separately determined by other considerations.

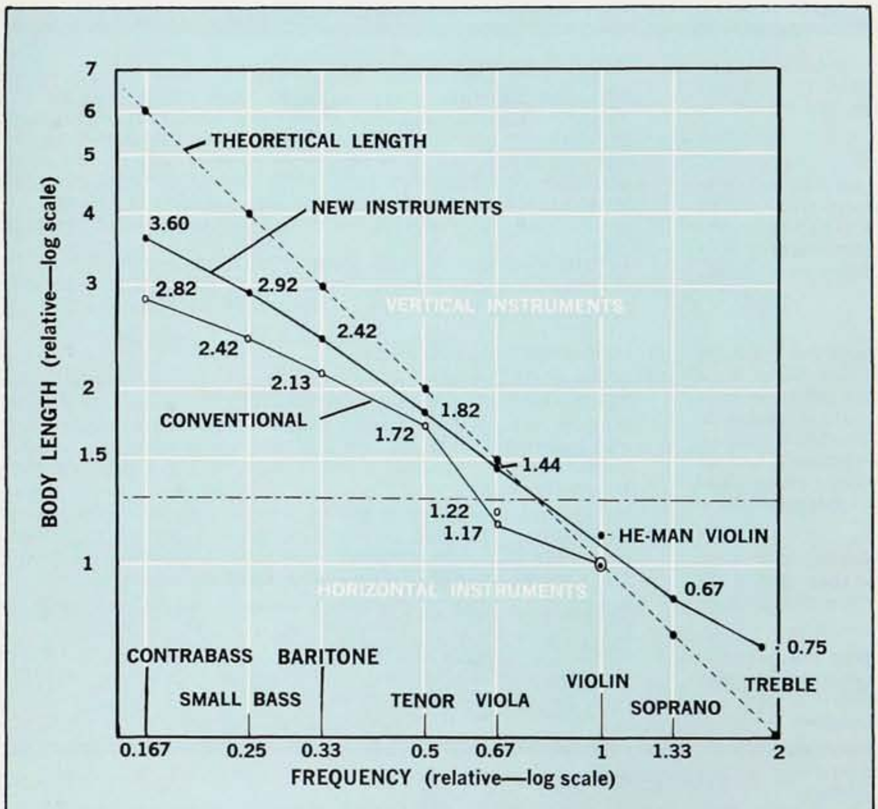
Current design practice

From all of this experience we have developed what we might call a "design philosophy." It depends mainly on resonance placement and loudness curves.

Our resonance principle, according to which each member of the new violin family has been made, can be stated as follows: The main body resonance of each of the instruments tuned in fifths is placed at the frequency of the open third string, and the main cavity resonance at the frequency of the open second string. Another way of stating the principle, and one that includes the instruments tuned in fourths as well as those tuned in fifths, is this: Wood prime is placed two semitones above the lowest tone, and the cavity resonance is a fourth above that. (Wood prime is the strengthened frequency one octave below the main body—"wood"—resonance.) These conditions are exemplified in Heifetz's Guarnerius violin and many other good ones, but they are not found in all good violins.

The loudness curve developed by Saunders is one of our most useful measures for evaluating overall instrument characteristics. We make such a curve by bowing an instrument as loudly as possible at 14 semitones on each string and plotting maximal loudness against frequency. Despite unavoidable variations in any test that requires a musician to bow an instrument, the loudness curve is significant because there is a fairly definite limit to the momentary volume an experienced player can produce with a short rapid bow stroke.

As you will see in figure 4, the loudness ceiling varies for each semitone on a given instrument. The curves of this figure were made by bowing each instrument without vibrato at a constant distance from a sound meter. From them you can see the placement of main body and cavity resonances in eight conventional instruments—two violins, two violas, two cellos and two basses. You can see that in the violins the wood prime adds power to the low range of the G string. In the violas, cellos and basses the two main resonances, which are higher in frequency relative to string tuning, create



SCALING FACTORS for old and new instruments are a useful reference guide for designers. —FIG. 5

a condition of somewhat weaker response on the lowest four or five semitones.

