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Mission Statement: The purpose of An International Journal of Exploratory Meta-Living is to provide a resource for the dissemination of creative works relevant to the subject of meta-living. The journal welcomes both academic and artistic exercises expressed in any medium capable of being transmitted through the physical mechanisms of the journal. Due consideration also will be given to submissions that do not conform to these mechanisms. The journal explicitly forbids the establishment of a regular publication schedule.

Meta-Living: One useful avenue leading toward an understanding of the term meta-living is through analogy, particularly by considering meta-fiction. Wikipedia, the oracle of all contemporary knowledge, defines meta-fiction as "the literary term describing fictional writing that self-consciously and systematically draws attention to its status as an artifact in posing questions about the relationship between fiction and reality, usually using irony and self-reflection."[1] By straight-forward analogy, meta-living is the existential term describing a manner of living that self-consciously and systematically draws attention to its status as an artifact in posing questions about the relationship between existence and reality, using irony and self-reflection among other devices. These other devices include, but are not limited to, scientific inquiry, ontology, various theologisms, sophistry, rhetoric, tomfoolery, transcendental perspectivism and, of course, the omnipresent specter of post-existential relativism.

[1]https://en.wikipedia.org/wiki/Metafiction, accessed 2014 April 16.

A Note on the Font: This font is Dax Compact Regular, designed by the late Hans Reichel, musician, instrument maker and font designer.

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A Materials Perspective on Waterphone Acoustics

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Abstract: The waterphone is a musical instrument used in the film industry to create eerie audio elements in the soundtracks of science fiction and horror movies. The waterphone is an idiophone, in which sound is generated via the reverberation of the entire instrument. The processing-structure-property-performance relationship of the waterphone was investigated via a materials science approach. Four waterphones were designed and fabricated, in which various material and structural elements were systematically varied, including size and composition of the basin as well as composition and heat treatment of the rods. The effect of these elements on the acoustics of the instrument was evaluated quantitatively through Fourier transforms and qualitatively through consultation with musicians. The fundamental frequency generated by the bowing of a rod on the instrument can be predicted as a function of instrument material and structure with an empirical, constant factor. Additional overtones, which impart much of the eerie atmosphere, are generated in a currently unpredictable manner based, presumably, on other structural (e.g. thickness of basin metal) and performance (e.g. amount of water in the basin and technical proficiency of the musician) parameters, beyond the scope of this introductory work.

I. INTRODUCTION

The waterphone, shown in Fig. 1, is a musical instrument categorized as an idiophone, which produces sound through vibrations of the entire body of the instrument. The instrument is composed of metal and consists of a resonating basin to which rods are attached. A central cylindrical pipe extends from an opening in the basin. The instrument is held, suspended in the air, with one hand gripped at the top of the pipe. The waterphone is played by either bowing the rods with a violin bow or striking the rods or basin with mallets.

The waterphone was invented by Richard Waters in the late 1960s and patented in 1975.[1-2] Typically, it is played with water partially filling the basin, which adds an eerie and unpredictable dampening effect to the reverberations of the instrument. The waterphone is most famous for its role in the soundtracks to such horror and science fiction films as *Poltergeist*, *The Matrix, and Star Trek*.[3]

In this contribution, the processing-structure-property-performance (PSPP) relationship of the waterphone was investigated via a materials science approach. In this relationship, the processing of the material impacts its structure at various scales including the atomic and microstructural. The structure impacts the material properties, which in turn dictate performance of the device in which the material is incorporated. All elements of the PSPP relationship were investigated in this work, including the acoustic performance of the instrument.

Figure 1. A model of the waterphone, composed of a basin, rods and a central pipe.

II. METHODS

A. Waterphone Design Parameters

As is clear from Fig. 1, there are numerous parameters of the waterphone instrument, which impact the sound of the instrument. In consultation with Prof. Andy Bliss, Director of Percussion Studies in the School of Music at the University of Tennessee, and his student, Wesley Fowler, four parameters were selected for investigation in this preliminary work. These parameters were chosen on the basis of the likelihood that they would have a significant and musically interesting effect on the sound of the instrument. These four parameters included (i) the composition of the basin, (ii) the size of the basin, (iii) the composition of the rods and (iv) microstructure of the rods controlled through thermal treatment.

