SANDERSON
ACCU-TUNER™
OPERATING MANUAL

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Table of Contents

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INTRODUCTION

The Sanderson Accu-Tuner ™ (SAT) and Sanderson Accu-Tuner II ™ continue to be the world's first and finest programmable computer-controlled tuning instruments. They are designed to aid the professional tuner-technician to achieve outstanding tuning results without spending an exorbitant amount of time doing so. Aural piano tuners can "memorize" their finest tunings. The Sanderson Accu-Tuner stores the cents deviation as a tuning program in its memory and recreates the settings on subsequent tunings automatically. This saves a substantial amount of time without sacrificing accuracy.

The built-in FAC Stretch Calculator feature automatically programs the Accu-Tuner to give a complete 88-note custom-stretch tuning. All operations of the SAT are controlled from the sealed membrane keyboard telling the computer which functions to perform. Push the CENTS up button to raise the pitch; press the CENTS down button to lower the pitch. Similarly, to go up a semitone, press NOTE up, or to go down an octave, press OCTAVE down. The present pitch settings are always indicated on the pair of LCD (liquid-crystal display) windows as NOTE/OCTAVE and CENTS. Fig. 1 shows the SAT set for the note A in the fourth octave, 0.0 cents.

Fig. 1. Sanderson Accu-Tuner II ™.

The pitch difference between the SAT and the note being tuned is displayed by the circle of LEDs (light emitting diodes) on the upper panel. Notes that are in tune with the pitch setting create a stationary pattern. Two to five lights may be on, but the important factor is that the pattern is stationary. Notes that are sharp create a light pattern that rotates clockwise, flat notes create a pattern that rotates counter-clockwise. The center LED flashes when the note is sharp, and is not lit when the note is flat--this is very helpful when the pattern is rotating too fast to determine the direction of rotation.

Tuning with the SAT can be thought of as a two step process:

1. Determining the correct settings for each note of a given instrument.
2. Tuning each note of the instrument to stop the lights of the LED display.

Once the SAT is mastered the investment will be well worth it in time and labor saved on each job along with increased pleasure in the tuning profession. The SAT will help take the drudgery out of tuning yet leave the artistry intact. This is the first and only tuning instrument designed and built by a professional tuner for professional tuners.

GETTING STARTED

When first turned on the Sanderson Accu-Tuner will be in the calibration mode or at the exact location where the unit previously "timed out". The SAT checks itself for accuracy during calibration. Two to five lights may be lit and any rotation shows the variation from A-440. The SAT will also automatically shut itself off or "time out" to conserve battery power if not used for ten minutes. The same settings it had when it turned itself off will appear when the unit is restarted.

The SAT will be fully charged when received. The Nickel Cadmium (NiCad) battery requires charging only once to twice weekly. This battery is tolerant of deep discharge.

LOW-BATTERY WARNING SIGNAL

A low battery warning signal will appear as "LO-BAT" in the display windows when battery energy is getting low. This indicates that there is approximately one half hour of operating time left. If the unit continues to be used, the SAT will automatically turn off when the battery is fully discharged. If this happens in the middle of a tuning, the SAT will continue to operate with the battery charger plugged into an AC outlet. A fully discharged NiCad battery will take approximately 12 hours to recharge.

CALIBRATION

The 440 Hz crystal oscillator verifies calibration on the LED display when the SAT is turned on in the CAL mode. If the display is stationary, the instrument is in perfect calibration. If the pattern is rotating, use the cents buttons to slow the pattern down until the display rotates as slowly as possible. When you press the TUNE button the calibration setting will be stored to memory and the display will respond to external tones rather than its internal CAL signal.

THE FOUR MODES OF OPERATION

The Sanderson Accu-Tuner has four different modes of operation:
1. The TUNE mode.
2. The MEASURE mode.
3. The FAC (stretch mode).
4. The MEMORY mode.

Each mode is entered by pressing the appropriate button or sequence of buttons on the keyboard, which is shown in figure 2.

Fig. 2. Keyboard of the Accu-Tuner II ™.

NOTE: For the moment, disregard the shift functions. Each will be explained below according to specific tuning application.

1. The TUNE mode works like most conventional tuning instruments already available. Only the six white buttons in the center of the keyboard are used, and they control the note, octave, and cents deviation to which the SAT is set. The TUNE mode is the best place to start learning to use the SAT keyboard.

2. The MSR (measure) button puts the SAT into the MEASURE mode as long as it is held down. In this mode the computer automatically stops the LEDs. Hold the MSR button down while the lights slow down and stop. When you release the button the cents reading indicates the cents deviation of the unknown pitch.

3. The FAC mode uses three measurements called stretch numbers to create an excellent tuning. This tuning is a complete 88 note stretch tuning from A0 to C8. The three stretch numbers are quick and easy to measure, they are based on the inharmonicity of the notes F3, A4, and C6.

4. The MEMORY mode enables a tuner to store and retrieve complete 88-note tunings. The number of pianos that each SAT can store depends upon the number of pages added in memory when it is purchased. The SAT II comes with 60 pages of memory, while the SAT is standard with 40. Additional pages can be added for a maximum of up to 206 pianos in either unit. This feature is ideal for pianos that are tuned often. Retuning a piano that is in memory consists of simply restoring each note to the pitch where the piano was previously tuned, and then verifying it aurally.