Fitting fiddles to players

After you decide what kind of acoustics you want, you still have another problem: You have to make fiddles that people can play. For years we worked toward design of an acoustically good instrument with genuine viola tone. Meanwhile we had to keep in mind such conflicting requirements as large radiating areas in the plates and adequate bow clearance in the C bouts (figure 2). Relation of string length to other dimensions that define tone spacing on the fingerboard —the violin maker's "mensure"—is another consideration important to the player. With our acoustic pattern as a model we undertook enlarging, scaling and redesigning all our new instruments, always keeping violin placement of resonances in each tone range.

From our set of experimentally adapted instruments, which represent a variety of styles and designs in violin making, we had learned many things. The vertical viola was about right in body dimensions, but its strings were too long for viola fingering and too short for cello fingering. The tenor was too small, and the cellists were asking for it to have strings as long as possible. The baritone was right for body size, but it had much too long strings. The bass players were asking for a long neck on the small bass and a short one on the large bass with string lengths as close as possible to conventional.

From such comments we realized that there were two basic designs for ease of playing in relation to string lengths and overall mensure of each instrument. Controlling factor in the instrument mensure is placement of the notches of the f holes because a line drawn between these two points dictates the position of the bridge and the highest part of the arch of the top plate. Mensure for the tenor and small bass would need to be as great as possible and for the vertical viola and baritone it would need to be as small as possible. Since the relative areas of the upper and lower bouts are critical factors in plate tuning, adjustment of these mensures posed quite a set of problems.

We developed a series of scaling factors[3] based on relative body length, relative resonance placement and relative string tuning that could be used as a reference guide in actual instrument construction. Figure 5 shows the set which has proved most useful in making the eight new instruments as well as those of conventional instruments.

We had a problem in measuring responses of plates of many sizes—all the way from the 10.5-in. (26-cm) one of the treble violin to the 51-in. (130-cm) one of the contrabass. We solved it by redesigning our transducer from a magnet-armature to a moving-coil type. Then the wooden fiddle plate, suspended at its corners by elastic bands, was made to vibrate as the cone of a loudspeaker (figure 6).

Using the know-how developed in making and testing several hundred violin, viola and cello plates, I could tune the plates of new instruments so that not only did each pair of top and back plates have the desired frequency relation,[2] but it also had its wood thicknesses adjusted to give a reasonable approach to what would be an optimal response.[15]

As a starting guide in adjusting plate frequencies I used the finding that a seven-semitone interval should separate the main body resonance of the finished violin from the average of the two frequencies of the free plates. It was soon obvious, however, that this relationship was not going to hold as the instruments increased in size. As the instrument gets larger the interval becomes smaller, but we do not have enough data yet to make a precise statement about it.

We used scaling theory and the three basic acoustical tools of scientific violin making: (a) frequency relationship between free top and back plates, (b) optimal response in each plate and (c) interval between body resonance and average of free-plate frequencies. We are able not only to create new instruments of the violin family but also to improve the present members. But we have to combine the acoustical tools with the highest art of violin making.

