Ξενarμονία ια΄

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Electronic Instruments Help Us Tune In the New Scales

In the seven years since *Xenharmonic Bulletin No. 10* came out, there have been remarkable advances in electronic musical instrument technology.

I knew this would happen someday, but some day kept receding as the 60 years since 1929 crept past. Quite regardless of the pessimists in the musical world, inventors kept on inventing, and engineers kept on reducing ideas to practice.

What has happened in the last few years is that a crossover has occurred: as the cost of electronic keyboards and equipment has come down to affordable figures for many persons, the cost of pianos and other conventional 19th-century instruments has escalated and then gone through the roof!

Read the ads in the papers and see the signs where you shop or look around; you don't have to take my word for it. Unfortunately, many musicians and people who write about music and musical events refuse

(Continued on Following Page)

Three Really Microtonal Systems: 41, 43, and 46 Tones Per Octave

In *Xenharmonic Bulletin No. 9* I discussed the trio of systems 31, 34, and 36. These lie on an important boundary: where the single degree or unit-interval, viz. $\frac{1}{31}$, $\frac{1}{34}$, or $\frac{1}{36}$ octave, is becoming too small to be a telling melodic interval. Systems like 17, 19, and 22 have decidedly distinctive unit-intervals that work fine melodically; but when you get beyond 31, the harmonic differences for one-unit different in a chord remain striking but the melodic impact of the single unit or degree is less than the harmonic effectiveness of a one-unit alteration in a chord.

Now with the 41, 43, and 46 tone systems being considered here the melodic value of one unit is further attenuated. The unit is still larger than a comma and still can make a noticeable harmonic difference.

41, 43, and 46 tones/octave are still suitable for special keyboards—and a number of designers, notably Ervin Wilson, have drawn up various plans for such keyboards. Most recent 41-tone design brought to me is by Helen Fowler of North Carolina, who labels it a Pythagorean design.

(Continued on Page 21)

[Electronic, continued]

to see what is staring them in the face. They insist it is still the 19th Century in Central Europe and their Religion takes pianos as Idols and the Romantic and Classical composers as Saints.

They hate progress in music with a fierce intensity. So I don't think they will be reading *Xenharmonic Bulletin*. My reason for bringing them up here is simply that economic conditions have changed in our favor, not theirs.

The objections brought up hitherto simply do not obtain any more. The problems adduced as precluding Xenharmonics are now pseudo-problems--in particular, the matter of providing more than twelve pitches per octave on instruments, available AT ALL TIMES.

Not 12 pitches out of just intonation nor 12 pitches out of 19 or 22 or 31; ALL the pitches of the system being used beyond our familiar twelve, up to 24 or even 31 in many cases. Of course it may be impractical to have all pitches of a system like 53 or 41 tones per octave on all instruments, but even there, it is only a pseudo-problem, a red herring.

We have computers. Not huge Mainframes of the 1950s but microcomputers on office desks and in many homes. Not just prosaic business applications or dryasdust scientific data, but games and graphics and art and software for MUSIC.

Not the impersonal remote computerized systems in some giant corporation building, but contemporary home appliances and many of the new synthesizers and other musical apparatus contain computer insides. You can walk over to your corner drugstore and get a pocket electronic calculator for a few dollars. It has pieces of computer circuitry inside it!

Some of you are wearing digital watches right now, that have counting circuits within them. A conventional windup watch of the 1930's might tick 5 times a second, but many digital watches and quartz analog watches some of you may have on your wrist, "tick" 32 768 times a second for the older quartz crystals and an incredible 4 million + times a second for newer models!

You may ask, What has this million-vibrations-per-second thing or Megahertz as that is now called, to do with music, or with Xenharmonics?

Maybe it didn't when you were a child, but it sure does now! Frequency is the reciprocal of time. Controlling the number of ticks per minute or hour on a clock so it will keep correct time is much the same affair as putting any musical instrument in tune or keeping it in tune or restoring its tuning.

Music is a multi-ordinal pattern in time. The mechanical clocks and watches of our childhood or the previous generation worked at infrasonic frequencies such that a watch-tick was 5 or 6 octaves below a note in the middle octave. The quartz crystal digital watch mentioned above might be 2 octaves beyond audible range and the 4 194 304 vibrations-per-second crystal in many modern watches will be 8 to 9 octaves beyond the keenest ear of any human.

We said "octaves"--Music anticipated the binary system of counting now used in digital equipment! The ratio 2:1 is built right into almost every part of a computer and into

digital watches. Those numbers up there, 32 768 and 4 194 304 are powers of 2—2^{15} and 2^{22}, respectively.

So, fellow-musicians, use this ammunition when computer buffs try to intimidate you! Octaves are powers of two, and the infrasonic frequencies used in music as rhythmic elements are also powers of 2 or of ½—whole, half, quarter, eighth, sixteenth, thirty-second, and sixty-fourth notes, so there.

While we are about it, a very common vibrato frequency is 6 to 7 pulsations per second, and this works out to 2 to 2½ octaves below that Note #1, the bottom or subcontra A on the piano keyboard.

That is, music actually counts elements to make patterns in time ranging from the slow infrasonic affairs like sections and phrases and measures and beats through ever more rapid notes to vibrato and tremolo frequencies to contrabass notes through middle and treble and altissimo frequencies up to the limits of human hearing.

And musical counting is mostly binary like the hardware inside computers. Music may not use the 1's and 0's mathematicians use to express the binary counting-system, but the open and closed noteheads and flags and beams on more rapid notes amount to the same thing. Yes, there are triplets and other non-binary notes, but they are the minority and the binary are the majority.

There is an electronic element called a flipflop which counts every other vibration of what is fed into it--or otherwise stated a flipflop outputs ½ the input frequency. It is not tuned in the way a string or organ pipe is tuned, but it does provide one octave below whatever pitch goes into it--however, it will also count every other vibration even if the vibrations put in are irregular or get faster or slower. Some electronic organs had similar divider circuits which were fed a note in the top octave of the organ and stepped it down octave by octave all the way to the contrabass. What that meant was that tuning the 12 tempered pitches of the top octave automatically tuned every note on that organ without the laborious tuning of each and every note--each and every reed or pipe of a conventional organ.

In fact, the two Farfisa transistor organs provided me in this studio by Buzz Kimball of New Hampshire are of this master-oscillator-divider type and thus 24 notes per octave are available in a total of six octaves, by tuning only 24 oscillator-coils by turning core-slugs with a screwdriver. No tedious business of having to tune all 146 notes.

So going from one tuning to another of the more than 100 possible tunings of these twin organs is a matter of 40 minutes or so, not of all day and into the night.

No wearisome back- and arm-straining elbow grease like tuning two PIANOS would be! Well if you tried to tune two pianos to most of the tunings these organs have been in for my compositions, you would break strings and never be able to afford either the time or the money to replace those strings! There, in a nutshell, is why xenharmonics has had to wait for modern electronic technology even for the tuning of new acoustic instruments to our new scales.

This is why I am writing this article and why you have to know certain things about digital counting circuitry.

[Electronics, continued]

Let's put in something else here about piano-tuning. With 49 years' experience I should be worth heeding on that. It takes 6 months for the average person to learn how to tune a piano the common oldfashioned way, by ear. Some people never learn; they lack the talent.

This means learning tuning well enough so that regular musicians can perform standard piano music properly. It does not mean real perfection. This means learning ONLY a system which is very close to, but not exactly, the 12-tone equal temperament. Just one system, not meantone or other members of the meantone family; not the unequal temperaments proposed by various theorists; just something close to the equal ideal.

Back to the electronic alternatives to conventional instruments. Keyboards are now PORTABLE. This makes a tremendous difference. Electronic instruments are no longer tied permanently to the light-socket, since many of the new one run off dry batteries, rechargeable batteries, or plug into the automobile battery.

Now why all that fussing & grumbling about piano-tuning? Because as I already said but cannot repeat too much, you cannot demand that a tuner learn several new tuning-systems that conflict in their very essence. You'll get a bad job and the tuner will take his frustration out on you, and have to charge more.

The piano will be put out of whack by retuning it too far from the 12-equal for which it was designed. It will try to go back and it will do that soon and ruin your experimental recordings. It's bad for the tuning-pin block and for the frame.

OK! Now with the electronic yattis-frammis and gizmos and flibbertygibbets, retuning doesn't strain its innards. True, many recent keyboards are permanently tied to 12--tone-equal at the factory. Others are either retunable or can be modified.

If conventional manufacturers and synthesizer companies won't make special retunable instruments, others will; and there are enough broad-minded people in various kinds of electronic business that somewhere somehow enough will be built and there will be do--it-yourself kits and there already is some computer software because I have HEARD it, and I have some sample tapes.

Now back to those flipflops that I mentioned earlier. Automatic octaves means as I said, only the need to tune a top octave and all other octaves fall in line, and even respond to retuning. When I put the Farfisa organs both of which were designed for ordinare 12-equal, into unequal tunings, into just arrays, into Pythagorean, into 24 notes of Meantone, into 17, 19, or 22, all the dividers in them AUTOMATICALLY obeyed the master oscillators and only 24 things had to be tuned, not 146.

Certainly not the four hundred twenty strings that two pianos would have! This is the crux of the matter, the reason why there has been so little progress toward new scales for 200 years--i.e. since the piano took over from the harpsichord and drove other keyboards out of business till electronic instruments could mature.

Now for another practical consideration: it is not enough to have just one non--twelve tuning. You need

[Electronics, continued]

several. Where would anybody put a dozen pianos? Why many piano stores these days don't keep a dozen of them on the floor at one time.

No sweat with electronics: there are instruments, and I have one right here, that will do over forty different tunings by just turning one knob! It takes an average of 15 seconds to go from one tuning to an other. It defaults to 12 if you turn the knob all the way. But it stays in the tuning you last set if you leave the knob alone.

Now really: if you can have an instrument that will retune in 15 seconds, why wait two hours for a piano merely to be corrected for its drift away from strict 12? Two pianos for 17, 19, or 24-tone? At least three hours and more likely over four hours. Who's got the time these days? Even if they had the money?

No wonder all this has been delayed and delayed. Now we are free to forge ahead. Lots of lost time to make up for.

Let's go back to those new clocks and watches for a moment--they have the built-in counters which take the inaudibly high vibration of 32 768 or 4 194 304 or whatever it may be, and bring it down an octave at a time through the audible range to the infrasonic range which is inaudibly low--one vibration per second, then it counts the seconds to show minutes and hours and then days--for nearly all of them have a calendar with day and month. Sometimes the battery which is about the size of a dried pea, runs down before it can count through the year.

So new musical instruments often have a similar counting system, not all that different from the way a computer counts and the little pocket calculators count.

This is how we can get rid of the necessity to tune instruments. Or, to tune acoustic instruments and those which do not contain digital counters built in, we now have tuning--devices which contain some kind of counting mechanism. The the user only has to tune unisons or in many cases, set the dials on the device and read an indicator that tells when the external instrument is in unison with the device.

The usual thing is to fake a 12-tone tempered scale on many organs and synthesizers and new keyboards.

Temperament is itself tempered! Here's how: An inaudibly high frequency, just like those watches and clocks, is generated by a stable oscillator. Someone does the arithmetic to find divisors for this large number of cycles per second, whose quotients will come near the frequencies for the 12-tone equal scale for the top octave on the instrument. The larger the high frequency chosen, the closer together the divided frequencies can be, so it is generally somewhere between 2 and 5 megahertz. This determines the accuracy of the audible frequencies. An exact 12-tone equality is impossible, since one cannot do the twelfth root of two and its powers digitally,

[Electronics, continued]

but it can be within a few cents or even a fraction of one cent, i.e. below the ability of any human ears to distinguish from perfect temperament.

It is possible to have something very close to just intonation, subject to a tiny error of a cent or so; it is possible to have any temperament one might long for by similar means; just pick the right divisors and set up counting circuits, or program a computer to produce these countings. This is not the only way to get rid of all necessity of anyone having to tune an instrument, but it is one of the commonly-used ways.

So, if you are at all interested or concerned with the theory of tuning, you should know the above.

Nothing at all like this was dreamt of in the 19th century or early 20th. For us in xenharmonics, it is one of the important spinoffs from computers.

There are synthesizers of the *analog* variety wh ch do not get their pitches that way, and we will go into this some later time.

Millions of electronic keyboards being sold. How could they be any good if humans had to keep tuning all of them?

However much the above may displease a theorist, it is a practical matter that has to be solved somehow in the real world. Pianos generally do not get tuned in the 1980's very often, partly because there are not enough tuners and partly because many owners cannot afford it. So the decline of the Pianofortic Empire is inevitable, sob, whimper, crocodile tears, anyone?

This was one of my motives for including the article *Metal Tubes and Bars* in this issue: once you tune a set of those, it will stay in tune for a century. Once a set of them has been made in a given just-intonation array or equal or unequal temperament, anybody else who wants such bars or a marimba or other stable acoustic instrument can copy its pitches and enjoy the same permanent tuning.