Storing a finished piano tuning to memory will take a few minutes, but the SAT will be able to recreate the same tuning quickly on the next tuning. Tuning two or more pianos for a concert with the MEMORY mode is as easy as tuning them separately and individually. No longer is it necessary to have the pianos side-by-side, or even in the same room during the tuning.

THE TUNE MODE

Immediately after pressing the TUNE button to exit from the CALIBRATION mode, the displays will appear as shown in Fig. 3.

Fig. 3. SAT display after pressing TUNE.

The NOTE/OCTAVE display shows A4 indicating that the SAT is set to A in the 4th octave. (Start counting the first A on the keyboard as A0, not A1. The first C is C1.) The cents display shows 0.0 to indicate that the cents deviation is zero. So the SAT is ready to tune the note A in the 4th octave at 440 Hz.

When ready to change the pitch settings from A4, zero cents, use the set of white buttons in the center of the SAT keyboard. To go up in the note setting, press the NOTE up button (top row). Watch the display until it steps to the desired note, then release the button. The sharps are indicated with a small square box in the top half of the display. Also, the display uses a "b" for a "B" and "d" for "D".

Stepping the NOTE display down is accomplished by depressing the NOTE down button until you reach the desired note. The OCT up and OCT down buttons work the same as the NOTE up and NOTE down buttons, stepping off the octaves to get to the desired setting. The SAT will not step beyond its mode ranges which are as follows:

1. C1 to B9 in the TUNE mode.
2. A0 to C8 in the FAC mode. (C3 to F6 in old stretch mode)
3. A0 to C8 in the MEMORY mode.

The CENTS buttons step differently from the other white buttons. The CENTS buttons step up or down slowly at first to step just 0.1 cent and accelerate as the button is held down.

To cover a large number of cents quickly, hold down the CENTS button and watch the display as the cents change. When the correct tens digit appears, release the CENTS button. Then hold the button down again until the correct single digit appears and release. Repeat this procedure for the tenths digit.

With these six buttons, the SAT does everything that previous tuning instruments have been able to do. Once familiar with its operation in the TUNE mode, you can expand into more intricate modes of operation. If you get into an area of operation that you don't understand, just press the TUNE button twice to quickly get back on track.

THE FAC MODE

Once the operation of the SAT in the TUNE mode is mastered, it is easier to understand the operation of the FAC mode. In this mode, the SAT follows a tuning program that is derived from the measurement of three stretch numbers (F3, A4, and C6) on the piano being tuned. This program, known as FAC, includes both an optimum partial selection and a calculated cents setting for all 88 notes on the piano. Once the stretch numbers are measured and stored in the SAT, the rest of the job is automatic. Every time the note or octave changes, the computer references the calculated tuning, then sets the SAT up correctly for the new note.

In the FAC mode the NOTE/OCTAVE display shows the note on the piano that is being tuned, while the CENTS display shows the cents deviation of the particular partial being tuned. The note and octave of the partial that the SAT is listening to (first, second, fourth, or sixth) does not show on the display. To view the partial, press the TUNE button to see the selected partial, but don't forget to switch back to the page in memory by pressing the MEM button before going on to the next note, otherwise the SAT will continue in the TUNE mode.

The pitch of the stored tuning can be at standard 440 pitch, or you may add or subtract a pitch correction to obtain stored tunings at other pitches such as 442 (eight cents sharp), early pitch (one semitone flat), or any pitch up to 100 cents flat or sharp.

The FAC tunings are designed to fit the piano better than the old F4 stretch-number tunings, and therefore sound better over the mid-range section as well as providing you with a beautiful bass and treble tuning. The high treble is tuned in double octaves, which will please many tuners, and those who prefer a less stretched tuning in the treble can easily modify the last few notes to suit your own taste.

MEASURING AND STORING THE THREE STRETCH NUMBERS

1. Set the SAT to F5, zero cents in the TUNE mode. Play and tune one string of F3 to stop the lights.

2. Go up one octave on the SAT to F6, play the note F3 again, and this time use the CENTS buttons to stop the lights. The CENTS window now displays the F3 stretch number, the difference between the fourth and eighth partials of F3.

3. Hold the SHIFT button down, press STO-STRETCH, release STO-STRETCH, then release the SHIFT button last. After this operation, the SAT will jump automatically to the correct settings for the next measurement, A5 and zero cents.

4. With the SAT at A5 and zero cents, tune one string of A4 to stop the lights. Now go up one octave on the SAT to A6, play A4 again, and stop the lights with the CENTS buttons. The CENTS window now reads the A4 stretch number, the difference between the second and fourth partials of A4.

5. Store the A4 stretch number by holding SHIFT and pressing STO-STRETCH as above. After this, the SAT will automatically go to the correct settings for the next measurement, C6 and zero cents.

6. With the SAT at C6 and zero cents, tune one string of C6 to stop the lights. Step up one octave on the SAT to C7, and stop the lights with the CENTS buttons. The CENTS window now reads the C6 stretch number, the difference between the first and second partials of C6. Store the C6 stretch number by holding the SHIFT button and pressing the STO-STRETCH button.

7. Now you have stored all three FAC stretch numbers and are ready to calculate and store the FAC tuning onto a page in piano memory. The FAC tuning cannot be used until it is stored, so if you really do not need a permanent record of this tuning, store it on page one, for example, and use page one for all your one-time tunings. Hold down SHIFT, and use the PAGE buttons to select the page in piano memory that will hold this tuning.