Traits of family members

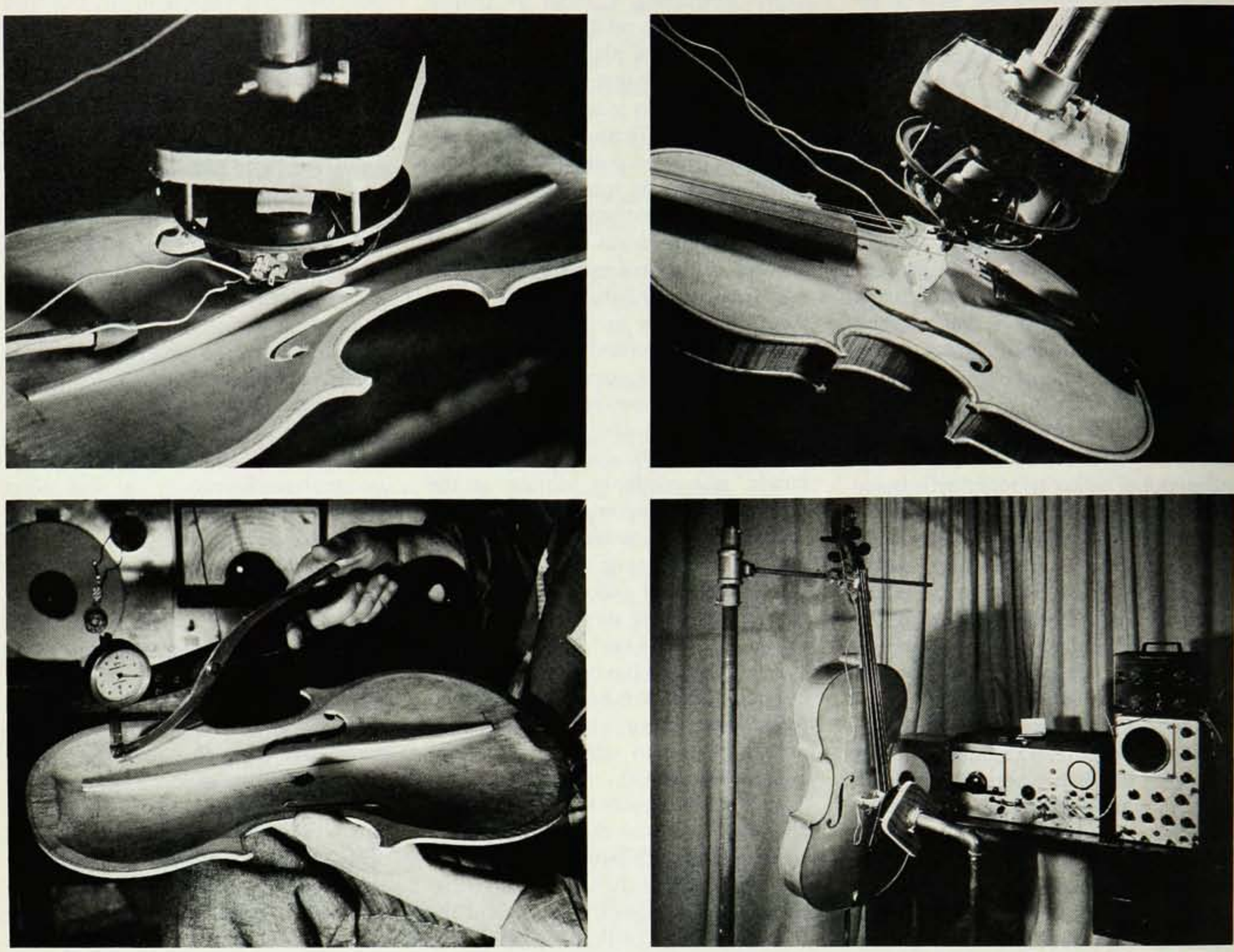
Any family has its resemblances and its differences. So it is with our violins. They make a family (figure 7) with basic traits in common. But they also have their own personalities.

Treble (G-D-A-E). The main problem with our treble has been to get the frequencies of body and cavity resonances high enough and still keep the mensure long enough for a player to finger consecutive semitones without having to slide his fingers around. We projected a theoretical body length of 10.5 in. (26.7 cm) and a string length of 10 in. (25.4 cm), but to have the proper cavity resonance in this size body, the ribs would be only 3 mm high—a potentially dangerous structural condition! Besides we knew of no string material that could be tuned to E 1320 at a length of 25.4 cm without breaking. At one point we thought we might have to resort to a three-stringed instrument in this range as was indicated by Michael Praetorius in 1619.[16]

The cavity-resonance problem was solved by making six appropriately sized holes in the ribs to raise its frequency to the desired D 587. A string material of requisite tensile strength to reach the high E 1320 was finally found in carbon rocket wire, made by National Standard Company. This proved suitable not only for the high E string but for a number of others on the new instruments. As a temporary measure the ribs were made of soft aluminum to prevent the holes from unduly weakening the structure. Redesign should eliminate the nasal quality found on the lower strings and improve the upper ones. Despite this nasal quality many musicians are pleased with the degree in which the upper strings surpass the normal violin in the same high range.

Plans are to redesign this instrument in several different ways in an effort to discover the best method of achieving desired tone quality throughout its entire range.

