INSTRUMENTS

A SET OF ALUMINUM JUST-INTONATION TUNING FORKS by Warren Burt

Warren Burt is an American composer living in Australia. In this article he describes a set of hand-held tuning forks he has created. What is especially interesting about these instruments is not so much their design, or how they sound individually (though the tone is wonderfully clear, pure and long-sustaining), but rather how the players handle them in performance. On a physical level, the individually-held forks can be manipulated freely to modify their sound. On a social level, some very appealing possibilities appear in the musical interaction of a group of people, with or without musical training, holding such simple yet fully musical sound sources. In the article below, Warren describes the design and construction of the forks, and then goes on to describe some of the ways he has brought out their musical and social potential.

About 1970, Edward Keyes, a friend who dabbled in acoustics, showed me a set of eight aluminum tuning forks he had made and tuned to the C major scale. These were band-sawed out of 20 x 40 mm aluminum. They filled the octave ending on the C above the treble staff, and had a lovely pure tone that rang on for about thirty seconds. At that time, he gave me a reject fork from his project, one tuned to approximately the D above his highest C, suggesting that I might find a use for it.

Over the years, that fork was used in a variety of contexts. It was especially useful between 1976 and 1979, when I was a member of the live electronic performance group Plastic Platypus, which specialized in performances with cassette recorders, home-built electronics and percussive trinkets of all kinds. The high ringing D of Ed's fork can be clearly heard in the recording of Ron Nagorcka's "Atom Bomb" (available on the cassette NMATAPE2, from NMA publications, PO Box 185, Brunswick, Vic. 3056 Australia, for \$6.50 Australian plus postage), and forms the central structural element in my 1977 piece "Tasmanian 'D'" for seven cassette recorders, hand-held percussion and hand-operated 7 channel sound switching system. More recently, the fork was used as a solo sound source in my 1985 accompaniment for choreographer Jane Refshauge's realization of Deborah Hay's "Leaving the House," where its single sustained highly directional sine-wave provided an ideal counterpoint for Jane's slow, elegant, and suspended movements.

These experiences convinced me of the desirability of having a set of these forks, and my interest in exploring various tuning systems provided further impetus in this direction. I did not have the opportunity to realize the project, however, until September, 1985, when I was selected to be one of the Australian Commonwealth Scientific Industrial Research Organization's (CSIRO)

artists-in-residence, as part of the Australia Council's "Artists and New Technology" scheme. I chose to work at the CSIRO's National Measurement Laboratory (NML) at Monash University in Melbourne, where precise frequency measuring equipment and a small machine shop were available. The forks were made here between September and December 1985.

A just intonation scale of 19 tones/octave was eventually settled on after a number of preliminary experiments. During these experiments, Schlesinger's ancient Greek modes (cf. The Greek Aulos, by Kathleen Schlesinger) and Yasser's 19 tone equal tempered scale (cf. A Theory of Evolving Tonality by Joseph Yasser) were considered. They were eventually passed over in favor of the much simpler just scale used here, based on the theories of Ptolemy and Partch (cf. Harmonics, Book II, by Claudius Ptolemaius, and Genesis of a Music, by Harry Partch). The scale that evolved is symmetrical, based on G=392 hz, and has as subsets a number of the ancient Greek genera. Of particular acoustic interest are the beating pairs of tones 10/9 & 9/8, 7/5 & 10/7, and 16/9 & 9/5, which produce quite lovely beats when played together.* For those interested in just tuning, here is the scale the forks are tuned to:

1/1 28/27 16/15 10/9 9/8 6/5 5/4 9/7 4/3 7/5 RATIOS:> CLOSEST "C#" ncu "G#" "G" PITCH IN E.T. 15/8 27/14 2/1 10/7 3/2 14/9 8/5 5/4 16/9 9/5 RATIOS: > CLOSEST 10[71 "F#" nC## PITCH IN E.T.

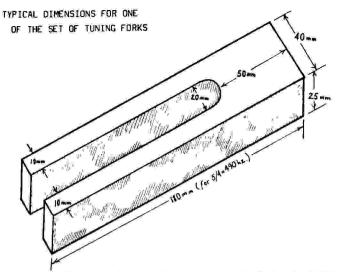
The forks themselves are made of standard aluminum bar, 25×40 mm for the top two octaves and 40×40 mm for the bottom two octaves. A number of experiments were carried out to determine the optimum design for them, and to see how the sound they made could be controlled. The end design had two times ten mm wide of equal length on top of a fifty mm base. The length of times varied as pitch varied. A computer program written by Robert Rigby of the NML calculated the lengths of bar necessary for each fork, and the amount of aluminum necessary to be milled off to fine-tune each fork. The metal work on the forks was carried out by myself, with very helpful and necessary assistance from NML's Stan Boothey, Ken Peel, and Ron Cook.

