INSTRUCTION MANUAL

THE COLVIG-HARRISON MONOCHORD

THE C&H MONOCHORD WAS DESIGNED specifically for the study of intonation. Any known ratio in an existing mode or an invented one can be produced. Also sounds can be tested and analyzed so that the mode of an existing rendition of music or the built-in setting of instrumental frets, bored holes, etc. can be determined.

Accuracy was of prime consideration in the design. The handmade construction, though not of industrial "laboratory standards," is quite accurate for the purpose; the tones come out to within a cent or so of the desired frequency if the tool is operated carefully.

A "tool" our monochord is, more than a "musical instrument," since its use is not directly for the production of music.

The meter-span string of .010" steel wire tunes well at E-165 vibrations per second. (If desired it can be tuned down to D or even C or up to G. A-220 is almost at the breaking point so is not recommended.) The A-440 point marked on the monochord gives the proper open-string E-165.

To test the monochord for accuracy first measure the effective string length with an accurate meter scale. Our tool should be within $\frac{1}{10}$mm of the 1000mm length or .0001 meter tolerance. Next, set the sliding bridge exactly on the center line. Be sure to pull the bridge toward you to fully contact the front rim of the monochord. Press straight down on the penny just firmly enough to hold the string for strumming then lightly strum the string first on one side of the bridge and then on the other. There should be no beats; the pitches should match exactly. Now try pushing down hard, try pressing a little sideways, try moving off-line a little each way — the proper operation will be apparent. The monochord is strongly built but will deflect if too much pressure is applied. Sideways pressure stretches the string on one and loosens it on the other, throwing the pitch off considerably. A too-strong strum will have the same effect.

Our monochord has two main functions, one on the right-hand side and the other on the left. The right-hand function is that of the monochord found in the physics lab — the demonstration of the natural harmonic series. (The terms "harmonic" and "overtone" both tend to lead to numerical confusion so we shall avoid using them and say "partial" to denote the number of parts of string we are causing to vibrate.) Our instrument has surface markings for the first 12 partials and more can be explored. The first partial is the tone produced by the vibration of the "string in one part" — the whole string, expressed as the ratio 1/1 of string length pitch. The second partial results from the dividing of the string into two parts or, in other words, the vibrating of half of the string; the third partial, one third of the string, etc. (Ratios for these are 2/1, 3/1, etc.) Lightly touching at these points while bowing or plucking the string will cause the tones to sound. This series is nature's Rule of the Arts of Sound. It is a beautiful, simple — and endless — font of tonal and rhythmic relations. It is "signal," as opposed to "noise." It is built into us as it is into the rest of the world. Inner and outer are the same; we have physiological recognition of this series that occurs also outside of us.

The other main function of our monochord is, of course, the principal one already stated — the study of intonation. Since an octave encompasses all possible musical pitches and since one half of the string gives an octave we only need to use a half, in this case the left half. (Exception: when studying a tone too close to full string length for the slider to accommodate, the right-hand side can be used, giving the octave-higher tone.) A "Mode Strip" is used to mark the positions at which to place the slider in order to produce the string lengths and resultant tonal relationships desired. One of these accompanies this monochord, and you will note that it is made of multi-ply art board. This resists length changes caused by humidity and temperature variations better than ordinary paper or cardboard; thin metal or plastic would be even more stable but are hard to mark.

In laying out the mode on the strip one can use either of two basic tonal relationship approaches and one can mix them, too. (Also there are two different ways of doing the mathematics. We'll start with one of them.) In the first basic approach we work from tone to tone. Let us take as example the Syntonon (Intense) Diatonic mode which appears on your strip. Ptolemy, who first wrote it down and published it during the 2nd century in Alexandria, gave it in the following form: ↓ 10/9 ↓ 9/8 ↓ 16/15 ↓ 9/8 ↓ 10/9 ↓ 9/8 ↓ 16/15. (Note: 10/9 is the usual manner in which a musical ratio is written, rather than the arithmetical 10:9. The larger number is always put on top. Don't forget that our ratios are ratios, not fractions, and cannot necessarily be manipulated as fractions. The written ratio should have the slanted dividing line to distinguish it from the the level line in the fractions: 10/9, $\frac{10}{9}$.)