8. To move the FAC tuning into memory, roll over from the STRETCH button to the MEM button. "Roll over" means to hold down the first button, STRETCH, and without releasing it hold down the second button, MEM, as well, release the STRETCH button, and release the MEM button last. The order of holding down and the order of releasing the buttons are both essential. If you do this correctly, the SAT will act stunned. Nothing will happen for ten seconds while the SAT calculates the FAC tuning and stores it on the selected page. The SAT comes back to life by jumping to the first note of an FAC tuning, A0, and displaying the page number in the CENTS window.

9. If you want to store the serial number of the piano to identify the tuning permanently, now is the time to do it. Go down two NOTE steps below A0 and the left window will indicate SEr for serial number. Use the cents buttons to set the right window to the first three (of six maximum storable) digits of the serial number. Hold down the SHIFT button and press the STO-MEM button to store these digits, and then change the right window to the last three digits of the serial number. Store them in the same way, (by holding SHIFT and pressing STO-MEM).

10. You may start tuning at A0 now, just press NOTE up and NOTE down once to make the SAT look up the note settings for A0 in memory. To start at any other note, just proceed to that note with the NOTE and OCTAVE buttons.

REVIEWING THE FAC NUMBERS

To review your FAC numbers, hold down the STRETCH button. While the STRETCH button is held, the left window will show the note F3 and the right window will show the F3 stretch number. Release the STRETCH button and hold it again to view the A4 stretch number. Release and hold the STRETCH button again for the C6 stretch number. After reviewing the stretch numbers you will have to press the MEM button to get back to the FAC tuning and out of the old stretch tuing range of C3 to F6.

It is be a good idea to write down these FAC numbers if you want to refer to them at a later date. Once the SAT is turned off the FAC numbers can no longer be recalled using the STRETCH button.

NOTE: Some tuners have reported that the stretch numbers tend to drift lower as a piano is tuned repeatedly to the same tuning.

Some customers have expressed a preference for starting with the A-4 measurement vs. the sequence described above. As long as you have the correct partials set up on the SAT, you can start with any of the three F-A-C notes.

The FAC numbers are automatically inserted into the header that is part of the tuning record of each piano. If you have an SAT II and the Piano Librarian program, you can view the FAC numbers. The format of the header is as follows:

001________________________________10.2 8.8 7.9 FAC 000000

IF NOTHING HAPPENS

Suppose you try to store a stretch number and nothing happens? This can be disconcerting, but the problem is usually very simple to solve. The SAT is very fussy about being on the correct note when it stores a stretch number. You must have the SAT on F6 in the TUNE mode (by pressing the TUNE button) to store an F3 stretch number, and if you are not, nothing at all will happen. To store an A4 stretch number you must be on A6, and to store a C6 stretch number you must be on C7. In other words you must be on the correct note in order to store a stretch number. This requirement reduces the possibilities for errors.

The other situation when nothing happens is if you try to transfer an FAC tuning to page zero in memory. Simply select a valid page in memory (SHIFT and PAGE up) and repeat the STRETCH rollover to MEM procedure.

OFFSETTING AN FAC TUNING TO NON-STANDARD PITCH

Tuning and pitch-raising a piano to non-standard pitch is very easy with the FAC program. Prepare the SAT with the RESET feature to get the SAT offset to the required pitch. For instance, to tune at 442 put 8.0 cents into the CENTS window and then hold down SHIFT and press RST. The CENTS window is reset to zero cents, and the 8.0 cents is stored as a pitch offset. The plus sign in the left window indicates this offset on the sharp side. Any pitch up to a semitone sharp or flat can be used as a pitch offset this way.

Now that the pitch offset is stored, take your FAC measurements as usual. When the tuning is created, the offset will be included in the stored number for each note, and the plus or minus sign will no longer be in the display.

AVERAGING STRETCH NUMBERS FOR HIGHER ACCURACY

The above procedure applies to one open string on each note. For greater accuracy, you may take the measurement on each string of a note individually and average the results. If one of the strings disagrees badly (more than two or three cents) with the others, throw out this reading before averaging.

"GOOD" FAC NUMBERS

You can tell a lot about a piano and its scale design from the FAC stretch numbers. The three numbers should be reasonably close to each other and lie in a reasonably straight line for the best results. For example, FAC numbers such as 10, 9, 8 or 5, 6, 7, or 8, 8, 8 represent well-scaled pianos. The lower the numbers, the lower the inharmonicity, so spinets tend to have higher stretch numbers than grand pianos.

The FAC method, or any other method, cannot produce perfectly progressing beat rates on a piano with widely scattered amounts of inharmonicity. The FAC tuning will be as good as one can expect or can achieve by any method given the scale-design problems inherent in the piano itself. Aural touch up might improve the tuning depending upon where the scale problems occur and the severity of the problems.

FAC TUNING FROM A0 TO C8

After the stretch numbers have been stored and the tuning created, you are ready to tune. Press the NOTE up once to have the Accu-Tuner look up the settings for the tuning or use the NOTE and OCTAVE buttons to step to where you would like to start tuning. For each semitone advanced the SAT will automatically change to show the next note to be tuned and its cents deviation. Continue stepping and tuning this way for the entire tuning.

