PIANO TECHNICIANS
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Happy Holidays...!

PIANO TECHNICIANS
Journal
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Editorial Perspective

Schools Need Encouragement...& Support!

Is piano technology a dying art? Will future generations have an opportunity to make a living practicing this honorable craft? Not according to the State of Washington.

Ken Serviss, Vice President and Manager of the Emil Fries Piano Hospital and Training Center in Vancouver, tells us that one of the school's students was denied benefits from the state Employment Security Department because "Reasonable work opportunities do not exist for you in the occupation for which you are going to school...Piano tuning is a diminished occupation."

The student in question was taking the Emil Fries course to prepare for a new career; however, this was a second-generation piano technician who certainly knew more about the profession than the person at ESD who denied benefits.

"Working with blind individuals, we're used to negative action by government agencies, but this turndown of a sighted student was unexpected," Serviss said. "It will be very interesting to see where and how it ends."

In a letter of protest, he noted that the Fries school has been training technicians since 1949 and is licensed and accredited. "An important part of the accreditation process is documentation of the fact that between 85% and 90% of our graduates are either employed or self-employed in the piano service field. This is particularly significant in light of the fact that the majority of our graduates are blind or visually limited — a group that, overall, has about a 10% employment rate. Our fully-sighted graduates have a successful self-employment rate of 100%."

He also noted that because the student's father is self-employed, he and his colleagues don't even turn up on ESD records. "Their employment security is in their files of repeat customers and the word-of-mouth advertising that continually broadens their client database."

Diminished occupation, indeed.

Ken makes another point, that tuning schools are rarely mentioned in the pages of the *Journal*. "I think it's time schools of piano technology were given recognition as a force in the piano service industry," he writes.

The Fries School is only one of a number of schools of piano technology around the country. Although teaching methods vary from school to school, it's safe to say that these institutions have contributed a great many of our leading technicians to the profession. And those who labor in the classroom also share their knowledge freely with new and established technicians who attend PTG conventions and seminars.

I suppose that as long as you do your job day in and day out, nobody notices. Only when you don't show up do people realize how important you were. In the Home Office, we frequently get requests for the names of schools, so we know the interest is out there. However, a number of schools have experienced declining enrollment in the past few years. If there were no more schools, this profession would certainly wither. The educators in our midst are doing their best for us. They need all the encouragement we can give them.

Speaking of making contributions and needing encouragement, there may be a perception that our coverage of last January's NAMM show and last July's convention was a little...spotty, that some companies were left out. Yat-Lam Hong, who covered both events, did a heroic job of trying to reach everyone. In doing so, he produced a great deal of beautifully written copy — exactly what we asked him to do. The piano manufacturers that were featured in the September issue were those that had been omitted from the NAMM coverage in May and June.

Perhaps we erred in trying to balance our coverage this way. It's the kind of thing that never works out the way you plan. But we're genuinely trying to bring you news from inside the companies that make the products that keep us in business. It's an effort they have consistently encouraged so, with their help, we'll keep trying.

Larry Goldsmith

PIANO TECHNICIANS
Journal
Volume 37 • Number 12 • December 1994

DEPARTMENTS

COVER ART

Happy Holidays from PTG Home Office to your home!

PACE

Professionals Advance through Continuing Education

LESSON PLAN

PTG*Review*

IN ADDITION

FEATURES

PTG President
Leon Speir, RPT

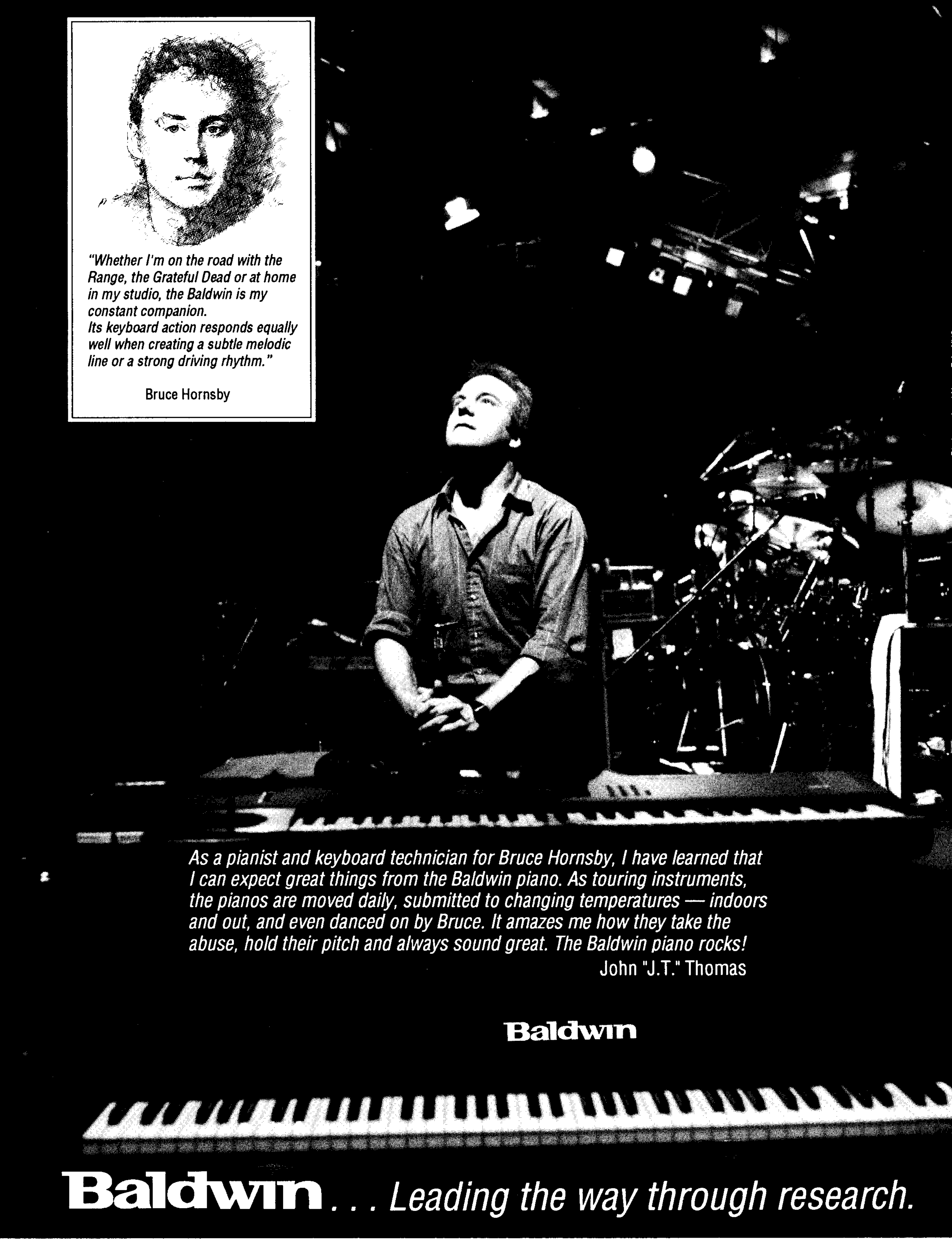
A Time To Reflect On The Past & Future

Each year at this holiday season we have an opportunity to pause and look at our achievements over the past year and to look ahead to the coming year. This special season also allows us to take the time to reacquaint ourselves with friends and family whom we may not have had the opportunity to see for some time. I do hope all of you have had a joyful and prosperous 1994 and wish each one a very happy holiday season and a rich and successful New Year.

Our joy this season is tempered with recent news of the passing of a some of our longtime friends and members who have meant a lot to PTG and to our craft. Our thoughts and sympathy are with the families of each one in their time of sorrow. Their legacy will live on and we are better for having known each of them.

As I look back over the past year, I am happy to report that PTG is in good shape financially and organizationally. Membership is up over last year and we look forward to continued growth in the coming year. Also we have had a 28% increase in Associates becoming RPTs. Our thanks go to all of those who have worked so hard this year to provide the informational tools to encourage testing and to those who have spent countless hours to administer those tests. We are now beginning to see the fruits of our labor.

From my family to yours, have a happy holiday season and a healthy and prosperous 1995!


"Whether I'm on the road with the Range, the Grateful Dead or at home in my studio, the Baldwin is my constant companion.
Its keyboard action responds equally well when creating a subtle melodic line or a strong driving rhythm."
Bruce Hornsby
As a pianist and keyboard technician for Bruce Hornsby, I have learned that I can expect great things from the Baldwin piano. As touring instruments, the pianos are moved daily, submitted to changing temperatures — indoors and out, and even danced on by Bruce. It amazes me how they take the abuse, hold their pitch and always sound great. The Baldwin piano rocks!
John "J.T." Thomas
Baldwin
Baldwin . . . Leading the way through research.

Q

What does that mouse really leave behind?

Here's a question: With all the scare about the Hantavirus, what is the best way to deal with mouse leavings? An article in the paper said to soak the area with a solution of bleach and water, but that would hardly do the piano much good! It went on to say to remove the leavings using gloves and a mask. The article also said that since the virus is thought to be transmitted through the air that a vacuum would only stir things up. Hence the information to soak first. Any tips or insights?

Julie Dunn
Culbertson, MT

A

From Larry Goldsmith

Larry Goldsmith is the Executive Director of the Piano Technicians Guild.

Hantavirus Pulmonary Syndrome, which begins with symptoms that include fever, muscle aches, headache and cough, and progresses rapidly to severe lung disease, was first identified in the Southwestern United States in May 1993. As of October 19, 1994, a total of 95 cases had been identified in 21 U.S. states, including Florida and Rhode Island. Only a few cases have been found east of the North Dakota-Texas tier of states. That doesn't sound like a serious problem, but unfortunately, 50 of those 95 cases have resulted in death.

According to material distributed by the U.S. Department of Health and Human Services' Center for Disease Control (CDC) in Atlanta, the Hantavirus is transmitted in the saliva, urine and feces of infected rodents, most often deer mice but also pinon mice, brush mice and western chipmunks. The deer mouse is highly adaptable and is found in different habitats, including human residences in rural or semirural areas, but generally not in urban centers.

Humans become infected when the virus is inhaled or ingested, or when contaminated materials are introduced into eyes or broken skin. Infection may also come from rodent bites. Biting insects like ticks, fleas, or mosquitos are not presently known to transmit the Hantavirus, nor is human-to-human contact a transmission factor.

Unfortunately, there aren't many alternatives to disinfecting an area where mouse droppings are found, according to John Suh of the CDC's Hantavirus Task Force. "To be safe, you will want to wet down the droppings with a disinfectant, because disinfectants tend to kill the virus. With bleach, you would use 1/2 cup of bleach to one gallon of water to make an effective disinfectant," he said.

He suggested that if you weren't able to soak an area with a liquid disinfectant, an alternative might be to dampen a paper towel with disinfectant and gently wipe the area or to use a spray disinfectant like Lysol. "Honestly, there isn't much else that we could recommend," he said.

He confirmed that a vacuum cleaner would indeed tend to make infective materials airborn, and therefore should not be used until after the area is disinfected. All potentially infective waste material should be double-bagged in plastic bags and either burned or buried in a two- to three-foot deep hole.

"If you're willing to invest some money, you might consider purchasing a good respirator, with an HEPA (high efficiency particulate air) filter," Suh said. "And always wear rubber gloves." He added that anyone who thinks he or she is experiencing any of the above symptoms should seek medical attention immediately, because prompt diagnosis and treatment does improve the victim's chances of survival.

All that said, remember that the disease is relatively rare, and that most infections have stemmed from activities like planting or harvesting field crops, cleaning barns or other outbuildings, occupying previously vacant cabins, or disturbing rodent-infested areas while hiking or camping. That's not to say that an infected deer mouse couldn't find a home in a customer's piano, but it would be a rare occurrence.

Q & A Continues on page 10

KAWAI...

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Symphonies, operas, music halls, festivals, artists and celebrities put their trust in **KAWAI**. The world's foremost pianist, Martha Argerich, performs on a **KAWAI**. Whether it's the *Aspen Music Festival, San Francisco Opera* or International Piano Competitions such as the *Frederic Chopin International,* Warsaw, Poland; *Arthur Rubinstein International,* Jerusalem/Tel-Aviv, Israel; *The International Music Competition of Japan*, Tokyo, Japan; *Sydney International,* Sydney, Australia; *Dublin International*, Dublin, Ireland; *International Pianoforte,*Cologne, Germany; *International Piano Competition "F Busoni"*, Bolzano, Italy; *Concours International "Vienna Da Motta"* Lisbon, Portugal;*Gina Bauchauer International Piano Competition,* Salt Lake City Utah; Santander International Piano Competition, Santander, Spain; Munich International Music Concour, Munich, Germany; *"George Enesco" International Piano Competition,* Bucharest, Romania; *The International Piano Competition of Taipei,* Taipei, Taiwan; *Hamamatsu International Competition,* Shizuoka, Japan, there is a **KAWAI** on center stage . . . also the winner of the prestigious *Van Cliburn Competition* won with **KAWAI**, not to mention Pop Artists and there even is a **KAWAI** In Chopin's Birthplace in Poland. **KAWAI** is the choice of the world's foremost pianists.Play **KAWAI...** play the best you can play.

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NOTE: Finalists choose Kawai in all fifteen (15) of the worlds most prestigious Piano competitions... In six (6) of the top competitions the first prize/gold was won by pianists who chose Kawai.

Q

What precautions should be used with Methanol?

How dangerous is methanol? I recently heard that it is so poisonous that just getting it on your skin is dangerous and exposure to spills can leave you blind. Is this true? Should we avoid the use of products that include methanol? Are there precautions that should be taken?

A

From Doug Wood

Doug Wood holds a Master of Science degree in Zoology and his background in the science field includes classes on chemistry for the piano technician.

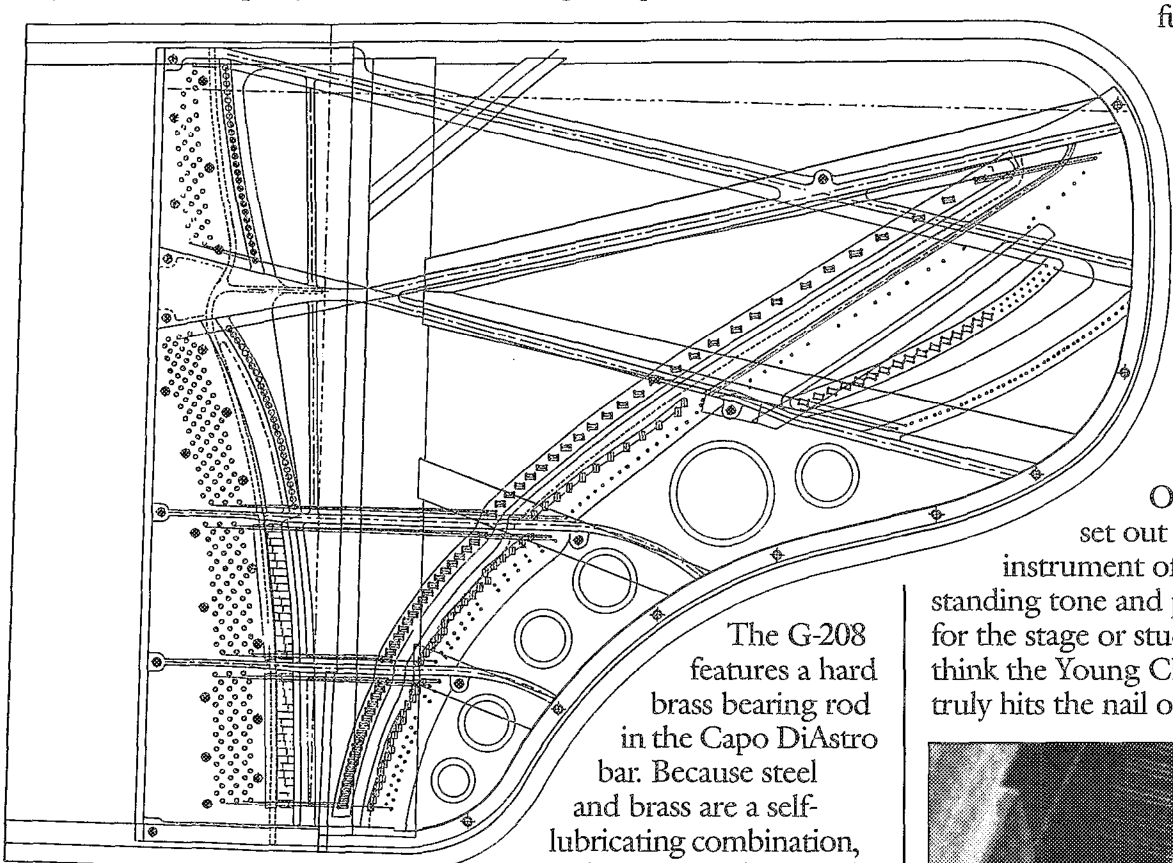
Most of the solvents that we use are poisonous, and as such should be treated with respect. Reading labels on products when you buy them is always a good idea. These days manufacturers, retailers, and employers who use hazardous materials are required to provide data to buyers and users. Some information is on the product label. Fuller data are available on the Material Safety Data Sheet (MSDS) for the product. You can order an MSDS for any hazardous product that you use from the seller. It will tell you what hazardous materials are in it, and how hazardous they are currently thought to be. If you want all this information in one place, it is in *Dangerous Properties of Industrial Materials,* by N. Irving Sax and Richard J. Lewis, Sr., Reinhold Pub. Corp, New York. Another book that I have found very helpful in my shop is *Artist Beware,* by Michael McCann, Watson-Guptill Publications, New York. In it you will find that methanol is considered "a human poison by ingestion...death from ingestion of less than 30 ml. (about one fluid ounce) has been reported." However, unless you drink it, you probably have to be exposed to quite a lot to be affected. Methanol is eliminated from the body fairly slowly. This means that exposure to moderate amounts day after day can produce toxic reactions, but those quantities are probably far in excess of what piano technicians usually experience (unless you happen to drink some!). By the way, it is most often sold as "wood alcohol."

Ethyl alcohol (ethanol) is the most readily available substitute for methanol. And in fact, when it is available, it is what I prefer. Sax considers it "moderately toxic to humans by ingestion...mildly toxic by inhalation and skin contact." A little better, at least. The main problem with ethanol is that it is a socially acceptable drug, and in its least toxic forms very carefully regulated and heavily taxed. The forms you find in the hardware store have purposely been tainted to be much more poisonous, usually "denatured" with methanol.

Also please note that ethanol usually has water with it — often more than 30%, and sometimes in different concentrations on the same drugstore shelf. If you recall, this makes for a very strong bushing shrinking solution! (In the "drinkable" alcohol, remember that 200 proof = 100%, so a 20% water/alcohol solution would be 160 proof.) If water content is not listed, ask for an MSDS.

It is always a good idea to pay attention to ventilation and wear rubber gloves (neoprene is best for most things) when you work with significant amounts of any solvent. If you refinish, or even do touch-up work regularly, you owe it to yourself and those you love to become knowledgeable about the chemicals you work with. For those of us who do very little finish work, most of our chemical exposure is infrequent and in small doses. Prudence is always in order, but most of the materials we work with, including methanol, can be used safely by following the usual safety procedures.

A nuts and bolts guide to the new Young Chang G-208.



Our engineers are obsessed with the little things because they recognize the importance of attention to detail. But lately, they've become equally obsessed with big things, and the result is 6′10″ long. Our new G-208 grand is a departure for us and represents the smallest and largest of our latest innovations.

The G-208 is a 6′10″ grand piano of an entirely new scale design. It features our new "Asymmetrically Crowned" soundboard which places the highest part of the crown in each rib directly under the bridge providing maximum support under the downbearing pressure of the strings. This new soundboard design exhibits improved power, projection and tuning stability, and offers a longer soundboard lifetime. We're so pleased with this new design, we're now incorporating it into all our grand pianos.

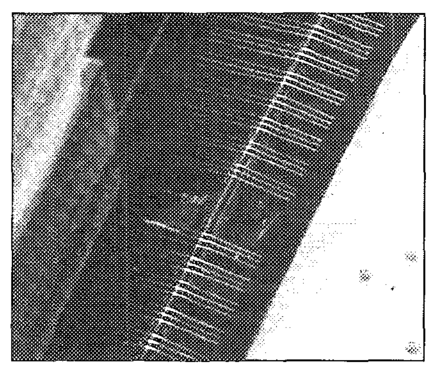
The G-208 features a hard brass bearing rod in the Capo DiAstro bar. Because steel and brass are a self-lubricating combination, we've discovered a brass rod offers better control of strings during tuning. In addition, the brass rod is easily replaced later in the life of the instrument eliminating the need for reshaping of the capo bar.

We also took a close look at our action and developed an all-new action design which improves response without loss of projection or clarity.

Our new double duplex system terminates the strings at the rear of the bridge and near the tuning pins with duplex bars. Both duplex lengths of the strings for each note are then terminated in equal length offering improved sustain, projection and clarity.

Together these innovations create an instrument with a rich, full sound, greatly improved response and a remarkable evenness of tone throughout the entire range of the keyboard.

Our engineers set out to design an instrument offering outstanding tone and performance for the stage or studio. And we think the Young Chang G-208 truly hits the nail on the head.



Because strings bear against a replaceable brass rod, tuning control is improved.

For technical information on our new G-208 grand piano, write to us at Young Chang America, Inc., 13336 Alondra Blvd, Cerritos, CA 90701. Or call 310/926-3200, ext. 237.

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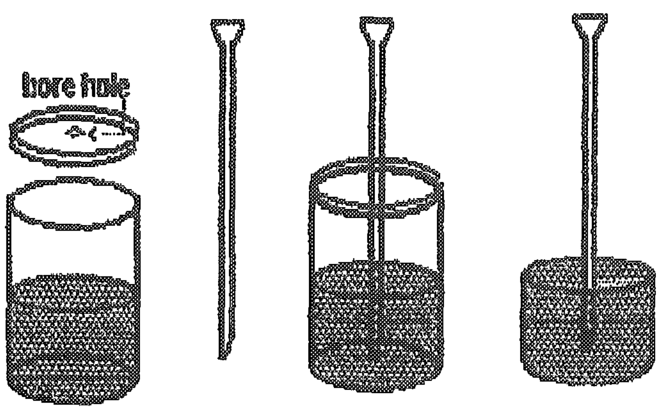
The best the world has to offer.

TT&T Recycling Epoxy...

In using epoxy in our shop, we often times end up with more glue than we needed. The garbage can is usually where it all ended up until we found another way to dispose of it. We now make handles with it for regulating tools, screwdrivers, files, etc...Besides being economical, this method gives you the feeling that you are doing something for the environment. Below, the illustration shows an example of making a handle for a regulating tool using a plastic 35mm camera film canister as a mold.