Now, more easily to make a strip, ratios should be arranged in ascending order. Thus: ↑ 16/15 ↑ 9/8 ↑ 10/9 ↑ 9/8 ↑ 16/15 ↑ 9/8 ↑ 10/9. We begin: Our string is 1000mm long and the tone it produces is 1/1 ratio of the string tone. We divide this length into 16 equal parts and find next that one part equals 62.5mm. Now we deduct this from the 1000mm and have a New String Length of 937.5mm, which represents the "15" part of the ratio, so that when we play the open string and then this new length we are playing 15 to 16, and (if you have tuned the string to E-165) the cycles per second being sounded are $\frac{16}{15}$ times 165 or 176 cps. (Note that when ascending the scale the string gets shorter as the tone frequency goes higher; therefore, the frequency ratio is upside-down from the string ratio when ascending.) So we see, in other words, that the old string length would vibrate 15 times in the same time that the new string length would vibrate 16 times and that the lengths themselves are in a 16-15 relationship so that it all goes together. Now to go on to the next tone; it is important to realize that we have a New String Length of 937.5mm — just forget the original length now; it is no longer useful. We divide this new length into 9 parts, giving us 104.166mm (plus infinite sixes, to be exact) and deducting one such part from the new length of 937.5mm we get 833.333mm (plus infinite threes) which represents the 9/8 above the 16/15. This becomes the new New String Length in turn and we may proceed in this way up to the 2/1, the octave, which concludes the mode, successively "chopping off" or dividing off segments until the octave is reached, which, being at the exact center of the string, is at the 500mm mark. (Physically, of course, we can mark only to within about a quarter of a millimeter in accuracy; a half of a millimeter discrepancy gives about 1½ cents at center-string and that is relatively indiscernable to the ear. As we go lower in tone by lengthening the string the tonal accuracy goes higher and higher.) Here is the rest of this modal computation: Tone #3 was at 833.33mm and we have 10/9 ratio to the next tone so $\frac{1}{10} \times 833.33 =$ 83.33mm. $833.33 - 83.33 = 750.00$mm, our next New String Length or tone #4. $750.00 - \frac{1}{9} \times 750.00 = 750.00 - 83.33 = 666.66$mm, tone #5. $666.66 - \frac{1}{16} \times 666.66 = 666.66 - 41.66 = 625.00$mm, tone #6. $625.00 - \frac{1}{9} \times 625.00 = 625.00 - 69.44 = 555.55$mm, tone #7. $555.55 - \frac{1}{10} \times 555.55 = 555.55 - 55.55 =$ 500.00mm, or octave, or tone #8.

N.B. — An Old-Fashioned Method for Adding and Subtracting Ratios —
To add; multiply across and reduce. Taking the first two ratios of the above mode, for example; add 16/15 to 9/8:

$$\frac{16}{15} \longleftrightarrow \frac{9}{8} = \frac{144}{120} = \frac{6}{5}$$

To subtract; multiply "criss-cross" and reduce. For example, find the difference ratio between 3/2 and 5/4:

$$\frac{3}{2} \bowtie \frac{5}{4} = \frac{12}{10} = \frac{6}{5}$$

This method has the distinction of having been printed by Sir John Hawkins, in 1776.

The second basic approach in finding the positions along the string for the tones desired is to refer each tone back to the basic open string (1/1). We note that the first two ratios in the mode we were setting up add up to 6/5. Thus it is possible to mark the third degree ("tone #3") directly up from the 1/1 by dividing the 1000mm by six and then deducting one sixth to get the "5" of the 6/5 — you will find that the results will be the same. As previously mentioned, the methods may be mixed.