Four waterphones were designed and fabricated for this project. One instrument served as a base case to which the others are compared. In Table 1, the primary variable instrument design parameters are summarized. The four instruments are designated “base case”, “small basin”, “steel rods” and “copper basin” to highlight the design differences. The “base case” waterphone has a nominally thirteen-inch wide stainless steel basin and brass rods. Second, the “small basin” waterphone replaces the thirteen-inch wide basin with a nine-inch wide basin. Comparison of the “base case” and “small basin” instruments evaluates the effect of basin size on the instrument. Third, the “steel rods” waterphone replaces the brass rods with steel rods. Comparison of the “base case” and “steel rods” instruments evaluates the effect of material choice of rods on the instrument’s sound. Finally, the fourth waterphone, “copper basin” replaces the steel basin with one manufactured from copper. Comparison of the “base case” and the “copper basin” waterphones allows for the evaluation of the effect of basin material on the sound of the instrument. 304 stainless steel and copper were selected based on their commercial availability and corrosion resistance.

For the “base case” and “copper basin” waterphones with 13-inch basin, 36 rods were arranged at equal points around the circumference, ranging in length from 2″ to 10 ¾″ with ¼″ increments. For the “small basin” waterphone with a 9-inch basin, 24 rods were arranged at equal points around the circumference, ranging in length from 2″ to 7 ¾″ with ¼″ increments. The reduction in the number of rods was necessary to create a spacing in which a violin bow could contact a single rod without touching the neighboring rods on either side. For the “steel rods” waterphone, as a second design parameter, the steel rods were subject to a thermal treatment. All the rods were heated to 950 °C. All rods were held at temperature for 30 minutes to normalize grain size. Half of the rods were then annealed (allowed to cool in the oven), while the other half were rapidly quenched in oil. In this case, 36 rods were composed of two identical sets of 18 rods with length from 2″ to 10 ½″ with ½″ increments, differing only in heat treatment.

There are, of course, other parameters that define the waterphone. In this study, those additional parameters were held as constant as possible. These parameters are reported in Table S.1. of the Supplementary Information Document. Fabrication of a jig was necessary, which was ratcheted to uniformly distribute the rods around the circumference of the basin and included an angled brace to enforce a uniform angle of all the rods relative to the central cylinder. Two jigs were made, one for the 13″ basins with 36 rods and another for the 9″ basin with 24 rods. Photographs of the jigs are shown in Fig. S.1. Photographs of the four instruments are shown in Figs. S.2 and S.3.

B. Materials Joining

In the fabrication of the waterphone, three joining operations were performed. The basins were created by purchasing commercially available pie tins, trimming the lip around the circumference, and joining them rim to rim. In this case, Tungsten Inert Gas (TIG) welding was used to join the top and bottom halves of the basin. TIG welding was also used to join the central pipe to the top of the basin. This operation was performed first from the underside of the top tin for esthetic purposes, before the basin was closed. Welding was the appropriate technique to join like metals and to form a waterproof seal. Finally, the rods were brazed using silver solder to the rim of the basin. Brazing was the appropriate technique to join either brass or carbon steel rods to either stainless steel or copper basins.

C. Materials Characterization

The velocity for longitudinal waves in a slender rod are related to material properties

$$v = \sqrt{\frac{Y}{\rho}} \tag{1}$$

where Y is the Young's modulus and ρ is the density. In this study, the rods were brass (face-centered cubic; $Y = 97\ GPa, \rho = 8.55\ g/cm^3$) and low carbon (A36) steel (body-centered cubic; $Y = 200\ GPa, \rho = 7.88\ g/cm^3$). The basins were 304 stainless steel (face-centered cubic; $Y = 196\ GPa, \rho = 8.00\ g/cm^3$) and copper (face-centered cubic; $Y = 196\ GPa$, $\rho = 8.00\ g/cm^3$). Energy-dispersive X-ray spectroscopy (EDXS) was used to confirm the steel composition. The microstructure of the annealed and heat treated rods was investigated via optical microscopy. The grain structure of the heat-affected zones of the welded components was investigated via scanning electron microscopy (SEM).