When using a tuning from memory you will notice that A4 is not tuned to 0.0 cents as you might assume. The reason for this is that while the Accu-Tuner is tuning the note A4 on the piano, it is listening to the pitch of A6 (the fourth partial of A4). Also you might notice that the cents deviation jumps lower four times when tuning the piano, this is where the partial the Accu-Tuner is set for changes. The partials change between the note B and C of the next octave. The partial that the Accu-Tuner is listening to is shown in the chart below:

Octave on Piano	Partial Number	Example
1	6	Tuning A1: listening to E4
2	6	Tuning A2: listening to E5
3	4	Tuning A3: listening to A5
4	4	Tuning A4: listening to A6
5	2	Tuning A5: listening to A6
6	1	Tuning A6: listening to A6
7	1	Tuning A7:listening to A7

UNISON TUNING

Unisons may be tuned aurally along with a stretch tuning of the center string, or each string may be tuned individually to the SAT and the unisons checked later on. The SAT will do an excellent job of tuning unisons when the strings of a given note are well matched. (They are on most notes.) The fact that some strings are mismatched makes it extremely important for the tuner to check all unisons aurally when they have been tuned with the SAT. However, do not try to check the unisons aurally during the course of a stretch tuning if there is more than a few cents pitch raise or drop involved. Pulling up adjacent strings affects the pitch of already tuned strings. The settling process on a string is not complete until another octave or so has been tuned.

Aural unison tuners should be aware that pulling in two outside strings to the tuned center string will affect the pitch of the center string. The amount is roughly equal to one-fifth of the net pitch change. As a result, when there is more than a few cents pitch change involved, tuning unisons aurally as you go can actually leave them out of tune in the end! To avoid getting into this situation, give the piano a quick pitch raising (or lowering) before trying to do a fine tuning. If the piano is more than five to ten cents flat, it will actually save time to do a quick pitch raise before attempting to fine-tune the piano.

THE MEASURE MODE

The MSR (measure) button makes it easy to measure an unknown pitch. If the lights are spinning around, the display can be stopped by pressing the CENTS buttons; however, the MSR button will do this job for you. Simply hold down MSR and wait for the LEDs to slow their rotation. Release the MSR button; the cents display will indicate the unknown pitch to an accuracy of one cent. After releasing the MSR button, the display may still be rotating slowly. For the quickest and most accurate results, go to within a few tenths of a cent with the MSR button, and then fine tune with the CENTS buttons.

THE MEMORY MODE

The SAT is not restricted to storing or tuning only on the fundamental pitch or a specified partial of each note. The choice is left to the tuner. This flexibility is necessary to tune all types and kinds of pianos which vary widely in the strength and audibility of their various partials.

The complete list of storable pitches relative to a given played note is as follows:

Fourth below

Semitone below
Fundamental, or first partial, i.e., the note itself
Octave above less one semitone
Octave above, or second partial
Double-octave less one semitone
Double-octave, or fourth partial
Seventeenth, or octave tenth, or fifth partial
Nineteenth, or double-octave fifth, or sixth partial
Double-octave diminished seventh, or seventh partial
Triple-octave, or eighth partial
Triple-octave second, or ninth partial
Triple-octave major third, or tenth partial
Triple-octave fifth, or twelfth partial
Triple-octave diminished seventh, or fourteenth partial

This list includes all partials from one to ten, plus the twelfth and fourteenth; one semitone low for the first, second and fourth partials; and one subharmonic, the fourth below. This set is complete with all the notes necessary for tuning pianos at pitch or below pitch, as well as pipe organs with mixture stops. Early musical instruments can be stored one semitone low (A=415 Hz by two methods:

1. Exactly with an offset of -101.3 cents.
2. Approximately with notes stored one semitone low (on the first, second, or fourth partials.)

In general, tuning is far more accurate when done on the higher partials, specifically the partials used by aural tuners. These vary from bass to treble with the highest partials preferable in low bass, and the fundamental preferable in the high treble.

The tuning of a particular piano can be stored either from a written record of a tuning, or from the piano itself during the tuning or immediately after completing a tuning. The SAT will be ready to repeat the correct settings from memory for you, whenever you are ready to tune that piano again. Just go to the correct page (hold down the SHIFT button and press PAGE to select the correct piano) and start to tune. Going from one note to the next is as easy as pressing the NOTE up button once, or use the foot switch.

RANGE OF MEMORY MODE

The range of notes covered in the MEM mode is different from that of both other modes. It includes just the 88 notes on a standard piano, known to the SAT as A0 through C8. Notice that although the three notes in octave zero can be stored in memory, they must be tuned to a partial other than the fundamental since the lowest note in TUNE mode is C1.

NOTE: It is better practice to refrain from tuning bass notes on the fundamental anyway.

TUNING FROM MEMORY

Assume there is a complete tuning of a piano stored on a page of memory. To use this tuning, turn on the SAT, press the TUNE button, hold SHIFT down and use the PAGE buttons to step to the page number assigned to this piano. (It is not necessary to press MEM because selecting a page automatically puts the SAT into the MEMORY mode). Releasing the SHIFT button sets the SAT at A0. To start tuning with the first note, go up one note and then back down to have the SAT look up the correct settings. To start elsewhere, step up to the desired starting note and begin tuning.

When ready to tune the next note, just press NOTE up or down, and tune away. The notes can be tuned in any sequence, up, down, or by octaves, and the previously stored values for the selected notes will appear. The fastest way to tune is with the foot switch or thumb switch since it leaves both hands free for tuning and you don't have to touch the SAT.