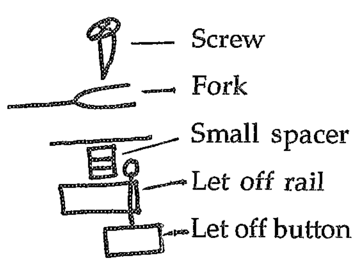
Denis Brassard
Banff. Alberta, Canada



TT&T A Regulating Tip...

When regulating an old piano, usually uprights, the letoff buttons are pretty worn down. You can put a small spacer between the fork and letoff rail to increase old button length. See illustration.

Francis Elmer



TT&T The Problem Of Broken Agraffes & Sleeping To The Keyboard Count

From time to time the problem of broken agraffes comes up. Extensive solutions have been suggested by different technicians. There is a simpler way of removing broken agraffes which has worked well for me. The only tool needed is a jack spring hole reamer and a pair of pliers to twist the reamer. Even with the teeth of the reamer going in the wrong direction for this repair, you may be surprised how easy it is to remove the stem. I wrote to one supply house to have the teeth go in the other direction for a better grip on a boken agraffe (it would be just as effective in removing glue in the jack spring hole), but I did not hear from them.

Do you as piano technicians have the problem of falling asleep at night? The universal remedy of counting sheep as they jump over a fence is usually non-productive. It is not long until you find your mind wandering, and that keeps you awake. You need to get out of the rote rut. You need an undisturbed scenario. This is where what I call "The Keyboard Count" comes in. It works this way: Imagine your finger on the first key on the keyboard and mentally say "A-1." Move to the next key and say "A#-1." Move to the next key and say "A#-2" — B-3 — C-4 — C#5, all the way to C-88 if you can get that far. Having to concentrate on the key and the number of that key reduces or eliminates mind wanderings. Pleasant dreams!

Sid Stone
Hayward, California

TT&T The Ice Cream Man Has Tools For The Piano Technician...

To strip mute the piano for tuning, I use a popsicle stick. It's small, doesn't slip out of my hand, is slim enough to fit comfortably between the strings, easy to find amongst all that shiny silver stuff in my tool case, cheap and easy to replace if I ever wear it out. It doesn't tear up the felt like some metal tools will. Using a vise grip, I break off part of the end and file off the rough edge. In uprights I use the pointed end to apply upward pressure, easing the felt between the strings.

Sandra Cooper, RPT
Napa, California

The Revised Twelve Days of Christmas

(Sung to the tune of "The Twelve Days of Christmas")

By Carl Radford, Waukegan Chapter

On the first day of Christmas I had to tune a Stark
In the city with nowhere to park.

On the second day of Christmas; a Story & Clark
With two sticking keys
In the city with nowhere to park.

On the third day of Christmas and yet another Stark
With three loose pins,
Two sticking keys
In the city with nowhere to park.

On the fourth day of Christmas, guess what? Another Stark
With four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the fifth day of Christmas; a player made by Stark
With five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the sixth day of Christmas; a Lester, not a Stark
With six screaming children,
Five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the seventh day of Christmas; a Lester and a Stark
With seven floppy flanges,
Six screaming children,
Five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the eighth day of Christmas a customer named Mark
Had eight barking Beagles,
Seven floppy flanges,
Six screaming children,
Five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the ninth day of Christmas, no angel, I did hark
Nine buzzing ribs,
Eight barking beagles,
Seven floppy flanges,
Six screaming children
Five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the tenth day of Christmas I tuned one in the dark
With ten busted elbows,
Nine buzzing ribs,
Eight barking beagles,
Seven floppy flanges,
Six screaming children,
Five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park.

On the eleventh day of Christmas; a high school filled with Starks
With eleven cracked plates,
Ten busted elbows,
Nine buzzing ribs,
Eight barking beagles,
Seven floppy flanges,
Six screaming children,
Five broken strings.
Four missing jacks,
Three loose pins,
Two sticking keys
In the city with nowhere to park

On the twelfth day of Christmas—I found a place to park!!
And no one was home...but hey,
No cracked plates,
No busted elbows,
No buzzing ribs,
No barking beagles,
No floppy flanges,
No screaming children
No broken strings.
No missing jacks,
No loose pins,
No sticking keys
And a ticket upon my Skylark!

FILE T

For Temperament...

"...Let The Piano Tell You"

By Jack Stebbins

One of the many difficulties encountered in tuning a temperament is how much or how little to temper intervals. Wouldn't it be great if there were a simple way to get the piano to tell you that, to tell you what beat speeds it would allow you to use? There is, indeed, a way for the piano to let you know, and it's not terribly difficult.

What we are dealing with is a rationale for making a framework upon which to hang a temperament. To be quite candid , the framework has been in existence for a long time, as has the rationale for establishing it. Since it is something new to me, however, I think it bears repeating. I am concerned here not so much with the theoretical implications, but more with the pedagogical importance of this rationale: I now have a tool to give to a relative beginner which will take some of the guesswork out of temperament tuning, guesswork more vexing at the beginning of the temperament where s/he has fewer fixed points of reference. Read on!

I owe much of the following discussion to one of my students at North Bennet Street School, David Sumrell. Of the many ideas that he has generated, a few have galvanized my attention, but none more so than this topic. Al Sanderson, Owen Jorgensen, and others will recognize the truths it contains, and I hope that you will be able to make use of them.

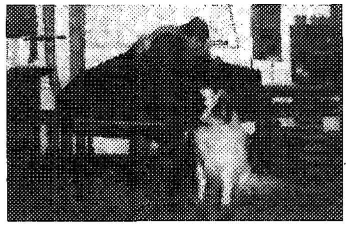
In 1981 Dr. Sanderson propounded the two-octave A temperament. The structure he used began with a 4:2 octave between A4 and A3, and a 6:3 octave between A3 and A2. This two-octave spread was then subdivided into six equal parts by tuning a series of continuous major thirds. He explained his operating philosophy this way: Tuning wide intervals first and then subdividing them is inherently more accurate than the usual process of building up from narrow to wide intervals. Furthermore, it is a foolproof way of building a temperament because the narrow intervals are forced to be compatible with the wider ones.

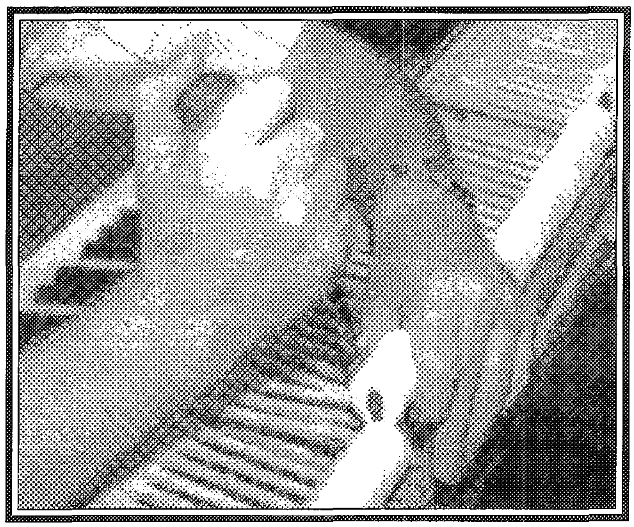
The framework we will use covers most of that territory, and we will be using contiguous major thirds. We dispense with the concept of rising contiguous thirds having a 5:4 ratio of beat speeds. We need not even try to obtain beat speeds that rise at 2 bps intervals. We are talking basically about slow-medium-fast. The difference for me, then, is in the thought process behind the building of the thirds.

First, let me talk about the value of what Mitch Keil calls Go/No Go. This means to me an acceptable range, a tolerance, parameters, low-end/high-end limits; within these limits we will identify the midpoint. Specifically, we will locate a beat speed in the middle between two others. The value of this concept is that it is easier to find the middle between two markers than to locate the correct place when no markers are given.

Let's begin.

1. Tune A4 to the fork.
2. Tune A3 to A4 as a 4:2 octave. Using F3 as your test note, make F3/A3 beat the same speed as F3/A4.
3. Tune C#4 to A3. **It does not matter how fast this major third beats.** We will say more about this later.
4. Tune C#3 to C#4 as a 6:3 octave. Using E3 as your test note, make C#3/E3 beat the same as E3/C#4.
5. Tune F3 by moving it to the point that the speed of F/A is midway between the contiguous major thirds that flank it: C#/F and A/C#.
   N.B.: Contingent upon your accuracy, the speed of this F/A is no arbitrary choice. It is the only speed the piano will allow.





6. Tune F4 to F3 as a 6:3 octave. Using G#3 as your test note, make F3/G#3 beat the same speed as G#3/F4.

7. Retune C#4. Move it to the point that the speed of A/C# is midway between the two other contiguous major thirds: F/A and C#/F. **If your accuracy is unfailing, you have now finished.**

8. As a check of your accuracy, retune C#3, and play the five contiguous major thirds from there up to A4.

   N.B.: What you hope to hear is a smooth increase in beat speeds. If there is a discrepancy, repeat steps 2 - 8.

Generically speaking, the speeds of your contiguous thirds are rounded off and called 5, 7, 9, 11, and 13 beats per second. Actually, the beat speeds vary from instrument to instrument depending upon differences in inharmonicity. In step 3, trying to set your initial major third, or any of the others, at a clocked speed can often be an exercise in futility. Part of the beauty of this method for beginners lies in the fact that it makes no difference, within practical limits, where you set C#4.

Let's say for example, that you placed C#4 a little flat of normal, and you obtained a major third beating at 8 bps with A3 instead of the normal 9 bps. When you tuned C#3 as an octave, it, too, would be a little flatter than normal. In consequence, when you finished placing F3 (step 5), your bottom third would then be correspondingly fast. In this example, instead of rising contiguity thirds beating at 5, 7, 9 bps, you would have something like 6, 7, 8. **This would be a distinct advantage.** By having to squeeze your 7 bps between 6 and 8, you should be reducing your margin of error.

If your C#4 were flatter still, the time creating a third beating around 7 bps, that works as well. Your beat spread would be something approaching 7, 7, 7.

Let's carry this one more step. If your C#4 were at 6 bps with A3, your C#3 would be that much flatter, and the bottom third correspondingly fast. Here your rising beat speeds would be 8, 7, 6.

My point is this: irrespective of where you locate C#4 or of whether your rising thirds can be described as slow-medium-fast, or same-same-same, or fast-medium-slow, **in every case the middle third is correct**, if it is midway between its neighbors.

And let me reiterate this: **The speed of the middle third is not arbitrary. It is what the piano dictates, therefore, it is right for that piano.** And no matter what temperament pattern you use, you have some immutable markers against which to compare the rest of your temperament.

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LESSON PLAN

Technical Lesson #16

Vertical Regulation—Damper Spoon Adjustment

By Bill Spurlock, RPT
Sacramento Valley Chapter

This monthly lesson plan is designed to provide step-by-step instruction in essential skills. Chapters are encouraged to use this material as the basis for special Associate meetings, or for their regular meeting program, preferably in a hands-on format. This method allows the written information to be transformed into an actual skill for each member participating.

In brief:

This lesson will cover adjustment of damper spoons for even damper lift with the keys. Participants will learn the proper tools and techniques for doing this important adjustment accurately and easily.

Getting started:

In order to pursue any serious study of piano technology, one must obtain basic resources. Catalogs from several piano supply houses, both large and small, are essential. Besides offering the necessary supplies, their pictures and item descriptions are valuable sources of information. Piano manufacturers' service manuals are also essential sources of valuable information. Most are available at no cost. Most important to participating in this Lesson Plan series are the PTG Exam Source Books, both the tuning and technical versions. Articles in these books will serve as reference material for the lessons.

Hands-on session setup:

To teach this lesson in a hands-on format you will need one or more 47" or larger vertical pianos in good condition. The dampers on these pianos must already be regulated for even lift with the pedal. Spoon adjustment is most easily learned on taller pianos with dowel capstan or sticker actions, so console or small studio pianos should be avoided at first. Old full-size uprights are ideal.

Depending upon time and pianos available, this lesson may consist of each participant adjusting a few spoons or an entire set.

Additionally, meeting setup should include:

- Good lighting
- Extra damper spoon benders (see photo 1)
- Extra damper lift gauge blocks and wedges (see figure 1)

Estimated lesson time:

2 hours

Tools & materials participants must bring:

For this lesson, participants should bring a selection of regulating tools, including:

- damper regulating tools listed for Lesson #15
- damper spoon bender; APSCO #16406 or equivalent
- 1" x 7/8" x 10" wood block and two wooden wedges (see figure 1)

Assigned prior reading for participants:

PTG Technical Exam Source Book (PTG Home Office, 816-753-7747), pages III.10-III.11

General instructions

Proper damper spoon adjustment is essential to good performance. The damper springs are a strong component of touch in a vertical piano, so even timing of damper lift by each key is critical to a uniform keyboard touch. Also, the player's ability to control tone requires that each note stop sounding at the same point of release for each key, and thus uniform spoon adjustment is vital to smooth legato playing.

Damper regulation is not really difficult compared to other skills such as setting unisons. However, spoon adjustment in particular has traditionally been considered very troublesome. There are two reasons for this: first, most technicians get much more practice at other skills such as tuning—after all, uneven damper spoon adjustment is usually not as obvious a problem as poor unisons. Secondly, many of the available spoon bending tools do not work well. However, with a logical approach, the correct tools, and a little practice, spoon adjustment is a straightforward and rewarding job.

It is often recommended that spoons on sample notes be set, then the remaining spoons adjusted with the action on the workbench. While such methods will work, they will never give as accurate a result as adjusting the spoons in the piano—at least not without pulling the action another time or two for further refinement. Such methods are based upon the assumption that it is too difficult to adjust the spoons with the action in the piano, using a spoon bender. In reality, for most pianos it is simpler, faster, and more accurate to adjust spoons in the piano. That's why piano factory workers do it this way. This lesson will describe a step-by-step method for mastering this skill.

Procedures

Vertical piano dampers must first be adjusted to lift evenly by the pedal before the spoons are adjusted for even lift by the keys. To understand why, refer to the previous Lesson #15. Notice that adjustment for even pedal lift is done by bending the damper wires, which moves the lower ends of the

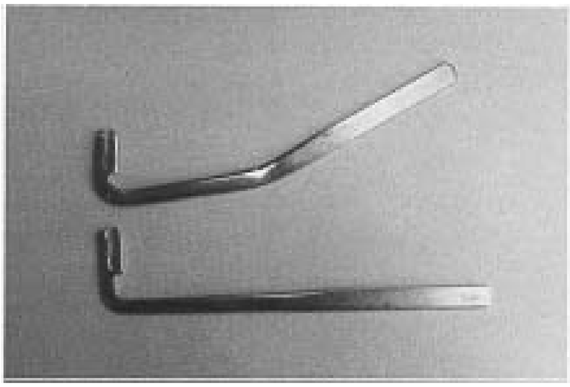


Photo 1: lower tool: a well-designed spoon bender; and upper: the same tool bent to provide key clearance on console pianos.

damper levers closer to or farther from the lift rod. Of course this changes the distance between the damper levers and spoons as well, upsetting damper lift by the keys. Thus adjustment for even lift by the pedal must be done first. Then, with the damper levers permanently and correctly positioned, the spoons are bent to provide even damper lift by the keys.

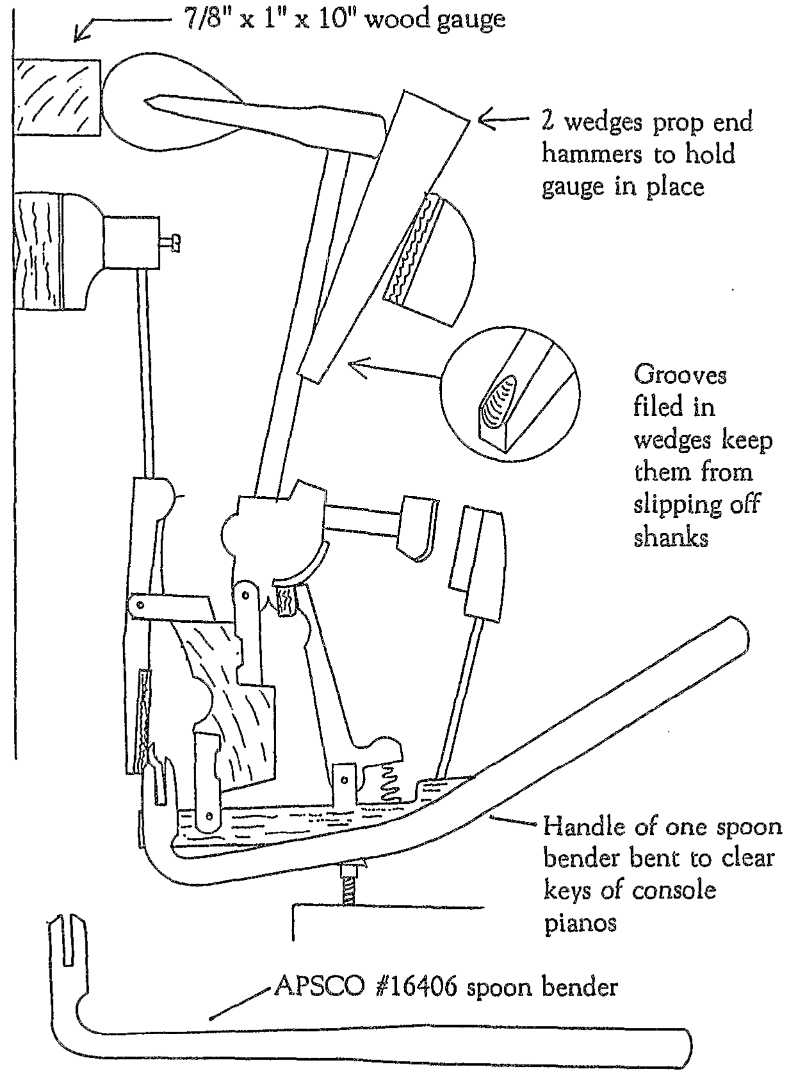
Learning to use a spoon bender

The first requirement is a properly designed spoon bender. Figure 1 and photo 1 show a particular model that I favor (APSCO #16406). The upper tool in each illustration has been bent for key clearance on console pianos). A good spoon bender should be compact and slender with tapered and rounded edges; most good ones are nicely chrome plated. The overall height of the slotted end should be no more than 1 1/2." By contrast, spoon benders sometimes supplied in "beginner's" kits or listed along with basic tools are usually 1 3/4" in height, made of plain flat stock with no tapering, nickel-cadmium plated and generally more bulky looking.

Spoon bending is done blind. That is, with the action in the piano you cannot see the damper spoons. Thus, you work by feel and sound—learning to recognize the feel of the tool slipping onto the spoon and the metal-to-metal click of spoon bender to spoon. To train your senses of feel and hearing, practice the following exercise:

- On a full-size vertical piano, remove the action nuts and tip the action back toward you slightly so you can see the spoons. Slip your spoon bender between two wippens and onto a spoon. Notice that the tool must lean to the side, toward the spoon, and that when you lean the tool you are twisting the handle as if lightly prying between the two wippen flanges. (In the bass, the spoons will lean toward the right, so the bender will be on the right side of the wippen but leaning left to engage the spoon, as in photo 2 (next page). In most pianos, the tenor spoons lean toward the left, so the bender is on the left side of the wippen and leaning to the right to engage the spoon. The treble spoons usually lean toward the right again as in the bass.)
- Slip the tool on and off

Figure 1: Adjusting damper spoons — Wedge a gauge block against strings, then lift each wippen to bump its hammer against the block and check for damper wink.



the spoon, learning the feel of the spoon slipping into place and the sounds as it bumps the flanges, spoon, and wippen screw. Notice that lifting the wippen moves the spoon away from the action rail, making it easier to slip the tool in place. Close your eyes and again focus on the feel and sound of the bender on the spoon.

- Have a piece of tape or a black felt pen handy. Then, holding the bender on the spoon, push the action back into place. Mark the handle of the spoon bender with the tape or felt pen to correspond to the end of the wippen. This mark will tell you how far in to reach with the bender when feeling for a spoon.
- With the bender on the spoon, hold the spoon bender with one hand while holding the end of the wippen with the thumb and forefinger of the other, as in photo 3. Next, slip the bender off the spoon and try to slip it back on again without looking. Remember to lift the wippen slightly to make the spoon more accessible. If you're not sure where you are, pull the action back and look. After a few tries your senses of feel and hearing should be trained enough to allow grabbing the spoons without too much trouble.
- Work the spoon bender and wippen up and down slightly in opposite directions, as if working two handles of a pair of scissors. You should notice that there is an area of free play in which the spoon bender moves but does not bend the spoon, even though the tool is engaged. Lift the wippen and push the bender down, and you will feel resistance as the bender bears against the spoon. Slight additional pressure at this point would bend the spoon back toward the rail, causing the damper to lift later. Next lower the wippen while lifting the bender. After passing through the area of free play, you will again feel resistance as the bender bears outward against the spoon. Additional pressure here will bend the spoon outward, causing the damper to lift sooner. Do not make any bends at this time.

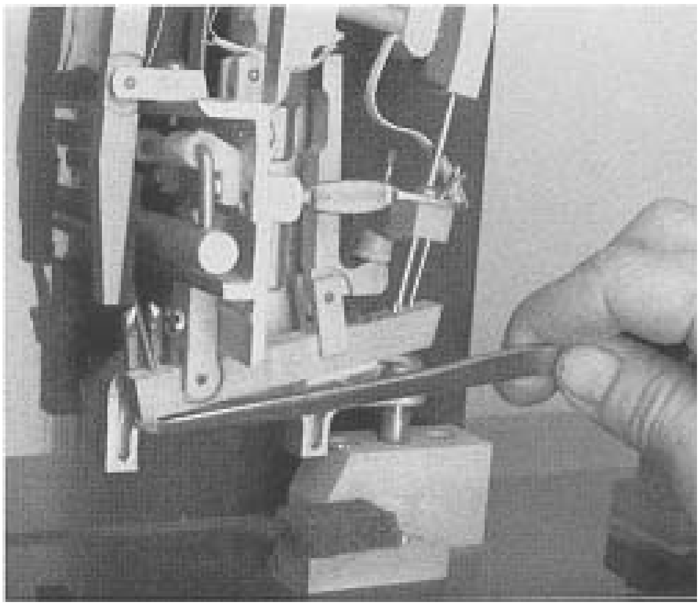


Photo 2—Left: Spoon bender engaging a spoon.