D. Acoustic Modeling

Instruments of all types have defined acoustics that are affected by a multitude of different factors and this holds true for the waterphone. However, unlike most conventional instruments the waterphone's acoustical parameters have not been well studied. The basin size and dimensions, length of the rods and tube, as well as the properties of the materials used to make the parts of the waterphone all could affect the note the instrument produces.[4-5]

In a waterphone, the rods typically are used to generate the note. When a rod is struck it will generate a frequency indicative of its length, degree of anchoring, and constituent material. For a waterphone the rods are welded to the basin and thusly are clamped on one end. However, if the rod is played continuously with a bow at an intermediate point there is the possibility that the rod would behave as a doubly clamped rod with a reduced effective length. For a singly clamped rod the fundamental vibrational frequency, f_1, and higher modes, f_n, are expressed in Eq. (2), where a is the rod thickness (m), L is the length of the rod (m), v is wave velocity (m/s).[6]

$$f_1 = 0.162\frac{a}{L^2}v; \quad f_n = 2.81\left[n - \frac{1}{2}\right]^2 f_1 \tag{2}$$

The size and shape of the basin are likely to affect the tone and pitch of the note based on standard drum music theory.[5-7] An increase in the basin size should correspond to a deepening of the note as the basin will vibrate slower and absorb higher frequencies. The duration with which the note can be sustained is determined by the loss coefficient of the basin materials, which is a measure of how much stored energy is lost over time. The lower the loss coefficient the longer a material can hold a clear note, which is desirable. In general, the loss coefficient decreases with increasing Young's modulus.[8] Therefore, a change in basin material should therefore impact the duration of the reverberation.

Material interfaces, such as that between the rod and the basin, could impact the sound of the waterphone, because the refractive index of sound is different for the two materials.[4] The frequency is generated in the rod, travels through a braze, into the basin, and into air directly or through water into air. These interfaces, which either reflect or transmit the wave, do not change the frequency, only the direction. These interfaces can dampen the intensity of the waves resonating through the instrument. If a wave is reflected at an interface, the percentage of the wave reflected must travel around the waterphone more than if it were transmitted, this leads to greater absorption of the wave and overall dampening of the emitted sound.

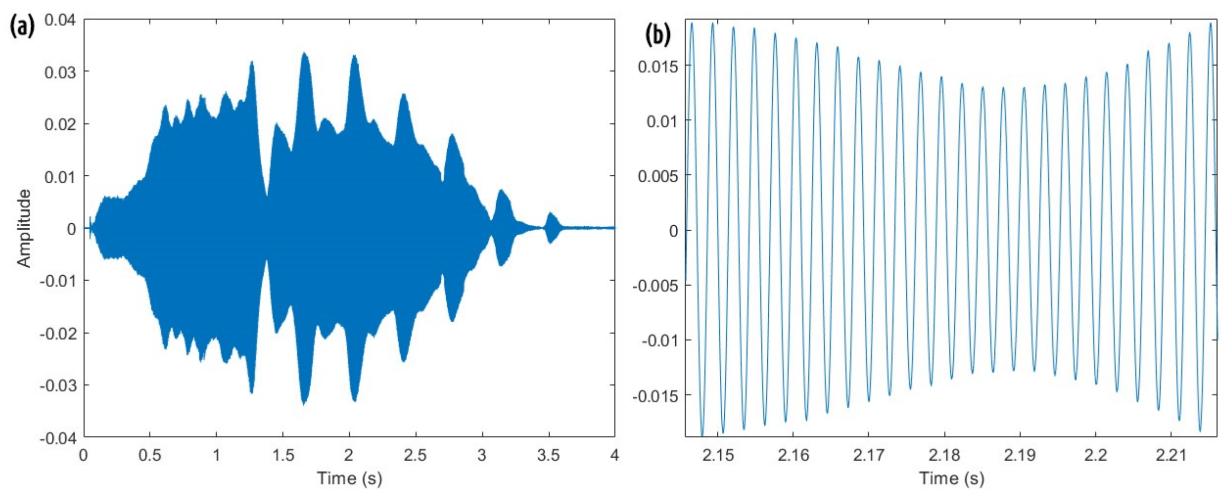

Figure 2. The audio of the three-inch brass rod on the "base case" waterphone without water in the basin. (a) full sample. (b) magnified selection.