The display in MEM mode shows the note being tuned, and the cents deviation of the partial. To check the page number, press the MEM button. To check the partial you are tuning, press the TUNE button and read the note corresponding to the pitch of the partial in the left display. (Note: Always remember to go back to the MEM mode by pressing the MEM button after this check or the SAT will be left in the TUNE mode.)

PITCH RAISING

The Sanderson Accu-Tuner is able to automatically calculate the overpull or anticipated drop of a given note during the course of a pitch raising. The SAT measures the unknown pitch first, then compares it with the corresponding note of the tuning on the page in memory, and then calculates a pitch-raise correction.

The pitch-raise calculator is designed to be used with a tuning in memory in order to pitch raise the entire piano to a realistic piano-tuning curve. Choose a page in memory with a piano similar to the one to be pitch raised or measure and store an FAC tuning. The pitch-raise calculator offsets the SAT the number of cents necessary to pitch raise the piano to the stored tuning (not just to the zero-cents line).

To access a page of memory, turn the SAT on, press the TUNE button, hold down the SHIFT button, and press PAGE up or down to access the correct page.

Let's start at A0, so after selecting the correct page, press NOTE up, then NOTE down. To use the pitch raise calculator, hold the MEASURE button down while striking A0 until the lights stop (or nearly stop). Continue to hold the MEASURE button down and press (roll over to) the SHIFT button, then release MEASURE, then release SHIFT. The SAT automatically offsets itself by one-quarter of the measured flatness. (For Example, a flatness of 40 cents will automatically result in an offset value of 10 cents sharp). Tune with the calculated offset for an octave or so, then repeat the measurement on the next untuned note to get a new pitch-raise correction. The correction changes quite slowly on a normal piano, and needs to be recalculated five or six times to cover the entire keyboard.

The pitch correction factor of one-quarter is designed to work with the "unisons-as-you-go" method of pitch raising. One quarter may be a little too much in the bass, and not quite enough in the high treble, but the error involved is never more than a few cents. You can modify the number given by the SAT if you wish. If the SAT calculates 10 cents, but you think 8 cents is better, just enter -2 cents and store this offset (Hold SHIFT and press RST button). The net offset will be 8 cents. Usually it will not be worth the trouble to try to outguess the pitch-raise calculator.

With the "unisons-last" method of pitch raising, the calculated correction will be a little light in the plain-wire section. Whatever the calculator gives for a correction on the plain wires, add one-third more to it. For example, if the calculator indicates 15 cents offset, add 5 to that for a net offset of 20 cents. A word of caution about overpulling too much in the treble as you could be close to the breaking point of a string.

Pitch lowering is just the reverse of pitch raising (to a piano), and the program works just as well for lowering pitch as for raising it. Just follow the above procedure, no changes have to be made.

THE RESET BUTTON

The Reset Button has four major functions:

1. Resetting to Non-Standard Pitch.
2. Perfecting the A-440 of a Stretch Tuning.
3. Displaying the Cents Offset.
4. Measuring the Width of Musical Intervals.

1. Resetting to Non-Standard Pitch:
The RST (reset) button is used to reset the cents display to zero without actually changing the pitch of the instrument itself. This is very useful in several ways. The first is setting the SAT to a non-standard pitch. For instance, to tune an instrument to A at 442 Hz, which is 8.0 cents sharp, turn the SAT on and then press the TUNE button, then step the CENTS display up to 8.0 cents as shown in Fig. 4.

Fig. 4. SAT just before offsetting pitch.

Now hold the SHIFT button down and press the RST button. The display will jump to zero cents as shown in Fig. 5, but will actually be at 442 Hz (8.0 cents sharp). Now your tuning can proceed exactly as it would normally, except the tuning will end up at 442 Hz. (This assumes your stored tuning is at 440 Hz.)

Fig. 5. Display with non-standard pitch warning.

It is also possible to tune off-pitch by accident. To help prevent this from happening, a plus sign appears in the NOTE/OCTAVE display window as shown in Fig. 5. Whenever the instrument is offset to the sharp side, a plus sign will appear. When the SAT is offset to the flat side, a minus sign will appear.

2. Perfecting the A-440 of Stretch Tuning:
A second use for the reset feature is to get the stretch tuning (see previous section on FAC) exactly on pitch at A-440. Pianos are rarely perfect, and the FAC stretch tuning uses the fourth partial of A4 (A6) to tune. This is where a slight error can occur. Sometimes the fundamental of A4 ends up as much as one-half of a cent off. If you need to correct this problem use the following procedure.

A. Measure the stretch numbers of the piano.
B. Store the FAC numbers to a page in memory, go straight to A4 and tune all three strings.
C. Switch to the TUNE mode by pressing the TUNE button.
D. Press OCTAVE down twice, set the cents deviation to zero, and the display should read A4 0.0
E. Play A4 on the piano.
F. If the note is right on pitch, simply switch back to the page in memory where the tuning is located. (Press MEM button, then NOTE up button). Tune the piano.
G. If the note is unacceptable, measure the pitch error with respect to A-440, and follow the instructions below.

For example: Let's assume it is 0.2 cents sharp. Store an offset that will counteract the error, namely 0.2 cents flat. Do this by putting -0.2 in the cents window, holding the SHIFT button down and pressing the RST button. Now you can return to the page in memory, and tune the piano knowing that A4 will wind up exactly on A-440.