Now we'll look at another way to do the mathematics, this strictly from a mathematical point of view. Since the length of string is inversely proportional to the frequency of tone produced, simply inverting the ratio will give the fractional proportion of the string for the next tone in upward order. Thus, with our Syntonon (Intense) Diatonic mode, we start again with 1000mm of string and wishing to go up 16/15 we simply take fifteen sixteenths of 1000 and that comes out 937.5mm. With simple proportions like these, longhand arithmetic works out very easily as you shall see, while with more complicated ratios longhand is tedious and error-prone so that other methods can be very advantageous. The slide rule is fast and may be accurate enough for most studies, logarithms are more accurate and more work, electronic calculators can really do the job in a hurry and quite accurately if you add enough zeros. The more digits capacity, the more accuracy, of course. Here's how our same mode comes out on a minimum 6-digit calculator, used to full capacity: $100.00 \times \frac{15}{16} = 937.50$ and now add a zero for more accuracy so 937.500 $\times \frac{8}{9} = 833.328$ (supposed to be 833.333). $833.328 \times \frac{9}{10} = 749.988$ (should be 750mm exactly), now times $\frac{8}{9} = 666.656$ (should be 666.666) now times $\frac{15}{16} = 624.990$ (should be 625mm), now times $\frac{8}{9} = 555.544$ (should be 555.555) and finally that times $\frac{9}{10} = 499.986$. As you can see, we are too close to quibble, the farthest we get off was $\frac{1}{10}$mm. When using longhand, hold on to your fractions and everything comes out nicely:

1st Degree ↑ 16/15 to 1000mm times $\frac{15}{16}$= 1000 × $\frac{15}{16}$=	2nd Degree ↑ 9/8 to 937.5mm times $\frac{8}{9}$ = $\frac{15000}{16}$ $\frac{\cancel{15000}^{5000}}{\cancel{16}_{2}} \times \frac{8}{\cancel{9}_{3}} =$
3rd Degree ↑ 10/9 to 833.33mm times $\frac{9}{10}$ = $\frac{5000}{6}$ $\frac{\cancel{5000}^{500}}{\cancel{6}_{2}} \times \frac{\cancel{9}^{3}}{\cancel{10}_{1}} =$	4th Degree ↑ 9/8 to 750mm times $\frac{8}{9}$ = $\frac{1500}{2}$ $\frac{\cancel{1500}^{500}}{\cancel{2}_{1}} \times \frac{\cancel{8}^{4}}{\cancel{9}_{3}} =$
5th Degree ↑ 16/15 to 666.66mm times $\frac{15}{16}$ = $\frac{2000}{3}$ $\frac{\cancel{2000}^{1000}}{\cancel{3}_{1}} \times \frac{\cancel{15}^{5}}{\cancel{16}_{8}} =$	6th Degree ↑ 9/8 to 625mm times $\frac{8}{9}$ = $\frac{5000}{8}$ $\frac{5000}{\cancel{8}_{1}} \times \frac{\cancel{8}^{1}}{9} =$
7th Degree ↑ 10/9 to 555.55mm times $\frac{9}{10}$ = $\frac{5000}{9}$ $\frac{\cancel{5000}^{500}}{9} \times \frac{9}{10} =$	8th Degree 500mm 500

If you wish to work in downward order, simply use the ratios as fractions to reach your next new length, thus: 500mm times $\frac{16}{15}$ equals 555.55mm and that times $\frac{8}{9}$ equals 625mm etc.

To note down and study any existing tuning as heard from a pre-tuned instrument (holes, frets, valve arrangements, etc.) or actual music being played whether live or recorded: Put a blank strip down against the upper rim on the left side of the monochord so that the pointer falls on the strip. Mark the center (or 500mm) line. Move the sliding bridge until you have matched the tone you hear and want to log and then mark the strip at the end of the pointer. In this way you may locate whatever tones you wish to study. A cent scale adjusted to our 500mm string length octave will enable you to determine how many cents "wide" the interval is, and thus locate its nearest ratio equivalent if it is not indeed already an exact ratio.

The tones marked on the mode strips may be transferred by ear, matching tone by tone, to some suitable stringed instrument; a harp is very good, or psaltery, or harpsichord, or some such instrument giving a wide range for serious musical study.