SOURCE

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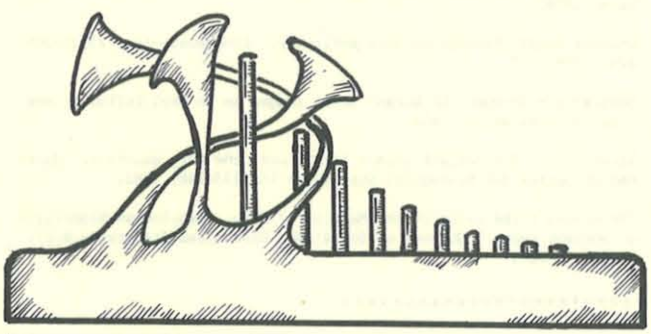
# EXPERIMENTAL MUSICAL INSTRUMENTS

FOR THE DESIGN, CONSTRUCTION AND ENJOYMENT OF NEW SOUND SOURCES

There have been a couple of noteworthy responses to the article, "Slit Drums and Boos" which appeared in the last issue of EMI. The article considered the question of whether it is possible to create a tongue drum of many tongues tuned to a preordained scale. It concluded that, for reasons having to do with interference between tongues of different frequency on the same drum, it is not. But both Michael Thiele and Stephen Smith have checked in with evidence to the contrary. They report that they have had great success with tongue drums accurately tuned to a variety of scales. Thiele, in a telephone conversation, said that he is aware of some of the problems discussed in the article, and also that some tunings are more problematic than others. But, he said, through a number of techniques, a sympathetic feeling for the wood, and a strong dose of good instinct, he is able to produce finely-tuned drums of full, rich tone. Stephen Smith felt that the problems described in the article were greatly exaggerated, and gives his reasons in his letter appearing on page two.

On another subject -- we have often thought it would be a good idea occasionally to run articles in EMI on lesser-known traditional instruments which, for one reason or another, could be of special interest to new instruments people. In this issue, for the first time, we have such an article. It discusses an instrument with a most peculiar and thought-provoking sound-generating system, the Lesiba of southern Africa. Charles Adams has studied the Lesiba and its culture extensively, and is currently writing a book on the subject. His excellent article follows below.



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## WIND, BREATH AND STRINGS ROUND AND FLAT

By Charles R. Adams

Many of the current explorations into new musical instruments have the refreshing advantage of being unencumbered by histories and conventions. Some approaches have no known precedents while others have recovered the excitements of long-neglected techniques. Creative development of the full spectrum of acoustical and musical potentials which is evident in these activities, and to which EMI is so delightfully devoted, stimulates our imagination (or, rather, musement) and greatly enhances our musical sensibilities. Musical explorers are increasing our understanding and making it possible to listen with new ears to instruments which have enjoyed long histories of

(continued on page 3)

## CALCULATING FREQUENCIES FOR EQUAL TEMPERED SCALES

In the following article, Christopher Banta provides the basic mathematics necessary for finding the frequencies for the pitches of equal tempered scales.

The overwhelmingly predominant scale system currently used in Western music is twelve-tone equal temperament. In 12-equal, we divide the distance between any two notes that are an octave apart into twelve equal steps. To make sense of that statement, though, we have to define 'equal.'

As a general rule, the human ear seems to hear equal increments in pitch when the frequency of each succeeding pitch in a series (i.e., a scale) is equal to the frequency of the preceding pitch multiplied by a constant:

$F1 \times C = F2$; $F2 \times C = F3$, and so forth.

This is a psycho-acoustic fact more than it is a purely mathematical one, and there are exceptions and ambiguous cases -- but it nonetheless serves as the basis for our mathematical calculations in generating scale systems.

If we are to have twelve equal scale steps to the octave, the constant described above must be such that when it is applied twelve times in succession the final pitch is indeed an octave above the starting pitch. The ear hears two pitches as being an octave apart when the frequency of the higher is twice that of the lower; thus the twelve applications of the constant must have the effect of doubling the frequency of the starting pitch:

$F1 \times C = F2$; $F2 \times C = F3 \ldots\ldots F12 \times C = 2(F1)$

In his article, starting below, Chris Banta shows how to find and apply this constant, first for twelve equal, and then for more exotic equal temperaments. In a coming article slated for one of the future issues, Banta will cover conversion of frequency to cents (cents is the logarithmic unit for fine pitch measurement widely used on tuning devices and in writings on intonational systems).

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## SCALES AND THEIR MATHEMATICAL FACTORS

By Christopher Banta



The twelve tone scale used in Western music is based on a mathematical factor. When properly applied this factor will yield an equal tempered scale of twelve notes to the octave. These twelve notes, having been systematically laid out, are used on the piano keyboard and on the guitar fingerboard, as well as other on instruments.