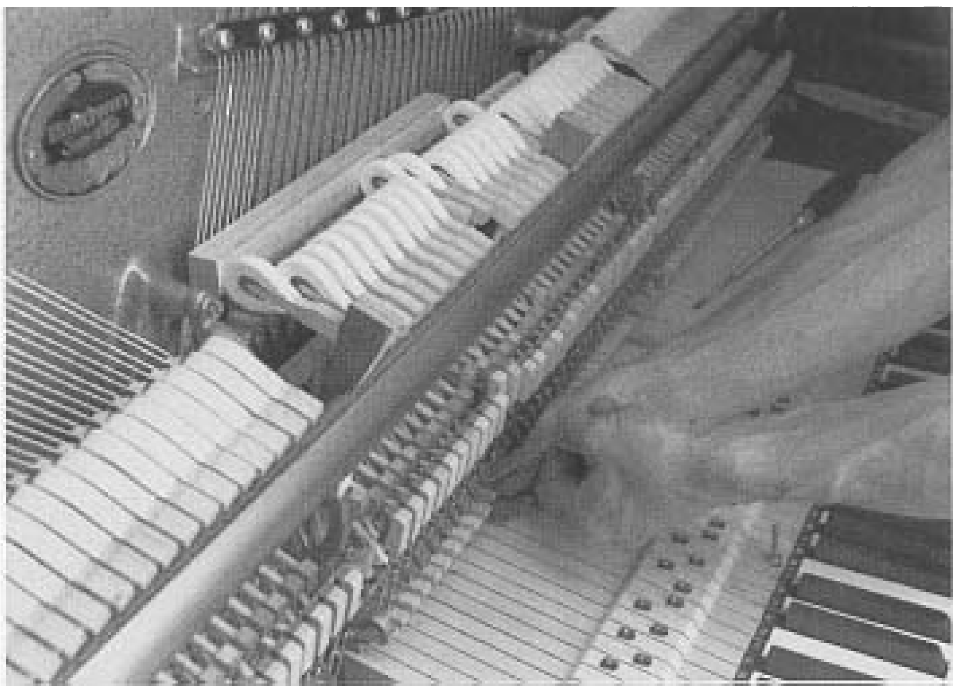


Photo 3—Below: Adjusting damper spoons — one hand holds the spoon bender while the other lifts the wippen, bumping the hammer against a wooden gauge block. If the damper does not wink, its spoon is bent outward to speed up damper timing. If it winks excessively, the spoon is bent back to slow damper timing.

Understanding damper timing

Dampers should begin to lift when the hammers are between one-third and one-half the distance to the strings. This does *not* mean the lift points of individual dampers on the same piano can vary within this range. Rather, all dampers in a given piano should lift at the same point of hammer travel, and that point will vary from piano to piano depending upon manufacturer or technician preferences. Here are some guidelines:

- If dampers lift much earlier than one-third hammer travel, there will be little clearance between spoons and damper levers when the action is at rest. Then as the action wears and the capstans are turned up, the spoons may be moved into contact with the levers, causing ringing dampers. Thus such early damper timing leaves very little margin for error in regulating hammer blow distance and lost motion.
- If dampers lift much later than one-half hammer travel, total damper travel is reduced, and trichord dampers may not lift enough to clear the center unison strings. Also, the touch resistance of damper lift will be encountered late in the keystroke, around the same time as the resistance due to the jack tripping. On very soft playing this can cause incomplete key strokes and consequent bobbling hammers.
- Earlier damper timing gives the sensation of a firmer touch because the resistance of the damper springs is encountered earlier in the key stroke, while later timing makes the action feel somewhat lighter. Of course this affect is only present when the pedal is not used. Thus the customer's touch preference can be considered when choosing damper timing.
- In most circumstances, damper spoons are simply regulated for uniformity if they are already lifting within the one-third to one-half hammer travel range.

Adjusting damper spoons

Adjustment is fastest and most accurate when a gauge is used to indicate the damper lift point, as shown in figure 1. This wooden block is approximately one-half hammer blow distance in width (if made 7/8" x 1", you can choose the dimension that best suits a given piano). A wooden wedge between the hammer rail and a hammer at each end of the block holds it in place. Then, each wippen is lifted, bumping its hammer against the block. If the damper winks slightly, its spoon is correct. If it does not wink, its spoon needs to be bent outward to speed up damper timing. And if the damper lifts more than just a wink, its spoon needs to bend back toward the rail to slow its timing. This gauge gives an immediate reading of exact damper timing for each note, just by lifting its wippen.

To practice adjusting spoons, use the following procedure:

1. Partially depress the damper pedal several times to confirm that all dampers start to lift simultaneously with the pedal.

2. Measure the hammer blow distance and choose the gauge block side that will stop the hammers at slightly less than one-half blow distance. For instance, if blow distance is 1 3/4", use the 1" side of the block. Prop the gauge block against the strings as in figure 1. You can then lift each wippen, causing its hammer to bump against the gauge, to observe damper timing.

3. When making adjustments hold the spoon bender in one hand and the end of the wippen with the other, and work one against the other. A slight bend makes a big difference to damper timing, so practice to develop a feel for making small bends.

4. Engaging the spoon with the bender is easiest when reaching between two neighboring wippens because leaning the bender to the side causes it to bear against the neighboring wippen flange. This positions the bender at the correct angle to engage the spoon. Because they lack neighboring wippens, the top bass and first tenor wippens will often be much harder to adjust than any others. Avoid these until you are more practiced.

5. If you are right handed, practice first on the bass or top treble dampers, where you will be holding the spoon bender in your right hand. Lefties should start in the tenor first. Once you have your primary hand trained, switch sections and train the other.

6. Each piano design is different so you may occasionally have to repeat the initial step of tilting back the action to visually place the spoon bender with new piano designs. Many compact actions require that you remove the keys to get enough room to operate the tool. On spinets the spoons are adjusted just like on larger uprights except that the tool is held under the keybed. These are actually easier than consoles because you can kneel down and see the spoons from underneath when first getting a feel for them.

Summary

As with any new skill, practice is essential. Don't avoid learning the skill of spoon bending just because you think you can avoid having to ever adjust them. Damper spoons are an important regulation adjustment, and once you can adjust them accurately and efficiently you will find this skill essential.

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Tuning Lesson #16

The Baldassin—Sanderson Temperament: Part 2 Dividing the F3-F4 Octave Into Six Equal Parts

By Michael Travis, RPT
Washington, D.C. Chapter

This monthly lesson plan series is designed to provide supervised practice of tuning skills as a supplement to independent study and practice. Chapters are encouraged to use this material as the basis for special Associate meetings, or for their regular meeting program. Each lesson is designed to take about one hour, with about four participants. Participants are assumed to have essential reference materials and tuning tools (see PACE checklist) and access to a well-scaled large upright or grand piano for independent practice

In brief

This lesson continues a series of three on the **Baldassin-Sanderson Temperament**. Participants will build on the results of the previous lesson, an ascending series of contiguous major thirds from A2-A4. This tuning should be in place on, or restored to the piano before proceeding, as we discussed in the last lesson. In this lesson, participants will move within the previously established double octave/thirds framework and learn how to divide the temperament octave, F3-F4, into six equal parts. They will each contribute hands-on to the final result as we follow steps 12-18 in the Baldassin-Sanderson Temperament, Part 2, outlined below.

In the next lesson we will learn how to divide the F3-F4 octave into the twelve equal parts of equal temperament. To preserve continuity and save set-up time, PACE providers may wish to offer either two or all three of the lessons on the Baldassin-Sanderson Temperament to the same group on the same day.

In conjunction with these lessons all participants should attend classes in this temperament system that may still be offered at regional and annual PTG conventions. You might think of these lessons as a "hands-on" version of the Baldassin-Sanderson Temperament class.

Chapter meeting set-up

These lessons are most conveniently taught to a small group of four or five. Each group should have its own piano and RPT instructor. Each piano should be in a quiet environment for close listening. Avoid using pianos that present serious obstacles to tuning, such as deeply grooved or misaligned hammers, string termination noises, etc.

If you are using the same piano for this lesson as for the last, restore the results of the last lesson by re-tuning from SAT memory. If you are using a different piano, you will have to prepare the tuning in advance for this lesson as described in the last lesson and below.

Tools & materials participants must bring

Tuning hammer, A-440 pitch source and mutes.

Home study assignment for participants

Review PACE tuning lesson #15. Practice setting up the double octave/major thirds framework. Review PACE tuning lessons #10-13 on tuning fourths and fifths. Practice tuning 4:3 fourths both pure and 1 bps wide.

General instructions

This lesson will follow steps 12-18 of the Baldassin-Sanderson Temperament procedure. At the conclusion of the lesson, the group should have tuned the series of rising 4:5 contiguous thirds from A2-C#3 through F4-A4, a smoothly rising series of parallel whole-tone thirds from F3-A3 to C#4-F4, and all unisons of these notes. PACE instructors may require participants to tune unisons as they go, or instead insert a strip mute in A2-A4 and tune all the unisons afterward. Either procedure should produce satisfactory results provided the piano is at pitch and reasonably in tune to begin with. The final check should be with unisons pulled in.

The first thing to do will be to establish or re-establish the double octave/M3 framework of the last lesson; check the contiguous thirds from A2-A4. What we're looking for here is a 4:5 progression of contiguous M3s, and in addition, the three upper M10s should echo the beat rate of the three lower M3s (M10s A2-C#4, C#3-F4 and F3-A4 beat in ascending 4:5 ratio, like M3s A2-C#3, C#3-F3 and F3-A3). We should also have four good single octaves, A2-A3, C#3-C#4, F3-F4 and A3-A4, with similar m3-M6 tests on the lower two and M3-M10 tests on the upper two, all within an A2-A4 double octave that is not more than 1 1/2 beats wide.

Next, we will go on to steps 12-18 of the Baldassin-Sanderson Temperament and tune notes in the following order: A#3 (initial), D#4 (initial), C4 (initial), G3 (initial), B3 (final), G3 (final), and D#4(final). The final tuning of A#3 and C4 will be part of the next lesson. The instructor may have participants select their notes by a random drawing or any other method, as long as everyone gets to do something.

The Baldassin-Sanderson Temperament: Part 2

12. Tune A#3 to F3, 1 beat wide.

13. Tune D#4 to A#3, 1 beat wide.

14. Tune C4 to F4, 1 beat wide.

15. Tune G3 to C4, 1 beat wide.

16. Tune B3 between G3 and D#4 so that the ratio between GB and BD# is 4:5 (ascending contiguous major thirds). B3 is now in the correct place, whether the width of the four fourths (steps 12-15) was correct, or not.

17. Retune G3 to B3 such that the GB third fits half way between FA and AC#.

18. Retune D#4 to B3 such that the BD# third fits half way between AC# and C#F, and GB-BD# are in the ratio of 4:5.

This creates a whole tone scale F-G-A-B-C#-D#-F. You have now divided the F3-F4 octave into six equal parts.

Some points to remember:

In steps 12-15 the absolute speed of the four fourths is not as important as tuning them as close as possible to the same speed; 1 bps is a good initial guess for that speed. Fine-tuning the thirds in steps 17-18 may alter the fourths slightly.

With unisons pulled in, recheck the following:

1. A4 at A-440.

2. Four good single octaves, A2-A3, C#3-C#4, F3-F4 and A3-A4, with similar m3-M6 tests on the lower two and M3-M10 tests on the upper two, and an A2-A4 double octave that is not more than 1 1/2 beats wide.

3. Contiguous M3s from A2-C#3 to F4-A4, beating in ascending 4:5 ratios.

4. Ascending M10s A2-C#4, C#3-F4 and F3-A4 which echo the beats of the three lower contiguous M3s, and also beat in an ascending 4:5 ratio.

5. Smoothly rising parallel whole-tone thirds (F3-A3, G3-B3, A3-C#4, B3-D#4, C#4-F4).

If stopping at this point, it may be convenient to measure and store the measurements of all tuned notes on a SAT memory page before leaving the piano to facilitate set-up for the next lesson on the same piano, which starts where you end here. Someone familiar with the SAT should do this. First measure any deviation of the center string of A4 from A-440, then enter that value as a pitch offset, and finally measure and store the values for the fourth partials of the center strings of all tuned notes. Since you will want to have a complete record of where you were, be sure to read and record A#3 and C4 in addition to the others, even though you may change these during the next lesson. You may also wish to keep a written record of results in case you have to use a different SAT for the next lesson.

Now we are ready to proceed with the next lesson, the third and final part of the Baldassin-Sanderson Temperament.

Note: *Do you find these lesson plans valuable? Do you have specific suggestions for changes or clarification? Please direct any comments or suggestions to the author c/o the* **Journal**.

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INHARMONICITY & THE TEMPERAMENT

ARTICLE • 5
The Math Of It All

Daniel Levitan, RPT
New York City Chapter

In previous articles in this series we have taken two commonly recognized facts about the inharmonicity of piano strings—that it forces partials sharp of their theoretical pitches, and that it does so to an increasingly greater degree as the partials ascend the harmonic series—and from those two facts we have developed some rules of thumb to guide us in tuning the temperament sections of pianos with high inharmonicity. These speculations regarding the effect of inharmonicity on the beat rates of temperament intervals have so far been entirely qualitative, avoiding the use of formulas. In this article we will review the territory we have already covered, this time using math to confirm, quantify, and extend our previous conclusions.

Our two basic facts about the inharmonicity of piano strings can be expressed more exactly by a formula that is generally accepted to be some version of the following, where *I* is the underlying inharmonicity of the string, *n* is the partial number, and *I(n)* is the inharmonicity of partial *n*:

I(n) = I * n^2

In other words, the inharmonicity of a given partial of a string is equal to the underlying inharmonicity level of the string times the square of the partial number. This formula accounts not only for the sharpness of the partials, but also for their geometrically increasing sharpness as they ascend the harmonic series.

In earlier articles in this series I have called the inharmonicity which this formula describes primary inharmonicity to differentiate it from inharmonicity as it is perceived by the ear in an interval. Primary inharmonicity is an aspect of the tone of an individual string, and as such it is not readily evident to the ear but is quite evident when one measures the frequencies of the partials of the string with an oscilloscope, electronic tuning device, or other frequency counter. I have used the term secondary inharmonicity to describe the aural manifestation of primary inharmonicity when two or more strings are sounding simultaneously. This is the kind of inharmonicity we grapple with when we are tuning aurally; and, just as we can quantify the exact degree of primary inharmonicity in a string with the inharmonicity formula, so too can we quantify the amount of secondary inharmonicity in an interval with a formula that I will derive later in this article.

Assuming that the formula for primary inharmonicity accurately represents the condition of an actual piano string, we can use it to calculate the frequencies of the partials of the thirteen strings of the temperament octave F3-F4, and so make a more accurate model of the imaginary piano which we used in previous articles to explore the effect of inharmonicity on temperament beat rates.

First, taking the inharmonicity of a partial to be directly proportional to its deviation in cents, we can use the inharmonicity formula to calculate the cents deviation *Y* of each of the first six partials of each string in our temperament octave. The formula becomes:

Y(n) = I * n^2

We need only calculate cents deviation for the first six partials because these are the only partials present in the six intervals smaller than the octave which are commonly used in temperament tuning: the 3:2 and 6:4 fifths, the 4:3 fourth, the 5:3 major sixth, the 5:4 major third, and the 6:5 minor third. Table 1 (see tables for entire article beginning on page 31) shows the cents deviations of the first six partials of a string for some representative values of *I* that are used in later tables—0, 0.1, 0.2, 0.4, and 0.8.

Next, we can convert these cents deviations to factors that, multiplied together with the underlying frequency of a string, give the frequency in Hz of each partial of that string. Where *Q(n)* is the multiplication factor for a given partial, that factor for partial *n* can be calculated using the following formula:

Q(n) = n * [2^(1/1200)]^Y(n)

This formula equates the multiplication factor for a given partial to its partial number times a sharpening factor which increases the partial's frequency by its cents deviation. 2^(1/1200), or the twelve-hundredth root of two, is equal to one cent; in the formula this one cent is multiplied by itself once for each cent of deviation.

Next, we can use these factors to determine the actual frequencies of the six partials of the thirteen strings of the temperament. Where *F* is the underlying frequency in Hz of a string, and *F(n)* is the frequency of partial n,

F(n) = F * Q(n)

If we begin with an underlying frequency for F4 of its theoretical value of 349.2282 Hz, we can determine the underlying frequency of F3 by dividing the value for F4 by an octave factor.

This octave factor should, in theory, be exactly 2, but we will keep it variable to enable us later on to expand and contract the width of our temperament octave. The underlying frequencies of the intervening semitones of the temperament can then be determined by multiplying each successive semitone above F3 by the twelfth root of the octave multiplier. When the octave multiplier is two, this factor will be the familiar twelfth root of two. The frequencies of the partials of each string can then be calculated by multiplying these 13 resultant underlying frequencies by their various factors, *Q*.

Finally, we can convert these frequencies and levels of primary inharmonicity to beat rates and levels of secondary inharmonicity and display them in a spreadsheet format. Table 2 is a spreadsheet that models the temperament section of a piano whose inharmonicity is zero and whose octave multiplier is exactly two.

The first column in Table 2, headed "Note," gives the note names of each of the thirteen strings of the temperament. The second column shows the primary inharmonicity, or "Ip", of each string—in this case, zero. The next column, headed "m3 BR", displays the beat rates in beats per second for all ten minor thirds in the temperament. The beat rate of each interval is given in the same row as the lower note of the interval. These beat rates were determined by calculating the differences in frequency between the coincident partials of the component notes of the interval. A positive beat rate indicates that the interval is wide; a negative rate, that the interval is narrow.

The next column, headed "m3 Is," shows the secondary inharmonicity for each minor third. As I mentioned earlier, the formula used for calculating secondary inharmonicity will be derived later in this article. In this table, it is zero for all the intervals.

The next column shows the major third (M3) beat rates. The following column, headed with a ratio symbol (:), shows the benchmark ratio of the five pairs of contiguous major thirds in the temperament octave. The ratio of the beat rates of a pair of contiguous major thirds is given in the same row as the note which is common to both intervals. In this table the ratio for all the major thirds is about 0.8, or 4:5; this is the ratio that is often used as a rule of thumb for tuning contiguous thirds in equal temperament.

Following that column is a column with the secondary inharmonicity levels (Is) of the major thirds. The remainder of the columns show beat rates (BR) and secondary inharmonicity levels (Is) for the perfect fourth (P4), the perfect fifths (P5), both 3:2 and 6:4, the major sixth (M6), and the 2:1, 4:2, and 6:3 octaves (P8).

Since the inharmonicity of this temperament is zero, the beat rates in Table 2 are the same theoretical values which are familiar to us from the beat rate tables found in most tuning texts.

Now let's alter our spreadsheet to explore the effect of rising levels of secondary inharmonicity on intervals when the underlying frequencies of their component notes remains constant. We did this in a qualitative way in the second article in this series. We can now do it more precisely by setting the primary inharmonicity of all the strings in our imaginary piano to 0.1 while we hold the pitches of the underlying fundamentals constant, as in Table 3A.

Note that with the addition of primary inharmonicity all the intervals appear to have narrowed: the wide intervals now beat more slowly, and the narrow ones more quickly, than when the primary inharmonicity was zero. The octave, which began pure at all its levels, is now narrow at all its levels, increasingly so at higher levels of coincident partials. The fifth, also, has narrowed more at the 6:4 level than at the 3:2 level. The secondary inharmonicity of all the intervals has increased, to a greater degree in the wider intervals that in the narrow ones, but it is constant for each size of interval. The ratio of the beat rates of the contiguous major thirds has remained virtually unchanged at about 4:5.

Table 3A confirms the conclusion we drew in Article 2 — that increasing the level of secondary inharmonicity in an interval, assuming that the fundamental pitches of its component notes remains constant, makes the interval appear to narrow. It also shows how the 3:2 fifth can be noisier than the 4:3 fourth if both beat at the same rate. Notice that the beat rate of the fifths have increased more at the 6:4 level than at the 3:2 level. This narrowing is increasingly pronounced at the higher levels of coincident partials in the fifth—9:6, 12:8, and so on—meaning that the fifth is noisier as a result of its increased secondary inharmonicity. No coincident partials of the fourth above the 4:3 level appear in the table because the fourth's next level, the 8:6, involves the eighth partial, which is outside the range of our present calculations. However, these upper levels of the fourth, which is a wide interval, would be narrowed, just as they are in the octave and fifth; but, since the fourth is a wide interval, they would, therefore, beat more slowly than if the secondary inharmonicity were zero. These upper levels of coincident partials in the fourth would become pure or narrow if the level of secondary inharmonicity climbed high enough, and eventually the 4:3 fourth itself would become narrow. In the case of the fourth, then, the addition of secondary inharmonicity to the interval makes it less noisy.

Table 3B shows the effect of setting the primary inharmonicity of all the strings to a higher level of 0.4. The trends are the same as in Table 3A, but all the effects are exaggerated.

Now let's expand our temperament octave to compensate for the narrowing effect of secondary inharmonicity, just as we did in Article 3. Table 4A shows the same inharmonicity condition as in Table 3B with the octave widened just enough to make the 2:1 octave pure. As the octave widens further, in Tables 4B through 4I, each kind of temperament interval returns to the beat rate it had when the inharmonicity was zero: first the 3:2 fifth; then the 4:2 octave; then the 4:3 fourth, the 5:3 major sixth, the 5:4 major third, the 6:3 octave, the 6:4

fifth, and finally the 6:5 minor third. Notice how the 3:2 fifth becomes pure and then wide as the octave expands. Notice also that widening the octave does not affect either the levels of secondary inharmonicity or the ratios of the beat rates of the contiguous major thirds.

Compare Tables 4C and 4G, which show beat rates when the 4:2 and 6:3 octaves, respectively, are pure. If you look at the beat rates of the intervals whose lower note is F3—in other words, all the beat rates in the last row—you will see that the beat rates of the 3:2 fifth, fourth, major third, and minor third have all changed by about the same amount, approximately one beat per second. At the same time, the 6:4 fifth and major sixth beat rates have both changed by about twice that amount. This reinforces our speculation in Article 3 about the relative rates of change of the various kinds of interval as the octave changes size.

In Article 4 we considered the case of a temperament octave in which primary inharmonicity changes along the scale. We observed that large grands, although their strings have primary inharmonicity, usually appear to have little or no secondary inharmonicity in octaves in the temperament area. We deduced that the levels of primary inharmonicity of the component strings of the octave in such a piano must combine in some way to eliminate secondary inharmonicity from the interval. We can mimic this effect on our spreadsheet piano. We'll begin by calculating the ratio of primary inharmonicities between the notes of the octave necessary to eliminate secondary inharmonicity from that interval.

In an octave, partials of the top note always coincide with partials of the bottom note that are twice as high in the harmonic series. Partial 1 of the upper note coincides with partial 2 of the lower note, partial 2 of the upper coincides with partial 4 of the lower, and so forth. If *I(1)* is the underlying primary inharmonicity level of the lower note of an octave and *I(u)* is the underlying primary inharmonicity level of the upper note, then the fact that the inharmonicity of these two sets of partials must match for the octave to be tuned pure at all its levels can be expressed as:

I(u) * (n^2) = I(l) * ((2n)^2)

Which reduces to:

I(u) * (n^2) = I(l) * 4 * (n^2)

I(u) = I(l) * 4; or, I(u) / 4 = I(l)

In other words, the inharmonicity of all coincident partials in the octave will match when the primary inharmonicity of the lower note is one fourth that of the upper note. Then the secondary inharmonicity of the octave will be zero—in other words, it will be capable of being tuned pure at all its levels simultaneously.