There are a total of 89 forks. Four octaves

*These ratios and those given below, in keeping with nomenclature encouraged by Harry Partch and now gaining wide currency, are a means of precisely indicating relative pitch relationships. The numerator and denominator correspond to the frequencies of two pitches, in this case, the frequency of a higher scale degree over that of the basic pitch on which the scale is built.

The word "beating" here refers to the tremolo-like rise and fall in volume that results as two simultaneous vibrations of close but not identical frequencies move in and out of phase, alternately reinforcing and cancelling one another.

"E.T." on the chart below refers to 12-tone equal temperament, the standard tuning system in most current Western music.



from G=98hz (bottom of the bass clef) to G=1678hz (an octave above the top of the treble clef) are covered. There are also two lower "experimental" forks of G=49 hz. and D=72.5hz., a few duplicated tones, and six "mutant" forks of tones dissonant with the scale that were made in the course of the work and were interesting enough to keep: 25/24=204.1hz, 35/18=381.1hz, 25/21=933.2hz, 297/200=1164.3hz, ca. 297/200=1164.7hz (these last two producing a very attractive high, slow beating), and 256/243=206.4hz (a nice low beating partner to the 25/24).

The lower two octaves need resonators and soft beaters for their fundamentals to be heard properly, while the higher forks' fundamentals can be easily heard with a variety of beaters. The lowest two forks are too low for 40 mm aluminum to efficiently project their tones, even with resonators. However, they make lovely deep bass tones which can be clearly heard when held close to the ears. Though amplification could make these two forks heard easily, I actually prefer to think of them as quite personal instruments, performable for only one person at a time.

The forks were made as follows: The aluminum bar was first sawed slightly longer than required on a circular metal saw. Then a 20 mm diameter hole was drilled in the center of the bar, 50 mm from the base end. A band saw was used to saw from the tine end to the hole, thus creating the groove. After that the inside of the tines were made smooth with a milling machine, although this was primarily for cosmetic purposes. For tuning, if the fork was flat, very small amounts of metal could be milled off the ends of the tines. If it was too sharp, the end of the groove could be slightly milled away to bring the fork into tune, though this was not as accurate a tuning method as working on the ends of the tines.

There are three principal ways of playing the forks:

- Hand-held, with one player using only a few forks, and the timbre of the forks modified in various ways, as used in my "Almond Bread Harmonies" series of pieces.
- 2) Standing on their ends, and lightly struck with percussion beaters. In this use, the sound is very soft, and some amplification has always been used so far when they are played in this mode, as

in "Ptolemaic Phase Dances" for forks and moving microphones and "The Exquisite" for solo fork performer wearing binaural microphones.

3) Mounted in a frame specially made for them which holds specially tuned resonators, and played in the manner of a normal keyboard percussion instrument. A frame capable of holding twenty forks and resonators has been made which allows both forks and resonators to be easily changed, allowing various scales and collections of pitches to be used at various times.

Method 3) provides great traditional musical flexibility, and for practical reasons, I have used the second method for a number of solo performances. But my favored way of performing with the forks is the first: hand-held and performed by a number of players. This is because in this mode the forks become not so much a musical instrument as a set of flexible sound resources for community music making. I find this concept much more socially appealing than the idea of simply making another instrument for musicians, professional and otherwise, to play. In this mode, a great number of people can explore playing and making sound together, and because the level of skill required to play the forks is so easily taught, lack of musical training or experience is no barrier. Thus, the experience of social music making is available to at least a few people that it might not otherwise have been.

In the hand-held mode, a number of timbral modifications of the forks are possible. They can be struck and then moved slowly or rapidly through the air, creating various doppler and phase-shifting effects. The lower treble ones can be moved close to the mouth and the changing shape of the mouth cavity used as a resonator. The highest forks can be held close to the mouth and whistling tones around the frequency of the forks can produce soft difference tones. Cardboard tube resonators can be moved close to the forks, or the forks moved over the ends of the resonators, to produce changes in amplitude. All of these techniques are used improvisationally in my recent pieces "Almond Bread Harmonies I & II" for five players of treble tuning forks. (A longer description of a number of pieces for the forks can be read in an upcoming issue of Interval). Another possible modification is attaching a stiff index card to one of the times with brown packaging tape. This produces a delightful buzzing sound reminiscent of the mbira. Needless to say, all these performance techniques are highly theatrical, producing a visually performance.

The essence of the forks is ultimately timbral. The long decay (ca. thirty seconds) of the pure sine waves the forks produce, coupled with the just tuning (and here we could ask just how much tuning effects, or is even to be considered a subset of, timbre) produces an overall "sound" that is quite distinctive. The forks, indeed, are not a universal instrument, capable of adapting to a great number of musical styles. They make only their own music, but the scope of that music is just beginning to be discovered.