### THE FACTOR

The factor can be determined by finding the 12th root of two, which is expressed as $\sqrt[12]{2}$ What this equation says is, "What times itself twelve times equals two?"

$$\sqrt[12]{2} = 1.0594631$$

This calculation can be performed on a scientific calculator with a $\sqrt[x]{y}$ function key.

$\boxed{1}$ $\boxed{\sqrt[x]{y}}$ $\boxed{1}$ $\boxed{2}$ $\boxed{=}$ 1.059631

$$\sqrt[12]{2}$$

The RADICAL corresponds to the number of notes per octave.

The RADICAND refers to the magnitude of a quantity, in this case the halving or doubling of frequency from octave to octave.

For example: Middle C vibrates 261.63 times in one second (Hz). Doubling it would cause it to vibrate at 523.25Hz, which is C an octave above. Halving middle C would bring it down to 130.8 Hz -- one octave below.

If we take the number "1" and multiply it by the factor (1.0594631) we have a total of 1.0594631. Multiply that result by the factor again and we get 1.122462. When we repeat the process twelve times we arrive at two.

| | | | | | | |
|---|---|---|---|---|---|---|
| (1) | 1.0000000 | × | 1.0594631 | = | 1.0594631 | (2) |
| | 1.0594631 | × | 1.0594631 | = | 1.122462 | (3) |
| | 1.122462 | × | 1.0594631 | = | 1.1892071 | (4) |
| | 1.1892071 | × | 1.0594631 | = | 1.2599209 | (5) |
| | 1.2599209 | × | 1.0594631 | = | 1.3348397 | (6) |
| | 1.3348397 | × | 1.0594631 | = | 1.4142134 | (7) |
| | 1.4142134 | × | 1.0594631 | = | 1.4983069 | (8) |
| | 1.4983069 | × | 1.0594631 | = | 1.5874008 | (9) |
| | 1.5874008 | × | 1.0594631 | = | 1.6817925 | (10) |
| | 1.6817925 | × | 1.0594631 | = | 1.7817974 | (11) |
| | 1.7817974 | × | 1.0594631 | = | 1.8877481 | (12) |
| | 1.8877481 | × | 1.0594631 | = | 2.0000000 | (1) |

Logarithmic

By doing this we have created a geometric progression of twelve equal steps from our starting number, one, to its double, two. The twelve steps correspond to the ratios of the frequencies of a twelve tone equal scale. Now, to apply this approach to a usable scale, we need a pitch of known frequency to use as a starting point.

### WESTERN SCALE

How do we determine a starting point? Basically that has already been established. Orchestras and bands usually tune to the pitch of "A". The letter "A" has been assigned to the frequency of 440Hz. However, in the past, orchestras used to tune to A-435, 438 even as high as 444Hz.

Now, knowing the frequency of the pitch "A", we can apply our mathematical factor. The result will be the next note of the scale. And by continuing the process, we will eventually reach A-880Hz -- one octave above.

| | | | | | | |
|---|---|---|---|---|---|---|
| (A) | 440.00 | × | 1.0594631 | = | 466.16 | (A#) |
| | 466.16 | × | 1.0594631 | = | 493.88 | (B) |
| | 493.88 | × | 1.0594631 | = | 523.25 | (C) |
| | 523.25 | × | 1.0594631 | = | 554.36 | (C#) |
| | 554.36 | × | 1.0594631 | = | 587.33 | (D) |
| | 587.33 | × | 1.0594631 | = | 622.25 | (D#) |
| | 622.25 | × | 1.0594631 | = | 659.25 | (E) |
| | 659.25 | × | 1.0594631 | = | 698.46 | (F) |
| | 698.46 | × | 1.0594631 | = | 739.98 | (F#) |
| | 739.98 | × | 1.0594631 | = | 783.99 | (G) |
| | 783.99 | × | 1.0594631 | = | 830.61 | (G#) |
| | 830.61 | × | 1.0594631 | = | 880.00 | (A) |

The same process can be used for going down in pitch by dividing the factor into each frequency.

(A) 440.00/1.0594631 = 415.31 (G#)
415.31/1.0594631 = 391.99 (G)
etc.

Continued dividing will bring 440.00 down to 220.00 -- one octave lower.

NON-TWELVE

Let's take this knowledge and apply it to a different quantity of notes per octave -- say five (called a "pentatonic" scale or five tone equal).

The factor for five is = 1.1486984.

We can use any pitch or frequency as a starting point just as we did with A-440. For example, we'll build a five tone scale on middle C. The pitch of middle C is 261.63Hz (which is derived from A-440 and the twelve tone equal tempered scale).