Tuning pipe organs or pianos or harpsichords or harps or psalteries is the labor of Sisyphus--all your effort and skill and dedication goes down the drain in a few months or even sooner. What a bummer!

So it's not just the difficulty of learning a whole variety of new tuning-systems ----it's the fact that many conventional instruments do not stay in tune, and so your new-scale instrument of that kind would be a useless white elephant pretty soon.

With fretted instruments the spacing of the frets, which can be worked out on a computer or pocket calculator of the "scientific" variety, sets the temperament or the just array and only 6 strings have to be brought up to pitch with the aid of those frets.

Here comes the Commercial: I have made up about 110 tables for fretting instruments of different string-lengths to different systems.

In various other issues of this BULLETIN, I have published frequency and beat tables as well as some fretting tables.

[Electronics, continued]

It should be obvious enough at this point that I was trying to connect the idea of pitch or musical use of audible frequencies to the idea of keeping time in both the musician's sense and the clockmaker's sense.

We can wind up this discussion by considering attainable accuracies today. A quartz crystal oscillator may often be accurate to one part per million --that is, a nominal 1 MHz crystal might stay between 999 999 and 1 000 001 Hz if properly mounted and temperature-controlled. In some cases, better than that. What does this mean in terms of timekeeping? One second per day variation would be one part in 86 400. One second per week would be 1 part in 604 800. One second in 11 days would be about one part per million. Of course, a clock or watch in the home or office wouldn't enjoy such a constant temperature and freedom from outside disturbances, but it generally does a pretty good job compared with regular watches and clocks that have pendulums and gears or springs.

That is to say, for the first time in history, the average person can get a clock that surely will do one part in a hundred thousand.

Now let's try to evaluate the tiny interval of one cent (.01 semitone, 1/1200 octave) in terms of clocks. About the gain or loss of one second in 28½ minutes would be a tuning--error of nearly one cent. If your clock or watch gained or lost that much you no doubt would complain. But a musical mistuning of that magnitude would not be audible except under very good conditions.

Double the error to 2 cents and many people would be able to hear it--that is about the normal threshold in the middle of the scale, with sustained tones. Still much too small to matter in any musical performance, but when you are tuning something and paying attention, it may be heard. Now we are talking about losing or gaining a second in 14 minutes or so.

This is about the error of the fourth or fifth in standard 12--tone tuning. But let's turn to the major third or minor sixth. Error nearly 14 cents. Now we are talking about losing or gaining a second in two minutes or so. Well that wouldn't be much of a clock. No way to run a railroad. This error is clearly audible.

Indeed the way that the 12-tone equal temperament ruins both sixths and thirds both major and minor is the chief reason why newcomers get interested in xenharmonics. Yet again the introduction of sustained tones through organs and synthesizers as opposed to the percussive noise of piano hammers and the dying-away tones, has altered the situation with regard to a heightened awareness of tempered tuning errors.

The way is wide open for me and anyone else to explore new scales, so I am already doing that and helping others explore without getting in one another's way since there is plenty of room in the new multitonal world, unlike the tight oppressive competition of the orthodox musical Establishment.

As I pointed out some time ago, the new scales all have new MOODS which could not be predicted mathematically, so that is why the experts and teachers and theorists missed them.

I can't write down the MOODS, but I can record compositions in them and copy the cassettes for you. So I did and they are now available.

It's your turn.

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Metal Tubes and Bars

As this is being written, the Sonic Arts Gallery in downtown San Diego is showing an exhibit called TUBULONGS, that being Ervin Wilson's name for new musical instruments constructed out of metal tubes.

Glen Prior, Jonathan Glasier, Ervin Wilson, Ivor Darreg, and others have been building instruments with aluminum, steel, brass, and copper tubing for several years now. At the Gallery, all those materials are represented, along with other instruments made of steel bars not too different in sound from the conventional glockenspiel.

Since the physical principles governing metal bars and tubes if they are mounted "free-free", i.e., not clamped at the end but supported at the nodes of the principal mode of vibration without too much constraint, are similar, we can consider bars and tubes together.

Why here and now, in *Xenharmonic Bulletin Number Eleven?* One of the reasons for the long time between No. 10 and No. 11 of this journal has been the opportunity to do more practice of xenharmonics--composition, adaptation of existing music, performance, recording, and now and then the availability of materials to build instruments and/or to repair instruments, amplifiers, etc.

So much theory has been written *about* possible new tunings and what might be done in the Sweet Bye And Bye, that the time has come to correct a severe imbalance between theory and practice! This article is about what HAS BEEN DONE, not about "vaporware" as the computer people call those airy prognostications.

Some people look around for instruments to adapt or convert to new scales, but this often leads to disappointing results or even failure. In particular, people want to make a piano over. That might have been the Only Game in Town in 1920, but this is 1988 well into the Electronic and Computer and Space Age, so let's leave Pianoforte Modification to incurable Nostalgiacs and Museum Repair Shops.

One very practical beginning is to use guitars refretted to non-12 as detailed in Xenharmonic Bulletin No. 7 for instance. That issue and other publications are still available and will continue to be.

Also cassette and other recordings in various new scales are now obtainable through various channels.

Now let's get into the reasons for describing metal tubes and bars. The main reason is that they don't cost too much to make, and the material is available at many stores and it is even possible to recycle used metal for instruments.

The cutting and mounting and other operations are within the ability of many persons and even if you personally don't have many such skills, it is easy enough to find some home-workshop person or even group willing to make metal tube and bar instruments.

The main problem for average people would be, do you have enough floor and storage space to keep such instruments after you have made them? Not for dwellers in trailers and furnished rooms and hotels, obviously!

However, there are enough meeting-halls and classrooms used only part-time and garages and back yards and other places to set up and play these instruments, and they are not too hard to transport or store, since they can be easily set up and taken down.

Best of all, they stay in tune much longer than other instruments. They are not that different from tuning-forks, accepted the world over as pitch-standards. Quite likely, a well-made set of bars or tubes will be in tune a century from now. Here is your chance to make something that will live after you.

True, the pitch of a metal bar or pipe will go up and down with temperature, but if returned to that temperature at which it was tuned, it should be right on the button. A group of bars or tubes will go up and down together, and remain in tune with themselves.

Why use bars or tubes for new tuning-systems and non-12 scales?

Metal Tubes & Bars *continued*

In recent years, percussion instruments have become much more popular than they had been in the past, and so there are new magazines for percussion players and more teachers of the various instruments. That is, it wouldn't make too much sense to build as your first project something so alien that you wouldn't be able to get beginner's help from books or regular musicians.

The principles of playing mallet instruments are the same even for these new tuning-systems, and in almost all cases, the new scale will have at least one pitch in common with commercial instruments such as vibes, glockenspiel, marimba, etc. We recommend that A=440 Hz or its octave 880 be that note in common.

If you are so inclined, you could take lessons on a conventional mallet instrument—be cautious, though: do not tell them too much about what you are building—they may try to stop you using non-12--tone scales. Why borrow trouble? It's your future, not theirs, that is at stake, and no use trying to convert others against their will!

You may wonder why this article doesn't feature wooden-bar instruments such as marimbas. Simply that it will be easier to get the pitches for a marimba or xylophone from a metal instrument than the other way around. The metal instrument will sustain longer and can be tuned more accurately to the tuning device or other pitch-standard. Especially if you are a beginner. Also, lower notes on marimbas require resonators in most cases, and that's another building problem that can wait.

No doubt another question is already in your mind: with the new Sampling Keyboards, couldn't you avoid building metal tube and bar instruments and let the keyboard imitate them? Well almost but not quite, and some of these keyboards are locked to the 12-tone scale at the factory. Besides, isn't it prudent to have one instrument at least in your collection that will still function when the power is off or you want to take an instrument out in the country for a day.

WARNING: Some samplers as of 1988 would take a sample of a bar or tube, then shift its pitch to other notes of the 12-tone equal temperament, not the new scale to which you will have tuned the bars or tubes! This would defeat your purpose. In years to come, this problem will be alleviated.

Comparison of tubes with Bars: Much of the tubing commercially available has welded seams. Some tubing is seamless. This is important because a tube having much of a seam (usually only noticeable by looking down its inside surface) will be somewhat irregular in its modes of vibration, such that it will beat with itself. For the ordinary 12-tone scale and some other scales 13 through 24 tones per octave, this may often be acceptable. Tubing having a seam may vibrate at a different frequency depending on where it is struck around the circumference. The most favorable or steadiest sound can be marked by placing a dot or other mark symbol at that point after completing the set.

For critical situations and especially for more than 24 tones per octave and where just intonation is the ideal with tiny comma intervals and steady beatlessness, it might be better to consider using flat bars.

On the other hand, for scales like 13, 14, 18, or certain ethnic tunings like those used with the gamelan, beats may even be sought.

The main point is, Don't spend a lot of money on enough tubing to build an instrument without first testing a sample tube for beats.

Tubes are generally loud enough for about three octaves from A=440 to the usual top C around 4200 Hz that they don't need resonators or amplification. That is the main advantage over metal bars, which

Metal Tubes & Bars, *continued*

size for size do not have as much sound-radiating surface exposed to the atmosphere as tubes do. At the top end of the scale, tubes may get too short, and if they have thin walls, they will not sustain enough. Length of sustain is dependent upon mass and stiffness,i.e. amount of energy that can be stored in the bar or tube from the energy imparted by the blow.

Even with tubes, it gets harder and harder to radiate enough sound as one goes to lower notes, i.e. longer wavelengths and more power needed to give the human ear an adequate sensation of loudness, hence our recommendation of not trying to take a set of tubes below A=440 or even C=528 Hz.

It would be nice if one could give tables of scales here with exact lengths to cut the tubing, but this is impossible since there are so many different metals and alloys suitable for tubing, and so many different sizes and thicknesses of the tube-walls on the market. A factory may quit making a particular kind of tubing, or change their alloy.The longest tube in one set here, sounding A 440 Hz and made of galvanized steel electrical conduit, is just over 23 mm outside diameter and is 570 mm long. This might serve as a typical dimension of the bottom note. A flat bar sounding the same note and made of similar steel might be 19 mm wide, 5 mm thick, and 230 mm long, but it must be added that this bar has been ground in the middle to make it thinner there.

This variation does not make your task hopeless. Once you have your first bar tuned to a definite pitch and a stock of similar material on hand, then you can estimate how much shorter or longer the next note above or below should be.

Begin that with a Rule-of-thumb which isn't perfect but close enough: Twice the length is TWO octaves lower, not ONE octave as is the rule for strings and for air-columns in flutes or organ pipes. And likewise, half the length is TWO octaves higher, not ONE octave higher, as it would be for strings or air columns. This does not apply to resonator tubes if you need to make resonators for bars—those resonator tubes are normal air-columns just like organ pipes and obey the organ pipe rules.

It would be very rare for the air-column in one of the metal tubes we are talking about here to be in tune with the note we are obtaining by striking that tube with a mallet when it is supported at its two nodes for the mode of vibration generally used with free-free bars or tubes. If it ever happened to coincide and resonate it would make that note louder than its neighbors since it would be a fortuitous coincidence of the one- and two-octave rules just mentioned.

Now let's discuss Nodes. If a tube or bar be struck at the very end or in the center, the points of no vibration for the normal mode of vibration will be approximately two-ninths of the length of the bar from either end. That is where the tube or bar should be supported, preferably by some soft resilient material such as foam rubber or certain foam plastics, or felt has been used for the heavy glockenspiel bars. The 2/9 rule is approximate: 0.224 of the distance is closer, but that would be hairsplitting in the case of these instruments.

We are not concerned with the modes of vibration used in tubular chimes of the kind used to imitate bells. Those follow still different rules.

Now comes the topic which differs greatly from any ordinary article on tuned percussions: For which scales are these tubes and bars suited? Is there some special reason for combining the use of these instruments with the exploration of new scales?

Yes, there is! It has to do with the Harmonic Series of normal overtones. Just intonation, and the equal temperaments with 19, 22, 31 tones per octave, and a number of unequal temperaments of certain kinds, take advantage of the Harmonic Series and it works well with

Metal Tubes and Bars,*continued*

them. That is, such common intervals as the fourth and fifth and major and minor thirds and sixths depend for their consonance and their definition upon the presence and relative amounts of harmonic overtones in the sound of the instruments playing them.

But the sounds from these bars and tubes under discussion here do not have harmonic overtones. They usually have *inharmonic* overtones which are not members of the harmonic series and part of the playing technique for these instruments is learning how to keep the loudness of inharmonic partials down in relation to the fundamental.

It is possible to reshape some bars so as to make certain overtones harmonic or nearly so. A handbook published several years ago by Chris Banta of Pasadena CA treats of this subject.

For certain new scales that are worth trying, this absence of harmonic partials and the exotic color given by the presence of inharmonic overtones is a definite and positive advantage. Take for instance the equal temperament with 13 tones per octave. All its intervals save the octave are weird and wacky. Ordinary musical notation is almost useless for 13-tone. The only good way to deal with it is to number the tones.