Soprano (C-G-D-A). The soprano was designed to have as large a plate area as possible, with resulting shallow ribs and fairly large f holes to raise the cavity resonance to the desired G 392. The overall tone has been judged good and is most satisfactory on the three upper strings. The instrument needs redesign, however, for a better quality on the lower strings. The mensure is as long as possible for playing convenience. J. S. Bach wrote for an in-



PHOTOS BY PETER PRUYN

TESTING FIDDLES. New techniques enable today's makers to achieve results their predecessors could not produce. Redesigned transducer measures response of plate that is made to vibrate like a loudspeaker cone in operation. —FIG. 6

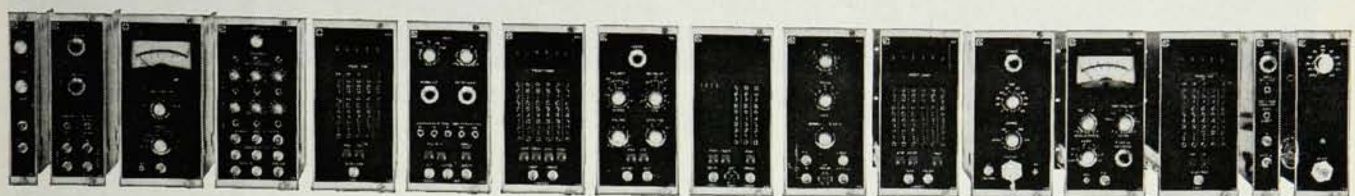
strument in this tuning, which Sir George Grove describes in Grove's dictionary:[17] "The violino piccolo is a small violin, with strings of a length suitable to be tuned a fourth above the ordinary violin. It existed in its own right for playing notes in a high compass. . . .It survives as the 'three-quarter violin' for children. Tuned like a violin, it sounds wretched, but in its proper pitch it has a pure tone color of its own, for which the high positions on the ordinary violin gave no substitute."

Mezzo (G-D-A-E). The present mezzo with a body length of 16 in. (40.5 cm) was added to the new violin family when musicians found that even an excellent concert violin did not have the power of the other members of the group. According to scaling theory[18] this instrument, which is 1.14 times as long as the violin, has somewhat more power than necessary to match that of the others. So a second instrument has been developed that is 1.07 times as long as the violin. It has violin placement of resonances yet is adjusted to have conventional violin mensure for the player.[19] It has more power than the normal violin and seems most satisfactory. In fact several musicians have indicated that it may be the violin of the future.

Alto (vertical viola) (C-G-D-A). The greatest difficulty with the alto is that it puts the trained viola player at a distinct disadvantage by taking the viola from under his chin and setting it on a peg, cello fashion on the floor. Even with an unusual body length of 20 in., its mensure has been adjusted to that of a normal 17.5-in. (44.5-cm) viola, and some violists with large enough physique have been able to play it under the chin. Cello teachers have been impressed by its usefulness in starting young children on an instrument that they can handle readily as well as one they can continue to follow for a career. The greatest advantage is the increase in power and overall tone quality.[20] Leopold Stokowski said when he heard this instrument in concert, "That is the sound I have always wanted from the violas in my orchestra. No viola has ever sounded like that before. It fills the whole hall."

Tenor (G-D-A-E). The body length of the tenor was redeveloped from the Dautrich vilon which had a length ratio of 1.72 to the violin. The pres-

Nuclear-Chicago's new RIDL® Research Series standard nuclear instrument modules conform to the AEC standard, but they're really not the same as all the others.



So why break a matched set?

AEC Report TID-20893 says that our Research Series modules, like everyone else's, should mount in standard bins, connect to standard power supplies, and be built to standard dimensions.

But there are other dimensions—besides the physical ones—to our Research Series modules. First of all there's the wide range of modules we offer. Just about everything you'd need, to do just about anything you'd want: amplifiers, timers, scalers, ratemeters, analyzers, high-voltage power supplies, pulse generators, discriminators, bins with power supplies, and more to come.

Another measure of the value of the Research Series is our depth of experience in doing just this sort of thing. We designed and manufactured the first family of modular nuclear instruments—the RIDL Designer Series™—still up-to-date, still available, and, of course, signal-compatible with the new Research Series modules. From this background, we've combined performance-proved design with carefully considered advances in circuitry to give you the Research Series.

Here's the final—and quite practical—point we want to make about the Research Series modules as they relate to your work. We'll go to great lengths to see to it that you get exactly what you want in nuclear instrumentation. To give you a system that's project-matched to your growing needs. To help you expand or change your system when you're ready.

If you'd like detailed specifications on the Research Series, call your Nuclear-Chicago sales engineer. Or write to us.

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THE WHOLE FAMILY poses for pictures with performers trying them out. —FIG. 7

MAX POLLIKOFF treble | ERNESTINE BREIMEISTER soprano | LILLA KALMAN mezzo

ent tenor has a ratio of 1.82 with other factors adjusted accordingly, and the strings as long as possible for convenience in cello fingering. Many musicians have been impressed with its potential in ensemble as well as solo work. They are amazed to find that it is not a small cello, musically, but a large octave violin.