If you want to save this tuning permanently at 440 Hz, store the FAC tuning again (STRETCH roll over to MEM). The offset will be included in the stored tuning and the temporary offset will be cancelled.

3. Displaying the Cents Offset:
The offset cents number used during a pitch raise can be displayed at any time.

Set the cents window to zero. Press SHIFT, hold it down, and press RESET. As long as the SHIFT button is depressed, the right display window will show the cents offset currently in use. Since the SAT has the ability to add or subtract increments from the stored offset, you must return the cents display to zero before looking at the cents offset.

On the other hand, if you know what the cents offset is and wish to change it, just enter the desired difference in cents. Press SHIFT-RESET and the new offset will be displayed in the cents window.

To set the cents offset back to zero, either recalibrate the instrument by holding the SHIFT and pressing the CAL button, or enter an opposite offset and store that in order to cancel the original offset.

4. Measuring the Width of Musical Intervals:
The fourth major use for the RST button is to measure the width in cents of musical intervals. To measure the width of an interval such as a third or fourth, take the following four steps.

A. Go to the note and octave of the coincident overtones of the two notes (i.e., A5 for the F3-A3 major third).
B. Stop the lights using the MSR and/or CENTS buttons on the lower of the two notes.
C. Reset the CENTS display to zero with the SHIFT and RST button.
D. Stop the lights again on the higher of the two notes.

The width of the unknown interval now appears in the CENTS display. No addition or subtraction is necessary to make this measurement with the SAT.

QUICK RESET OF CENTS WINDOW TO ZERO

It is often convenient to be able to reset the cents reading to zero without having to go to the trouble of counting the cents down to zero. This can be done with the CAL button. Hold the SHIFT button down, and press the CAL button quickly. The CENTS window will revert to zero cents, but the NOTE window will remain as it was and the SAT will not go over to the CAL function. If you want to complete the CAL operation, hold the CAL button down instead of just giving it a quick push.

PAGE NUMBER DISPLAY

In the memory mode the CENTS display doubles as the PAGE number display. It displays the current PAGE number or the current CENTS setting as required. To see how this works, hold SHIFT down and press PAGE up once. A numeral 1 will appear in the CENTS display, to indicate that storing or retrieving a piano can now be done on or from PAGE 1. To change the PAGE, hold the SHIFT button down and press PAGE up or down.

NOTE: The PAGE number will step up only to the maximum number of pages installed in your particular SAT.

Stepping down, the page numbers will eventually get you to PAGE 0. PAGE 0 will not store any information and is there to make it difficult to accidentally overwrite a valuable tuning. When the SAT is turned on, the PAGE number defaults to 0. You have to select a page before you can store a tuning to memory.

STORING AN AURAL TUNING IN MEMORY

Assuming the piano is tuned and you are storing notes from AO to C8:

1. Turn the Accu-Tuner on and press the TUNE button.

2. Select the PAGE by holding SHIFT and then using PAGE to get to the desired page in memory that you want to devote to this piano. Press NOTE up and then NOTE down to start on AO.

3. To set the partial, press the TUNE button. Set the display for the NOTE and OCTAVE of the desired partial, such as E3 (sixth partial) or A2 (fourth partial) to record the note A0 on the piano.

4. Now measure the pitch of the note on the piano by playing the note on the piano and using MEASURE and CENTS buttons to stop the lights.

5. Pressing the MEMORY button will show you the NOTE and OCTAVE you want to store along with the PAGE number you have chosen. Pressing the TUNE button will display the partial you have selected and the CENTS deviation for this partial.

6. Switch to MEMORY mode (by pressing the MEMORY button) to correct the NOTE or OCTAVE to be tuned on the piano.

7. Switch back to TUNE mode (by pressing the TUNE button) if you want to modify the partial setting.

8. When the settings are correct, store the tuning for this note by holding down SHIFT, then pressing and releasing STO-MEM.

9. The Accu-Tuner will carry along the partial and the cents deviation after you store a note to memory. All you have to do is measure the cents deviation. You determine cents deviation (by stopping the lights with the cents buttons) then store the note by holding SHIFT and pressing STO-MEM. You will notice while you are holding down the SHIFT button just after storing a note, the display will show the NOTE/OCTAVE of the note being stored and the PAGE in memory. Releasing the button toggles the display back to the partial and cents deviation (allowing you to check as you store the tuning.)

10. After you store from A0 up to around C3 you will notice the LED's will not register as clearly. When the display starts to become vague it is time to lower the partial. Let's assume you were using the sixth partial and it is time to lower the partial. You would accomplish this by pressing the TUNE button, then use the NOTE and/or OCTAVE buttons to get the display to the desired partial. Next measure the cents deviation (stop the lights while playing the note). Now before you store this, let's double check ourselves by pressing MEM button to display the note, octave and page number. Press the TUNE button to display the partial and cents deviation. If all settings are correct, then store the setting (SHIFT and STO-MEM).

11. You will have to lower the partial at different points on different pianos. FAC tunings use the octave fifth (sixth partial) in the bass at A0-B2, double octave (fourth partial) C3-B4, octave (second partial) from C5-B5, and fundamental (first partial) from C6 on up through the high treble.