Conventional rules of harmony will not work in 13, but it is melodically interesting and effective for atonal music. If we try to play 13-tone in ordinary timbres like organ, the chords can get very hairy, so many experimenters have given up on it. But suppose we tune a set of mellow metal or wooden bars to 13—much better! We have now tamed this wild exotic creature and are ready to explore a new corner of the tonal world.

Take the 17-tone system. Its fourths, fifths, and major seconds are more brilliant than those of ordinary twelve-tone; the leading-tones are more decisive and snappy than those of 12, so that even conventional pieces such as unaccompanied violin solos or regular songs take on an added color. This new brilliance is purchased at the price of harshness when the usual kind of harmony is attempted in 17-tone, because of the dissonant nature of the thirds and sixths in this system.

However, the near-absence of harmonic overtones in the sound of our tubes and bars being discussed here, tames 17-tone so much that we don't have to worry about harshness when playing most familiar music on a seventeen-tone tube or bar instrument; just go ahead and enjoy the melodic brilliance.

Similar reasoning applies to some other tuning-systems that can be used with these tubes and bars, such as 14, 15, or 21 tones/octave.

Followers of the Harry Partch tradition have constructed many bar instruments with various just intonation arrays. In recent years, there has been a growing interest in the Indonesian gamelan idea and other exotic tuning-systems found around the globe. This has contributed to the expansion in tuned percussions.

Very well: Tuning. How do you tune bars and tubes? By sawing, filing, and grinding, mostly. Yes, but! You probably didn't mean that.

You tune them to <u>what</u>? That's more like the answer you wanted. Back in the 1930's an article like this would have been unrealistic and pointless. Tuning two or three octaves of bars to an unheard-of scale like 17 or 19 tones per octave, or to a selection of that many pitches from Just Intonation, well no way for the average person—tuning them to ordinary 12 would have been difficult enough, unless one had access to a commercial already-tuned metal-bar instrument.

Without a series of harmonic overtones, even a trained piano-tuner could not set the 12-tone temperament on the bars by ear, since the beats would not be there.

Metal Tubes & Bars, *continued*

It would do you no good to take a piano- or organ-tuning class somewhere, since the 12-tone routine for tuning by ear will not work for the tubes or bars. However, in the 1940s and 1950s, electronic tuning-devices such as the Hale, Conn, Peterson, and others were put on the market and many but not all of these units can be used to tune bars to non-12 scales even though they were not designed for this job.

.Most of these devices are expensive, so you may have to rent or borrow from somewhere. There are signs that the cost is coming down and in a few years it could become reasonable.

To use these tuners for non-12, you need a Cents Table for the tuning-system in question, and some such tables have been published by Ivor Darreg and others and more will appear soon. The abovementioned tuners will tune 12-tone by turning dials to the wanted semitone pitch-class but outside 12--tone equal temperament you must have a +- cents table, i.e. the pitches of the non-twelve tuning have to be presented as 0 to 50¢ *below* or *above* some standard 12--tone equal-tempered-semitone pitch usually designated by letter name, as follows *F+23, C#-30, G+21, A-3, F exactly*, etc.

You could use a straight cents table like 386 ¢ for E a just 5:4 major third above just C, but then you would have to do oodles of subtracting, which can be mighty confusing when you are sawing and grinding bars! Cents, of course, are one-hundredths of a regular 12-tone-tempered semitone and the designation is due to A.J. Ellis a century ago.

To use a frequency-measuring device that reads out in hertz as a Frequency Counter does, you would need not only a Frequency table for the tuning-system, but also an oscillator to provide a steady tone to your ear and to the frequency-counter, which counter cannot work with percussion tones that die away. Hence the adjustable sustained-tone oscillator with an amplifier and speaker is necessary. for the frequency-counter method.

Signal generators where you dial your wanted frequency may become affordable later on. At present they are high-priced laboratory treasures.

Again, if you had an electronic keyboard instrument that was not locked into 12-tone equal temperament, you could set it to 13 or 17 or whatever and tune your tubes and bars to that. But this is only recently becoming affordable and available, so you might have to wait a couple of years or so for that.

When tuning, have a thermometer handy! Metal expands with heat and bars and tubes go flat; metal contracts with cold and bars and tubes go sharp. Considerable heat is produced by hacksawing, filing, and grinding, so it is easy to overcut at the final stage of tuning. Keep a record of room temperatures when you work on the instrument so that it will be in tune with itself when finished.

Other instruments, such as bowed stringed instruments or electronic instruments or the woodwinds, will go up or down differently with temperature than the percussions. Metallophones and xylophones are often tuned slightly sharp, say to A=442, for this reason.

IMPORTANT: A very common auditory illusion is that tones above 1100 Hz, when tuned to perfect octaves with their counterparts an octave lower, will seem to be flat to almost every listener. It is almost universal to tune all notes on a piano higher than High C second leger line above the treble staff, sharper than theory calls for, and as one goes to the top the amount of sharpness increases.

For metal bars and tubes the degree of sharpening will be somewhat less than on a piano. This illusion obtains, regardless of the new tuning system you may be using.

Last but not least: Do not begin a project like this unless you have the patience and energy to see it through. Nothing is more pitiful than an unfinished instrument! * ***

PARTCH'S PITCHES

Most readers of the Xenharmonic Bulletin are familiar with the life and work of the late Harry Partch, who pioneered in the actual use of non-12-tone-tempered intervals in the face of dreadful and fanatical opposition over a very long term.

His ghost is not allowed to rest either: the usual courtesy of *De Mortuis nil nisi bonum* is not often extended to him. Small wonder, then, that he reacted against his assorted opponents in the musical establishment.

One form this reaction took, that has not been commented on in the literature to my knowledge, was his rejection of many musical standards —well we might call them norms or trade-customs or textbook precepts— or in the case treated below, engineering standards.

Future publications may treat of these other rebellions against the standards, but for now the question is: What pitch did Partch take as a starting-point for tuning his instruments, and why?

In *Xenharmonic Bulletin No. 11* we are discussing the trio of equal temperaments 41, 43, 46, and of course Partch is Famous for a 43-tone system which the Great Uninformed Majority obstinately keeps calling 43-tone Equal, when it IS NOT!

Honestly, college-trained and worldly-wise people who ought to know better! Don't they care? We can pardon innocent ignorance, but these writers bill themselves as seasoned experts. They know whom their favorite composer slept with and how often. They know which side of Tchaikovsky's bread it was buttered on. They know how many buttons were on Schubert's coat.

But when it comes to American composers—and this includes Canadians and Mexicans, they don't even want to know anything, and are quite willing to let misinformation go through unchecked.

Very well: does it matter? Am I nitpicking or fussing over trifles? In particular, why should it matter *now?*

First, because Partch's instruments are getting old, and for quite understandable reasons very few people have had access to them; and since Partch was careful to give many details of their construction in his book, the only way the average newcomer is going to duplicate the sound of Partch's music is to build and tune instruments to Partch's directions or to get the same set of pitches on a computer or electronic instrument, and if one attempts to do so with the 43-tone Equal Temperament, it would be a terrible waste of time and possibly money, since 43-equal does not sound like Partch's 43 UN-equally-spaced Extended Just Intonation System.

The 43-tone equal temperament was invented long before Partch, and for a purpose having little or nothing to do with Partch's theory or practice. 43-equal is a variant of meantone temperament, and a very close approximation to what is called 1/5-comma meantone, and so far I have been unable to hear anybody's composition using all 43 of its tones. If you must use an equal temperament to approximate Partch's tuning, try forty-ONE equal, not forty-three. This was investigated some time ago by Ervin Wilson.

Actually, 43 unequally-spaced tones is merely Partch's norm or nominal set of pitches—early in his work he used 29, and later on had to use more than 43 occasionally.

There is nothing sacred about the number 43, and frankly, I could not perform most of my justly-intoned compositions, using his selection of 43 pitches. Nor could most other composers who use just intonation do theirs either. He had his own private reasons for his idiosyncratic choice and we don't need to copy him.

PARTCH'S PITCHES, continued

Since most of Partch's reasons for choosing 43 just pitches and not some other array of 43 just pitches (hundreds are possible) are given or implied in *Genesis of A Music*, I needn't recap them all here. Just what is relevant to the present-time situation, such as the huge amount of misinformation and garbled reports getting into the public press these days, and they get further and further from the truth year after year, and as we get further removed from the memory of live Partch performances.

"Live" in the sense that Partch coached the performers and was present to see that it went off right.

Do you want a parallel? Take Bach—his harpsichord or clavichord might be at a different pitch from the organs his church pieces had to be played on, and many 19th and 20th century performances have been at very different pitches from those. The temperaments used also differed; and there is now a huge literature of speculation on what is and what is not correct tuning for Bach works. Incredible amounts of energy and time have been expended over arguing about that instead of playing the music.

Too many people would rather argue with each other or write about minutiae, than get good performances or arrangements HEARD.

There are many followers of Partch and some of them forget how unique he was and that certain equipment and facilities and possibilities simply did not exist during Partch's lifetime, but are available to them today, so imitating all the dreadful privations and constraints he went through, or refusing to take advantage of today's technology, will NOT help Partch's music to survive and will not help their own composing either. His instruments and notation and nomenclature and selection of a pitch-array and a pitch-standard were not for you or me, just for HIM. It should be clear enough, reading his book, that he wasn't trying to impose it upon us outside performances of his own compositions.

I am alarmed by the way some people treat him as a religious leader and use his system where it does not apply instead of using it as he intended.

The late Peter Yates who spent a lot of time and trouble promoting Partch's works, used the term "private jokes" to describe the way in which Partch was trying to get even with the Musical Establishment. This concept of Yates's is relevant here, for good or ill, but please don't blame me for it! What Yates meant was that Partch continually needled the standardized, Classical and Romantic, European musical tradition and its instruments and performers and teachers and academics.

Some of this protest and complaint is obvious and clear and readily understood, but the "private" portion of it is almost encoded in an esoteric jargon, or has to be read between the lines. His deliberate incompatibility, such that almost no existing music and practically nothing by other contemporary composers including me can be performed on his instruments, might not be clear enough to the music critic listening to Partch recordings or attending a Partch performance, then or now. This incompatibility extends to the tuning of his instruments, what they can and cannot do, the total elimination of traditional pitch-names A B C D E F G and the sharps and flats, or even new accidentals for small intervals that some composers have invented, and his replacing them by a system of FRACTIONS expressing ratios. All these fractions are "improper" or in the older musical-theory jargon, "superparticular"—what is meant is that these fractions must have values between integers 1 and 2 no more and no less.

The above-mentioned integers are written in the forms 1/1 and 2/1, so that all his ratio-expressions will have the best uniform appearance. The larger number is always the numerator, i.e. the fraction's value is always unity or greater,

but it may not exceed 2/1.

Intervals greater than an octave, i. e. larger than 2:1, are reduced to the same octave—OK for him, but don't ask me to do this in my own writings! I want the freedom to write 1:2 here a and 2:1 there, and to use simply 2 here or to write 0.5 somewhere else when that is the best way for my purposes.

He abolishes the familiar names for intervals, such as Fifth or Second or Major Third, and uses only the fractions as stated above. Good for his book because he had to avoid the confusion in English between the fraction 1/5 and the interval called a Fifth because it occupies five successive degrees counting inclusively on the staff or five successive letter-names in ordinary nomenclature.

I almost wish he had written in German where there cannot be any confusion between Fünftel and Quinte. So far, so good. He gets rid of what could have ruined his chances and nobody would have followed him. But he introduced a new Fly In The Ointment that affords us no relief at all! This is his treating the set of ratio--fractions between 1/1 and 2/1 as both names of intervals regardless of where they are in the range of hearing, down in the sub-basement or up in the stratosphere; and at the same time these same fractions have to do double duty for ABSOLUTE PITCHES, such that 1/1 = 392 Hz.

This reflects the solfeggio in English- and German-speaking countries where DO RE MI FA SOL are movable to any pitch you please, keeping their relations or ratios; but in the Latin countries, **DO** is a FIXED pitch the same as our **C** and RE is always D (or D-sharp or D-flat by adding the proper name for accidentals in the language). I just said "absolute pitches" but I must immediately qualify: he does not express octaves, so if 1/1 denotes 392 Hz it can also denote 784 or 196 or 98 or 1568. Other composers who use Partch's fractions to name absolute pitches sometimes take their 1/1 to be C or A or something else, such as the old Physical Pitch C=256 Hz (or 512 or other octave), or some such standard as A=435 or A=440 or C=261, etc.

If you want your instruments to be tuned to unison with Partch's instruments, take G=392 Hz. That still leaves the question, Why? Where did he get that from?

This is where that Private Joke business comes in! Here he rebels against traditional music, pianos, the names of notes, the fact that orchestras tune to A and bands to B-flat in many cases, the A=440 tuning-forks piano-tuners carry, the 12-tone equal temperament in general use, and a lot of other standards.

Some people tune to A, others to C, some band instruments to B-flat, and guitarists to E in most cases. A=440 is almost an international standard in the 1980's, but there is some use of lower and higher pitches such as A=435 and A=442 and A=444 or higher.