In the fifth, partials of the upper note always coincide with partials of the lower note which are one and a half times as high in the harmonic series. Partial 2 of the upper note coincides with partial 3 of the lower note, partial 4 of the upper coincides with partial 6 of the lower, and so forth. We can express this relationship as:

I(u) * (n^2) = I(l) * ((1.5n)^2)

I(u) * (n^2) = I(l) * 2.25 * (n^2)

I(u) = I(l) * 2.25; or, I(u) / 2.25 = I(l)

Similarly, for a fourth:

I(u) * (n^2) = I(l) * ((1.33...N)^2)

I(u) = I(l) * 1.77...; or, I(u) / 1.77... = I(l)

If we adjust the levels of primary inharmonicity in the component strings of a fourth and a fifth to eliminate secondary inharmonicity, and then stack the two intervals to make an octave, the progression of the primary inharmonicity in the two intervals will result in an octave whose secondary inharmonicity is also zero:

2.25 X 1.77... = 4

Let's scale our imaginary piano so that the top and bottom strings of the temperament octave F3-F4 have primary inharmonicities in the ratio 1:4 that eliminates secondary inharmonicity from the octave. In Table 5A, the primary inharmonicity of F3 is 0.1 and the primary inharmonicity of F4 is 0.4. We can make the primary inharmonicity of the intervening strings progress smoothly by increasing the primary inharmonicity of each successive note above the lower note by the twelfth root of the overall factor of four. Note that when we do so the secondary inharmonicity of all the intervals, including the octave, becomes zero, and the beat rates of the intervals become virtually the same as when the primary inharmonicity of all strings was zero, in Table 2.

Note that the primary inharmonicity of note C4 in Table 5A is 0.224. In other words, the primary inharmonicity of the upper note of the fifth F3-C4 is 2.24 times the primary inharmonicity of the lower. This is a slightly different factor than the factor of 2.25 that we derived earlier for the fifth . The discrepancy between these two factors results from the fact that we have tuned the fifth equally tempered rather than just. In equal temperament, the ratio of the fifth is not exactly 3:2, or 1.5, but rather the slightly smaller [2^(1/12)]^7, or 1.4983. The factor of 2.24 elimates all secondary inharmonicity from this smaller, equally tempered, interval. An even progression of primary inharmonicity from 0.1 to 0.4 by steps equal to the twelfth root of four likewise eliminates secondary inharmonicity from all the other equally tempered intervals.

This brings up an interesting point. If a piano is scaled for an even progression of primary inharmonicity to eliminate secondary inharmonicity from its octaves, all its other intervals will have no secondary inharmonicity only when the temperament is tuned in an equal temperament, not in a just, mean, well, or any other sort of temperament. These discrepancies in secondary inharmonicity are very slight, to be sure; still, it's interesting to note that a smoothly curving bridge, such as has always been a characteristic of stringed keyboard instruments and their predecessors, produces secondary inharmonicity curves with an inherent affinity for equal temperament.

We are now in a position to derive a formula for the secondary inharmonicity of an interval. Given the primary inharmonicity of the upper note of the interval, we first of all determine a level of primary inharmonicity for the lower note which would eliminate secondary inharmonicity from that interval. The wider the interval, the smaller this level of primary inharmonicity must be. Where W is the width of the interval in number of semitones, the level of primary inharmonicity in the lower note which will eliminate secondary inharmonicity from the interval can be expressed for any interval in terms of the primary inharmonicity of the upper note as:

I(u)/{[2^(1/12)]^W}^2

Subtracting this ideal level of primary inharmonicity from the actual value of the primary inharmonicity of the lower note gives us a convenient way to quantify the level of secondary inharmonicity (Is) in the interval:

Is = I(l) - (I(u)/{[2^(1/12)]^W}^2)

When *I(l)* is equal to the amount of inharmonicity which will eliminate secondary inharmonicity from the interval, *Is* will be zero. When *I(l)* is larger, *Is* will be positive. When *I(l)* is smaller, *Is* will be negative. When the interval is a unison—in other words, when *W* is zero, Is will be zero when *I(l)* is equal to *I(u)*.

All intervals of a given width with the same level of secondary inharmonicity will have the same relationship among the beat rates of all their coincident partials, and in that respect they will be indistinguishable. To demonstrate this, Table 6 shows two octaves, both with the same secondary inharmonicity of 0.1. The strings of the first octave have what might be considered normal levels of primary inharmonicity; the strings of the second octave have much higher levels of primary inharmonicity, to the extent that the fifth partial of the upper note is an entire semitone above its theoretical level! In spite of this, both octaves have the same beat rates at the 2:1, 4:2, and 6:3 levels.

In a smaller piano, the constraints of string length rarely allow enough spread between the primary inharmonicity levels of the outside notes of the temperament octave to eliminate secondary inharmonicity from the octave. Instead, the temperament octave usually exhibits some degree of positive secondary inharmonicity. Table 7B represents just such a temperament octave, in which the primary inharmonicity of F3 is 0.2 and the primary inharmonicity of the F4 is 0.4, resulting in a level of secondary inharmonicity for the octave of 0.1. The primary inharmonicities of the intervening semitones in this table have been calculated with a formula analogous to that which created constant levels of secondary inharmonicity in all intervals of like size in Table 5A: the primary inharmonicity of each successively higher semitone has been increased by the twelfth root of two, two being the factor of the overall level of change of primary inharmonicity in this octave. This function is sometimes used as a generic rule of thumb to approximate the relationship between note number and inharmonicity throughout the treble section of a typical piano. The relationship between the log inharmonicity factor and note number in such a function is a straight line, and the factor, in this case two, is the slope of that line.

Note that when the slope is two, as in this table, this function does not produce primary inharmonicity levels for the intervening semitones that result in constant levels of secondary inharmonicity in intervals of like width. Instead, the secondary inharmonicity levels decrease as the intervals progress downwards. In fact, using this function to derive values for the intervening semitones of a temperament octave only results in constant levels of secondary inharmonicity in that octave when the slope is 4, as in Table 5A, or 0, as in Tables 2A-4I.

A temperament octave with an identical overall range of inharmonicity as Table 7B is represented in Table 5B, but in this table the levels of primary inharmonicity of the intervening semitones do result in constant levels of secondary inharmonicity for all like-sized intervals. It would be interesting to know the nature of the underlying function which generates these primary inharmonicities, but unfortunately, that function, whatever it is, is beyond the reach of my math. Instead, I have calculated the primary inharmonicity levels in Table 5B by working backwards, using the secondary inharmonicity formula. Briefly, the spreadsheet first solves for the primary inharmonicity of B3 in terms of the primary inharmonicities of F3 and F4, which is possible because the formula for the secondary inharmonicity of the tritone F3-B3 can be equated to that for the secondary inharmonicity of the tritone B3-F4. Similarly, the spreadsheet solves for G#3 and D4 in terms of F3 and B3, and B3 and F4, respectively, by equating the formulas for the secondary inharmonicity of the minor thirds F3-G#3 and G#3-B3, and B3-D4 and D4-F4. The spreadsheet then equates the formulas for the secondary inharmonicity of the intervening semitones of these contiguous minor thirds and solves for the primary inharmonicities of the semitones in terms of the component notes of the minor thirds.

Table 5C presents the (unlikely) case of a negatively inharmonic temperament octave containing constant levels of negative secondary inharmonicity for all like-sized intervals. Notice that in this case the octave factor must be less than 2 to make the 6:3 octave pure; in other words, the octave must be increasingly narrowed to bring successively higher levels of coincident partials into tune. (See Article 4 for more discussion of the rare, but perfectly possible, phenomenon of negatively inharmonic octaves in the piano.)

In Article 4, we observed that the treble bridges of large pianos with low levels of secondary inharmonicity all tend to have the same approximate shape, curving away from the upper bridge in the temperament area. We speculated that constraints on string length in this area of the scale, which force the designers of small pianos to compromise this curve, contribute significantly to the high levels of secondary inharmonicity which we observe in the temperament area of all small pianos. The important contribution of string length to inharmonicity is evident in the following equation, which states that inharmonicity is proportional to the square of the diameter *(d)* and the inverse square of the frequency *(F)*, but the inverse fourth power of the length *(L)*. Where *k* is a constant for steel wire:

$$I = [(d^2) * k] / [(F^2) * (L^4)]$$

Observing that the curve of the treble bridge in the temperament area of many small pianos ranges between a straight line and an S-shape, in which the bridge curves back towards the upper bridge just before its termination, we speculated that the greater the reverse curve of the bridge, the higher would be the levels of primary, and consequently secondary, inharmonicity in the lower part of the temperament relative to their levels in a large piano. From the above equation, it is evident that relatively shorter string lengths, as well as lower tensions and larger wire sizes, both of which also characterize the low end of the temperament section in small pianos, would all tend to produce relatively higher levels of primary inharmonicity in the lower end of the temperament octave.

Let's assume that we have determined the string length, frequency, and wire diameter for notes F4 and F3 such that the primary inharmonicity levels for those two notes are 0.4 and 0.2, respectively. The overall secondary inharmonicity of the temperament octave will then be 0.1; but there are an infinite number of bridge curves that could connect these two points on the bridge, and each one would result in a different distribution of primary and secondary inharmonicity among the intervening semitones and intervals of the temperament.

The three simplest classes of this distribution of secondary inharmonicity within the octave would be, first, constant levels of secondary inharmonicity throughout the octave; second, steadily declining levels of secondary inharmonicity as intervals descend; and third, steadily increasing levels of secondary inharmonicity as intervals descend. We can use our spreadsheet to create examples of all three classes.

We have already seen an example of the first class, constant levels of secondary inharmonicity, in Table 5B.

Tables 7A and 7B have secondary inharmonicity levels representative of the second class. In Table 7A, the levels of primary inharmonicity for the intervening semitones were derived from a straight-line arithmetic function. The function for the intervening semitones in Table 7B was described above.

Note that in both tables secondary inharmonicity diminishes as intervals descend the scale. Narrow intervals progress more rapidly, and wide ones more slowly, than if the levels of secondary inharmonicity were constant. Note in particular the ratio of the contiguous major thirds—in these two tables it is greater than the theoretical value of 0.8.

Tables 7C and 7D represent the third class, in which secondary inharmonicity levels increase as the intervals progress downwards. Table 7C shows the result of an extremely exponential increase of primary inharmonicity levels throughout the temperament. In Table 7D primary inharmonicity is derived from a parabolic function with its lowest value at A3, below which note primary inharmonicity begins to increase again. In both of these last two tables, narrow intervals progress more slowly, and wide ones more quickly, than when secondary inharmonicity is constant. Again, note the benchmark ratios of the contiguous major thirds, which, in Table 7D, are closer to 2:3 than 4:5.

These tables support our speculation in Article 4 that the greater the reverse curve of the bridge in the lower end of the temperament area, the higher the levels of secondary inharmonicity will be in that area. But which, if any, of these tables best represents the secondary inharmonicity condition produced by the bridge curve of any particular small piano? We'll explore that question next month.

TABLE 1

Cents deviation (Y) of first six partials for various I Formula:
Y(n) = I * n^2

I	Partial number (n) 1	2	3	4	5	6
0	0	0	0	0	0	0
0.1	0.1	0.4	0.9	1.6	2.5	3.6
0.2	0.2	0.8	1.8	3.2	5	7.2
0.4	0.4	1.6	3.6	6.4	10	14.4
0.8	0.8	3.2	7.2	12.8	20	28.8

TABLE 2

Primary Inharmonicity: 0
Octave Size: Pure at all levels
Octave factor: 2

Note	Ip																
F4	0	m3	m3														
E4	0	BR	Is	M3	M3	M3											
D#4	0			BR	:	Is	P4	P4									
D4	0	-15.8	0				BR	Is	P5	P5	P5						
C#4	0	-15	0	11	0.79	0			BR	BR	Is						
C4	0	-14.1	0	10.4	0.79	0	1.2	0	3:2	6:4							
B3	0	-13.3	0	9.8	0.8	0	1.1	0				M6	M6				
A#3	0	-12.6	0	9.2	0.79	0	1.1	0	-0.8	-1.6	0	BR	Is				
A3	0	-11.9	0	8.7	0.79	0	1	0	-0.7	-1.5	0			P8	P8	P8	P8
G#3	0	-11.2	0	8.2		0	0.9	0	-0.7	-1.4	0	9.4	0	BR	BR	BR	Is
G3	0	-10.6	0	7.8		0	0.9	0	-0.7	-1.3	0	8.9	0	2:1	4:2	6:3	
F#3	0	-10	0	7.3		0	0.8	0	-0.6	-1.3	0	8.4	0				
F3	0	-9.4	0	6.9		0	0.8	0	-0.6	-1.2	0	7.9	0	0	0	0	0

TABLE 3A

Primary Inharmonicity: Constant 0.1
Octave Size: Same as Table 2
Octave Factor: 2

Note	Ip																
F4	0.1	m3	m3														
E4	0.1	BR	Is	M3	M3	M3											
D#4	0.1			BR	:	Is	P4	P4									
D4	0.1	-17	0.029				BR	Is	P5	P5	P5						
C#4	0.1	-16	0.029	10.3	0.8	0.037			BR	BR	Is						
C4	0.1	-15.1	0.029	9.7	0.79	0.037	0.8	0.044	3:2	6:4							
B3	0.1	-14.3	0.029	9.2	0.79	0.037	0.7	0.044				M6	M6				
A#3	0.1	-13.5	0.029	8.7	0.79	0.037	0.7	0.044	-1	-3.2	0.056	BR	Is				
A3	0.1	-12.7	0.029	8.2	0.79	0.037	0.6	0.044	-0.9	-3	0.056			P8	P8	P8	P8
G#3	0.1	-12	0.029	7.7		0.037	0.6	0.044	-0.9	-2.8	0.056	8.5	0.065	BR	BR	BR	Is
G3	0.1	-11.3	0.029	7.3		0.037	0.6	0.044	-0.8	-2.7	0.056	8	0.065	2:1	4:2	6:3	
F#3	0.1	-10.7	0.029	6.9		0.037	0.5	0.044	-0.8	-2.5	0.056	7.5	0.065				
F3	0.1	-10.1	0.029	6.5		0.037	0.5	0.044	-0.7	-2.4	0.056	7.1	0.065	-0.1	-0.5	-1.6	0.075

TABLE 3B

Primary Inharmonicity: Constant 0.4
Octave Size: Same as Table 2
Octave Factor: 2

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-20.4	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-19.3	0.117	8.1	0.8	0.148			BR	BR	Is						
C4	0.4	-18.2	0.117	7.7	0.079	0.148	-0.5	0.176	3:2	6:4							
B3	0.4	-17.2	0.117	7.3	0.079	0.148	-0.5	0.176				M6	M6				
A#3	0.4	-16.2	0.117	6.8	0.79	0.148	-0.5	0.176	-1.6	-8.1	0.222	BR	Is				
A3	0.4	-15.3	0.117	6.5	0.78	0.148	-0.4	0.176	-1.5	-7.6	0.222			P8	P8	P8	P8
G#3	0.4	-14.5	0.117	6.1		0.148	-0.4	0.176	-1.4	-7.2	0.222	5.6	0.259	BR	BR	BR	Is
G3	0.4	-13.6	0.117	5.8		0.148	-0.4	0.176	-1.3	-6.8	0.222	5.3	0.259	2:1	4:2	6:3	
F#3	0.4	-12.9	0.117	5.4		0.148	-0.4	0.176	-1.3	-6.4	0.222	5	0.259				
F3	0.4	-12.2	0.117	5.1		0.148	-0.3	0.176	-1.2	-6.1	0.222	4.7	0.259	-0.2	-1.9	-6.6	0.3

TABLE 4A

Primary Inharmonicity: Constant 0.4
Octave Size: Pure 2:1
Octave Factor: 2.002

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-20.1	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-19	0.117	8.5	0.79	0.148			BR	BR	Is						
C4	0.4	-17.9	0.117	8	0.8	0.148	-0.2	0.176	3:2	6:4							
B3	0.4	-16.9	0.117	7.6	0.79	0.148	-0.2	0.176				M6	M6				
A#3	0.4	-16	0.117	7.1	0.8	0.148	-0.2	0.176	-1.3	-7.5	0.222	BR	Is				
A3	0.4	-15.1	0.117	6.7	0.79	0.148	-0.2	0.176	-1.2	-7	0.222			P8	P8	P8	P8
G#3	0.4	-14.2	0.117	6.4		0.148	-0.1	0.176	-1.2	-6.7	0.222	6.2	0.259	BR	BR	BR	Is
G3	0.4	-13.4	0.117	6		0.148	-0.1	0.176	-1.1	-6.3	0.222	5.8	0.259	2:1	4:2	6:3	
F#3	0.4	-12.7	0.117	5.7		0.148	-0.1	0.176	-1	-5.9	0.222	5.5	0.259				
F3	0.4	-12	0.117	5.3		0.148	-0.1	0.176	-1	-5.6	0.222	5.2	0.259	0	-1.4	-5.8	0.3

TABLE 4B

Primary Inharmonicity: Constant 0.4
Octave Size: P5, 3:2, at Theoretical Rate
Octave Factor: 2.004

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-19.6	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-18.5	0.117	9.1	0.79	0.148			BR	BR	Is						
C4	0.4	-17.4	0.117	8.6	0.79	0.148	0.4	0.176	3:2	6:4							
B3	0.4	-16.4	0.117	8.1	0.79	0.148	0.3	0.176				M6	M6				
A#3	0.4	-15.5	0.117	7.6	0.79	0.148	0.3	0.176	-0.8	-6.4	0.222	BR	Is				
A3	0.4	-14.6	0.117	7.2	0.79	0.148	0.3	0.176	-0.7	-6.1	0.222			P8	P8	P8	P8
G#3	0.4	-13.8	0.117	6.8		0.148	0.3	0.176	-0.7	-5.7	0.222	7.2	0.259	BR	BR	BR	Is
G3	0.4	-13	0.117	6.4		0.148	0.3	0.176	-0.7	-5.4	0.222	6.8	0.259	2:1	4:2	6:3	
F#3	0.4	-12.3	0.117	6		0.148	0.3	0.176	-0.6	-5.1	0.222	6.4	0.259				
F3	0.4 -	11.6	0.117	5.7		0.148	0.2	0.176	-0.6	-4.8	0.222	6	0.259	0.5	-0.5	-4.5	0.3

TABLE 4C

Primary Inharmonicity: Constant 0.4
Octave Size: Pure 4:2
Octave Factor: 2.0055

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-19.2	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-18.1	0.117	9.4	0.8	0.148			BR	BR	Is						
C4	0.4	-17.1	0.117	8.9	0.79	0.148	0.7	0.176	3:2	6:4							
B3	0.4	-16.2	0.117	8.4	0.8	0.148	0.6	0.176				M6	M6				
A#3	0.4	-15.2	0.117	7.9	0.8	0.148	0.6	0.176	-0.5	-5.8	0.222	BR	Is				
A3	0.4	-14.4	0.117	7.5	0.79	0.148	0.6	0.176	-0.5	-5.5	0.222			P8	P8	P8	P8
G#3	0.4	-13.6	0.117	7		0.148	0.5	0.176	-0.4	-5.2	0.222	7.7	0.259	BR	BR	BR	Is
G3	0.4	-12.8	0.117	6.7		0.148	0.5	0.176	-0.4	-4.9	0.222	7.3	0.259	2:1	4:2	6:3	
F#3	0.4	-12.1	0.117	6.3		0.148	0.5	0.176	-0.4	-4.6	0.222	6.9	0.259				
F3	0.4	-11.4	0.117	5.9		0.148	0.5	0.176	-0.4	-4.4	0.222	6.5	0.259	0.7	0	-3.7	0.3

TABLE 4D

Primary Inharmonicity: Constant 0.4
Octave Size: P4 at Theoretical Rate
Octave Factor: 2.0078

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-18.7	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-17.7	0.117	10	0.79	0.148			BR	BR	Is						
C4	0.4	-16.7	0.117	9.4	0.79	0.148	1.2	0.176	3:2	6:4							
B3	0.4	-15.7	0.117	8.9	0.79	0.148	1.1	0.176				M6	M6				
A#3	0.4	-14.8	0.117	8.4	0.79	0.148	1.1	0.176	0	-4.9	0.222	BR	Is				
A3	0.4	-14	0.117	7.9	0.8	0.148	1	0.176	0	-4.6	0.222			P8	P8	P8	P8
G#3	0.4	-13.2	0.117	7.4		0.148	0.9	0.176	0	-4.4	0.222	8.6	0.259	BR	BR	BR	Is
G3	0.4	-12.5	0.117	7		0.148	0.9	0.176	0	-4.1	0.222	8.1	0.259	2:1	4:2	6:3	
F#3	0.4	-11.8	0.117	6.6		0.148	0.8	0.176	0	-3.9	0.222	7.7	0.259				
F3	0.4	-11.1	0.117	6.3		0.148	0.8	0.176	0	-3.7	0.222	7.3	0.259	1.1	0.8	-2.5	0.3

TABLE 4E

Primary Inharmonicity: Constant 0.4
Octave Size: M6 at R=Theoretical Rate
Octave Factor: 2.00975

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-18.3	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-17.3	0.117	10.4	0.79	0.148			BR	BR	Is						
C4	0.4	-16.3	0.117	9.8	0.8	0.148	1.6	0.176	3:2	6:4							
B3	0.4	-15.4	0.117	9.3	0.78	0.148	1.5	0.176				M6	M6				
A#3	0.4	-14.5	0.117	8.7	0.79	0.148	1.4	0.176	0.4	-4.1	0.222	BR	Is				
A3	0.4	-13.7	0.117	8.2	0.79	0.148	1.4	0.176	0.4	-3.9	0.222			P8	P8	P8	P8
G#3	0.4	-12.9	0.117	7.8		0.148	1.3	0.176	0.3	-3.6	0.222	9.4	0.259	BR	BR	BR	Is
G3	0.4	-12.2	0.117	7.3		0.148	1.2	0.176	0.3	-3.4	0.222	8.9	0.259	2:1	4:2	6:3	
F#3	0.4	-11.5	0.117	6.9		0.148	1.1	0.176	0.3	-3.2	0.222	8.4	0.259				
F3	0.4	-10.8	0.117	6.5		0.148	1.1	0.176	0.3	-3.1	0.222	7.9	0.259	1.5	1.5	-1.4	0.3