12. Continue along in measuring and storing until you have stored each note on the piano.

STORING A TUNING IN MEMORY FROM A PRINTOUT

1. Turn the Sanderson Accu-Tuner on and press the TUNE button.

2. Select the PAGE by holding SHIFT and then using PAGE button to get to the desired page in memory that you want to devote to this piano. Then press OCT and NOTE buttons to get to the first note to be recorded.

3. Press the MEM button (above the ON/OFF button) and the SAT will show you the NOTE and OCTAVE you are about to store along with the PAGE number you have chosen. (If the display is not set up correctly, use the OCTAVE and NOTE buttons to correct the error.)

4. Press the TUNE button and the SAT will display the partial of the note you are about to store and the CENTS deviation for this partial. (If the display is not set up correctly use the OCTAVE, NOTE, CENTS buttons to do so.)

5. Store this note by holding down SHIFT and then press STO-MEM.

6. The SAT will carry along the partial and the cents deviation after you have stored a note to memory. All you have to do is adjust the cents to agree with the cents listed on the tuning chart. Then store the note by holding SHIFT and pressing STO-MEM. You will notice while you hold down the SHIFT button during storing a note, the display shows the note and octave of the note you are storing and the PAGE in memory. This allows you to check yourself as you go along.

7. Continue along entering the cents from the printout and then storing to memory (hold SHIFT and press STO-MEM) until there is a change in the partial to be stored.

8. In the case of an FAC tuning chart, the partial changes occur at C3, C5, C6. When you come to these points press the TUNE button and then enter the correct the partial and the cents deviation (using the OCTAVE, NOTE, and CENTS buttons). Then double check (as in steps 3,4) by alternating between MEM, and TUNE buttons to verify the information before storing it (hold SHIFT and press STO-MEM).

9. Once the partial is set up correctly you only need to change the cents setting and store until the next partial change. Continue the methods described above until the entire tuning is stored.

UP OR DOWN MEMORY STORAGE

The direction in which the memory advances while storing a tuning can also be changed at will. When the SAT is first turned on, storing a note setting will increment the note setting to the next higher semitone. This is not convenient when storing from the treble bridge down into the bass. To change the direction, hold down the MEM button, hold down the NOTE down button, then release the MEM button and release the NOTE down button last. (roll over from MEM to NOTE). This procedure "teaches" the STO-MEM button that it should store and decrement the note setting. To get back to the normal direction, repeat the procedure using the NOTE up button instead of the NOTE down button.

MEMORY STORAGE WITH THE FOOT SWITCH

Storing a note to memory ordinarily requires two hands, one to hold the SHIFT button, and one to press the STO-MEM button. This was done deliberately to make it difficult to store notes accidentally, possibly wiping out a valuable tuning. When storing a piano in memory from a written record, or tuning and storing a piano as you go, you can "teach" the foot pedal to store notes for you.

To teach the foot pedal to store notes, hold the foot pedal down, hold down SHIFT button, hold down STO-MEM, release the foot pedal, then release STO-MEM button, then release the SHIFT button. Now be sure to use the foot pedal with care, because it will put new information into memory whenever it is pressed, and wipe out the information that was previously stored at that location.

If you want the footswitch to stop storing to memory, teach the footswitch a different task: hold down footswitch, hold down NOTE up, release footswitch, and then release NOTE up.

UP OR DOWN FOOTSWITCH\THUMB SWITCH

The direction in which the foot switch progresses across the keyboard can be changed from "up" to "down" and back again at will. When the SAT is first turned on, the foot switch moves up the keyboard. To reverse the direction, hold the foot switch down, hold the NOTE down button, release the foot switch, and then release the NOTE down button. This procedure "teaches" the foot switch that you want to move down the keyboard instead of up. To reverse the direction again, repeat the above procedure holding the NOTE up button instead of NOTE down. (This procedure works for the thumb switch as well).

PIANO SERIAL NUMBER STORAGE

The SAT can store six digits of the piano's serial number along with the tuning, to identify the tuning record with the piano. Serial numbers are stored on a page beginning two note locations below the lowest note, A0, with a maximum of three digits at each location. The CENTS buttons set the number and then the SHIFT and STO-MEM buttons are used to store them.

A. To store a serial number on a page:
Go to the bottom of the memory page with OCT down. The left window will display SEr , short for Serial Number. Use the CENTS buttons to set the right window to the first three digits of a six digit number corresponding to the serial number of the piano. (If the number exceeds six digits, ignore digits to the left of the sixth). Then store these digits with the SHIFT and STO-MEM buttons. The left window will still say SEr, and you can set the last three digits of the serial number with the CENTS buttons, and then store it also. The left window will now indicate A0, the first note of the piano.

B. To read the serial number:
Go to a specific page, and use OCT down to get to the bottom of the page. Read the first three digits of the serial number. then press NOTE up and read the second three digits.

C. To search for a specific serial number:
When the page is not known, remember the first three digits of the number while you search through memory. Look at the bottom storage location of each page. On each page, press NOTE down to see the serial number, and then press SHIFT, PAGE up to go to the next page. Alternate between NOTE down and SHIFT, PAGE up until the desired serial number is found. Then press NOTE up to check the last three digits and make sure you have the right piano.

TRANSMITTING PIANOS FROM ONE SAT II TO ANOTHER

No computer is necessary to transmit pianos from one SAT II to another. Connect a MIDI cable from the MIDI OUT connector of the transmitting SAT II to the MIDI IN connector of the SAT II that is about to receive a piano memory transplant.