G as 1/1, the starting-point from which to tune everything else, has some justification—it is the note symbolized by the G or treble clef, for one thing. All the Violin Family have G strings (but they do not have C strings on violin or doublebass). As a compromise between C and A, why not G? So that is not the Private Joke.

The joke is that here is Partch, the champion of Just Intonation and indefatigable enemy of all tempered scales and especially implacable denouncer of the twelve-tone equal temperament, choosing 392 Hz for his G which is almost exactly the 12-tone G for the standard A=440 Hz. He ranted and raved against 12-equal then lets it in the back door!

Oh I know! The table for 12-tone equal temperament gives 391.99545 Hz for G or more usually 391.995 to 3 places. Now before quarrelling over split gnat's eyelashes, realize that this deviation or discrepancy is about 1/60000 octave and most people would be happy if their clocks and watches kept time to better than one second per day. Tuning forks for G would be stamped 392.0 to nearest .1 Hz.

PARTCH'S PITCHES, continued

Tuning-forks and even electronic apparatus will shift in pitch with temperature, and this will be considerably more than one--tenth of a vibration per second. So the above difference between the value of the sixth root of two, times A=440, and the rounding-off by Partch and the Fork Manufacturers to an integer, is of no importance in the Real World. This should be proof enough of Partch's common sense.

392 Hz does look a little peculiar still. Why the 12-tone G, not the just G, from A=440? My best guess is this: there is more than one Just G for A, viz. the one 8/9 the frequency of A, and the other one 9/10 the frequency of A. The lower G has a frequency of $391\frac{1}{9}$ Hz, while the higher G has a frequency of 396 Hz. The interval between them has a ratio of 80:81 or Partch would have written it 81/80, but no matter——same difference. It's called a comma or Didymus or Syntonic Comma if you must call it something. Frankly, it's a nuisance to musicians and pianists never understand it and piano tuners know only the other comma whose ratio is 531441:524288, called the Pythagorean comma, and not relevant here.

But Partch knew and demanded Just Intonation, which has an infinite number of notes only a comma apart. Now suppose he was thinking about the cello or viola tuned in fifths, C G D and A, and the fact that the C which is a perfect major sixth below A is higher in pitch than the C you would get on a viola or cello by tuning it the conventional way.

The C a perfect major sixth below A=440 is 264, while the C belonging to a series of perfect fifths is 260.74+. Can you imagine the problems explaining this over and over to musicians of various kinds who could care less, and don't want to hear about such mathematical minutiae and were already hostile to Partch and he's got enough trouble as it is, so if he was to get any more assistance or sponsorship or help in his career, better not make enemies of everybody!

Helmholtz in *Sensations of Tone*, and his translator Ellis, chose A to be 440 Hz, anticipating much of Europe and America by decades, and doing better than they knew——435 and many other pitches for A were held to, over the musical world, and real standardization had to wait a very long time——and even now the pressure is mounting to raise the pitch to 444 or higher. At least, we do have a rather official paper 440 standard in effect at present.

Now Helmholtz and Ellis chose C to be 264 and 528 Hz, a perfect major sixth below A and a perfect minor third above it, so that the A=440 was really what Ellis wrote as A_1——i.e. A-one--comma-down-from-the-A obtained by taking perfect fourths or fifths from C. A normal, plain, unnumbered A would then have to be 445.5 Hz.

So, with C and A being standard notes to start counting from for most musicians and instrument-makers and tuners, if Partch had been a good little boy and had chosen C as his fundamental basic resting-point for his system of tuning, this subscript and comma business would have gotten him into terrific trouble and would have crushed him. Maybe I'm botching this job of explaining. Maybe I too will get into a peck of trouble by this thankless task of attempting to ferret out Partch's motives for choosing G instead of C or A and then building into his pitch for G the 6th root of 2, rather than some nice neat pure just interval such as 9:8 or 10:9.

It may not be immediately obvious why abandoning C and going up a fifth to G would help him in his dilemma. This affair revolves around the second degree of the ordinary major scale. In ordinary 12-tone equal temperament, and in Pythagorean intonation often used for melodic purposes, especially by string players, there is only ONE major second. But in just intonation and in some equal temperaments that

PARTCH'S PITCHES; continued

have a small interval functioning as a comma, such as 22, 34, 41, 53, 72, &c., there will be at least two intervals entitled to the name of major second or whole tone and the major third can be divided into unequal parts. Unequal systems also exist that have this property.

Now if Partch chose C=264 Hz as Helmholtz and Ellis in fact did, and made his starting-pitch C and kept all the letter-names for the conventional major and minor system, the nagging problem of the comma (81/80 in Partch's notation) immediately appears!

Which pitch, $293\frac{1}{3}$ or 297 Hz, shall be called D? Why, both! But how can D be two pitches so dreadfully out-of-tune with each other? Go to any library or store and find a whole shelf of harmony books and books on how to arrange or compose or play some instrument, and there will be no mention of commas and nothing to suggest any problem about how to tune the second degree of the C scale, major or minor.

Nothing to suggest that if you tune the standard just C-major scale, the D will make a horrid beating with the A. Nothing to suggest that the chord D F A_1 is NOT a D-minor triad, but a discordant jangle. Early investigators of just intonation such as Moritz Hauptmann, whom Helmholtz used as one source for his work, solved this problem by using small d for the lower pitch and capital D for the higher.

Ellis went along with that for a while in the English translation of Helmholtz's book, but it created typographical problems, since as soon as you go to flat keys and minor scales you need more comma-distinctions, so Ellis borrowed the sub- and super-script notation used in mathematics and then the two D-notes are distinguished as D and D_1.

Fine and dandy, if you are a music theorist writing a scholarly article, or an instrument-builder trying to figure out some kind of special instrument that would be capable of playing conventional harmonic music in just intonation and modulating to a number of different keys. (Say some kind of an organ having 24 notes per octave.) This or another comma-notation will take care of what Partch called the 5-Limit.

Yes, it will on paper. But try and get anywhere with it if you are confronted by any ordinary musician or music-teacher or piano-tuner! You will get thrown downstairs on your hind end, or told to Get Lost, or they might send for the young fellows in white coats with handcuffs and straitjackets.

Ellis has been slandered and misunderstood for a whole century and there has been no respect for the dead in his case but rather vicious unfounded attacks in book after book and the most unkind and unreasonable accusations and falsehoods. All because he tried to explain and straighten out just intonation and other tuning-systems which would be useful for progres in musical compositions and performance and instrument-construction.

I know of no greater ingratitude.

Partch surely was aware of what happened to Ellis even beyond the grave, so he sought some artful dodges or way of escaping Ellis's fate. Now, suppose he chose G instead of C as the starting-point. Then project the standard just intonation scale upon G as tonic. By standard I mean that form of a just major scale which can be found in physics and acoustics books and which was officially set forth as a standard in some engineering publications. Now! look what happens. The ratios are: 1/1, 9/8, 5/4, 4/3, 3/2, 5/3, 15/8, 2/1.

Based on the just-intonation C=264 Hz for A=440 Hz, the above scale projected onto C as tonic would make D out-of-tune with the standard A=440. Instead of a perfect fifth, ratio 3/2 in Partch's notation, we would get a false "fifth" of ratio 40/27 in his notation.

Now if we keep the letter-names, and still want to show what is going to be out-of-tune, we could use Ellis's notation and show the false "fifth" as D A_1.

PARTCH'S PITCHES, continued

But that would go against every musician in every orchestra and all the music-instrument manufacturers in the world, and your name would be MUD if you tried that. Worse yet, some people use subscripts and superscripts to mean octaves, such that A_1 would be 110 Hz or 108.75 Hz for A=435, or A_1 might even be 55 Hz an octave lower than the other fellow's A_1 and neither having the slightest thing to do with commas. To make the whole mess even more nasty, the A which is now 440 Hz has been called A3 by some people and A4 by others. Don't try to mediate this eight- or nine--cornered dispute—they are all angry with one another and will never give in.

Funny how the persons concerned with Harmony and especially the very smooth harmony of Just Intonation, write the angriest polemics! They show no mercy and don't even bother to check the facts.

Back to the standard just major scale on the preceding page. If G were chosen as tonic, then A would no longer be a false fifth but now a true perfect 3:2 fifth from D. The set of perfect fifths C G D A on cello or viola open strings would now be a full member of the G-major just scale. So Partch chose G. All right, A is no longer the starting point, and A=440 Hz calls for G $391\frac{1}{9}$. But Partch wanted Unity, 1/1, as he writes, to start his calculations, and wouldn't it look odd if his starting-pitch were a fraction, or worse still the decimal expression of that number, 391.11+? Besides: somebody wants a tuning-fork for Partch's system. To get forks for everybody for 391.1 or 391.111 or however they might be marked, would be a special order that I am sure no American factory would consider. Eureka! How about G=392, which was available from a few manufacturers? Even if only as part of a 12-tone set. 392 is an integer and so that makes it much more acceptable as a published standard. Besides, it might be available as one of the metal bars in a vibraphone or other metallophone instruments, such as a school or popular band or orchestra might have.

I can't guarantee that this is how Partch's reasoning went back in the 1920's or 1930's but nobody has come up with anything to contradict it. I suppose that now some angry purist that wants to take all the fun out of life will try to start a fight with me about it. Frankly I haven't time.

At least part of the above educated guessing has to be true. Should one or two points be proved mistaken, it doesn't really matter.

This isn't quite the end of the affair however: Partch simply threw out the customary letter-names and their accidentals (and presumably that would mean that he threw out the Spanish, French, and Italian fixed pitch names also, such as RE=D and MI = E and FA = F) because they do not take care neatly of his 43-tone 11-Limit just system.

Up to this point I have not brought in the real problem Partch faced in addition to the comma above which makes say an E_1 derived as tuning a perfect 5/4 major third from C different from an E tuned by taking four just fifths upward from C as C G D A E. His system is not a 5-Limit one: i.e. his intervals cannot all be derived by tuning just fifths and thirds 3/2 and 5/4—5-limit because the only prime numbers in the calculations are 2 (for what we call octaves and he would not), 3, and 5. No, his is an Eleven-Limit System because calculating frequencies or string-lengths for it involves prime factors 2,3,5,7, and 11.

Alexander J. Ellis referred to above could denote commas above and below the conventional pitches easily enough but his methods for dealing with sub-minor sevenths (Partch's 7/4) and other intervals based upon them such as 7/5 or 7/6, are awkward, and when one gets to the eleven-based intervals and/or to what Partch called Utonalities (extensions of the minor chord idea to more complex intervals

PARTCH'S PITCHES, continued

and sort of mirror-images of the upward-reckoned intervals), Ellis almost gave up on it. It would be a printer's nightmare and very puzzling on the music-staff. So Partch didn't attempt to supplement conventional names with three sets of additional signs.

Nobody would have understood him if he had, and so it would have hindered his composing and building instruments and teaching others how to play them. It would not have helped preserve his music for posterity.

We needn't go into the details of the special set of 43 just pitches here, since they are diagrammed in his Book, *Genesis of a Music*, along with some hints on how to tune them.

Partch also gave many dimensions for duplicating his instruments, and instructions on how they were played, and he set forth the various performance-notations for them. Actually many of these notations are tablatures.

His instructions on how to tune are of course based on his expert ear and long practice; it might be difficult or impossible for the average person to do it well enough.

Fortunately, he has a table of cents values for his intervals and related intervals. From this table another table can be constructed and used with any of the new electronic tuning-devices which are based on the ordinary 12-tone system, but which divide each ordinary semitone into 100 cents, and because they have the 12 semitones to begin with, will have Partch's 1/1 starting pitch as G=392 Hz. So in this respect, his choice of 392 Hz wasn't such a bad deal! It was a lucky accident.

Otherwise there would be no hope of people living thousands of miles away, being able to use his tuning-system, and being sure they had it right.

We don't have to do EVERYTHING the HARD WAY just because Partch didn't have our measuring equipment and portable electronic keyboards and computers with software that can be used to make music in almost any scale. Some people take Partch's system as some kind of masochistic religion when he didn't want a cult. Others become highly intolerant of me and lots of other composers because we won't compose all of our music with exactly the same pitches, intervals, and instruments that he used. He didn't want any clones!

Few people will have the money, the strength and skill, the time, or the floor and storage space to copy his instruments, practice on them and maintain them and get other performers to use them also.

But why not use modern electronic means to keep his music alive and not let it be forgotten? Sure, I will be denounced for heresy; but his legacy to us is in danger of perishing unless somebody does this by the new methods.

Now that we have computers and recording machines and all kinds of sound-altering instruments, each of us can do our OWN thing.

It would be stupidity rather than loyalty to stay within his scale when our compositional talents may and should run in quite different directions. There are many thousands of extended just intonation systems possible. We don't have to stay inside his Eleven-Limit which was imposed by practical considerations of the time in which he lived.

He couldn't modulate as much as we now can, simply because there would have been nowhere to add the needed tones; but for us those restrictions have vanished.

His instruments are incompatible with most existing music, and with much that is being done today, whether just or tempered. That is, the tones are his and not necessarily ours.