TABLE 4F

Primary Inharmonicity: Constant 0.4
Octave Size: M3 at Theoretical Rate
Octave Factor: 2.0124

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-17.7	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-16.7	0.117	11	0.79	0.148			BR	BR	Is						
C4	0.4	-15.8	0.117	10.4	0.79	0.148	2.2	0.176	3:2	6:4							
B3	0.4	-14.9	0.117	9.8	0.8	0.148	2.1	0.176				M6	M6				
A#3	0.4	-14	0.117	9.2	0.79	0.148	1.9	0.176	0.9	-3	0.222	BR	Is				
A3	0.4	-13.2	0.117	8.7	0.79	0.148	1.8	0.176	0.9	-2.8	0.222			P8	P8	P8	P8
G#3	0.4	-12.5	0.117	8.2		0.148	1.7	0.176	0.8	-2.7	0.222	10.4	0.259	BR	BR	BR	Is
G3	0.4	-11.8	0.117	7.8		0.148	1.6	0.176	0.8	-2.5	0.222	9.8	0.259	2:1	4:2	6:3	
F#3	0.4	-11.1	0.117	7.3		0.148	1.5	0.176	0.7	-2.4	0.222	9.3	0.259				
F3	0.4	-10.5	0.117	6.9		0.148	1.5	0.176	0.7	-2.2	0.222	8.7	0.259	1.9	2.4	-0.1	0.3

TABLE 4G

Primary Inharmonicity: Constant 0.4
Octave Size: Pure 6:3
Octave Factor: 2.0125

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-17.7	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-16.7	0.117	11	0.79	0.148			BR	BR	Is						
C4	0.4	-15.7	0.117	10.4	0.79	0.148	2.2	0.176	3:2	6:4							
B3	0.4	-14.8	0.117	9.8	0.8	0.148	2.1	0.176				M6	M6				
A#3	0.4	-14	0.117	9.3	0.78	0.148	2	0.176	0.9	-3	0.222	BR	Is				
A3	0.4	-13.2	0.117	8.7	0.79	0.148	1.9	0.176	0.9	-2.8	0.222			P8	P8	P8	P8
G#3	0.4	-12.5	0.117	8.2		0.148	1.8	0.176	0.8	-2.6	0.222	10.5	0.259	BR	BR	BR	Is
G3	0.4	-11.8	0.117	7.8		0.148	1.7	0.176	0.8	-2.5	0.222	9.9	0.259	2:1	4:2	6:3	
F#3	0.4	-11.1	0.117	7.3		0.148	1.6	0.176	0.7	-2.4	0.222	9.3	0.259				
F3	0.4	-10.5	0.117	6.9		0.148	1.5	0.176	0.7	-2.2	0.222	8.8	0.259	1.9	2.4	0	0.3

TABLE 4H

Primary Inharmonicity: Constant 0.4
Octave Size: P5, 6:4, at Theoretical Rate
Octave Factor: 2.0159

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-16.9	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-16	0.117	11.8	0.8	0.148			BR	BR	Is						
C4	0.4	-15.1	0.117	11.1	0.79	0.148	2.9	0.176	3:2	6:4							
B3	0.4	-14.2	0.117	10.5	0.79	0.148	2.8	0.176				M6	M6				
A#3	0.4	-13.4	0.117	9.9	0.8	0.148	2.6	0.176	1.6	-1.6	0.222	BR	Is				
A3	0.4	-12.6	0.117	9.4	0.79	0.148	2.5	0.176	1.5	-1.5	0.222			P8	P8	P8	P8
G#3	0.4	-11.9	0.117	8.8		0.148	2.3	0.176	1.5	-1.4	0.222	11.8	0.259	BR	BR	BR	Is
G3	0.4	-11.3	0.117	8.3		0.148	2.2	0.176	1.4	-1.3	0.222	11.1	0.259	2:1	4:2	6:3	
F#3	0.4	-10.6	0.117	7.9		0.148	2.1	0.176	1.3	-1.3	0.222	10.5	0.259				
F3	0.4	-10	0.117	7.4		0.148	2	0.176	1.2	-1.2	0.222	9.9	0.259	2.5	3.6	1.8	0.3

TABLE 4I

Primary Inharmonicity: Constant 0.4
Octave Size: m3 at Theoretical Rate
Octave Factor: 2.0206

Note	Ip																
F4	0.4	m3	m3														
E4	0.4	BR	Is	M3	M3	M3											
D#4	0.4			BR	:	Is	P4	P4									
D4	0.4	-15.9	0.117				BR	Is	P5	P5	P5						
C#4	0.4	-15	0.117	12.9	0.79	0.148			BR	BR	Is						
C4	0.4	-14.1	0.117	12.2	0.79	0.148	4	0.176	3:2	6:4							
B3	0.4	-13.3	0.117	11.5	0.79	0.148	3.7	0.176				M6	M6				
A#3	0.4	-12.6	0.117	10.8	0.8	0.148	3.5	0.176	2.6	0.3	0.222	BR	Is				
A3	0.4	-11.9	0.117	10.2	0.79	0.148	3.3	0.176	2.4	0.3	0.222			P8	P8	P8	P8
G#3	0.4	-11.2	0.117	9.6		0.148	3.1	0.176	2.3	0.3	0.222	13.6	0.259	BR	BR	BR	Is
G3	0.4	-10.6	0.117	9.1		0.148	3	0.176	2.2	0.3	0.222	12.8	0.259	2:1	4:2	6:3	
F#3	0.4	-10	0.117	8.6		0.148	2.8	0.176	2	0.3	0.222	12.1	0.259				
F3	0.4	-9.4	0.117	8.1		0.148	2.6	0.176	1.9	0.2	0.222	11.4	0.259	3.3	5.2	4.2	0.3

TABLE 5A

Primary Inharmonicity: F4=0.4 to F3=0.1 as 4^ (1/12)
Octave Size: Pure at All Levels
Octave Factor: 2

Note	Ip																
F4	0.4	m3	m3														
E4	0.356	BR	Is	M3	M3	M3											
D#4	0.317			BR	:	Is	P4	P4									
D4	0.283	-16.1	0				BR	Is	P5	P5	P5						
C#4	0.252	-15.2	0	11.1	0.79	0			BR	BR	Is						
C4	0.224	-14.3	0	10.5	0.79	0	1.2	0	3:2	6:4							
B3	0.2	-13.5	0	9.9	0.79	0	1.1	0				M6	M6				
A#3	0.178	-12.7	0	9.3	0.8	0	1.1	0	-0.8	-1.6	0	BR	Is				
A3	0.159	-12	0	8.8	0.8	0	1	0	-0.7	-1.5	0			P8	P8	P8	P8
G#3	0.141	-11.3	0	8.3		0	0.9	0	-0.7	-1.4	0	9.5	0	BR	BR	BR	Is
G3	0.126	-10.7	0	7.8		0	0.9	0	-0.7	-1.3	0	8.9	0	2:1	4:2	6:3	
F#3	0.112	-10.1	0	7.4		0	0.8	0	-0.6	-1.3	0	8.4	0				
F3	0.1	-9.5	0	7		0	0.8	0	-0.6	-1.2	0	8	0	0	0	0	0

TABLE 5B

Primary Inharmonicity: F4=0.4 to F3=0.2; Is Constant
Octave Size: Pure 6:3
Octave Factor: 2.0042

Note	Ip																
F4	0.4	m3	m3														
E4	0.371	BR	Is	M3	M3	M3											
D#4	0.345			BR	:	Is	P4	P4									
D4	0.322	-16.6	0.039				BR	Is	P5	P5	P5						
C#4	0.301	-15.7	0.039	11.1	0.79	0.049			BR	BR	Is						
C4	0.283	-14.8	0.039	10.5	0.79	0.049	1.5	0.059	3:2	6:4							
B3	0.267	-13.9	0.039	9.9	0.79	0.049	1.5	0.059				M6	M6				
A#3	0.252	-13.1	0.039	9.3	0.8	0.049	1.4	0.059	-0.2	-2	0.074	BR	Is				
A3	0.239	-12.4	0.039	8.8	0.8	0.049	1.3	0.059	-0.2	-1.9	0.074			P8	P8	P8	P8
G#3	0.228	-11.7	0.039	8.3		0.049	1.2	0.059	-0.2	-1.8	0.074	9.8	0.086	BR	BR	BR	Is
G3	0.217	-11	0.039	7.8		0.049	1.2	0.059	-0.2	-1.7	0.074	9.3	0.086	2:1	4:2	6:3	
F#3	0.208	-10.4	0.039	7.4		0.049	1.1	0.059	-0.2	-1.6	0.074	8.7	0.086				
F3	0.2	-9.8	0.039	7		0.049	1	0.059	-0.2	-1.5	0.074	8.2	0.086	0.7	0.8	0	0.1

TABLE 5C

Primary Inharmonicity: F4=0.8 to F3=0.1; Is Constant
Octave Size: Pure 6:3
Octave Factor: 1.9958

Note	Ip	m3 BR	m3 Is	M3 BR	M3 :	M3 Is	P4 BR	P4 Is	P5 BR 3:2	P5 BR 6:4	P5 Is	M6 BR	M6 Is	P8 BR 2:1	P8 BR 4:2	P8 BR 6:3	P8 Is
F4	0.8																
E4	0.698																
D#4	0.607																
D4	0.527	-15.9	-0.04														
C#4	0.455	-14.9	-0.04	11.3	0.79	- 0.05											
C4	0.39	-14	-0.04	10.6	0.78	-0.05	0.8	-0.06									
B3	0.333	-13.2	-0.04	10	0.79	-0.05	0.8	-0.06									
A#3	0.282	-12.4	-0.04	9.4	0.79	-0.05	0.8	-0.06	-1.4	-1.2	-0.07						
A3	0.237	-11.7	-0.04	8.9	0.79	-0.05	0.7	-0.06	-1.3	-1.1	-0.07						
G#3	0.197	-11	-0.04	8.3		-0.05	0.7	-0.06	-1.2	-1	-0.07	9.2	-0.09				
G3	0.161	-10.4	-0.04	7.9		-0.05	0.6	-0.06	-1.2	-1	-0.07	8.7	-0.09				
F#3	0.129	-9.8	-0.04	7.4		-0.05	0.6	-0.06	-1.1	-0.9	-0.07	8.2	-0.09				
F3	0.1	-9.2	-0.04	7		-0.05	0.6	-0.06	-1	-0.9	-0.07	7.7	-0.09	-0.7	-0.8	0	-0.1

TABLE 6

Comparison of two octaves (A & B) with same secondary inharmonicity of 0.1
Octave Size: Pure 6:3
Octave Multiplier: 2.004

Note	Ip	Cents 1(v)	deviation for each partial 1(a)	2	3	4	5	6	BR 2:1	BR 4:2	BR 6:3	Is
Octave A												
F4	0.4	0	0.4	1.6	3.6	6.4	10	14.4				
F3	0.2	0	0.2	0.8	1.8	3.2	5	7.2	0.7	0.8	0	0.1
Octave B												
F4	4	0	4	16	36	64	100	144				
F3	1.1	0	1.1	4.4	9.9	17.6	27.5	39.6	0.7	0.8	0	0.1

TABLE 7A

Primary Inharmonicity: F4=0.4 to F3=0.2; Straight Line
Octave Size: Pure 6:3
Octave Factor: 2.0042

Note	Ip	m3 BR	m3 Is	M3 BR	M3 :	M3 Is	P4 BR	P4 Is	P5 BR 3:2	P5 BR 6:4	P5 Is	M6 BR	M6 Is	P8 BR 2.1	P8 BR 4:2	P8 BR 6:3	P8 Is
F4	0.4																
E4	0.383																
D#4	0.367																
D4	0.35	-17.7	0.067														
C#4	0.333	-16.5	0.062	10.5	0.83	0.081											
C4	0.317	-15.4	0.057	10	0.83	0.075	1.2	0.092									
B3	0.3	-14.4	0.053	9.5	0.83	0.069	1.2	0.085									
A#3	0.283	-13.4	0.048	9.1	0.82	0.063	1.2	0.078	-0.3	-2.9	0.105						
A3	0.267	-12.5	0.043	8.7	0.83	0.057	1.2	0.07	-0.3	-2.5	0.096						
G#3	0.25	-11.7	0.038	8.3		0.051	1.2	0.063	-0.2	-2.1	0.087	9.5	0.109				
G3	0.233	-10.9	0.033	7.9		0.044	1.2	0.056	-0.2	-1.8	0.077	9.1	0.098				
F#3	0.217	-10.2	0.028	7.5		0.038	1.2	0.048	-0.1	-1.5	0.068	8.7	0.087				
F3	0.2	-9.5	0.023	7.2		0.032	1.1	0.041	-0.1	-1.2	0.059	8.4	0.076	0.7	0.8	0	0.1

TABLE 7B

Primary Inharmonicity: F4=0.4 to F3=0.2 as 2^ (1/12)
Octave Size: Pure 6:3
Octave Factor: 2.0042

Note	Ip																
F4	0.4	m3	m3														
E4	0.378	BR	Is	M3	M3	M3											
D#4	0.356			BR	:	Is	P4	P4									
D4	0.336	-17.2	0.054				BR	Is	P5	P5	P5						
C#4	0.317	-16.1	0.051	10.8	0.81	0.066			BR	BR	Is						
C4	0.3	-15.1	0.048	10.2	0.81	0.062	1.4	0.075	3:2	6:4							
B3	0.283	-14.1	0.045	9.7	0.81	0.058	1.3	0.071				M6	M6				
A#3	0.267	-13.2	0.043	9.2	0.8	0.055	1.3	0.067	-0.3	-2.5	0.089	BR	Is				
A3	0.252	-12.4	0.04	8.7	0.82	0.052	1.3	0.063	-0.2	-2.2	0.084			P8	P8	P8	P8
G#3	0.238	-11.7	0.038	8.3		0.049	1.2	0.06	-0.2	-1.9	0.079	9.7	0.096	BR	BR	BR	Is
G3	0.224	-10.9	0.036	7.9		0.046	1.2	0.056	-0.2	-1.7	0.075	9.2	0.091	2:1	4:2	6:3	
F#3	0.212	-10.3	0.034	7.4		0.044	1.1	0.053	-0.2	-1.5	0.071	8.7	0.086				
F3	0.2	-9.7	0.032	7.1		0.041	1.1	0.05	-0.1	-1.4	0.067	8.3	0.081	0.7	0.8	0	0.1

TABLE 7C

Primary Inharmonicity: F4=0.4 to F3=0.2; Exponential
Octave Size: Pure 6:3
Octave Factor: 2.0042

Note	Ip																
F4	0.4	m3	m3														
E4	0.36	BR	Is	M3	M3	M3											
D#4	0.326			BR	:	Is	P4	P4									
D4	0.299	-15.8	0.015				BR	Is	P5	P5	P5						
C#4	0.276	-15	0.021	11.6	0.76	0.023			BR	BR	Is						
C4	0.257	-14.3	0.026	10.8	0.77	0.03	1.8	0.032	3:2	6:4							
B3	0.241	-13.6	0.03	10.1	0.76	0.036	1.6	0.039				M6	M6				
A#3	0.229	-13	0.034	9.5	0.77	0.041	1.5	0.045	-0.1	-1.3	0.05	BR	Is				
A3	0.219	-12.3	0.037	8.8	0.77	0.045	1.4	0.051	-0.1	-1.5	0.058			P8	P8	P8	P8
G#3	0.211	-11.7	0.041	8.3		0.049	1.2	0.056	-0.2	-1.6	0.066	10.1	0.069	BR	BR	BR	Is
G3	0.205	-11.1	0.044	7.7		0.054	1.1	0.061	-0.2	-1.7	0.072	9.4	0.078	2:1	4:2	6:3	
F#3	0.202	-10.6	0.047	7.3		0.058	1	0.067	-0.2	-1.7	0.079	8.7	0.086				
F3	0.2	-10.1	0.051	6.8		0.062	0.9	0.072	-0.2	-1.8	0.086	8.1	0.095	0.7	0.8	0	0.1

TABLE 7D

Primary Inharmonicity: f4=0.4 to A3=).2; Parabolic
Octave Size: Pure 6:3
Octave Factor: 2.0057

Note	Ip																
F4	0.4	m3	m3														
E4	0.355	BR	Is	M3	M3	M3											
D#4	0.315			BR	:	Is	P4	P4									
D4	0.281	-14.8	-0.00				BR	Is	P5	P5	P5						
C#4	0.254	-14.1	0.003	12.4	0.74	0.002			BR	BR	Is						
C4	0.231	-13.5	0.009	11.6	0.72	0.008	2.4	0.007	3:2	6:4							
B3	0.215	-12.9	0.016	10.8	0.71	0.016	2.1	0.016				M6	M6				
A#3	0.204	-12.4	0.025	10	0.7	0.027	1.9	0.028	0.3	0	0.026	BR	Is				
A3	0.2	-12	0.036	9.2	0.7.	0.04	1.7	0.042	0.2	-0.5	0.042			P8	P8	P8	P8
G#3	0.201	-11.7	0.049	8.4		0.055	1.5	0.058	0.1	-0.9	0.06	10.8	0.059	BR	BR	BR	Is
G3	0.208	-11.4	0.063	7.7		0.072	1.3	0.078	0.1	-1.4	0.082	9.9	0.082	2:1	4:2	6:3	
F#3	0.22	-11.1	0.079	7		0.091	1	0.1	0	-1.9	0.107	9	0.109				
F3	0.239	-10.8	0.097	6.4		0.113	0.8	0.124	-0.1	-2.4	0.136	8.1	0.139	0.9	1.1	0	0.139

The Historical Temperaments: Part 2

Owen Jorgensen, RPT
Northern Michigan Chapter

The historical temperaments should be restored and applied for the performance of all classical piano music composed before 1887, the general date when modern equal temperament began to evolve in practice on pianos. The art of keyboard temperament before the 20th century enhanced the harmonious and expressive qualities of classical piano music. In the past, chords in the white keys contained fewer beat frequencies, and these were heavily used by Mozart and the other 18th-century composers when the most harmonious effects were desired. The fewer the beatings, the more harmonious was the music. The totals of the beat frequencies of the intervals included in major and minor white key triads in some historical temperaments were only 27.8% as much as the totals for the same triads in equal temperament. In contrast to 18th-century practice, composers in the 19th century were more interested in drama and expressive effects than in harmoniousness; therefore, they wrote predominantly among the black keys. Melodies composed among the black keys were more expressive in the 19th century because the major intervals were more major or wider by as much as 8 cents compared to equal temperament and up to 22 cents wider than white key major intervals in the oldest meantone temperament. The black key minor thirds were more minor or narrower by as much as 6 cents compared to equal temperament and up to 16 cents narrower than white key minor thirds in meantone. Wider major thirds and narrower minor thirds caused greater modal differences than exist in equal temperament. Also, the leading tones were sharper than in equal temperament. It is natural for musicians to strive for the sharpest leading tones possible in melodic passages. In 1768, Jean-Jacques Rousseau summed all of this up when he wrote, "The organists and keyboard instrument makers look upon this temperament as the most perfect that can be used. In effect, the natural tones enjoy, by this means, all the purity of harmony; and the transposed tones, which form less frequent modulations, offer great assistance to the musician when he is in want of marked expressions."[1]

It is true that the beatings of the major and minor intervals played among the black keys were increased compared to equal temperament; but, this was more than offset by two advantages. First, the chords among the black keys contained great clarity of sound because of the many just and close to pure fourths, fifths, and twelfths causing identical and proportional beatings. Second, depending on the form of well temperament used, the major thirds, sixths, tenths, and 17ths (the most important intervals for melodic construction and the color-quality determination of vertical harmonies), were increased in their beatings by as much as 57% compared to equal temperament. This had the effect of increasing the singing tone and resonance of the piano. Chopin utilized the latter quality to an extreme degree in his compositions; that is, like most classical 19th-century composers, Chopin instinctively composed predominantly in many sharps and flats in order to augment the singing tone, resonance, and expressiveness. To eliminate harshness, he rarely applied Pythagorean type chords in the middle of the keyboard without accompanying them with low bass notes that had the effect of reducing the beatings or harshness by as much as two to four times. On pianos, the power of beatings from low tenths or 17ths always masks over and conceals the fast beating intervals in the middle of the keyboard. Using Chopin's composing philosophy, greater resonance was acquired without increasing the harshness. Chopin and other composers adjusted to the temperaments of the past, and they instinctively utilized the best qualities of these temperaments.

Modern equal temperament contains no color contrasts, and this quality accommodates atonalism and serialism in 20th-century music. Contrary to this, pre-20th-century temperaments accommodated tonality in music; that is, the musical intervals were tuned or tempered in proportion to however many sharps or flats were in the tonic key signature of the diatonic scale containing the intervals. Consequently, each scale, key-center, or tonality contained unique characteristics, and this was the reason composers in the past published their works in specifically chosen keys and why performers seldom transposed the piano classics after they were published. The original temperaments were an integral part of the music compositions, and they controlled the sizes of all the musical intervals and their musical effects.

In conclusion, performing the pre-1887 classics in the 20th-century equal temperament is like removing color from paintings, and this causes a loss of the harmoniousness, the expressiveness, the resonance, the tonality, and the characters of the keys intended by the composers. For usefulness in the tuning examinations administered by the Piano Technicians Guild, the very difficult to tune modern equal temperament remains valuable for assuring that great skill in theoretical aural tuning proficiency is acquired by aspiring tuners.

Recent research proves that equal temperament was not fully developed in practice on harpsichords and pianos until 1917. In contrast to this, the commonly believed notion today has been that J.S. Bach almost two centuries previously in 1722 had invented, tested, and composed in equal temperament and that musicians have been using it ever since. These concepts are based on statements by 19th-century historians. As an example, Frederick Westlake wrote in 1893 in *Grove's Dictionary* that "it was Bach's intention by this work[*Das Wohltemperirte Klavier*] to test the system of equal temperament in tuning." This was typical of statements written throughout the 19th century. For acoustical reasons to be explained, however, the first techniques for tuning today's equal temperament on harpsichords and pianos were not discovered until 1887, and they were not fully developed and published until 1917. For other acoustical reasons, equal temperament has been possible on organs since 1810.