III. RESULTS

The acoustic properties of the four waterphones were characterized by audio sampling at a frequency of 44.1 kHz in an environmentally controlled sound-room. Rosin was applied to a violin bow to increase the friction between the bow and the rods. The bow was pulled once or twice, and the sound recorded. A sample visualization of the resulting wave file from the 3" rod is shown in Fig. 2. An example Fourier transform of the audio file for the 3" rod is shown in Fig. 3(a). Visualization of the audio file and the corresponding Fourier transforms for one rod from each waterphone in the presence and absence of water in the basin, as well as for both the annealed and quenched rods on the "steel rods" instrument are provided in Fig. S.4(a) through (j).

A. Effect of Rod Length

In order to evaluate the effect of rod length on the acoustic properties of the instrument, audio samples

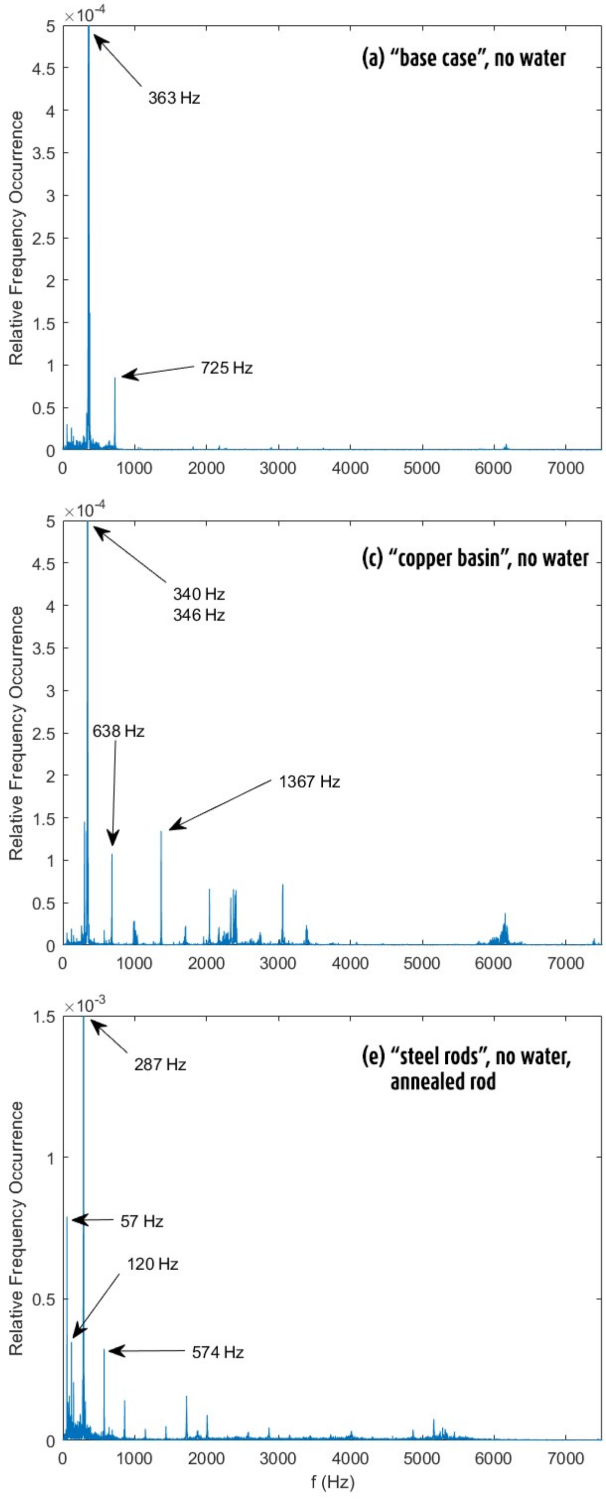

Figure 3. Fourier analysis of the 3″ rods of the (a) "base case" waterphone without water and (b) with water, (c) "copper basin" without water, (d) "small basin" without water, (e) 4″ annealed rod of "steel rods" without water, and (f) 4″ quenched rod of "steel rods" without water.

were collected from the first 14 rods on the "base case" waterphone, ranging in length from 2.0 to 5.25 in. A Fourier transform was applied to each audio file to identify the fundamental frequency and higher modes. In each case, an unambiguous fundamental frequency was identified. The fundamental frequency is plotted against rod length in Fig. 4. The frequency decreases as the length of the rod increases. The R^2 measure of fit for all fourteen data points is 0.984. The coefficient for the fundamental frequency is 0.128. This is smaller than the reported empirical coefficient of 0.162 for a rod clamped at one end, as reported in eq. (2). If the two outliers at rod lengths of 2.5 and 2.75" are omitted, the coefficient is 0.130 and the measure of fit is 0.995. We attribute the modest outliers to variations in the way that the silver solder solidified around rod at the point it contacted the basin. The frequencies are presented in tabular form in Table S.2.