With versatile instruments and computers also, we can have his system to play his music without giving up our systems—just change the tuning-memory or something like that.

I didn't write this article merely to make you long for something you

couldn't do or can't have because you are too old or no money or not enough time, or nowhere to put a bass marimba or no time to practice or learn his system or whatever.

I wrote it in the hope that some people who have access to suitable equipment can get Partch's music recorded in the new media such as cassette, DAT, CD, computer software, whatever, and also to prevent such expensive mistakes as someone doing it in the 43-tone EQUAL temperament or for that matter, thinking that Partch's tuning doesn't matter and daring to ruin it by performing it in 12-tone equal temperament.

This last danger is very real. I have seen articles and essays that flatly deny any value of Partch's tuning. There are opera-oriented people who want to present or perform or record his singing and drama, but would just as soon play all the music on a piano or other 12-tone instrument. I don't know how they can be stopped.

Why this article in this issue of the Bulletin? Because in No. 11 we are focussing upon the set of temperaments 41-43-46, and many publications have carried misinformation about Partch's music to the effect that it is in 43-equal, when in fact it is 43 unequally-spaced pitches that are not tempered at all. Also, Partch's music is definitely xenharmonic—i.e., it does not sound like 12-tone equal temperament and thus is relevant to this Bulletin.

A while ago, someone tried to imply that just intonation was not a part of xenharmonics, but it <u>is</u> xenharmonic in most cases. Exceptions are rare—a few cases where old music is being improved by playing it in just intonation but the harmonies are so tame or the melody so simple that the differences between the just and 12-equal intervals are not clear.

The particular kind of xenharmonic effect in Partch's music is produced by the many intervals involving 7 and 11 in their ratios: —something completely alien to the ordinary 12-tone equal temperament. The presence of these intervals is hard to ignore because Partch has so ordered and patterned his set of tones and the way he uses them that they occur frequently throughout a performance. Most composers in just systems use a very different array of pitches and most or even all their pitches lie within the 5-Limit. Or they have a 7-limit with fewer 7's than Partch has, and no 11's. Partch's array forces him to sprinkle the music with lots of 11's and 7's, while someone else's array might not contain the very peculiar constraints which Partch built in. A few people are now trying 13 and 17. Partch discusses 13, but decided that a 13-limit would complicate his instruments too much and of course cost more.

Theoretically the number of just pitches is INFINITE. But in the Real World he had to make do with 43 and occasionally just a few more. With modern electronics we could go into the hundreds, far more than we could hear.

Partch did not let his theory spoil his practice. There were some pitch-bends and sliding tones, for instance, not part of the theory, so in any performance, even by computer, this must be retained, in order that the affair be live instead of "dead". Purist insistence on uptight theory could spoil it.

The unusual peculiar unique timbres of the Partch ensemble are just as important as the pitches! And they are in considerable danger of being forgotten and lost as the memory of performances during Partch's lifetime recedes into the past.

Ironically enough, it may be easier to preserve the visual aspects of the instruments and performances than it will be to preserve the SOUND.

An important lesson to be learned from his system is: Do not be seduced by the Standardization and Mass-Production Ideal of our society! Do your own thing and don't worry about whether or not it can be turned out in millions of copies.

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41, 43, and 46

(Continued from Page 1)

When it comes to fretted instruments, such as guitars of the standard size, problems appear. We are dealing with about one--seventh of the ordinary whole step. (42 tones/octave would be exactly 1/7 whole-step and this is one of the systems that Julián Carrillo had made up on one of his pianos.)

For people with average-sized hands and fingers, going beyond a 31-tone guitar presents problems. Remember that where two frets are placed on a regular 12--tone guitar, one of these guitars will have about seven!

Getting down the fingerboard to the octave, the spacing is going to be real tight. I have had the experience of playing the 41-tone guitar that Ervin Wilson had fretted some two decades ago--he had to have the neck extended by a graft.

This in turn made it imperative to tune the guitar a major second lower; and some sets of strings would not reach far enough to put them on. However, the tone-quality was excellent. And it proved once and for all that the 41-tone equal temperament was satisfactory.

In the coming 1990's, we will have many instruments capable of these three systems, 41, 43, and 46, and beyond; so nothing to worry about. The MOOD of 41 is not the same as that of 31: it is more assertive and of course capable of sublety. As we already have stated in another article, Partch's 43-tone just unequal system is more similar to 41 than to 43 equal. The way in which intervals of the Harmonic series are approximated is more important than the number of tones per octave.

The MOOD of 43-equal is more like that of 31 than the mood of 41 is.

41 is a "positive" system; that is, it has a slightly-sharp fifth. What this means is that a circle of 41 just fifths fails to close, so a tiny amount, not quite half of a cent, must be added to each fifth in order to make the circle close with the tempered fifths. As we are so familiar with our conditioning to the 12-tone system with FLAT fifths, some people may have trouble getting used to the idea of a circle of fifths which requires ADDING something to close the gap rather than SUBTRACTING something as is necessary for 12, 19, 31, and the 43 system to be discussed here. However, these errors of fifths in 12 and 41 are very tiny and the newcomer to Xenharmonics especially must try to attain a realistic perspective about such niceties.

The 12-tone fifth's error of not quite 2 cents works out to 1/614 of an octave, an amount that never could matter in any actual musical performance. The error of the 41-tone fifth is only 1/2479 of an octave, which nobody could hear and it would require some kind of instruments to detect it--beats of such a fifth will be very slow and frankly useless for anyone trying to tune 41-tone by ear.

If I had to face the problems faced by someone in 1870 like Ellis or Helmholtz or Janko who was interested in the 41-tone scale, there would be no point my writing about these really microtonal systems and I would better have been doing something else.

But we are in the electronic and computer age, the age of precision instruments available now as never before in history. So it behooves us to re-examine these questions which music-theorists took up a century ago and didn't have the means to evaluate as we now can.

Conventional acoustic instruments like violins and horns are hardly suitable for this kind of investigation of tuning-systems that split the octave into such

[41, 43, and 46, continued]

If you are going to compose or perform in the teen scales, your room in which to bend or slide or have frequency vibrato or make leading-tones sharper as a violinist does, is about the same as you have been doing in 12-tone, nearly all the way up to Quarter-tones or the 24-tone temperament.

This is why I have been recommending for 20 years or so that newcomers should start with 19-tone temperament, even if they are going to use something else and even if they are going to do most of their later work in Just Intonation. It just would be too "tough" for you to have to deal with tighter tolerances and special new considerations while starting to explore beyond 12.

In 19, or in 17 or 22 for that matter, you can employ most of the nuances and deviations and habits like vibrato that you always have been using in 12 and deal with just one new thing at a time--in this case the moods and possibilities and character of your first outside-twelve scale.

Jumping from ordinary 12-tone to something like 41, 43, or 46 is far too much to expect of a composer or performer! Even the jump from 12 to 31 is too much. I recommend that those who have heard 31 and fallen madly in love with it, first get a little experience in 22 or 19 before practicing and composing in 31. All the more if you want to pioneer in 41, 43, or 46.

Another good point is that the mood-differences beyond 31 are less and less. The mood--contrast among 17 18 19 20 is tremendous and greatly expands the composer's vocabulary. That between 31, 34, and 36 is more subtle but still of value. On actual trial with sustained chords and various figurations in 41, 43, and 46, the differences are much smaller and more subtle than any guesses or theories could predict. This comparison test was run with relatively brief passages in each system and not very much wait between systems.

Definitely, the difference in the moods of 31, 34, and 36 is far greater. 41-43-46 still presents some mood-change, but other factors would now be the chief reasons for choosing one or another for a particular composition, new or existing. In *Xenharmonic Bulletin No. 12* we will describe the trio of systems 50-53-55 and from some experience with preliminary trials, any mood-difference is going to be slight.

Reason for discussing mood just now is that the gradual decline in mood-contrast as one goes up the Numbers Of Tones Per Octave should not lead anyone to discount mood down in the regions below 31. Nor should a preoccupation with Just Intonation discourage anyone from exploiting moods. In that case, the Limits and the extent of a Just Array will influence mood. Sure, the number of just pitches is infinite, but the number of pitches even on a computer will not be infinite and that on some just instruments is going to be limited by hardware factors. Also by the time we get to 41, and certainly by the time we get to 53, very hard practical considerations limit accuracy and stability of tuning whether live-performance instruments or computers; and in the case of recording and record-copying, the difficulties of keeping speed constant will affect systems beyond 31. Most of us will have to be content with recorded music when these many--small-interval systems are concerned and so the theoretical arguments about a Just Utopia of Infinitely Many Pitches are not

[41, 43, & 46, continued]

realistic for real people listening to real music under normal conditions. The limitations of the human ear come first--we cannot distinguish pitches as well at the ends of the spectrum as we can in the middle.

That means we can get away with mistunings at both ends even if we must be careful in the midrange.

How many pitches per octave could we do with a computer or a special instrument such as a sophisticated synthesizer?

How about 2000 per octave in midrange? That is attainable on a number of present-day tuning-devices. Those that could do 1000 or 1024 per octave are actually on the market now, with some restrictions as to how to get them heard.

In my Electronic Instrument Article in this issue, I was leading up to this point.

A tuning-scheme as programmed might call for strict just intonation for many pitches, but what comes out of the computer or synthesizer or other sound-producer may be slightly tempered--not enough to be audible under ordinary conditions, but yet enough to offend the mathematician and the stickler for perfection who demands exact just intonation and never mind the cost and never mind whether he/she can hear it or not.

No advertiser of a piece of music equipment is ever going to be that honest. It would be Far Beyond the Call of Duty. Don't expect it and don't demand it.

Some existing instruments and some computers will give you Just Intonation close enough for any conceivable actual music you want.

You've got to be reasonable. Progress in music has been halted by zealots as much as it has been stymied by opponents. "With that kind of 'friends' who needs enemies?"

Listening to slow beats in a laboratory or reading dials on a tuning device is not the same thing as sitting in a living room or concert hall and listening to actual music.

So when we come to things like the 41-tone system, and its half-of-one-cent error in the fifth, and its audible error of nearly 6 cents in the major third, as compared with .7 of a cent for the major third in 31 but 5 cents in the fifth, and try to evaluate this situation by mathematics and abstract argument, this doesn't have as much to do with composition and use of new scales for previous music and instrument-building and performance as it seems to.

There are other considerations that cannot be fully evaluated in advance. One that I discovered a long time ago when trying the 41-tone guitar was the melodic value of two units of 41.

This is something that no amount of pencil-and-paper or calculating could reveal--you have to hear 31 and 41 without too much time between them. That would lead you to choose 41 when certain melodies were to be played and when other things were to be done, then choose 31 instead.

Similar considerations with 43 & 46 if those were available. There has been too much of the Numbers Game by those who never heard new systems. I had to hear enough of many different systems before I dared write about them.

An important point is that with some computer music programs and many of the instruments that can now do non-12 or be modified so that they could, their version of just would be a teeny bit off such that the errors of certain intervals in a system like 31 or 41 for that interval would not count, since they might improve the temperament or reduce the difference

[41, 43, & 46, continued]

between that device's version of that temperament and that device's version of Just Intonation for that interval.

Now these differences will be very tiny indeed. They will hardly ever matter for a musical performance. But they will distort a tuning-device reading, or change the beat-rate of a tempered interval or cause slow beats in what should be a beatless Just interval, so that someone with good test equipment will complain about it. Or if you happen to own a frequency-counter, the readings will be "wrong" enough, above or below, to wonder if the computer program or the musical instrument is defective.

One of the synthesizers here was connected to a frequency-counter to check its pitches for the standard 12. As expected from the methods now used to secure 12-tone at the factory in such instruments, it was slightly off, above here and below there, and some of the octaves were out, where theory called for perfect octaves in any temperament (this is not a piano, so presumably the stretched-octave practice tuners use on pianos will not apply to synthesizers). Now why were the octaves out? Why did most octaves beat when theory said they shouldn't?

Then I went through the circle of fourths and fifths that most piano and organ tuners use to set a 12-tone equal temperament. Would they beat at the same rate they do on a well-tuned piano?

Nope, they didn't—most were too fast or too slow. Again, why should that be? This latter has to do with the counting-down process described on pp. 5 & 6 of our Electronics article in this issue. If the synthesizer only has to do 12, the circuitry is somewhat simpler than if it has to do a number of tuning-systems; the space between successive quotients can be larger and so fewer divisors are needed. That may or may not be the case here. What we have here is a *tempered temperament !*

In my *Xenharmonic Bulletin No. 2* way back in May 1974, I discussed tempered temperaments. Perhaps I should do a new article on it since there weren't so many countdown circuits and special computer methods of approximating temperaments back then.

A tempered temperament is one where the big errors have little errors attached to them. It's kind of like compound interest or chain discounts or a tax upon something already subject to another tax.

Why do it? Because it saves money and it saves time, and permits the mass production of instruments which never have to be tuned--no tuner required. Actually, most of these countdown units tune better than can be done by ear.