The main problem for this instrument is that there is little or no music for it as yet. Early polyphonic music, where the tenor's counterpart in the viol family had a voice, has been rearranged for either cello or viola. It has no part in classical string or orchestral literature, and only a few contemporary compositions include it. Grove[17] has this to say: "The gradual suppression of the tenor instrument in the 18th century was a disaster; neither the lower register of the viola nor the upper register of the violoncello can give its effect. It is as though all vocal part music were sung without any tenors, whose parts were distributed between the basses and contraltos! It is essential for 17th century concerted music for violins and also for some works by Handel and Bach and even later part-writing. In Purcell's *Fantasy on One Note* the true tenor holds the sustained C. . . The need for a real tenor voice in the 19th century is evidenced by the many abortive attempts to create a substitute."

Baritone (C-G-D-A). The body resonance of our baritone is nearly three semitones lower than projected, and this departure probably accounts for the somewhat bass-like quality on the low C 65.4 string. Its strings are 0.75 in. (1.8 cm) longer than those of the average cello. One concert cellist said after playing it for half an hour, "You have solved all the problems of the cello at once. But I would like a conventional cello string length." Thus a redesign of this instrument is desirable by shortening the body length a little. This redesign would raise the frequency of the body resonance and at the same time make possible a shorter string.

Small bass (A-D-G-C). Our first newly constructed instrument in the bass range is shaped like a bass viol with sloping shoulders, but has both top and back plates arched and other features comparable to violin construction. This form was adopted partly to discover the effect of the sloping shoulders of the viol and partly because a set of half-finished bass plates was available. The next small bass is being made on violin shape with other features as nearly like the first one as possible. Bass players have found the present instrument has a most desirable singing quality and extreme playing ease. They particularly like the bass-viol shape. It has proved most satisfactory in both concert and recording sessions.

Contrabass (E-A-D-G). Our contrabass[21] is 7 ft (210 cm) high overall; yet it has been possible to get the string length well within conventional bass mensure at 43 in. (110 cm) so that a player of moderate height has no trouble playing it except when he reaches into the higher positions near the bridge. For sheer size and weight it is hard to hold through a 10-hr recording session as one bassist did. When it was first strung up, the player felt that only part of its potential was being realized. The one constructional feature that had not gone according to plan was rib thickness. Ribs were 3 mm thick, whereas violin making indicated they needed to be only 2 mm thick. So the big fiddle was opened; the lining stripes cut out, and the ribs planed down on the inside to an even 2 mm all over—a job that took 10 days. But when the contrabass was put together and strung up, its ease of playing and depth of tone delighted all who played or heard it. Henry Brant commented, "I have waited all my life to hear such sounds from a bass."

How good are they really?

All who have worked on the new instruments are aware of the present lack of objective tests on them—aside from musician and audience comments. In the near future we plan to compare comments with adequate tonal analyses and response curves of these present instruments as well as new ones when they are made. The

STERLING HUNKINS alto **PETER ROSENFELD** tenor **JOSEPH TEKULA** baritone **DAVID WALTER** small bass **STUART SANKEY** contrabass

only objective evaluation so far comes from A. H. Benade at Case Institute: "I used my 100-W amplifier to run a tape recorder alternately at 60 and 90 cps while recording a good violin with the machine's gearshift set at the three nominal 1-, 3.5- and 7.5-in/sec speeds. This was done in such a way as to make a tape which, when played back at 3.5 in/sec, would give forth sounds at the pitches of the six smaller instruments in the new violin family (small bass and contrabass excluded). There were some interesting problems about the subjective speed of low- compared with high-pitch playing, but the musician was up to it and we managed to guess reasonably well. The playing was done without vibrato. It is a tribute to everyone involved in the design of those fiddles that they really do sound like their scientifically transposed cousin violin."

But as yet we know only part of *why* this theory of resonance placement is working so well. Probing deeper into this "why" is one of the challenges that lie ahead. Still unsolved are the problems of the intricate vibrational patterns within each free plate as compared to those in the assembled instrument; the reasons for the effect of moisture and various finishes on the tone of a violin and the possibility of some day being able to write adequate specifications for a fabricated material that will equal the tone qualities of wood!

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