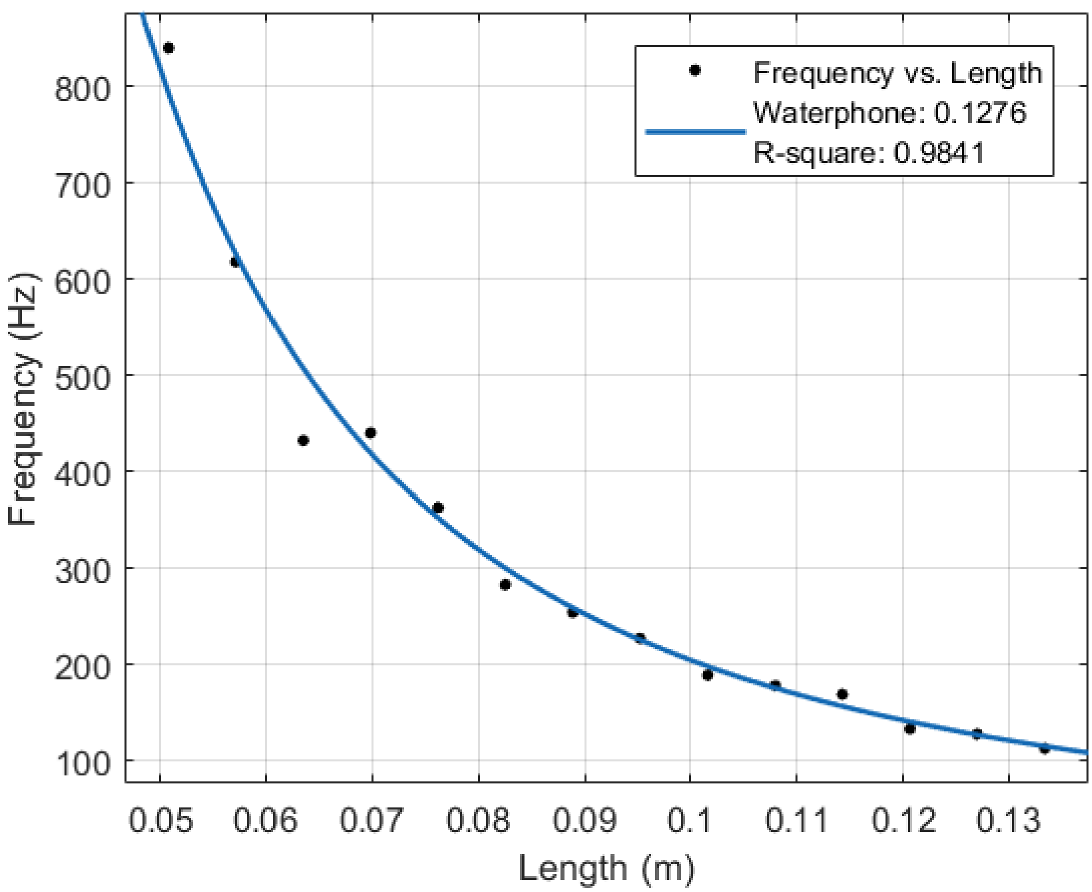

Figure 4. Fundamental frequency of the first fourteen rods on the "base case" waterphone, without water, as a function of rod length.

On the waterphone, the rods produce different sounds depending upon where they are bowed. For the shortest rods, for which fundamental frequencies are reported in Fig. 4, bowing at the free end of the rod produces a clear, audible note. Moving the bow to the midpoint, generates the same note. Moving too close to the end clamped to the basin does not create a sufficient deflection of the rod to generate a note. For rods of intermediate length, from 5.0" to 8.5", two distinct notes can be generated, a low note when bowed near the top of the rod and a higher note bowed on the bottom half, though not too near the basin, of the rod. As the length of the rod increases beyond 8.5", bowing at the free end generates a sound that is increasingly not perceptible to the ear, as its frequency becomes too low. A higher note is generated at the midpoint. A third, highest note is generated in the bottom quarter of the rod.