The other question I left hanging: Why are the octaves out on that synthesizer? Because when there is a slight difference from perfect octave lock-in, the general effect is not so "dead"--this is important with electronic instruments. Also, when a given note is held, then its octave above or below is then sounded, if the octave is "dead on", it may sound like a change in *timbre* of the first note, rather than the *addition* of a new note.

Below 31, this sort of thing may be actually beneficial. It is only when we get up to large numbers of closely-spaced pitches that the discrepancies arising from countdown might alter the system enough to be a real concern. One advantage of the countdown-dividing method is the ease of going from one system to another, and the fact that just one stable master frequency has to be carefully controlled, instead of many.

[41, 43, & 46, continued]

The attraction to 41-tone, in theory, lies in its very close approximation to Pythagorean such that no-one could hear a difference, coupled with its good representation of the Harmonic Series all the way up to the 16th Harmonic.

The possibility of having 13-limit chords on any of 41 starting-points is hardly to be sneezed at. Advocates of Just Intonation will of course complain loudly about the 6--cent errors of major and minor thirds and sixths, just as they will pooh-pooh the 31--tone system for its flat fifths. They often condemn both systems and a whole raft of others, literally without a hearing.

Polemic arguments and denunciations continue to be published in many journals in spite of the fact that with new electronic instruments and computers, having a wide range of temperaments does not rule out also having easy access to Just Intonation with a large number of pitches.

I don't need to debate the matter because the instruments in this studio prove my point right on the spot! Furthermore cassettes sent me from distant places prove that others have the same ability with today's facilities.

If some Nostalgiac wants to do everything the Hard Way by using only acoustic instruments, of course I can't intervene to stop them. That's THEIR problem! not mine at all. I have never been a member of any masochistic cult religion and I don't see why music has to be such a cult either.

The tables have turned: it is now cheaper to use the latest equipment for new scales than to do it the 1880 or 1920 way. If the cost of exploring beyond 12-tone were still at the 1935 or the 1945 level, I would not be getting out Bulletins like these, since it would be cruel to increase your sadness, hopelessness, and frustration. Besides that, my assorted spoilsports and enemies and nasty mean opponents would be sneering at me for even discussing systems like 41, 43, 46, or Just Intonation! They would win all the arguments and leave me in Black Despair.

Now on to 43: So far as I know at present, there are no dedicated 43-tone instruments in existence, but for quite some time there have been experimental instruments with 12 tones of 43 or what is practically the same thing, the 1/5-comma Meantone System. Experimental instruments do exist that have 16 or more tones of 1/5-comma meantone. Now if only that many of the pitches are made available, no audible discrepancy between 43-equal and 1/5-comma meantone would be heard in any musical performance, so it's not worth using up space to discuss here. "1/5-comma" refers to how flat the fifth is--4.3 cents as against some 5.2 cents for 31 and quarter--comma meantone the standard kind.

Would it have been worth the trouble to have built 43-tone instruments with all the tones? I think not. If we didn't have this new power on computers and synthesizers of changing from one system to another quickly, I would have omitted 43 from this article. While it has usable representations of higher harmonics such as 11 and 13, and a practically-perfect major seventh--who is going to quibble over a tenth of a cent, one-twelve--thousandth of an octave?, financial considerations alone would have dictated dedicating instruments to cheaper systems with fewer tones, that still could afford new chords and melodies.
***And a 43-tone guitar? Why, the UNAVOIDABLE errors in fretting and of the strings you put on it would wipe out much of the difference between that and other systems.

As Jonathan Glasier was saying recently, "Do you actually enjoy putting your fingers into the pencil-sharpener in order to get between those frets?"

[41, 43, & 46, continued]

The main reason why I had to include 43-equal here is not the historical business of 43-equal or 1/5-comma authentic performances of certain old keyboard and organ music, but rather the serious confusion between the 43-tone equal temperament and the 43-tone 11-limit just system devised by the late Harry Partch and quite different in its effect.

Too many magazine and newspaper articles have said "Harry Partch's 43-tone equal temperament" and it is extremely important to point out that Partch's system was untempered and UNEQUALLY-SPACED through the octave. This is my reason for putting this article in the same issue as the other article on PARTCH'S PITCHES. I can append frequency-tables of both and thus anyone can see the difference.

Many people who now have computers can have BOTH systems on disk and compare their sounds with certain new software that would permit this. Hopefully this will get rid of the shameful confusion that has been repeated in print far too much. 41, not 43, is the closest equal temperament to Partch's system unless you are willing to go to very large numbers of tones. But if you go that far, why temper?

Now for 46: I never heard 46 till this week. February 1989. All I knew about it was from Ervin Wilson's experiments related to me some time ago when he had a guitar temporarily fretted to 23 and tuned two strings 1/46 octave apart to get 46-tone out of it.

The fifth and major third of 23 are so bad that 2 x23 = 46 simply had to be better. Much as the impossible thirds and sixths of 17 suggest using 34 which has excellent thirds and sixths.

Trying out harmonic-series chords in 46, they are satisfactory enough to make the system interesting, now that it won't cost extra to use it if one has the new adjustable or reprogrammable equipment for other beyond-12 scales.

Also, its harmonic-series performance would be better than that of 48-tone, which has been in the music-theory literature as one of Julián Carrillo's scales for which a special piano and fretted instruments were built, and which also is available for some new electronic instruments.

(In future issues we can deal with Carrillo and other exponents of the multiples-of-twelve and multiples-of-six ideas.)

There is no point in inventing or using special notations for scales with so many tones as these. I've said this before but it needs repeating. Progress is RETARDED or even HALTED by all the mental gymnastics required to compose in such scales while juggling three or even ten different kinds of notations with multiple meanings for the same accidentals and with too many rival notations where the same accidental in the same system has multiple meanings. The quartertone situation is a public disgrace!

To compare a group of systems like 41 43 46 [and 48], it has to be possible to try over IN SOUNDS this or that chord or melody, and laying a notation problem on top of that would simply stop composers dead-cold! If you must, number the tones as Carrillo did.

The new device called the Sequencer will play automatically and solve the problem of finger-technique and strange new keyboards--Now you won't have to learn them! We didn't mention scales like 42 44 45 47 49 --- well, they are not important enough to invest in, and if they intrigue you, a computer will take the hassle off your back and save loads of money and time. One reason why I started XENHARMONIC BULLETIN was to find out and tell people which scales are more useful. ###

PARTCH'S 43 EXTENDED JUST PITCHES, BASED UPON G = 392 HZ

Ordinal No.	Ratio Fraction	Name for the Interval	Frequency Hertz	TUNING DEVICE SETTING
0	1/1	Unison or Prime	392.000	*G exactly*
1	81/80	Didymus Comma	396.900	*G + 22*
2	33/32	Semiaugmented Prime	404.250	*G# - 47*
3	21/20	Subminor Second	411.600	*G# - 15*
4	16/15	Minor Second	418.133	*G# + 12*
5	12/11	Neutral Second	427.636	*A - 49*
6	11/10	Larger Neutral Second	431.200	*A - 35*
7	10/9	Smaller Major Second	435.556	*A - 18*
8	9/8	Larger Major Second	441.000	*A + 4*
9	8/7	Supermajor Second	448.000	*A + 31*
10	7/6	Subminor Third	457.333	*A# - 33*
11	32/27	Pythagorean Minor Third	464.593	*A# - 6*
12	6/5	Minor Third	470.400	*A# + 16*
13	11/9	Neutral Third	479.111	*A# + 47*
14	5/4	Major Third	490.000	*B - 14*
15	14/11	Enlarged Third	498.909	*B + 18*
16	9/7	Supermajor Third	504.000	*B + 35*
17	21/16	Septimal Sub-fourth	514.500	*C - 29*
18	4/3	Fourth	522.666	*C - 2*
19	27/20	Acute Fourth	529.200	*C + 20*
20	11/8	Semiaugmented Fourth	539.000	*C# - 49*
21	7/5	Septimal Augmented Fourth	548.800	*C# - 17*
22	10/7	Septimal Diminished Fifth	560.000	*C# + 17*
23	16/11	Semidiminished Fifth	570.182	*C# + 49*
24	40/27	Grave Fifth	580.741	*D - 30*
25	3/2	Fifth	588.000	*D + 2*
26	32/21	Septimal Super-fifth	597.333	*D + 29*
27	14/9	Semiaugmented Fifth	609.778	*D# - 35*
28	11/7	Lowered Sixth	616.000	*D# - 18*
29	8/5	Minor Sixth	627.200	*D# + 14*
30	18/11	Neutral Sixth	641.455	*E - 47*
31	5/3	Major Sixth	653.333	*E - 16*
32	27/16	Pythagorean Major Sixth	661.500	*E + 6*
33	12/7	Enlarged Sixth	672.000	*E + 33*
34	7/4	Subminor [Harmonic] Seventh	686.000	*F - 31*
35	16/9	Smaller Minor Seventh	696.889	*F - 4*
36	9/5	Larger Minor Seventh	705.600	*F + 18*
37	20/11	Enlarged Minor Seventh	712.727	*F + 35*
38	11/6	Neutral Seventh	718.667	*F + 49*
39	15/8	Major Seventh	735.000	*F# - 12*
40	40/21	Septimal Super-seventh	746.667	*F# + 16*
41	64/33	Semidiminished Octave	760.242	*F# + 47*
42	160/81	Grave Octave	774.321	*G - 22*
43	2/1	Octave	784.000	*G Exactly*

NOTES:

Of course Partch did not name his intervals but used the ratio-fractions given above. Names are partly those of Alexander J. Ellis and supplied for those intervals Ellis did not name. Theoretically the 12-tone-equal G of the Tuning Devices would be 0.00455 Hz flatter than Partch's 392 Hz starting pitch "1/1", but this has no practical meaning in the Real World. The devices are not that accurate. Most makes of tuning-devices on the market use the above designations, of 12-equal pitches plus or minus up to 50 cents.

CENTS VALUES FOR PARTCH'S 43 EXTENDED JUST INTERVALS

No.	Ratio	Name for the Interval	CENTS	DIFFERENCES	TUNING DEVICE
0	1/1	Unison or Prime	0.000		*G exactly*
				21.506	
1	81/80	Didymus Comma	21.506		*G + 22*
				31.767	
2	33/32	Semiaugmented Prime	53.273		*G# - 47*
				31.194	
3	21/20	Subminor Second	84.467		*G# - 15*
				27.264	
4	16/15	Diatonic Semitone/Minor Second	111.731		*G# + 12*
				38.906	
5	12/11	Neutral Second	150.637		*A - 49*
				14.367	
6	11/10	Larger Neutral Second	165.004		*A - 35*
				17.400	
7	10/9	Smaller Major Second	182.404		*A - 18*
				21.506	
8	9/8	Larger Major Second	203.910		*A + 4*
				27.264	
9	8/7	Supermajor Second	231.174		*A + 31*
				35.697	
10	7/6	Subminor Third	266.871		*A# - 33*
				27.264	
11	32/27	Pythagorean Minor Third	294.135		*A# - 6*
				21.506	
12	6/5	Minor Third	315.641		*A# + 16*
				31.767	
13	11/9	Neutral Third	347.408		*A# + 47*
				38.906	
14	5/4	Major Third	386.314		*B - 14*
				31.194	
15	14/11	Enlarged Third	417.508		*B + 18*
				17.576	
16	9/7	Septimal Supermajor Third	435.084		*B + 35*
				35.697	
17	21/16	Septimal Sub-fourth	470.781		*C - 29*
				27.264	
18	4/3	Fourth	498.045		*C - 2*
				21.506	
19	27/20	Acute Fourth	519.551		*C + 20*
				31.767	
20	11/8	Semiaugmented Fourth	551.318		*C# - 49*
				31.194	
21	7/5	Septimal Augmented Fourth	582.512		*C# - 17*
				34.676	
22	10/7	Septimal Diminished Fifth	617.488		*C# + 17*
				31.194	
23	16/11	Semidiminished Fifth	648.682		*C# + 49*
				31.767	
24	40/27	Grave Fifth	680.449		*D - 30*
				21.506	
25	3/2	Fifth	701.955		*D + 2*
				27.264	
26	32/21	Septimal Super-fifth	729.219		*D + 29*
				35.697	
27	14/9	Semiaugmented Fifth	764.916		*D# - 35*
				17.576	
28	11/7	Lowered Sixth	782.492		*D# - 18*
				31.194	
29	8/5	Minor Sixth	813.686		*D# + 14*
				38.906	
30	18/11	Neutral Sixth	852.592		*E - 47*
				31.767	
31	5/3	Major Sixth	884.359		*E - 16*
				21.506	
32	27/16	Pythagorean Major Sixth	905.865		*E + 6*
				27.264	
33	12/7	Enlarged Sixth	933.129		*E + 33*
				35.697	
34	7/4	Subminor (Harmonic) Seventh	968.826		*F - 31*
				27.264	
35	16/9	Smaller Minor Seventh	996.090		*F - 4*
				21.506	
36	9/5	Larger Minor Seventh	1017.596		*F + 18*
				17.400	
37	20/11	Enlarged Minor Seventh	1034.996		*F + 35*
				14.367	
38	11/6	Neutral Seventh	1049.363		*F + 49*
				38.906	
39	15/8	Major Seventh	1088.269		*F# - 12*
				27.264	
40	40/21	Septimal Super-seventh	1115.533		*F# + 16*
				31.194	
41	64/33	Semidiminished Octave	1146.727		*F# + 47*
				31.767	
42	160/81	Grave Octave	1178.494		*G - 22*
				21.506	
43=0	2/1	Octave	1200.000		*G exactly*

NOTES: The DIFFERENCES between each 2 successive intervals are given here because: 1) it shows the patterning of Partch's system; 2) it emphasizes the UNequal nature of his tuning--that it is NOT 43 Equal Temperament, but untempered! We have to combat that misinformation before it is too late. Names of intervals supplied by Darreg often reflecting those of Ellis. Cents to three places to permit your carrying on extensive calculations or expanding Partch's or another 11-limit system without accumulating rounding-off errors. The Tuning-Device column is also a guide comparing Partch's scale to 12.