NON-TWELVE

Let's take this knowledge and apply it to a different quantity of notes per octave -- say five (called an equal pentatonic scale or five tone equal).

The factor for five is $\sqrt[5]{2}$ = 1.1486984.

We can use any pitch or frequency as a starting point just as we did with A-440. For example, we'll build a five tone scale on middle C. The pitch of middle C is 261.63Hz (which is derived from A-440 and the twelve tone equal tempered scale).

(1) 261.63 x 1.1486984 = 300.53 (2)
300.63 x 1.1486984 = 345.22 (3)
345.22 x 1.1486984 = 396.55 (4)
396.55 x 1.1486984 = 455.52 (5)
455.52 x 1.1486984 = 523.25 (1)

NOTE: Sometimes the black keys on the piano are referred to as a pentatonic scale because there are five notes. This is not an equal pentatonic scale because the interval distances vary within the scale.

It is possible to start with any frequency, including ones that have no relation to standard scales. As an example, we'll try 100Hz (a very sharp G).

(1) 100.00 x 1.1486984 = 114.86 (2)
114.86 x 1.1486984 = 131.95 (3)
131.95 x 1.1486984 = 151.59 (4)
151.95 x 1.1486984 = 174.11 (5)
174.11 x 1.1486984 = 200.00 (1)

The twelve tone equal scale has letter names for identification of each note. But on non-twelve scales we assign numbers to designate the steps of the scale.

The interval distance in all equal tempered scales remains consistent throughout. This is what makes modulation from one key to the next possible. The same can be done with 5-tone equal except that the key name might instead be labeled as a number.

TABLE

The following is a list of factors each relating to the quantity of notes within an octave.

| QUANTITY | NAME | FACTOR |
|---|---|---|
| 2 | Duotonic (tri-tone) | $\sqrt{2}$=1.4142136 |
| 3 | Tritonic (augmented) | $\sqrt[3]{2}$=1.2559921 |
| 4 | Quadritonic (diminished) | $\sqrt[4]{2}$=1.1892071 |
| 5 | Pentatonic | $\sqrt[5]{2}$=1.1486984 |
| 6 | Hexatonic (whole-tone) | $\sqrt[6]{2}$=1.122462 |
| 7 | Septatonic (1/2 augmented) | $\sqrt[7]{2}$=1.1040895 |
| 8 | Octatonic (1/2 diminished) | $\sqrt[8]{2}$=1.0905077 |
| 9 | Nonatonic (1/3 augmented) | $\sqrt[9]{2}$=1.0800597 |
| 10 | Decitonic (1/2 pentatonic) | $\sqrt[10]{2}$=1.0717735 |
| 11 | Eleven tone | $\sqrt[11]{2}$=1.0650411 |
| 12 | Twelve tone (chromatic) | $\sqrt[12]{2}$=1.0594631 |

## RECORDINGS

MUSICWORKS 30: SOUND CONSTRUCTIONS

Presents the music of sound sculptures and instruments built by the Logos Foundation, Leif Brush, Richard Raymond, Thaddeus Holownia, Paul Panhuysen and Johan Goedhart.

Published by The Music Gallery; Distributed by Musicworks, 1087 Queen Street West, 4th floor, Toronto, Canada, M6J 1H3. Price, including both the paper and the cassette, is $20/year (4 issues) in Canada, $24 elsewhere. Write for individual issue prices.

Musicworks is Canada's leading new music publication. Each quarterly issue of the journal focuses on a topic of current importance in contemporary music, featuring articles, reviews and scores pertinent to the subject. As part of each issue, subscribers receive a cassette tape through which the journal can talk, sing and play, conveying in sound the substance of the printed pages.

Musicworks 30, dated Winter 1985, bears the title Sound Constructions, and presents the work of several people dealing with various forms of sonic sculpture and sound installations. Samples of the sounds of the installations appearing in the journal are gathered on the Musicworks 30 tape.

Let it be known right away that neither Number Thirty nor the other Musicworks tapes are prepared like a commercial record company's sampler record. John Oswald, who does the mixing and carries the title "cassette editor" for the journal, apparently has made the decision that the integrity of the tape as a whole should override that of the individual pieces. Accordingly, on his tapes he edits freely, mixes material from different sources, and superimposes environmental sounds, recitations and informal talk, all with an ear to creating an aesthetically satisfying whole.

The Sound Constructions tape begins with the work of Godfried Willem-Raes and Moniek Darge of the Logos Foundation of Belgium. First we hear their Pneumafoons. The Pneumafoons are a motley collection of instruments designed to work with irregular and unpredictable fluxes of air from an outside source. Some have whistle-like arrangements, some have single or double reeds, some have