Interesting, in the intermediate and longer rods, the note that is produced by bowing at a particular point is dependent upon the current vibrational state of the rod. This phenomenon of sound hysteresis can be generated reproducibly on the waterphone. For example, in the rods of intermediate length, one can slide the bow, as it is drawn, along the axial length of the rod. If the bow starts at the free end, a low note is generated and a continuous low note can be sustained as the bow slides to the middle of the rod. Alternatively, if the bow starts near the basin of the same rod, a high note is generated and can be sustained as the bow slides to the same point in the middle of the rod. This example depends only on the bowing of one rod. However, if the bow is drawn across many rods, the particular note that is generated at a point capable of producing more than one note depends in general upon the immediately preceding vibration state of the instrument, as some frequencies can cancel out or amplify each other.

B. Effect of Rod Composition

The rods in the "base case" waterphone were brass. In the "steel rods" waterphone, the rods were low carbon steel. According to equation (1), the wave speed in brass is 3368 m/s compared to that in low carbon steel of 5038 m/s, a brass:steel ratio in speed of 0.67. Thus, the change in rod material from brass to steel will generate higher notes. In Fig. 3(e), the Fourier transform of the audio file for the 4" steel rod shows a fundamental frequency of 245 Hz compared to the measured frequency of 189 Hz for 4" brass rod, a brass:steel ratio in frequency of 0.77. While the correct qualitative behavior is observed, the discrepancy in the ratio can be attributed to a number of factors. Presumably, the most important factor is that the modulus of the annealed steel rod used in this calculation was an estimate.

C. Effect of Rod Heat Treatment

The "steel rods" waterphone contained two sets of 18 low carbon steel rods ranging in length from 2" to 10.5", identical in every respect except heat treatment. The A36 steel rods initially were predominantly ferrite (body centered cubic) with a small fraction of pearlite, in which lamellae of ferrite & cementite (orthorhombic Fe_3C) alternate. Both sets of rods were heated above the austenite (face-centered cubic) transition temperature. One set of rods was annealed (slow cooled in the oven) and the other quenched (rapidly cooled in oil). In steel metallurgy, annealing relieves internal stress and results in a softer but more ductile material. Quenching can transform austenite to martensite, a non-equilibrium phase of steel (body-centered tetragonal), which is hard but brittle. If the quench rate is not sufficiently fast, martensite will not form. In that case, the difference between the annealed and quenched rods is largely in the characteristics of the minority constituent, pearlite.

Optical microscopy revealed the quenching process did not result in the formation of martensite. This was due to the usage of A36 low-carbon steel rather than a medium or high-carbon steel and an insufficient cooling rate. Even in the absence of martensite, the heat treatment impacts hardness and yield strength. However, according to equation (1), the wave velocity is a function of density and Young's modulus alone. Therefore, the predicted impact of this heat-treatment on low carbon steel on acoustic properties should be nominal. Comparison of Fig. 3(e) and (f) shows that the fundamental frequency of the 4" annealed and quenched steel rods were respectively 287 Hz and 245 Hz, an annealed:quenched ratio in frequency of 1.17. The precise origin of this deviation from unity remains unresolved at this time.

D. Effect of Basin Composition

The "base case" and "copper basin" waterphones were intended to be the same in all respects except composition of the basin, which was 304 stainless steel in the "base case" and copper in the "copper basin" case. Comparison of Fig. 3(a) and (c) shows that the fundamental frequencies of the 3" rod on the "base case" and "copper basin" instruments were respectively 363 Hz and 340 Hz. This difference of 23 Hz is likely within the limits of the accuracy of the fabrication of the instrument and corresponds to a difference of 2.5 mm in rod length.