PARTCH'S UNEQUAL 43-TONE SCALE COMPARED WITH 41-EQUAL AND 43-EQUAL

PARTCH'S			41-TONE EQUAL			43-TONE EQUAL		
No.	RATIO	CENTS	No.	CENTS	DIFFERENCE	No.	CENTS	DIFFERENCE
0	1/1	0.000	0	0.000	0.000	0	0.000	0.000
1	81/80	21.506	1	29.268	+ 7.762	1	27.907	+ 6.401
2	33/32	53.273	2	58.537	+ 5.264	2	55.814	+ 2.541
3	21/20	84.467	3	87.805	+ 3.338	3	83.721	- 0.746
4	16/15	111.731	4	117.073	+ 5.342	4	111.628	- 0.103
5	12/11	150.637	5	146.342	- 4.295	5	139.535	-11.102
6	11/10	165.004	6	175.610	+10.606	6	167.442	+ 2.438
7	10/9	182.404	(6)	""" """	- 6.794	7	195.349	+12.945
8	9/8	203.910	7	204.878	+ 0.968	8	223.256	+19.346
9	8/7	231.174	8	234.146	+ 2.972	9	251.163	+19.989
10	7/6	266.871	9	263.415	- 3.456	10	279.070	+12.199
11	32/27	294.135	10	292.683	- 1.452	11	306.977	+12.842
12	6/5	315.641	11	321.951	+ 6.310	12	334.884	+19.243
13	11/9	347.408	12	351.216	+ 3.808	13	362.791	+15.383
14	5/4	386.314	13	380.488	- 5.826	14	390.698	+ 4.384
15	14/11	417.508	14	409.756	- 7.752	15	418.605	+ 1.097
16	9/7	435.084	15	439.024	+ 3.940	16	446.512	+11.428
17	21/16	470.781	16	468.293	- 2.488	17	474.419	+ 3.638
18	4/3	498.045	17	497.561	- 0.484	18	502.326	+ 4.281
19	27/20	519.551	18	526.829	+ 7.278	19	530.233	+10.682
20	11/8	551.318	19	556.098	+ 4.780	20	558.140	+ 6.822
21	7/5	582.512	20	585.366	+ 2.854	21	586.047	+ 3.534
22	10/7	617.488	21	614.634	- 2.854	22	613.954	- 3.534
23	16/11	648.682	22	643.902	- 4.780	23	641.861	- 6.821
24	40/27	680.449	23	673.171	- 7.278	24	669.767	-10.682
25	3/2	701.955	24	702.439	+ 0.484	25	697.674	- 4.281
26	32/21	729.219	25	731.707	+ 2.488	26	725.581	- 3.638
27	14/9	764.916	26	760.976	- 3.940	27	753.488	-11.428
28	11/7	782.492	27	790.244	+ 7.752	28	781.395	- 1.097
29	8/5	813.686	28	819.512	+ 5.826	29	809.302	- 4.384
30	18/11	852.592	29	848.781	- 3.811	30	837.209	-15.383
31	5/3	884.359	30	878.049	- 6.310	31	865.116	-19.243
32	27/16	905.865	31	907.317	+ 1.452	32	893.023	-12.842
33	12/7	933.129	32	936.585	+ 3.456	33	920.930	-12.199
34	7/4	968.826	33	965.854	- 2.972	34	948.837	-19.989
35	16/9	996.090	34	995.122	- 0.968	35	976.744	-19.346
36	9/5	1017.596	35	1024.390	+ 6.794	36	1004.651	-12.945
37	20/11	1034.996	(35)	"""" """"	-10.606	37	1032.558	- 2.438
38	11/6	1049.363	36	1053.659	+ 4.296	38	1060.465	+11.102
39	15/8	1088.269	37	1082.927	- 5.342	39	1088.372	+ 0.103
40	40/21	1115.533	38	1112.195	- 3.338	40	1116.279	+ 0.746
41	64/33	1146.727	39	1141.463	- 5.264	41	1144.186	- 2.541
42	160/81	1178.494	40	1170.732	- 7.762	42	1172.093	- 6.401
43[0]	2/1	1200.000	0= 41	1200.000	0.000	43	1200.000	0.000

NOTE: Further tables and charts, including keyboard layouts and other designs, relevant to Partch's 43 pitches and the 41-tone equal temperament, are available from Ervin M. Wilson, Los Angeles California.

FORTY-ONE-TONE EQUAL TEMPERAMENT BASED ON A=440 HZ.

0 and 41 at top and bottom of columns are taken as the note C very close to what it would be in Pythagorean intonation.

Nº	FREQUENCIES IN HERTZ						
0	32.565	65.131	130.261	260.522	521.044	1042.089	2084.178
1	33.121	66.241	132.482	264.964	529.928	1059.856	2119.792
2	33.685	67.370	134.741	269.482	538.963	1077.926	2155.852
3	34.260	68.519	137.038	274.076	548.152	1096.305	2192.610
4	34.844	69.687	139.375	278.749	557.498	1114.996	2229.992
5	35.438	70.875	141.751	283.502	567.003	1134.007	2268.013
6	36.042	72.084	144.168	288.335	576.671	1153.341	2306.682
7	36.656	73.313	146.626	293.251	586.503	1173.006	2346.011
8	36.731	74.563	149.126	298.251	596.502	1193.005	2386.009
9	37.917	75.834	151.668	303.336	606.673	1213.345	2426.690
10	38.564	77.128	154.254	308.508	617.016	1234.033	2468.066
11	39.221	78.442	156.884	313.768	627.536	1255.073	2510.145
12	39.890	79.779	159.559.	319.118	638.236	1276.471	2552.942
13	40.570	81.140	162.279	324.559	649.117	1298.235	2596.470
14	41.262	82.523	165.046	330.092	660.185	1320.369	2640.737
15	41.965	83.930	167.860	335.720	671.441	1342.880	2685.762
16	42.681	85.361	170.722	341.444	682.888	1365.777	2731.553
17	43.408	86.813	173.633	347.266	694.532	1389.063	2778.127
18	44.148	88.297	176.593	353.187	706.373	1412.746	2825.492
19	44.901	89.802	179.604	359.208	718.417	1436.833	2873.666
20	45.667	91.333	182.666	365.333	730.665	1461.331	2922.661
21	46.445	92.890	185.781	371.562	743.123	1486.246	2972.492
22	47.237	94.474	188.948	377.897	755.793	1511.587	3023.173
23	48.042	96.085	192.170	384.340	768.679	1537.358	3074.716
24	48.862	97.723	195.446	390.893	781.785	1563.570	3127.140
25	49.695	99.389	198.779	397.557	795.114	1590.229	3180.457
26	50.542	101.084	202.168	404.335	808.671	1617.541	3234.683
27	51.404	102.807	205.615	411.229	822.458	1644.916	3289.832
28	52.280	104.560	209.120	418.241	836.481	1672.962	3345.924
29	53.171	106.343	212.686	425.371	850.743	1701.485	3402.971
30	54.078	108.156	216.312	432.624	865.248	1730.495	3460.991
31	55.000	110.000	220.000	440.000	880.000	1760.000	3520.000
32	55.938	111.876	223.751	447.502	895.004	1790.008	3580.016
33	56.891	113.783	227.566	455.132	910.263	1820.526	3641.053
34	57.861	115.723	231.446	462.892	925.783	1851.566	3703.132
35	58.848	117.696	235.392	470.784	941.567	1883.135	3766.270
36	59.851	119.703	239.405	478.811	957.621	1915.243	3830.485
37	60.876	121.743	243.487	486.974	973.948	1947.896	3895.792
38	61.910	123.819	247.638	495.277	990.554	1981.107	3962.214
39	62.965	125.930	251.861	503.721	1007.442	2014.884	4029.770
40	64.039	128.077	256.155	512.310	1024.619	2049.238	4098.477
0=41	65.131	130.261	260.522	521.044	1042.089	2084.178	4168.356

NOTE: To compare Partch's 43-UNEQUAL with 41-EQUAL: This 41-tone table is not based on Partch's pitch of G, "1/1" as 392 Hz. If it were, then Partch's 9/8 would correspond to A=441 Hz and 41-tone on that basis would give A = 441.2465 Hz. If someone sounded those two A's together, they would beat only once in 4 seconds.

FORTY-THREE-TONE EQUAL TEMPERAMENT BASED ON A = 440 Hz

Lines 0 and 43 are taken as the note C as it would be in most systems of the Meantone Family and closely-related equal temperaments.

NO	FREQUENCY IN HERTZ						
0	33.369	66.738	133.475	266.951	533.901	1067.803	2135.605
1	33.911	67.822	135.644	271.289	542.578	1085.155	2170.311
2	34.462	68.924	137.849	275.697	551.395	1102.789	2205.577
3	35.022	70.044	140.089	280.177	560.355	1120.710	2241.420
4	35.591	71.183	142.365	284.730	569.461	1138.922	2277.843
5	36.170	72.339	144.679	289.357	578.715	1157.430	2314.859
6	36.757	73.515	147.030	294.059	588.119	1176.238	2352.476
7	37.355	74.710	149.419	298.838	597.676	1195.352	2390.705
8	37.962	75.924	151.847	303.694	607.389	1214.778	2429.555
9	38.579	77.157	154.315	303.629	617.259	1234.518	2469.035
10	39.206	78.411	156.822	313.645	627.290	1254.579	2509.158
11	39.843	79.685	159.371	318.742	637.483	1274.966	2549.932
12	40.490	80.980	161.961	323.921	647.843	1295.685	2591.369
13	41.148	82.296	164.593	329.185	658.370	1316.740	2633.481
14	41.817	83.634	167.267	334.534	669.069	1338.138	2676.275
15	42.496	84.993	169.985	339.971	679.941	1359.882	2719.765
16	43.187	86.374	172.749	345.497	690.991	1381.990	2763.980
17	43.889	87.777	175.555	351.110	702.220	1404.439	2808.877
18	44.602	89.204	178.408	356.815	713.631	1427.261	2854.523
19	45.327	90.653	181.307	362.614	725.228	1450.455	2900.909
20	46.063	92.127	184.253	368.506	737.013	1474.026	2948.051
21	46.812	93.624	187.247	374.495	748.989	1497.979	2995.958
22	47.573	95.145	190.290	380.580	761.161	1522.322	3044.643
23	48.346	96.691	193.382	386.765	773.530	1547.059	3094.119
24	49.131	98.263	196.525	393.050	786.100	1572.200	3194.400
25	49.930	99.859	199.719	399.437	798.874	1597.749	3195.498
26	50.741	101.482	202.964	405.928	811.856	1623.713	3247.425
27	51.566	103.131	206.262	412.525	825.049	1650.099	3300.197
28	52.404	104.807	209.614	419.228	838.457	1676.913	3353.826
29	53.255	106.510	213.020	426.041	852.082	1704.163	3408.326
30	54.121	108.241	216.482	432.964	865.928	1731.857	3463.714
31	55.000	110.000	220.000	440.000	880.000	1760.000	3520.000
32	55.894	111.788	223.575	447.150	894.300	1788.600	3577.200
33	56.802	113.604	227.208	454.417	908.833	1817.666	3635.333
34	57.725	115.450	230.900	461.801	923.601	1847.203	3694.405
35	58.663	117.326	234.653	469.305	938.611	1877.221	3754.443
36	59.616	119.233	238.466	476.932	953.864	1907.727	3815.455
37	60.585	121.171	242.341	484.682	969.364	1938.728	3877.456
38	61.570	123.140	246.279	492.558	985.116	1970.232	3940.464
39	62.570	125.141	250.281	500.562	1001.125	2002.250	4004.500
40	63.587	127.174	254.348	508.697	1017.394	2034.787	4069.574
41	64.620	129.241	258.482	516.963	1033.926	2067.852	4135.704
42	65.670	131.341	262.682	525.364	1050.728	2101.456	4202.912
0=43	66.738	133.475	266.951	533.901	1067.803	2135.605	4271.210

Since the 1/5-comma meantone temperament is used sometimes on harpsichords and organs for early music, we shall give the differences in cents and hertz for an A-major chord in the treble staff: 1/5-comma: A same as 43-tone; C# 390.615¢, 551.368 Hz; E 697.654¢, 658.362 Hz. 43-equal: C# 390.698¢, 551.395 Hz; E 697.674¢, 658.370 Hz. Differences: 1/5-comma C# is 0.083¢ flatter, 0.027 Hz flatter; 1/5-comma E is 0.02¢ and 0.008 Hz flatter. There is no way of making such minutiae audible and the unavoidable errors in tuning and even in constructing instruments will greatly exceed the above differences!