The contradiction between historical fact and the 19th-century writings about Bach is explained by the changing terminology. During the 15th century, there was the "common keyboard tuning" in which modulation was restricted. One could not perform in all the keys without encountering badly out-of-tune "wolf" intervals. This was not called "meantone temperament" until C.J. Smyth invented the term in 1810. In the late 17th century and early 18th century, the freely modulating or circular temperaments in which one could perform in all keys became popular. At that time, the previous "common keyboard tuning" became known as the "old tuning," and the freely modulating temperaments collectively as a group became known as "the new tuning" or "the new common established temperament." After William Jones invented the term "equal temperament" in 1781, the late 17th-, the 18th-, and the 19th-century freely modulating "common established temperament" was also called "equal temperament" even though it was *not* truly equal. In fact, any temperament in which one could play all the harmonies in every key without encountering a so-called "wolf" interval was called "equal temperament" throughout the 19th century. To the 19th-century ears not trained in modern listening techniques, the semitones in these temperaments sounded somewhat equal even though variety in tonal effects between the keys existed. During the 19th century, the term "unequal temperament" was used to denote only the original restrictive 15th-century temperament sometimes called "meantone temperament" after 1810. In a simplified manner, 19th-century writers usually described either the "equal" temperament or the "unequal" temperament. After the middle of the 20th century, the freely modulating late 17th-, 18th-, and 19th-century circulating temperaments collectively have been called "well temperament" in order to distinguish them from equal temperament as practiced today. "Victorian temperament" is the advanced form of "well temperament" that previously was thought to be "equal temperament" during the 19th century. Victorian temperament was practiced during the lifetime of Queen Victoria (1819-1901).

In conclusion, Westlake was able to write his statement about Bach and temperament because the term equal temperament had a different technical meaning in the past than it does today.

Thomas Young (1773-1829), an almost exact contemporary of Beethoven, was a physician, professor of physics, editor and writer for the *Encyclopaedia Britannica*, foreign secretary and fellow of the Royal Society, member of the National Institute of France, office holder in several important scientific organizations, and a master of many languages. He was one of the first to decipher Egyptian hieroglyphics. He is famous in history for his discovery of the principle of interference of light, his establishment of the undulatory theory of light, his research in physical optics and color perception, his discovery of important physiological traits of the eye, and his lecture on the "Functions of the Heart and Arteries" in 1808.

In music, he mastered music theory and played the flute. In Germany in 1795, he studied the clavichord under Johann Nikolaus Forkel, who is renowned as the father of musicology and also as the first to extensively research the life and music of J.S. Bach with the assistance of Bach's sons. In tuning, Young was the first to write that a fourth is an aurally tuneable interval and therefore fourths could alternate with fifths to create a circle of fourths and fifths. Young's method reduced the traditional bearing section from nineteen notes down to 12 for greater efficiency.

As an acoustician, Young studied the known information on temperaments published before 1800, and he analyzed and published the most important historical temperaments in logarithmic forms. His representative temperament must not be confused with his second temperament which is really a transposed form of Vallotti temperament. Thomas Young wrote that his representative temperament reflected the qualities in general that the best instrument makers and musicians in 1799 were applying on their pianos and harpsichords. However, this temperament represents more than the sounds heard in 1799; it represents the general sounds of most of the historical temperaments practiced on harpsichords and pianos from around 1722 through around 1885. It is therefore appropriate for the performance of all harpsichord and piano music written from the time of Bach's *Well-tempered Clavier* through the complete lifetime of Franz Liszt.

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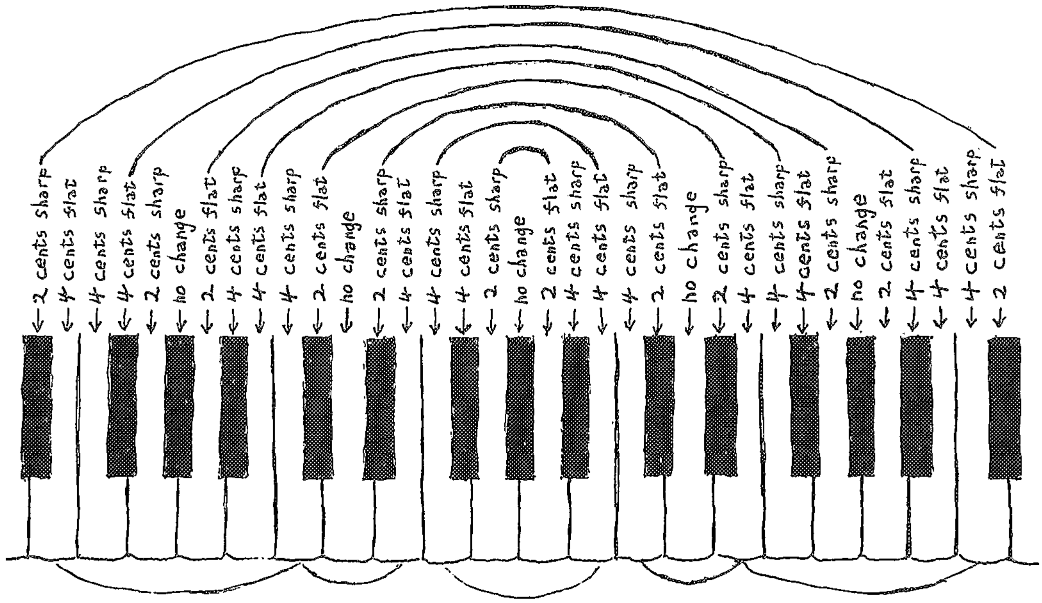
1. Jean-Jacques Rousseau, *A Complete Dictionary of Music . . . Translated . . . by William Waring*, 2nd ed. (London: J. Murray and Luke White, 1779), 247.

Charts continue page 40...

Chart of Symmetry

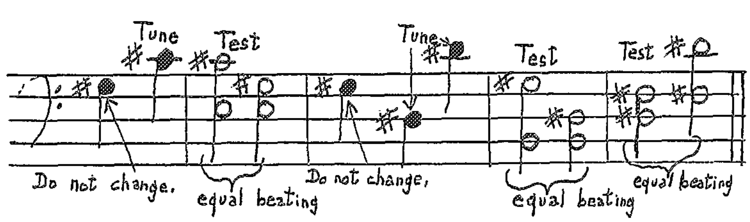
The symmetrical design of the keyboard centers on the keys for D and G-sharp which are in equal temperament at standard pitch. Thomas Young's representative temperament of 1799 completely adheres to this symmetry and to the rules of conventional tonality. The deviations of the Young from equal temperament are given in rounded cents figures. Notice that A is flat and C is sharp even though the overall tension is at an A-440 level. The reason the tension can be maintained at 440 is that for every note that is flat, there is an equivalent note at a symmetrical distance away that is exactly the same amount sharp. As an example, E is 4 cents flat and is four keys down from G-sharp; the equivalent note C is 4 cents sharp and is four keys up from the same G-sharp. Also, E is up two keys from D, and C is down two keys from the same D.



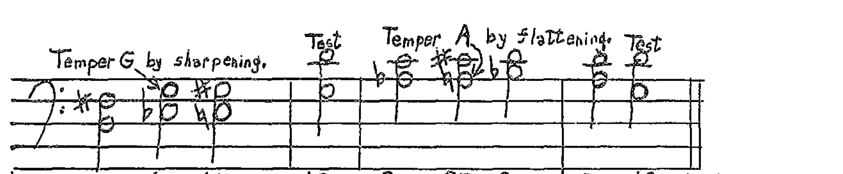
Tuning Young's Representative Well Temperament of 1799 Almost Exactly According to Theory While Maintaining the Overall String Tension Level at A-440

1. Before beginning make certain that the piano is in perfect equal temperament at standard pitch from D below middle C to the D above.

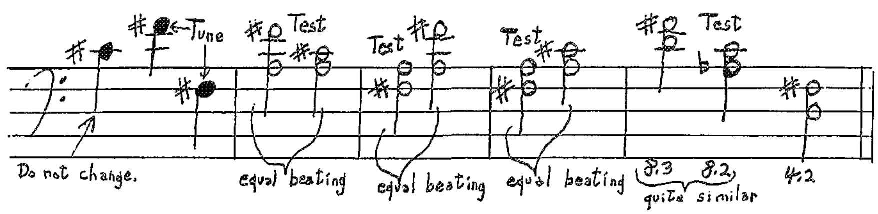
2. Do not alter G-sharp. From G-sharp, tune C-sharp and both D-sharps in just intonation.



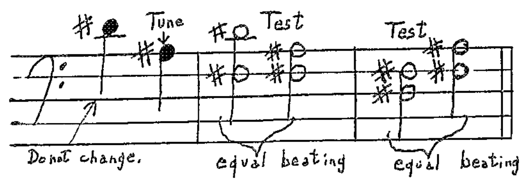
3. Temper G and A so that the following thirds progress exactly the same as they do in equal temperament.



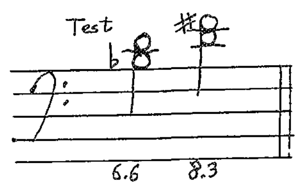
4. From C-sharp, tune both F-sharps in just intonation.



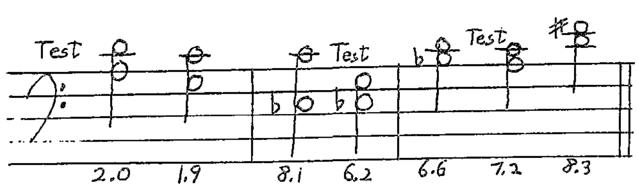
5. From D-sharp, tune A-sharp in just intonation.



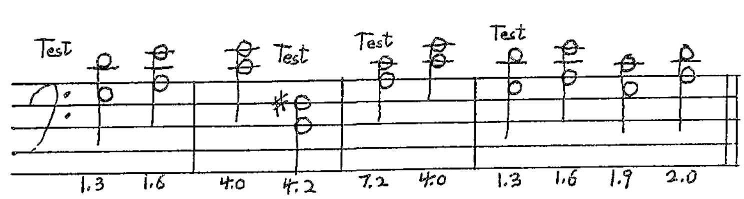
The two equal tempered standard pitch tones D and G-sharp are never to be retuned or altered. The following two contiguous major thirds will be slow, but nevertheless they should still be progressing in a 4 to 5 type proportion of beats.



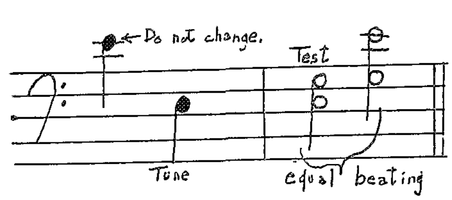
6. Using the fourth AD as an example, sharpen middle C until the wide fourth GC beats an almost imperceptible amount slower than AD. At 1.9 beats per second, GC will be larger than AD.



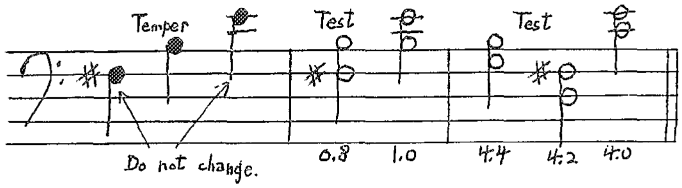
7. Using the fifth GD as an example, flatten E above middle C until the narrow fifth AE beats faster than GD. At 1.6 beats per second, AE will be smaller than GD.



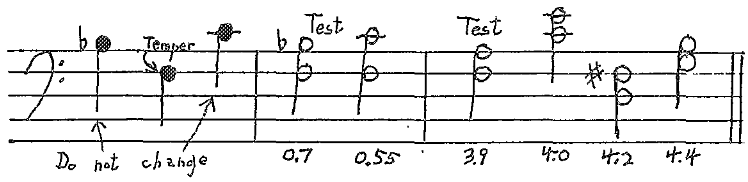
8. Tune the lower E from the upper E.



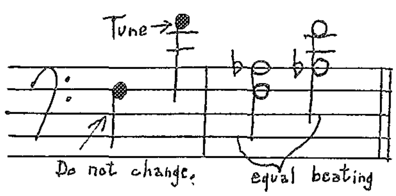
9. Average or compromise B so that the wide fourths F-sharp, B and BE progress in a proper proportion similar to the way they do in equal temperament.



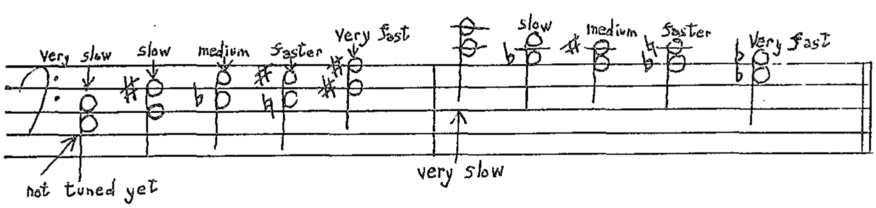
10. In a manner similar to tuning in equal temperament, average or compromise F below middle C so that the wide fourth FB-flat is in a proper proportion with the narrow fifth FC.



11. Tune the upper F from the lower F.



A test valid for most historical well temperaments as practiced is to check the following intervals for progressing beat frequencies.



The above tests are expanded into tenths and 17ths while tuning the high treble.

12. This completes the bearing section from D below middle C to F-sharp above middle C. Tune the remainder of the instrument by octaves using the same tests for proper octave stretching that you are accustomed to applying when tuning in equal temperament. There will be no just thirds.

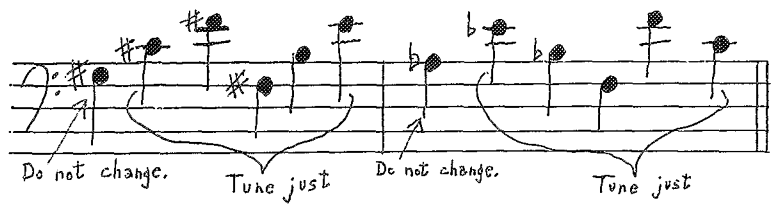
Converting Young into the Vallotti Well Temperament

The original bearing section is from D below middle C to F-sharp above middle C. By retuning B pure or beatless to F-sharp and also by retuning both F's pure to B-flat, a temperament very similar to the much practiced 18th-century Francesco Antonio Vallotti (1697-1780) well temperament is created. There are no just thirds in this temperament.

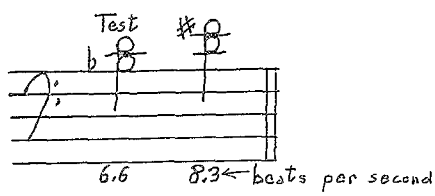
Tuning the Prinz, Kirnberger III, Aron-Neidhardt Type
Well Temperament Described from 1752 through 1808 while
Maintaining the Overall String Tension Level at A440

1. Before beginning, make certain that the piano is in perfect equal temperament at standard pitch from G-sharp below middle C to D above middle C.

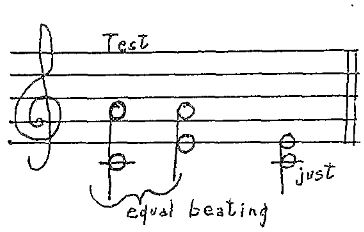
2. Do not alter G-sharp. From G-sharp, tune C-sharp, both F-sharps, B, and E in just intonation. Also from A-flat (G-sharp), tune E-flat, B-flat, both F's, and C in just intonation.



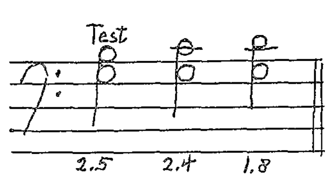
Do not retune or alter D. Nevertheless, the following two contiguous major thirds should be progressing in a 4 to 5 type proportion of beats.



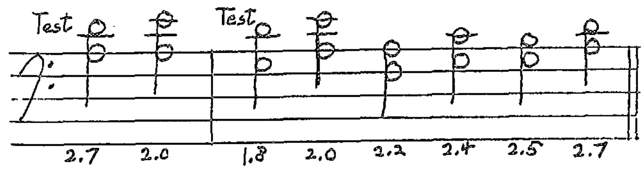
At this stage according to theory, the major third CE should result in being two cents narrow. If it is, then the major sixth CA will be beating slower than the fourth EA. In this case, sharpen E a shade and flätten C a shade until CA and EA beat exactly the same speed. This will assure that CE is in just intonation. The fourths BE and CF will each become 1/2 schisma wider.



3. Temper G (sharpen) so that the wide fourth GC still beats faster than the narrow fifth GD but in a proper proportion.



4. Temper A (flatten) so that the wide fourth AD beats faster than the narrow fifth AE in a proper proportion.

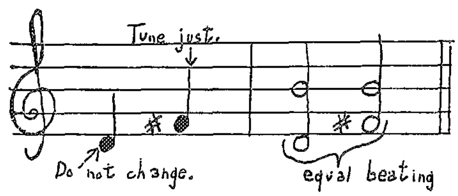


5. This completes the bearing section from F below middle C to F-sharp above middle C. Tune the remainder of the instrument by octaves. There will be one just major third per octave.

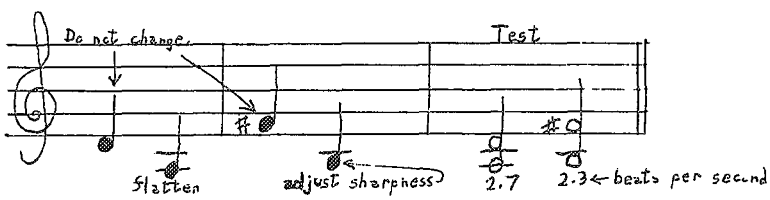
Tuning the Pietro Aaron Meantone Temperament Published in 1523 while Maintaining the Overall String Tension Level Nearly at A-440[1]

1. Before beginning, make certain that D above middle C is at standard pitch in equal temperament.

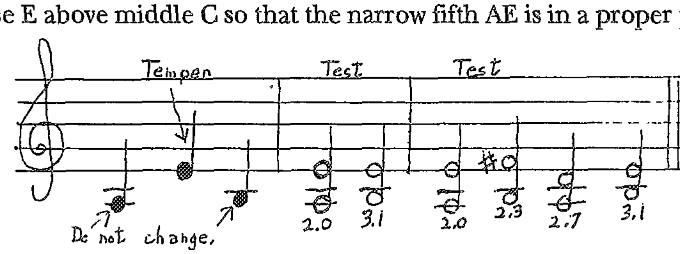
2. From D, tune F-sharp above middle C in just intonation.



3. From D flatten A, and from F-sharp sharpen B. The wide fourth and narrow fifth will beat nearly three times as fast as they do in equal temperament.

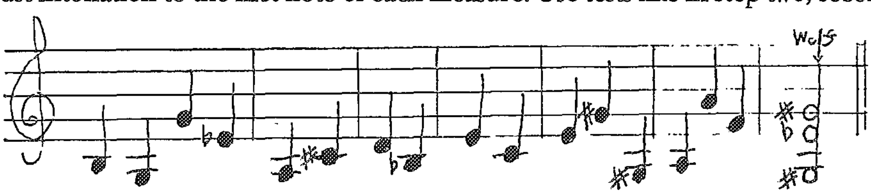


4. Average or compromise E above middle C so that the narrow fifth AE is in a proper proportion with the wide fourth BE.



1. Actually, G-sharp will be too flat for maintaining the whole instrument at exactly A-440.

5. From the notes already tuned, tune the remaining notes of the bearing section by means of just intonation major thirds and octaves. Do not alter the first notes of each measure; they are already tuned. Tune only the second, third, and fourth notes of each measure in just intonation to the first note of each measure. Use tests like in step two, second measure.

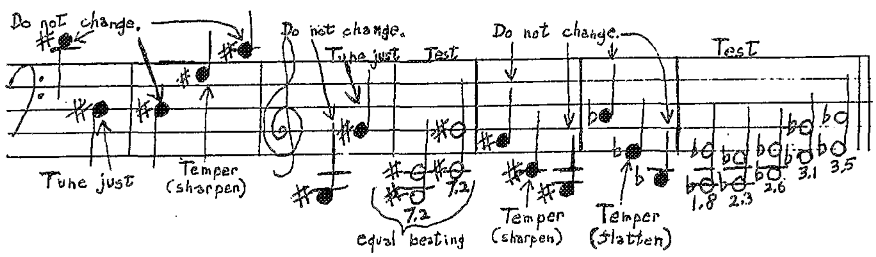


6. Except for all the diminished intervals, augmented intervals, and the wolf, check all the fifths, fourths, minor thirds, and major sixths for evenly changing beat frequencies from G below middle C to A above middle C. Tune the remainder of the instrument by octaves. There will be eight just major thirds per octave.

Converting Meantone Temperament into a Basic Modified Meantone Temperament for Early Music before Well Temperament Became More Common

If the previous instructions for tuning meantone temperament were followed, then these instructions will completely restore the overall string tension level at exactly A-440, although A itself will be very flat. Also, the complete symmetry of all the intervals will be restored.

1. Temper G-sharp; then, temper C-sharp and E-flat. Contrary to your usual practice, temper the fifths *wide* and the fourths *narrow*. There will be no wolf fifths or fourths.



2. This completes the bearing section from G below middle C to A above middle C. Tune the remainder of the instrument by octaves. There will be five just major thirds per octave. For a temperament that was used for performing in all twenty-four major and minor tonalities, this contained the most key-color contrast that existed in history. The extreme difference in size between the major third CE and the diminished fourth F-sharp B-flat prevents this from being classed as a well temperament. The diminished fourth F-sharp B-flat is only 7.7 cents narrower than a just intonation ratio 9 to 7 interval; therefore, it is not a regular ratio 5 to 4 major third. Well temperament requires that the diminished fourths sound like tempered ratio 5 to 4 thirds.

BEHOLD
THE UPRIGHT

By Don Valley, RPT
Western Carolinas Chapter

As we consider the sides of the key, attention is given primarily to the lead weights. The condition usually observed is the white powdery surface indicating an oxidizing state. Since this continues to compound and grow, it must be removed. This is done by using a stiff brush, preferably one with fine brass bristles. To prevent the continuation of growth, coat the newly cleaned leads with a diluted lacquer solution—3:1 lacquer thinner and lacquer. Use a Q-tip or small brush dipped in the solution and paint the lead surfaces.

Sticking Keys. We have all encountered them. Well, oxidization is one of the causes because of the excessive swelling of the lead compound. This is not one of the "usual" culprits, although not terribly unusual. Just be aware. When the oxidization process becomes acute enough to protrude to adjoining keys, the keys must be removed and the leads filed flush with the sides. When filing is finished, seal the leads. The keyboard will now be free. I have actually encountered one piano where the entire keyboard was frozen stiff and swollen leads was the only problem. This can be corrected in the home quite simply. I use old newspaper to catch and contain the filings. Just remove one key at a time, rest the back end of the stick on a solid surface as you file away. Caution says to wear a face mask because of this dusty residue being toxic. Seal the leads and place right back into the piano. The sealing process is to keep the oxygen from reacting again and recreating the problem you have just solved.