The expectation was that the basin would impact the duration of the sound. Based on the inverse correlation between Young's modulus and loss coefficient, one would expect that the stainless steel ($Y = 196\ GPa$) basin would have a lower loss coefficient and thus sustain a note longer than the copper ($Y = 120\ GPa$) basin. Visual inspection of the sound files shown in S.4(a) and (c) indicate that the stainless steel basin held a note longer. This was also the distinct perception of the musicians who tested the instruments. However, this proved difficult to quantitatively establish, since the duration of the note is also tied to the force applied by the bow to the rod, which determines the initial stress and strain state of the rod. In this work, the rods were bowed by hand, and there was inevitable variation in the force applied. Additionally, there were several other secondary differences in the basin. As reported in Table S.1., the thickness of the materials used in the construction of the basin were slightly different, the copper basin being thicker. Also, the stainless steel basin was flat while the copper basin was dimpled with circles nominally 1 cm in diameter.

E. Effect of Basin Size

In the violin family, as the size of the instrument increases from violin to double bass, both the lower and upper limits of the range of fundamental frequencies decreases. However, Fourier analysis of audio samples reveals a spectrum of resonances that range from 60 Hz to 15,000 Hz for the violin through 40 Hz to 1000 Hz for the double bass. In other words, lower limit of frequencies decreases modestly with increasing size, while the upper limit decreases more significantly.[9] The "base case" and "small basin" waterphones were intended to be the same in all respects except the diameter of the basin, which was 13" in the "base case" and 9" in the "small basin" instrument. The smaller waterphone also had only 24 rods. Comparison of Fig. 3(a) and (d) shows that the fundamental frequencies of the 3" rod on the "base case" and "small basin" instruments were respectively 363 Hz and 336 Hz. This difference of 27 Hz is likely within the limits of the accuracy of the fabrication of the instrument.

The Fourier transform does show that high-frequency overtones were more prevalent in the smaller basin. This observation is valid in the absence and presence of water. (See Fig. S.4.) This observation for waterphones is in line with that from the violin family that the upper limit of the frequency range of the small instrument is much higher and that smaller instruments sustain these higher resonances with greater amplitude, compared to larger instruments.[9]

F. Effect of Water

The waterphone is played with water in the basin. As Hopkin notes, "The player rocks the vessel's base during performance. This causes water, which is in the base of the vessel, to move, resulting in a shift in the predominant resonance frequencies in the body of the instrument. When the rods' steady vibrations are introduced into this shifting-resonance medium, effects analogous to electronic chorusing or flanging result, but in a freer and less predictable manner."[10] A comparison of the frequencies generated by a rod in the presence and absence of water can be seen by comparing Fig. 3(a) and Fig. 3(b). Clearly, the presence of water does not affect the frequencies present. However, the flanging effect is immediately apparent to the ear. Comparison of one rod from all fabricated waterphones in the presence and absence of water are reported in are provided in Fig. S.4(a) through (j). In other cases, the presence of water is more clearly seen in the muting almost to the point of elimination) of some peaks.

Water in the waterphone has one other effect on the instrument. When the two pie tins are welded at the exterior rim along circumference to create the basin, there is the possibility that the interior portion of the flat rim vibrates against each other, creating an unwanted rattling sound. Certain rod frequencies activate this rattling mode. The presence of water eliminates it to the point where it is undetectable by ear.

G. Absence of Joining Issues

As noted above the TIG welding was used to join the two pie tins around the perimeter, which formed the basin, and to join the center cylinder to the basin. A welding analysis was performed to verify that the joining process did not introduce flaws in the instrument. The need to check a weld originates from the varying cooling rates in the weld pool and heat affected zone (HAZ). A weld that contains a section higher than 35 Rockwell C hardness is susceptible to cracking upon air cooling. In other words, the weld becomes brittle rather than pliable and cracks. Welding was examined by (i) reference to Schaeffer diagrams, (ii) microscopy and (iii) hardness testing.

The Schaeffer diagram provides a description of the phases present in a weld as a function of steel composition.[11] The composition of the 304 stainless steel pie tins was verified via Energy Dispersive X-ray Spectroscopy and reported in Table S.3. The choice of 304 stainless steel, used in many commercial applications, places it inside the safe chemistry zone of stainless steel welds, where sigmatization, hot cracking or cold/Martensitic cracking is absent.[12] As shown in Fig. S.5, scanning electron microscopy of the weld zone confirmed the absence of problematic phases and micro-cracks. As shown in Fig. S.6, nanoindentation confirmed no abnormalities in the hardness and modulus of the HAZ. Thus the conclusion is that no defects were introduced by the welding, which would impact the sound of the instrument.