FORTY-SIX-TONE EQUAL TEMPERAMENT BASED ON A = 440 HZ

Lines 0 and 46 are for a consonant note C to A = 440.

NO	FREQUENCIES IN HERTZ						
0	32.951	65.901	131.802	263.604	527.208	1054.417	2108.834
1	33.451	66.902	139.803	267.606	535.213	1070.425	2140.851
2	33.959	67.917	135.835	271.669	543.339	1086.677	2173.354
3	34.474	68.948	137.897	275.794	551.588	1103.176	2206.351
4	34.998	69.995	139.991	279.981	559.962	1119.925	2239.849
5	35.529	71.058	142.116	284.232	568.464	1136.928	2273.856
6	36.068	72.137	144.274	288.547	577.095	1154.189	2308.378
7	36.616	73.232	146.464	292.928	585.856	1171.713	2343.426
8	37.172	74.344	148.688	297.376	594.751	1189.502	2379.004
9	37.736	75.473	150.945	301.891	603.781	1207.562	2415.124
10	38.309	76.618	153.237	306.474	612.948	1225.896	2451.792
11	38.891	77.782	155.564	311.127	622.254	1244.508	2489.016
12	39.481	78.963	155.564	315.851	631.701	1263.401	2526.805
13	40.081	80.162	160.323	320.646	641.292	1282.584	2565.169
14	40.689	81.379	162.757	325.514	651.029	1302.057	2604.114
15	41.307	82.614	165.228	330.456	660.913	1321.826	2643.651
16	41.934	83.868	167.737	335.474	670.947	1341.894	2683.789
17	42.571	85.142	170.283	340.567	681.134	1362.268	2724.535
18	43.217	86.434	172.869	345.738	691.475	1382.950	2765.901
19	43.873	87.747	175.493	350.987	701.974	1403.947	2807.894
20	44.539	89.079	178.158	356.316	712.631	1425.262	2850.525
21	45.216	90.431	180.863	361.725	723.451	1446.902	2893.803
22	45.902	91.804	183.609	367.217	734.435	1468.869	2937.738
23	46.599	93.198	186.396	372.793	745.585	1491.170	2982.340
24	47.307	94.613	189.226	378.453	756.905	1513.810	3027.620
25	48.025	96.050	192.099	384.198	768.397	1536.793	3073.587
26	48.754	97.508	195.016	390.031	780.063	1560.126	3120.252
27	49.494	98.988	197.977	395.953	791.906	1583.812	3167.625
28	50.246	100.491	200.982	401.965	803.929	1607.859	3215.718
29	51.008	102.017	204.034	408.068	816.135	1632.270	3264.450
30	51.783	103.566	207.132	414.263	828.526	1657.052	3314.104
31	52.569	105.138	210.276	420.553	841.105	1682.210	3364.420
32	53.367	106.734	213.469	426.938	853.875	1707.750	3415.501
33	54.177	108.355	216.710	433.420	866.839	1733.678	3467.357
34	55.000	110.000	220.000	440.000	880.000	1760.000	3520.000
35	55.835	111.670	223.340	446.680	893.361	1786.721	3573.442
36	56.683	113.366	226.731	453.462	906.924	1813.848	3627.696
37	57.543	115.087	230.173	460.347	920.693	1841.387	3682.774
38	58.417	116.834	233.668	467.336	934.672	1869.344	3738.688
39	59.304	118.608	237.216	474.431	948.863	1897.725	3795.450
40	60.240	120.409	240.817	481.634	963.269	1926.538	3853.075
41	61.118	122.237	244.473	488.947	977.894	1955.787	3911.574
42	62.046	124.093	248.185	496.370	992.740	1985.481	3970.962
43	62.988	125.977	251.953	503.906	1007.813	2015.626	4031.251
44	63.945	127.889	255.778	511.557	1023.114	2046.228	4092.455
45	64.915	129.831	259.662	519.324	1038.647	2077.295	4154.590
0= 46	65.901	131.802	263.604	527.208	1054.417	2108.834	4217.668

PARTCH'S 43-TONE JUST SYSTEM BASED ON 1/1 = G = 392 Hz

No.	Ratio	Frequencies in Hertz							
0	1/1	24.5	49.	98.	196.	392.	784.	1568.	3136.
1	81/80	24.806	49.613	99.225	198.45	396.9	793.8	1587.6	3175.2
2	33/32	25.266	50.531	101.063	202.125	404.25	808.5	1617.	3234.
3	21/20	25.725	51.45	102.9	205.8	411.6	823.2	1646.4	3292.8
4	16/15	26.133	52.267	104.533	209.067	418.133	836.267	1672.532	3345.064
5	12/11	26.727	53.455	106.909	213.818	427.636	855.273	1710.545	3421.091
6	11/10	26.95	53.9	107.8	215.6	431.2	862.4	1724.8	3449.6
7	10/9	27.222	54.444	108.889	217.778	435.556	871.111	1742.222	3484.444
8	9/8	27.563	55.125	110.25	220.5	441.	882.	1764	3528.
9	8/7	28.	56.	112.	224.	448.	896.	1792.	3584.
10	7/6	28.583	57.167	114.333	228.667	457.333	914.667	1829.333	3658.667
11	32/27	29.037	58.074	116.148	232.296	464.593	929.185	1858.37	3716.741
12	6/5	29.4	58.8	117.6	235.2	470.4	940.8	1881.6	3763.2
13	11/9	29.944	59.889	119.778	239.556	479.111	958.222	1916.444	3832.889
14	5/4	30.625	61.25	122.5	245.	490.	980.	1960.	3920.
15	14/11	31.182	62.364	124.727	249.454	498.909	997.182	1995.636	3991.273
16	9/7	31.5	63.	126.	252.	504.	1008.	2016.	4032.
17	21/16	32.156	64.313	128.625	257.25	514.5	1029.	2058.	4116.
18	4/3	32.667	65.333	130.667	261.333	522.667	1045.333	2090.667	4181.333
19	27/20	33.075	66.15	132.3	204.6	529.2	1058.4	2116.8	4233.6
20	11/8	33.688	67.375	134.75	269.5	539.	1078.	2156.	4312.
21	7/5	34.3	68.6	137.2	274.4	548.8	1097.6	2195.2	4390.4
22	10/7	35.	70.	140.	280.	560.	1120.	2240.	4480.
23	16/11	35.636	71.273	142.545	285.091	570.182	1140.364	2280.727	4561.455
24	40/27	36.296	72.593	145.185	290.370	580.741	1161.481	2322.963	4645.926
25	3/2	36.75	73.5	147.	294.	588.	1176.	2352.	4704.
26	32/21	37.333	74.667	149.333	298.667	653.333	1306.667	2613.333	5226.667
27	14/9	38.111	76.222	152.444	304.889	609.778	1219.556	2439.111	4878.222
28	11/7	38.5	77.	154.	308.	616.	1232.	2464.	4928.
29	8/5	39.2	78.4	156.8	313.6	627.2	1254.4	2508.8	5017.6
30	18/11	40.091	80.182	160.364	320.727	641.455	1282.909	2565.818	5131.636
31	5/3	40.833	81.667	163.333	326.667	653.333	1306.667	2613.333	5226.667
32	27/16	41.313	82.625	165.25	330.5	661.	1322.	2644	5288.
33	12/7	42.	84.	168.	336.	672.	1344.	2688.	5376.
34	7/4	42.875	85.75	171.5	343.	686.	1372.	2744.	5488.
35	16/9	43.555	87.111	174.222	348.444	696.889	1393.778	2787.556	5575.111
36	9/5	44.1	88.2	176.4	352.8	705.6	1411.2	2822.4	5644.8
37	20/11	44.545	89.091	178.182	356.364	712.727	1425.455	2850.909	5701.818
38	11/6	44.917	89.833	179.667	359.333	718.667	1437.333	2874.667	5749.333
39	15/8	45.938	91.875	183.75	367.5	735.	1470.	2940.	5880.
40	40/21	46.667	93.333	186.667	373.333	746.667	1493.333	2986.667	5973.333
41	64/33	47.515	95.03	190.061	380.121	760.242	1520.485	3040.97	6081.939
42	160/81	48.395	96.79	193.58	387.16	774.321	1548.642	3097.284	6194.568
43	2/1	49.	98.	196.	392.	784.	1568.	3136.	6272.

Note: The omission of trailing zeros in the above table is to emphasize the point that Partch was using a Just Intonation system with rational fractions and integers, rather than a temperament with mainly irrational numbers, such as the roots of 2 and their powers. Decimal expressions of common fractions had to be rounded to three places to save space. A difference of 1 in the third decimal place means 0.001 Hz or one vibration in 1000 seconds or 16 minutes and 40 seconds, an accuracy far beyond what ordinary musical instruments can attain. The main value of going to three decimal places is to ensure that those wishing to make further calculations will not incur noticeable or audible errors.

SETTINGS FOR TUNING DEVICES, expressed as ± cents from 12-tone-equal

41-TONE EQUAL

No.	Setting
0	A exactly
1	A + 29
2	A# - 41
3	A# - 12
4	A# + 17
5	A# + 46
6	B - 24
7	B + 5
8	B + 34
9	C - 37
10	C - 7
11	C + 22
12	C# - 49
13	C# - 20
14	C# + 10
15	C# + 39
16	D - 32
17	D - 2
18	D + 27
19	D# - 44
20	D# - 15
21	D# + 15
22	D# + 44
23	E - 27
24	E + 2
25	E + 32
26	F - 39
27	F - 10
28	F + 20
29	F + 49
30	F# - 22
31	F# + 7
32	F#+ 37
33	G - 34
34	G - 12
35	G + 24
36	G# - 46
37	G# - 17
38	G# + 12
39	G# + 41
40	A - 29
41 = 0,	A exactly

43-TONE EQUAL

No.	Setting
0	A exactly
1	A + 28
2	A# - 44
3	A# - 16
4	A# + 12
5	A# + 40
6	B - 33
7	B - 5
8	B + 23
9	C - 49
10	C - 31
11	C + 7
12	C + 34
13	C# - 37
14	C# - 9
15	C# + 18
16	C# + 47
17	D - 16
18	D + 2
19	D + 30
20	D# - 42
21	D# - 14
22	D# + 14
23	D# + 42
24	E - 30
25	E - 2
26	E + 26
27	F - 47
28	F - 29
29	F + 9
30	F + 37
31	F# - 35
32	F# - 7
33	F# + 21
34	F# + 49
35	G - 23
36	G + 5
37	G + 33
38	G# - 40
39	G# - 12
40	G# + 16
41	G# + 44
42	A - 28
0= 43	A exactly

46-TONE EQUAL

No.	Setting	*CENTS FOR 46*
0	A exactly	0.000
1	A + 26	26.087
2	A# - 48	52.174
3	A# - 22	78.261
4	A# + 4	104.348
5	A# + 30	130.435
6	B - 43	156.522
7	B - 17	182.609
8	B + 9	208.696
9	B + 35	234.783
10	C - 39	260.870
11	C - 13	286.957
12	C + 13	313.044
13	C + 39	339.130
14	C# - 35	365.217
15	C# - 9	391.304
16	C# + 17	417.391
17	C# + 43	443.478
18	D - 30	469.565
19	D - 4	495.652
20	D + 22	521.739
21	D + 48	547.826
22	D# - 26	573.913
23	D# exactly	600.000
24	D# + 26	626.087
25	E - 48	652.174
26	E - 22	678.261
27	E + 4	704.348
28	E + 30	730.435
29	F - 43	756.522
30	F - 17	782.609
31	F + 9	808.696
32	F + 35	834.783
33	F# - 39	860.870
34	F# - 13	886.957
35	F# + 13	913.044
36	F# + 39	939.130
37	G - 35	965.217
38	G - 9	991.304
39	G + 17	1017.391
40	G + 43	1043.478
41	G# - 30	1069.565
42	G# - 4	1095.652
43	G# + 22	1121.739
44	G# + 48	1147.826
45	A - 26	1173.913
0=46	A exactly	1200.000

NOTE: "Tuning Device" here means such apparatus as the Hale, Peterson, Conn, and other makes of tuners which are based upon A = 440 Hz and the 12-tone equal temperament pitches derived from that, and also have dials or adjustments calibrated in cents above and below those 12-tone norms. Tuning-device data for Partch's system will be found on Pages 28 and 29 of this issue. Another reason for giving tuning-device data here is to provide an easy comparison of these scales with ordinary 12.