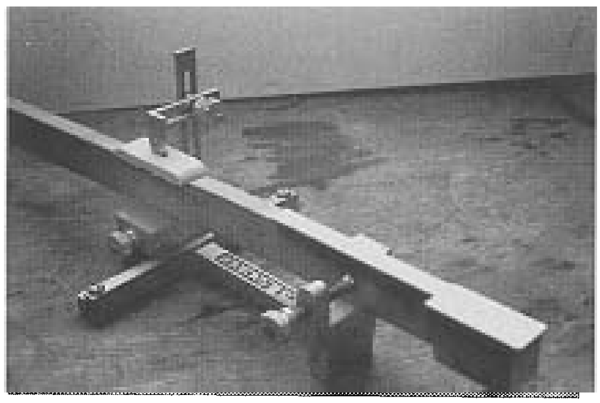


Photo 1

Now we can get to that part of the key where most attention is given — the top. The three areas of the top to be concerned with are the front covers, the buttons, and the capstans. For the most part these are all alike from piano to piano. Some deviations from the typical are those keys in older pianos having rocker arms in place of the capstans. Also some smaller pianos do not have buttons but have mortises directly in the keytop at the balance rail. Starting with the capstan, there are two concerns: 1) A rough top surface; 2) Loose in the wood causing it to go out of regulation. A rough top surface needs to be smoothed in order to reduce friction. Should this be a heavy buildup of rust, they must be replaced. Otherwise, buff them to a high polish on your wheel. Do not use a coarse abrasive buffing compound as you will defeat your purpose. The way to check for looseness is to try to turn the capstan with your fingers. If you can, they are too loose. These can be tightened adequately by using one of the pin-tightening solutions acquired through your favorite supply house. Another product many of your have in your shop is Chair-Lok. Similar solution for similar purpose.

The Key Button. Determine whether this needs to be replaced or rebushed. Perhaps only a few buttons have to be replaced. To do this, first remove the old button and any old glue. Place the button strip with one mortise positioned correctly. With a pencil, mark the sides of the key line on the underside of the button strip. Cut it a little larger than your mark to allow for final positioning. **Remember:** The accurate position of the bushed mortise on all keys, no matter the angle of the stick, is perpendicular to the front of the piano! I find the Jaras key button jig to be of extreme help in positioning the button accurately. (See photo 1). Set the key over the balance rail pin. Lock the front into position. The center will slide into place. Position the button locator over the pin and down into the button. At this point the button is located accurately to be perpendicular to the front of the key. Lift the button off and place glue on the underside of the button. Replace it and fit it with the jig. While holding it in place with one hand, unclamp the front of the key, lift it off and clamp it for drying. When dry, shave and sand or file the sides of the button flush with the sides of the key. You may have some slight easing to do, but that will be all.

Follow the forgoing procedure for an entire set of buttons. However, in doing an entire set, you can shorten the time for marking the undersides by determining the angle you need for that number of bass or treble. Then you can just duplicate that angle and cut halfway between the mortises in the button strips. There will be a lot of "handover" but this is easy to remove after it is dried onto the key by sipping most of the excess off with a band saw and then following up with your final fitting. **Another warning:** do not make the misjudgment of thinking you can save time and eliminate the jig by just using your eye and placing these in the center of each key. As you scan your keys with the old buttons gone, you can quickly determine the mortises are not cut equally between the sides of the key. This is not a mistake. It is purposeful. Therefore, do not try to correct what might seem to be poor workmanship. If you do, you will have a royal mess on your hands when you place the keys back onto the frame. (See photo 2). You will have to do the set all over again. The key mortise must be in the same position as that of its "predecessor." An entire set of key buttons or rebushing the key buttons (if they are in solid condition) gives a marked improvement to the touch control of the pianist.

Rebushing the button follows the same procedure as that of rebushing the front of the key. Refer to the previous article in covering that topic. With the key button, the gluing surface is not as large as in the key front so make certain your glue is properly placed. Repetition aids learning so again I caution you to avoid the temptation of inserting more than 3/16" of cloth into the mortise. **It will bind your key travel if you do!** Another assumption to avoid is that the balance rail pin and the front rail pin are the same diameter. Make certain you use a micrometer to determine the size of each set.

Now that the back of the key and the middle of the key are in good order, let us progress to the front of the key where we find the key tops: ivory, plastic, or sharps. There are many people who offer key covering services and who advertise in the classified section of the *Journal*. Also many technicians choose to do their own work in order to avoid the shipping time. As an independent technician, you can achieve very fine results in key covering. But like anything else, you must be meticulous in all aspects of the process. To set the record straight, key blanks already formed to the contour of the keys are not meant to be the final result when installed onto the key stick. The real technician sees to it that the key and its new thicker top is the same dimension as the original and that the lip is the same as the original and that the front piece is the same as the original. I have seen many sets of new key tops where the new .090 keyblanks have been glued to the unprepared top of the old keystick. The for/aft has been determined by mating the notches. The blank is glued on top of old glue, cloth, etc. The lip is as much as 1/4" extended and the sides extend beyond the sides of the keystick. The one factor of improvement is that they are white! Lest I appear too critical, there may be those who do not understand my observations and, therefore, that is what these writings are meant to do — to help you understand and know how to come up with positive and accurate results. Now that some ground work has been laid, the progress will be in three sectors: replacing the entire set of naturals, incidental ivory replacements, and replacing or restoring sharps.

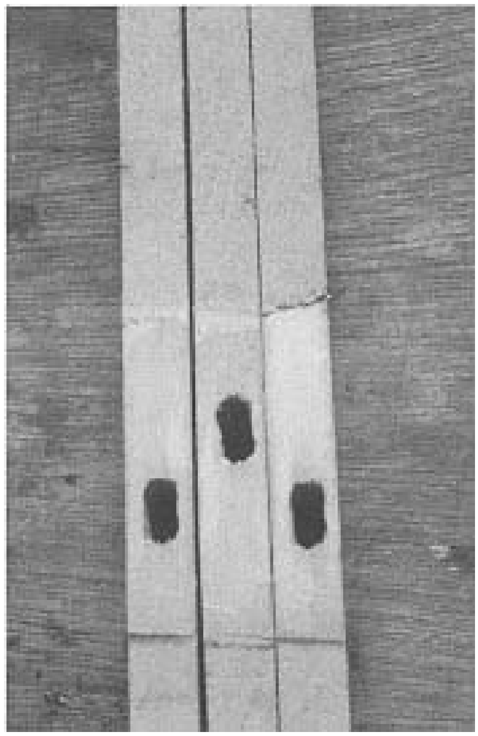


Photo 2

Replacing the Naturals

1. Measure the key thickness with the original keytop on and measure the front.
2. Measure the thickness of the new plastic keytops and fronts — keep these measurements.
3. Remove old tops. A warm iron will serve to soften the glue, then a thin blade can slice under the top and peel it off.
4. Subtract the measurement of the old keytop from the new to determine the thickness of wood to be removed from the key stick.
5. Set up your router in its table to remove this .030-.040. With a clamp, set yourself a stop so you take the exact length from each key.
6. In the same way, determine the amount to be removed from the key front to accommodate the added thickness of the new blank. Set it up with a jig on your band saw and proceed to remove about .020. This will avoid having to affect the keyslip in any way.

Comment: There are some who would try to justify not milling down the top of the key but would remove paper shims from the balance rail to accommodate the additional thickness. If this aids in one direction, it creates another problem elsewhere — that in the area of regulation. Also, the reason for duplication to original specs is that the distance from the top of the natural to the top of the sharp is generally consistent from piano to piano (about 1/2"). Any deviation from that standard causes inaccurate kinesthetic training and thus, the inability to comfortably transfer from piano to piano.

7. Place the blanks in order and begin your process. There are any number of glues you can use. Duco Cement will bite well into the plastic and create

good adhesion. But, any touch of it onto the top surface bites instantly leaving a permanent mark that must be buffed out. PVCE has amazing holding power: it dries quite rapidly with any excess easily rubbed away just as with rubber cement.
8. Apply the glue to the keystick; place the top, preserving the rounded-off edges as flush as possible. Let the squared edges be the ones to be filed as you later fit them to the stick.
9. Place this in the bench clamp and let set for a few minutes. You can use spring clamps and wood strips to protect the tops. When you have gotten up to about six, you can begin to alternate until your job is done.
10. After it has set for two to three hours, place a key in your wood vise. With a medium to coarse bastard file, cut down those extra edges flush with the sides of the key. Remove the key from clamp. Use a fine file, while holding the key, to polish the rough edges and round off those sharp corners. File the notch clean and exact. You may also have to file an occasional front corner to match the rest.

This ten-step process can be done in most any workspace with professional results. Care and consistency is the key to it all.

Incidental Ivory Replacements

I recommend filling in the gaps when the set is generally in good condition with no more than fifteen needed replacements. With more I usually suggest a complete set of plastic.

1. From your collection, select color, size and thickness, choosing the notching configuration in the blank to match the key.
2. Remove old keytop and all glue and other matter from the key.
3. Whiten the keytop. White lacquer brushed on is excellent — two or three coats. Titanium oxide mixed with white glue is good. Let these dry well.
4. Glue top on with white glue or PVCE. Clamp and let dry overnight. If not clamped long enough, ivory may curve away at edges because of glue moisture.
5. Remove clamp and final fit with fine file.
6. Using palm sander and fine abrasive paper (220-350), sand keytop to remove any yellowing and to blend better into the set.
7. Place ivory on buffing wheel of white abrasive until polished and without sanding scratches.

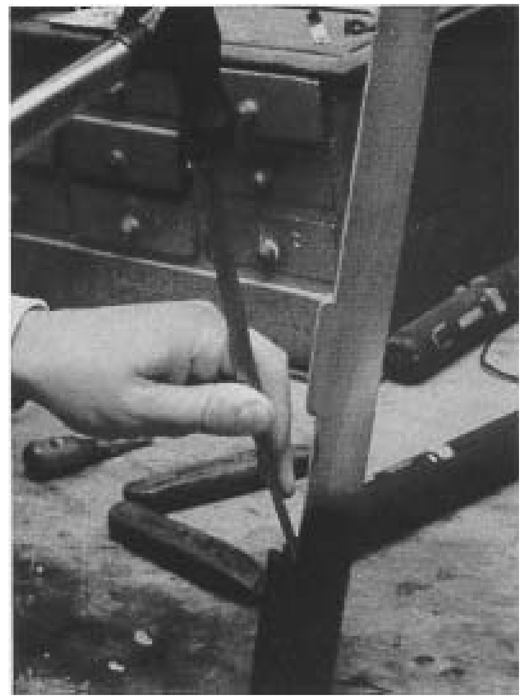


Photo 3

Sharp Restoration and Replacement

Keeping the same sharps and doing an impressive restoration is not difficult, and there is no need to spray them with black lacquer. When they have been played so that the finish is worn and wood shows through, you need to apply leather dye. Not sole dressing. Not polish. These do not penetrate into the wood, but leather dye will dye wood fiber too. Shoe repair and sales establishments stock this in bottles.

1. First, make sure the key is clean and free from all finger grease.
2. With the applicator, paint leather dye onto affected key areas. Let dry a few minutes.
3. Buff dry with soft cloth.
4. Rub briskly with soft cloth to polish, or take to polishing wheel and buff lightly. This is to remove any black residue. Sometimes buffing with 4/0 steel wool gives a nice satin-rubbed effect.

Replacement of the set of sharps is not difficult and can be done in a few steps.

1. Take key, rest front edge on solid table. Using chisel as shown (see photo 3), strike with hammer and it will pop the sharp quickly and cleanly off the stick.
2. After doing this for all sharps, clean any debris from the key. If pieces of sharp have remained, set router depth to remove the extra.
3. Make certain new sharps are proper length. Cut if necessary.
4. Using carpenter's glue, place a fine line on bottom edge and set in place on stick.
5. Use spring clamps to hold in place. After six or eight clamps, begin to rotate.
6. With finished set, clean away any glue ooze. Take leather dye and paint stick below the sharp and in back of it so white wood is not seen when playing.

With the keys all back in order and in good shape, progress will now go to the action area.

The Tuner

By Paul Monroe, RPT

This subject was discussed a few years ago by our good friend, the late Carl Wicksell and I feel it should be discussed again, especially for the beginning Associate.

Many technicians, including me, believe that you can not set A4 accurately to 440HZ by listening to a tone generated by a fork or an electronic device and playing the note A4. You must make use of another note where you can utilize the use of a beat rate. You can hear the smallest of changes in beat rates which makes accuracy possible. This may sound complicated up to now but it is really simple.

First use A3 as a beginning note. Set your A-440 fork in motion, place it against the underside of the keybed (or between your teeth), play F2 at the same time and establish in your mind the beat rate you hear. Play A3 and F2, tune A3 until you have the same beat rate.

You need to know nothing more than this to set an accurate A. However, there are some technicians who will wonder what is happening. When you activate the A-440 fork and play F2, the 5th partial of F2 and the fundamental or 1st partial from the fork set up a beat rate. In theory the 5th partial of F2 should have a frequency of 436.3HZ and the fundamental of A4 should be 440HZ. The differential in these frequencies create a beat rate you can easily count. Therefore if you establish a beat rate with the tuning fork and F2, then tune A3 until the beat rates match you will then have set A with accuracy.

Some may be saying, "but the fundamental of A3 is 220HZ" and that is true. In reality you are using the 2nd partial of A3 to establish the beat rate and if you want to double check your accuracy, depress F2 and A3 only to lift the dampers off the strings then strike A4. This will cause the 5th partial of F2 and the 2nd partial of A3 to vibrate and create the beat rate you hear.

After you have used this method a few times you can utilize it to raise pitch, remembering that in all cases of raising pitch you must raise your beginning note 25% above (sometimes called override or overshoot) in your first time through the keyboard in order to have the A4 end up on 440HZ — i.e., A = 12HZ flat. Raise it to 3HZ sharp. It will be at 440HZ when you start your final tuning. Refer to my article on raising pitch for a detailed description of raising pitch.

Why should you always tune a piano to standard pitch? Better yet, why not leave all pianos tuned to standard pitch? In my opinion the only reason for not raising pitch to the standard 440 (plus or minus 2HZ) is when the piano structure will not stand the increase in tension.

In my conversations with tuners who rarely raise pitch, I believe the reason they don't is fear based on a lack of knowledge and experience. When you overcome that inhibition you will be able to raise pitch with confidence and have it last for three to six months, depending on the area you live in. When you achieve that confidence you will want to tune all pianos at standard pitch. Most of all, however, for me it is a joy to know I have contributed to the proper ear training of anyone, especially children, who listen to the pianos I have tuned. I hope you will share that joy also.

Techno-*Stuff*

By Richard Anderson, RPT
Feature Writer
Chicago Chapter

Last month we settled on the notion that for any and each tuning pin position in the block, there is a range of frequencies that can obtained in the speaking length by manipulating the tension differential in the front duplex and waste end. This month we'll look at how the range changes over time, and next month we'll discuss hammer technique and its application to various types and conditions of pianos.

Let's begin by amending our beginning statement to read "at any point in time, and for any and each tuning pin position in the block, there is a range of frequencies that can be obtained in the speaking length by manipulating the tension differential in the front duplex and waste end." The range will decrease over time as the tension differential in the wire segments fights against the friction in the front bearing points trying to equalize the tension between the wire segments.

The moment you lift your hammer off the tuning pin, the wire is slowly creeping over the agraffe/capo bar and front string rest in its search for peace with the physical universe. How fast it creeps is a function of the friction at these points, and the amount of tension differential you leave.

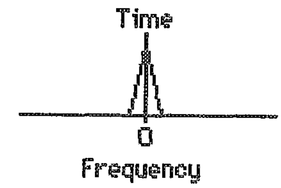
Further complicating the issue are the changes in the piano itself that occur over time. The tension of the speaking length is continually changing as the soundboard moves up and down in response to its environment, and the friction at the front bearing points is gradually increasing as the wire corrodes and buries itself into the softer material of the agraffes and bearing bars.

We can visualize these changes by graphing the frequency range over time. Frequency will be on the horizontal axis with the zero at the center representing the frequency at the center of the range, or that frequency that the piano will eventually move towards over time. Time will be on the vertical axis. The width of the range at the start is most dependent on the friction at the front bearing segments.

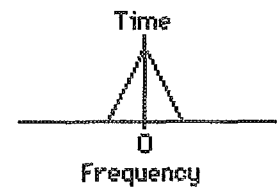
The shape of the curve is determined by the condition of the piano, type of playing, and place in the scale. Pianos with rusty strings will have lots of initial friction, but produce lots of tension differential, and, therefore; little stability over time.

Pianos with fresh wire and/or little front counterbearing will have little initial friction and little potential tension differential which yields a rapidly narrowing range in a short time.

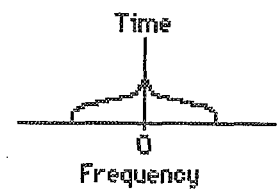
The ideal situation would be fresh wire that flowed smoothly, coupled with enough initial friction and counter-bearing to provide tension differential for a wide range that was stable over time. This condition also exists in the lower half of the piano where the speaking length represents the greatest percentage of the total string length.



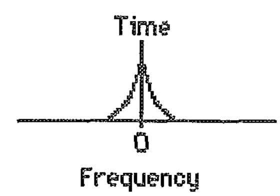
Piano with little friction.



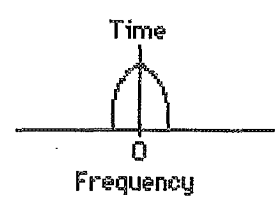
Piano with more friction.



Rusty strings



Fresh strings



Ideal Situation

PTGReview

PIANO TECHNICIANS GUILD

Dedicated To PTG News • Interests & Organizational Activities

Passages

Danny Boone, RPT
November 29, 1938
October 23, 1994

Danny Boone, a member of PTG since 1967, died at his home in Waco, Texas on Monday, October 23, 1994, of a heart attack. Danny was 55.

Danny was born November 29, 1938, in Ft. Worth, Texas. He moved to Saint Jo as a child, and attended school there. He earned an Associate degree from Decatur Baptist College, and a Bachelor's degree from Howard Payne University. He also attended Southwestern Baptist Theological Seminary.

He married Barbara Schooling in 1961, and they had two daughters; Carole and Rebekah.

Danny started learning to tune pianos in 1966 through a home-study course. He joined PTG in 1967 and became a Registered Tuner-Technician in 1968.

Danny served as a minister of music in Baptist churches for 22 years. He served as resident piano technician at Baylor University for 20 years, and was instrumental in securing the new carillon at Baylor several years ago. Danny was well-liked and appreciated at the college, and was a highly visible character. He rode a motor scooter around campus, as his work took him from building to building all over campus daily.

Danny was a member of the Dallas-Ft. Worth Chapter from 1967-74, and the Heart of Texas Chapter from 1974 to present. He served the Heart of Texas Chapter as President, Secretary, Newsletter Editor and Chairman of the Examination Committee, He was chapter delegate to Council six of those years and set up the Area Examination Center at Baylor University. Danny had been a member of the National Association of Parliamentarians for many years, which showed in the work he did at many levels running meetings, setting up operating organizations within PTG and on the Council Floor at numerous PTG annual business meetings.

Danny Boone

He served as President of the Texas State Association, which he helped organize.

He was a regular instructor at chapter, regional and national seminars, was Seminar Director of the Texas State Association Convention in 1984 and the Mexico City Seminar in 1989 and 1990.

He served as South Central Regional Vice President from 1988 to 1990, chairman of the South Central Regional Examination Board and had served on a number of PTG committees.

He served on the Bylaws Committee 1991-1993, the Nominating Committee 1993-1994, and was currently serving on the College and University Technicians Committee.

Danny was an active writer. He was compiler of the 1989 Annual Index and the 1984-1989 Cumulative Index of the Piano Technician *Journal*, and wrote articles that were published in the *Journal* and *Keyboard Companion* magazines. He had almost completed his current project, an 11-year cumulative index of the *Journal*.

Danny is, perhaps, best known for his recent book *Regulating Grand Piano Touch and Tone*, which was published in 1993.

Danny is survived by his wife, Barbara; their two daughters; Carole Ruth Blackmon of Dallas and Rebekah Boone of Bedford, his mother, Elizabeth Boone of Saint Jo; one sister and one brother.

Memorials may be made in Danny's honor at Baylor University Memorial Piano Scholarship Fund.

—Randy Potter, RPT

Danny Boone is the personification of what is best in PTG: skilled, dedicated and a devoted friend. Always ready to help, always ready to speak for and defend his principles; but never allowing disagreement to affect friendship. Danny touched many in PTG and he lives on in all of us.

—Charles P. Huether, RPT, Past President

My association with Danny has been a long one and I believe his association with PTG has been a most dedicated one - one he enjoyed to the

Passages continued next page—

fullest by being of service. Danny was a fine human being and will surely be missed.

—Fred Drasche

Only a short few weeks ago I attended the NYSCON convention in Syracuse NY. It gave me a chance to see my good friend, Danny Boone, who was one of the instructors. Danny was happy and had a great time. I even shared the limo back to the airport with Danny and his lovely wife. We spoke a lot about PTG, politics and the world. I will always remember Danny as the happy and cheerful devoted man I saw on that day.

—Ernest Juhn, RPT

Planning something different for the Auxiliary program is always a challenge. Danny came to my aid when we met last in Texas by offering to bring his wife's harp, tune it and persuade her to play it for one of our Auxiliary classes. It was a "hit." Danny's graciousness, enthusiasm and good humor will always be remembered and missed.

—Agnes Huether
Past Pres., Auxiliary

Danny Boone was a frequent guest in the Austin TX Chapter, often driving the 175 mile round-trip from Waco to attend our meetings. With his help, our chapter doubled its membership, became a Testing Center and successfully hosted a Texas State Seminar, all within a few years.

Danny was a voice of calm, reason and dignity in our sometimes rancorous organization. It was Danny's unwavering faith in his church, his family, and himself which made him such a pleasure to know. And even though he had his share of disappointments at the hands of others, Danny was always gracious and forgiving in defeat, never letting bitterness or rancor affect his relationships with people.

We will miss him.

—Austin, Texas Chapter

Herman Koford
October 2, 1898
September 19, 1994

After more than 70 years as an actively engaged piano technician, death came to Herman Koford, September 19, 1994; he was 95. A long time resident of Southern California and member of the South Bay Chapter, Koford represented three generations of piano technicians.

Born in Manchester, N.H., October 2, 1898, Herman received his training from his father, an emigrant from Denmark, who took his training in Boston, returned to New Hampshire and continued tuning until he was 85 years of age.

The third part of the generation is a son, Lynwood Koford, Past President of the South Bay PTG Chapter and an active member of the Chapter, having received his training from his father.

After World War II, Herman moved to Southern California and over the years earned the admiration, respect and affection of technicians not only in the Southern California area but all across the country for he was in great demand for seminars, state conventions and at annual conventions.

A great contribution to our craft on the part of Herman Koford was his unusual talent of creativeness. There was a time when all a tuner needed to do, in paying homage to Herman, was to look in his tool kit and he would see several creations bearing the Koford seal; inventions that assisted the technician in doing a better job easier and with greater efficiency.