IV. DISCUSSION

A. Economic Analysis

The waterphones were constructed from commercially available pie tins (basin), pipe (cylinder) and brazing or steel rods. The cost of manufacturing each instrument is reported in Table 2. The labor estimate includes 10 hours per waterphone. The labor estimate explicitly does not include the creation of the jigs, which can be reused for waterphones of a given basin diameter. An estimated cost of $21.00 per hour for welders and machinists was used.[13] These costs, which do not include profit, predictably fall below current prices for commercially available waterphones. Commercially, the cost of the instrument increases significantly with size of the instrument. Because the cost of the instrument is primarily labor, rather than materials, it appears that the profit margin rises with instrument size.

B. Reproducibility & Esthetics of Screechiness

The four waterphones were presented to musicians to be evaluated in qualitative terms of playability. Unlike a violin, with which a proficient musician could move from one example to the next and perform a similar composition, each waterphone possesses a unique character and requires significant time for a musician to become familiar with the idiosyncrasies of the instrument. The relationship between rod length and note, as investigated above, is not sufficiently well established that an instrument can be designed with rods of a certain length, which generate the same series of notes as a piano, for example. Additionally, the presence of sound hysteresis complicates the identification of points on the rods where certain notes can be reliably generated. Thus, reproducibility of a desired sound is a challenge, especially with water in the basin, which serves the purpose of unpredictably distorting the sound. Also, there are numerous positions on any given rod that do not generate a clear note but rather result in a screeching sound. Such sounds were compared to fingernails on a chalkboard more than once. For many applications, these characteristics of the waterphone make it an undesirable instrument.

However, the incredible variety of music in the world corresponds to the broad distribution of musical tastes among individuals and cultures. Any instrument, including the waterphone, can be used in multiple contexts for different purposes. The prevailing use of the waterphone as an instrument to generate eerie sounds in the soundtracks of horror films is only one application. The instrument also has been used in a more musical sense. For example, the American free jazz double bassist and multi-instrumentalist, William Parker, released an album featuring songs performed by a waterphone quartet in 2018.[14] In this work, which includes elements of composition and improvisation, the screechiness of the instrument is embraced as part of a sonic landscape that includes an element of tension in the otherwise languid reverberations of the instrument.

C. Cultural Impact

The use of unusual instruments like the waterphone play a role in strengthening the social fabric through providing a diversity of musical voices. Monoculture is a term that arose from agriculture and describes the "practice of growing a singular crop species in which all plants are genetically similar or identical over vast acres of land."[15] In the absence of crop rotation, the practice of monoculture depletes the soil of nutrients. Worse yet, a genetically uniform crop is susceptible to being wiped out by a single pest. For example, a monoculture of potato crops contributed to the severity of the "Irish Potato Famine" of the 1840s.[16] In human society, the monoculture refers to a cultural homogeneity in which elements of a prevailing culture dominate to the exclusion of other cultures. Instruments like the waterphone that hail from the cultural margins play a role in diluting the effect of the monoculture and strengthening the ability of that culture to respond to new challenges by diversifying thought.[17]

V. CONCLUSIONS

In this contribution, the processing-structure-property-performance relationship of the waterphone was investigated. Four waterphones were designed and fabricated. The size and composition of the basin as well as composition and heat treatment of the rods were varied. The effect of these elements on the acoustics of the instrument was evaluated quantitatively and qualitatively. The fundamental frequency generated by the bowing of a rod on the instrument can be predicted as a function of rod length and material instrument with an empirical, constant factor. To within the accuracy of instrument fabrication, the size and composition of the basin do not impact the fundamental frequency but strongly influence the duration with which the notes can be sustained and the relative amplitude of numerous overtones. The presence of water in the basin does not change the frequencies present but does imbue the instrument with a notable flanging effect. Heat treatment of the rods produced a modest effect in this study, although the choice of steel used in the rods did not generate significant differences in the annealed and quenched rods. This study provides a preliminary acoustic characterization of the waterphone with respect to several geometric and material parameters. Subsequent research could focus on the effect of numerous other design parameters on the acoustic and musical properties of this unique and interesting instrument.

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The Poison Pie Publishing House is an independent publisher specializing in post-existential fantasy generated through a non-idiomatic improvisational writing process. In addition to serving as a publishing house, PPPH hosts an arts blog and "An International Journal of Exploratory Meta-Living".