While there are ever so many inventions, may we mention: the small, compact lid prop for upright, studio and spinet pianos; a piano string-pin-coil that held the master's touch; the small carriage on wheels making it possible for one man to safely transport a piano action into or out of a house, up or down stairs, by himself; an adjustable — to fit all grand pianos — block to support the pinblock when

Herman Koford

repinning a piano. The above is to name but a very few of his inventions.

Herman's seminars and conventions were always crowded, for it was here that the piano technician learned the reward of learning to laugh at himself and other valuable lessons; not the least of which was the lesson of how rewarding it is to pass on to others those valuable secrets of the trade.

Many, many honors were bestowed upon Koford and while he accepted those honors graciously, he never failed to give credit to those about him whose contributions were to be remembered and appreciated.

It is difficult to describe Herman's dedication to our craft and our Guild until you found yourself in trouble and you called Herman for direction and assistance. His background knowledge and awareness of older and unusual piano actions not only made him a "store" of information, but his willingness to drop everything and come to your assistance is an emotional experience I shall never forget.

In later years failing eyesight made it difficult for Herman to drive, read and continue his tool research, his favorite pastime, yet his memory remained acute and he was happiest when he could pass on his knowledge and direction to those he called: "My Family the piano technicians."

One last directive of this remarkable man was that his remains be donated to the University of California, Los Angeles, Medical School, for research. An exemplification of his entire life: "That I might be of help and assistance to another."

Herman is survived by his wife, Ellen Koford, Los Angeles; two sons, Lynwood Koford, Torrance California; Kenneth Koford, Murphys, California; a daughter Lee Merialdo, Las Vegas, NV; one sister, Edith Lee, Laguna Beach, California.

—James A. Collins
Pismo Beach, California

Bob Wolf
August 17, 1901
June 4, 1994

Bob Wolf was born Reuben Wolf-Jerusalem to Russian immigrant parents in New York City. He was one of eleven children. At a very young age he started playing the drums and was playing regular gigs by the time he was a teenager. In 1925 he began a long career as a Broadway pit musician in Rodgers and Hart's first production, "Garrick Gaities." He continued playing in Rodgers & Hart's musicals, and later joined Rodgers and Hammerstein playing nearly all their shows, both on Broadway and on the road. His artistry can still be heard on many original cast recordings.

During his Broadway days Bob met his wife, Velma Valentine Ziegler, a tap dancer, who died in 1971. He left Broadway after "Flower Drum Song" and began a new career as a piano tuner/technician. He had a shop in Baldwin, Long Island for many years. Later he worked for Ford Piano Supply Company managing the parts department for over twenty years before retiring at about age 85.

He was an active PTG member since its inception and was presented with a special award at the Washington, D.C. annual convention for bringing in more new members than anyone else in the history of the Guild. He became a chapter sustaining member in 1985. Many of the newer members in the New York City chapter will remember his generosity in volunteering his time and the use of his home for testing and board meetings. PTG members throughout the country knew Bob as the friendly, helpful man behind the Ford Piano Supply booth at annual and regional conventions.

He is survived by three grand nieces.

—Nancy Hazzard
New York City Chapter

Reclassifications to RPT

REGION 1

101-NEW YORK CITY

LINNEA C. JOHNSON
218 THOMPSON STREET, #12
NEW YORK, NY 10012

151-PITTSBURGH, PA

RICHARD E. ANKNEY
930 SEWICKLEY ROAD
BEAVER FALLS, PA 15010

REGION 4

612-QUAD CITIES, IL

DAVID C. LIVINGSTON
270 18TH PLACE
CLINTON, IA 52732

REGION 6

851-PHOENIX, AZ

LARRY J. MESSERLY
2222 W. MONTEBELLO AVENUE
PHOENIX, AZ 85015

RONALD R. SHIFLET
3213 11TH STREET
THATCHER, AZ 85552

951-SANTA CLARA VALLEY, CA

JOE MALECKI
22185 VIA CAMINO CT.
CUPERTINO, CA 95014

October Deceased Members

In Memory...

REGION 1

LEO SATZMAN, RPT
Long Island-Nassau, NY

ERNEST VAGIAS, RPT
Pittsburgh, PA

REGION 3

DANNY BOONE, RPT
Heart of Texas

REGION 4

GEORGE DE BOLT, RPT
Western Michigan

REGION 7

RICHARD SAUNDERS
Salt Lake City, UT

PTG
SHORT TAKES

NOMINATING COMMITTEE ISSUES MARCH 1 DEADLINE FOR INPUT

Nominations for 1995-96 PTG officers should be sent to Nominating Committee chairman Bill Spurlock, RPT, by March 1, 1995.

Nominations should be sent to: Bill Spurlock, 3574 Cantelow Road, Vacaville, CA, 95688. According to PTG's Bylaws, "Any chapter may submit a nomination. Any member in good standing may offer his or her name for consideration."

WOULD YOU GO A MILE FOR A MEETING? HOW ABOUT 2,445?

We had our state PTG meeting last Sunday. As you may know, we all travel quite long distances for our meetings. Other than those who live in Helena where we meet, I am one of the closer ones. I travel 95 miles one way. One of our members travels 400 miles one way and usually makes every other meeting. We also had a new member join as an associate. Her name is Julie Dunn from Culbertson, Montana. She travels 465 miles one way! I don't know if she will attend regularly, but I get the impression she will attend most times.

We had 15 (14 members and one guest) attend our last meeting. Our total membership is 23. The mileage traveled one way for this meeting totaled 2,445 miles! That's an average of 163 miles one way per person. Those elsewhere in the country that say it is too far to travel for meetings don't know what they are talking about.

The mileage breakdown per person is as follows:

0, 65, 85, 90, 90, 90, 95, 95, 120, 200, 205, 220, 225, 400, 465

What fun! And what's more, we always have good attendance at our meetings!

Ward Guthrie, RPT
Bozeman, MT

EVENTS CALENDAR

All seminars, conferences, conventions and events listed here are approved PTG activities.

Chapters and regions wishing to have their function listed must complete a seminar request form. To obtain one of these forms, contact PTG Home Office or your Regional Vice President.

Once approval is given and your request form reaches Home Office, your event will be listed through the month in which it is to take place.

Deadline to be included in the Events Calendar is at least 45 days before the publication date, however, once the request is approved, it will automatically be included in the next available issue.

January 6-7
Arizona State Convention
Arizona State University
Contact: Rick Florence
602-965-6760
602-926-4328

February 17-19
California State Convention
Torrance Marriott Hotel
Contact: Teri Meredyth
1666 W. 126th Street
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310-326-6447

March 21-23
Pacific Northwest Conference
Vancouver, B.C.
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Vancouver, B.C. V6P 2R4
604-321-7357

March 30 - April 2
Pennsylvania State Convention
Ramada Inn-Wilkes-Barre, PA
Contact: Earl Orcutt,
141 Fort Street
Forty Fort, PA 18704
717-287-0940

April 21-23
Florida State Seminar
Orlando, FL
Contact: Robert Carr
320 West Rich Avenue
Deland, FL 32720-4120
904-736-0551

April 27-30
NEECSO
White River Junction, VT
Contact: Ed Hilbert
40 Pleasant Street
Bristol, VT 05443

May 5-7
Central West Regional
St. Louis, Mo
Contact: Wim Blees
515 Poplar
Webster Groves, MO 63119
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July 19-23
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Contact: PTG Home Office
816-753-7747

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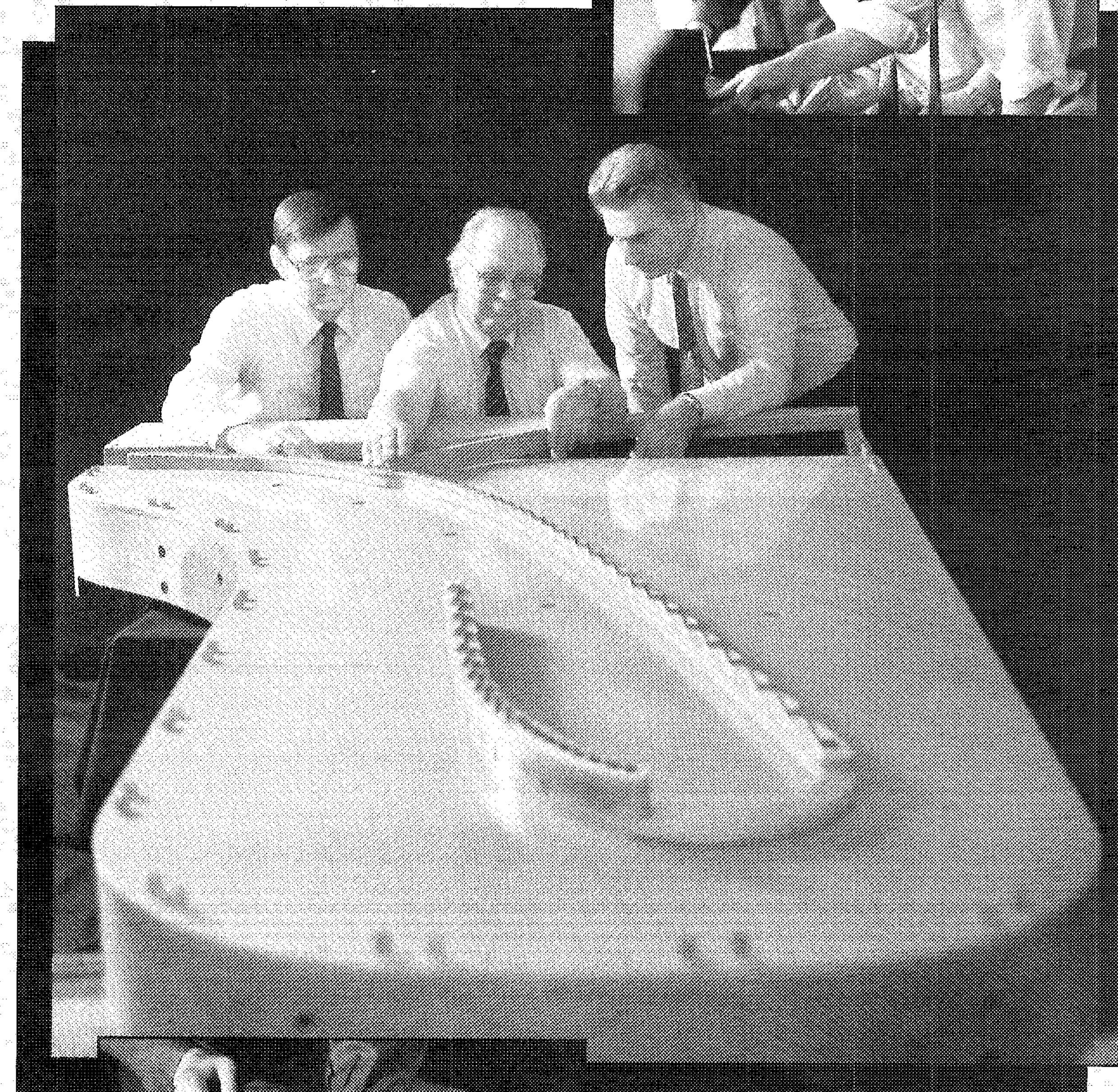

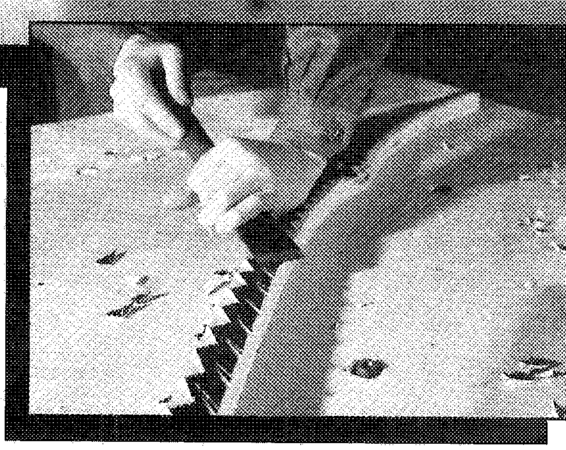

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PTG Foundation
Mission Statement

"The Piano Technicians Guild Foundation is formed to support the goals of PTG by preserving and displaying historical materials and providing scholarships and grants for piano performance, study and research."

Dear Fellow PTG Member:

Each individual member of the Piano Technicians Guild is very important to this organization. We pride ourselves on dedication, loyalty, trust, ethics, and a bond of friendship with others in our chapter, our region and around the world.

The PTG Foundation's mission statement is a common objective that we can all support. That's why, on behalf of the officers and directors of the Piano Technicians Guild Foundation, I'm asking each PTG member to consider bequeathing his or her PTG death benefit to the Foundation. A brochure that is included with your invoice for 1995 PTG dues explains how you can plan now to make sure this important work continues for future generations, or you can simply contact the Home Office for a new beneficiary card. A special certificate and acknowledgement to your family will be presented in their honor on behalf of the Foundation.

Please join me as a member of this new team of Foundation benefactors by taking a moment to complete this important task.

Roger H. Weisensteiner, RPT
President, PTG Foundation

AUXILIARY
E X C H A N G E

Dedicated To Auxiliary News and Interests

The Holiday Season Is Upon Us

December is an exciting month. The holiday season is upon us. Snow covers most of the countryside. Shopping, visiting and consuming large quantities of food are all part of the season's agenda. Family membership and fellowship reach the apex of the year. I sincerely hope that your holiday season is the merriest ever. Then comes the new year...a time for a fresh start and new beginning.

By now our scholarship store should be doing quite well, thanks to your efforts. I ask that you continue your efforts and support the Piano Technicians Guild Auxiliary's Scholarship Store. The proceeds from the store, as you know, go to support our scholarship effort in the piano teaching industry. We very much want to expand that effort to at least five states per year, and hopefully more.

I also want to remind you to keep the pressure on the school boards in your district to fully fund the music education programs. This is a very important part of our effort, and I sincerely appreciate your involvement.

Lastly, I would like to remind you to write the regional vice president in your area and ask them to vote in favor of Auxiliary attendance at appropriate convention classes when they meet in January. As Ginger Bryant points out, approximately 90% of the families involved in the piano business are "Ma and Pa" operations, where both the husband and wife are involved in the business. It would be very beneficial to the majority of the membership to be able to expand their business education while their spouses expand on their piano tuning capabilities. It is for the good of all that I am asking you to give your best effort to help this become a reality by writing to your regional vice president. Please do it now while you are thinking about it.

Paul Cook, Auxiliary President

In Loving Memory

After a long and valiant struggle with heart disease, Ginny Russell died on November 1, 1994 (All Saints Day).

She was the widow of Bob Russell, Sr., who died February 10, 1988, and is survived by their five children, Candy, Bob Jr., Mike, Bill, Diane and three grandsons.

Next to family, music was the most important part of Ginny's life. She had more than 30 piano students, played regularly in a nursing home to entertain the residents and was found at a piano sometime during every seminar and convention.

Ginny loved life and she loved people. Every time she went to a PTG function she sought out new faces and would introduce herself. That is how I met her. We attended our first seminar in October of 1968 in Cleveland. I cautiously approached the door of the hospitality suite and this bubbly lady came right up to me and said, "Hi, I'm Ginny Russell. I don't believe I know you yet." That was the beginning of a wonderful friendship.

Another seminar — another opportunity to make a new friend. That was Ginny's motto.

She was an active member of the Cleveland Chapter Auxiliary and served on the International Auxiliary board as Treasurer, Recording Secretary, 1st Vice President, President, Immediate Past President and was an Honorary Life Member.

I believe she held the #1 salesperson position in PTGA. If you own an auxiliary cookbook or sun catcher, the chances are good that you bought it from Ginny.

Ginny was ready to move along to another life, and that makes it easier to say goodbye. She will always be loved, and never forgotten by those of us she called friend.

—*Celia Bittinger*

Ginny Russell

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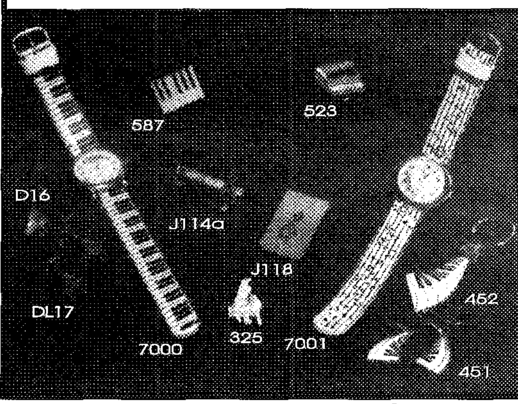

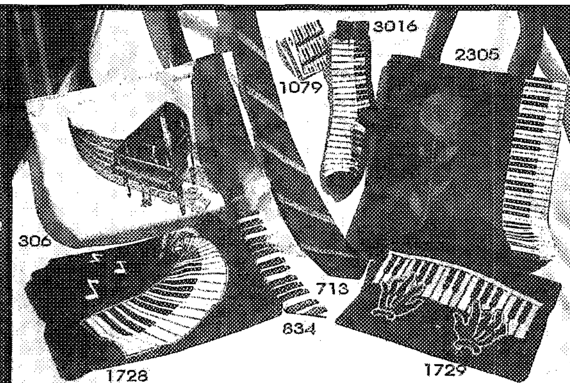

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CLASSIFIED ADS WORK! Your products or services ad will reach over 4,000 piano service industry professionals each month. To place a classified ad in the next Journal, contact PTG Home Office at 816-753-7747. The deadline to be included in the February issue of the Journal is December 15, 1994. Call today for details.

VIDEOS

WANTED

Statement of Ownership. **1. Publication Title:** Piano Technicians Journal. **2. Publication No.:** 0031-9562. **3. Filing Date:** 10/10/94. **4. Issue Frequency:** Monthly. **5. No. of Issues Published Annually:** 12. **6. Annual Subscription Price:** $85.00. **7. Complete Mailing Address of Known Office of Publication (Street, City, County, State, Zip+4)(Not Printer):** The Piano Technicians Guild, 3930 Washington, Kansas City, MO 64111-2963. **8. Complete Mailing Address of Headquarters of General Business Office of Publisher (Not Printer):** The Piano Technicians Guild, 3930 Washington, Kansas City, MO 64111-2963. **9. Full Names and Complete Mailing Address of Publisher, Editor and Managing Editor (Do Not Leave Blank):** Publisher, Larry Goldsmith, The Piano Technicians Guild, 3930 Washington, Kansas City, MO 64111-2963; Managing Editor, Jami Henry, Piano Technicians Guild, 3930 Washington, Kansas City, MO 64111-2963. **10. Owner:** The Piano Technicians Guild, 3930 Washington, Kansas City, MO 64111-2963. **11. Know Bondholders, Mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities:** None. **12. For completion of nonprofit organizations authorized to mail at special rates. The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:** Has not changed during Preceding 12 months. **13. Publication Name:** Piano Technicians Journal. **14. Issue Date for Circulation Data below:** September 94.

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b. Paid and/or requested circulation		
1) Sales through dealers, vendors	0	0
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c. Total paid and/or requested circulation	3,914	3,973
d. Free distribution by mail	31	31
e. Free distribution outside by mail	0	0
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g. Total distribution	3,945	4,004
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1. Office use, leftovers, spoiled	419	326
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16. This statement of ownership will be printed in the: December 1994 issue of this publication. **17. Signed by:** Larry Goldsmith, Publisher, 10/10/94

DISPLAY AD INDEX

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PianoDiscussions™

December 1994

News From The World Of PianoDisc

Tech training is better than ever

Starting this year PianoDisc has added a day to the PianoDisc Installation Training Seminar. This addition was prompted by a number of our most recent innovations , including a new individual note detail calibration method recently introduced in our newest software version. "Technicians will now have the ability to satisfy even the most demanding customer's desires," says Tom Lagomarsino, Vice President of Marketing. "Installers will be impressed by this new feature's flexibility. Now more than ever, PianoDisc training is becoming a valuable addition to a piano technician's skills."

Fact is, PianoDisc installation skills have opened up income possibilities for technicians across the country. Technicians skilled in the installation and maintenance of PianoDisc systems routinely report that they are having great success in their practices, with barely enough time to count their profits. And with PianoDisc's enormous growth just in the last year alone opportunities exist for even more technicians in many areas of the country.

So if you've thought about coming out to Sacramento, then think again, and harder. Our classes are taught right in our factory, right next to the recording studios where famous artists like Floyd Cramer and Peter Nero have recorded (in fact, last October's class actually met Peter Nero, who stopped in for a visit). The classes and lunches are FREE, the instruction first rate, and the knowledge you gain could profit you $$$. So call and reserve your class space TODAY!

PianoDisc Installation Training

- January 24-28
- February 21-25
- March 21-25
- April 19-23
- May 10-13
- June 20-24

Continuing Education Series

- May 4-5
- June 15–16

*Tuition for the Installation and the Continuing Education seminars is **free**, but a $50.00 refundable deposit is required for confirmation. The PianoDisc Continuing Education Series seminars are restricted to PianoDisc certified technicians in good standing. For more information about attending a PianoDisc Installation Training seminar or a Continuing Education seminar, call PianoDisc at (916) 567-9999 during regular office hours.*

PianoDisc
4111 North Freeway Blvd.
Sacramento, CA 95834
Phone: (916) 567-9999
Fax: (916) 567-1941

Tech Support: (619) 258-1460
(916) 567-9999

Our telephone lines are open daily (except week ends and holidays) from 8 AM–5 PM Pacific Time.

Save some $$$!!

A hot travel tip for you techs that are booking airline reservations to attend a PianoDisc seminar: **try to include a Saturday overnight stay in your itinerary.** The difference that this can make in your airfare could be as much as a 70% reduction in cost! For example, in a call to United Airlines we found that a round trip from Chicago to Sacramento booked a month in advance would cost $1300, but that a Saturday night stay would reduce the fare to as little as **$398!!**

So, if you're planning to attend the PianoDisc Installation Training course, try to stay an extra day or two and leave on the following Sunday or Monday. If you're thinking about the Continuing Education seminar, you're in luck - the airlines reserve their rock bottom fares for folks who fly on Saturday, Tuesday and Wednesday. So, just plan to fly in on the Wednesday prior to your class, enjoy Saturday in beautiful Sacramento, and fly out the following Sunday. You'll get a great class, and save a bundle to boot!

Steinway Artist Judy Carmichael records diskette for PianoDisc

Noted New York jazz pianist Judy Carmichael stopped by PianoDisc for a quick record session recently and left us with an Artist Series PianoDiskette worth remembering. She's so proud of it she even mentions it in her ad (above) in the Dec. 5th issue of the New Yorker.

Judy's early jazz stylings are often mentioned in the New Yorker, which gave her the ultimate compliment when, in making a passing reference to the legendary jazz composer Hoagy Carmichael, they added the parenthetical clarification "No relation to Judy." Not bad for a girl...

Her new PianoDiskette is available this month.

Happy Holidays from your PianoDisc Family!

Happy Holidays

from your friends

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