CAUTION: The receiving SAT II's pianos in memory will be lost when the transmitting SAT II writes information on top of them.

Press the MIDI IN button of the receiving SAT II, and then press the SHIFT and MIDI OUT buttons on the transmitting SAT to start the transmission. After 4 to 32 seconds, depending on the number of pianos, the transfer will be completed. There is no external sign of this on either SAT II, but the keyboard of the transmitting SAT II will be locked up during transmission and will release after transmission is completed.

The transmitting SAT II will always transmit its entire piano memory. The receiving SAT II may have the same piano memory capacity, or it may have more or less, it doesn't make any difference to the MIDI operation.

If more pianos are transmitted than the receiving SAT II can accommodate, the pianos are received and numbered correctly up to the receiver's maximum storage capacity. The extra pianos are transmitted but ignored, and they still remain in the transmitting SAT II's memory.

If the receiving Accu-Tuner has greater piano capacity than the transmitting Accu-Tuner, then the pianos are received and numbered correctly up to the maximum number transmitted. Pianos that are above the number of the transmitting pianos will not be disturbed. If the receiving Accu-Tuner has a larger number of pianos, the keyboard of the receiving SAT II will not unlock because it is still expecting more pianos and will wait indefinitely. To unlock the Accu-Tuner, turn off the Accu-Tuner.

OLD F4 STRETCH TUNINGS

The SAT still does one-point F4 stretch tunings as before. From a cold start, press the TUNE button, set the SAT to F5, tune F4. Then set the SAT to F6 and play the note F4, use the cents buttons to stop the lights on the SAT. Next hold SHIFT button down, and press STO-STRETCH button, release STO-STRETCH, then release the SHIFT button. Next press the STRETCH button once more to get the SAT calculating the C3 through F6 stretch tuning. Now the SAT will be set up at C3 and ready to tune.

TUNING THE HIGH TREBLE WITHOUT FAC

Tuning the high treble without FAC is relatively easy. The best tuning for each note can be determined by referencing one, two or three already-tuned notes. These notes lie one octave, an octave-fifth, and two octaves lower than the note you are tuning.

1. Set the SAT to the NOTE and OCTAVE of the note being tuned.
2. Play the reference notes one at a time and see how they look on the rotating lights.
3. Step the CENTS up or down until you find a setting that is a reasonably good compromise. In other words a setting where some of the reference notes rotate slowly sharp and some rotate slowly flat.
4. Then tune the note.

Tuning is more of a problem in the last octave because a good compromise is difficult to find. Decide which interval will take priority and tune mainly to satisfy that partial.

At this point many tuners stick to the single octave, but tune one or two cents wide. Others prefer to tune the double octave which gives a considerably sharper top end, or the octave-fifth, which is even sharper. The choice is up to you and your customer.

TUNING THE BASS WITHOUT FAC

Tuning the bass is similar in principle to tuning the high treble. Set the SAT with reference to several previously tuned notes and compromise among them to place the note being tuned.

The best reference notes lie an octave, an octave-fifth, and a double octave-fifth higher than the note being tuned. To use these reference notes, set the SAT a double-octave-fifth higher than the note being tuned (on its sixth partial).

1. Play each reference note one at a time.
2. Step up or down with the CENTS buttons until a good compromise setting is found, one where some reference notes are rotating slightly flat, others slightly sharp.
3. Tune the note.
4. Continue this procedure all the way down to A0.

In contrast to the situation in the high treble where the three tests diverge, the three bass tests usually work nicely all the way to the last note.

PATENT NOTICE

The method of tuning a piano by measuring its inharmonicity and then creating a numerical tuning customized to fit that piano are the subject of Patent No's 3,968,719, 3,982,184, 4,014,242, 5,285,711 issued to Dr. Albert E. Sanderson of Inventronics, Inc., and other patents pending.

INPUT-OUTPUT JACKS

There are six input-output jacks on the back of the SAT that increase the versatility of the SAT for various special purposes. The jacks on the back of the SAT II are shown below.

Left-Side Jacks MIDI Jacks Right-Side Jacks

1. AUDIO IN: An electrical audio input jack. Signals are fed into this phono jack for silent measurements of pitch, or tuning electronic musical instruments. This input is suitable for levels from 0.01 to 10 volts.

2. MAG IN: A miniature telephone jack for magnetic pick-ups. These typically have an output of a few millivolts, and this input is designed only for such low-level signals. Connecting a large signal to this input will destroy the input circuit. So, you must use the AUDIO IN jack for large signals.

3. FLTR OUT: A phono jack output from the audio filter. The audio filter amplifies sounds whose pitch corresponds to the pitch selected on the SAT. It is useful for listening to the beats at the coincident partial of two notes forming a musical interval. As such, this feature can be a valuable training aid for aural tuners. The speaker/amplifier that we sell is modified just for this job.

4. OSC OUT: A phono jack which puts out a modified sawtooth wave (one that is quite pleasant to listen to) at the pitch called for by the settings of the SAT controls. This has a variety of uses. The frequency calibration of the instrument can be checked with this output. It can also be fed into an amplifier and broadcast, to give an aural pitch standard for any purpose. One purpose might be as an aid to fast piano chipping or rough pitch raising.

5. NOTE SWITCH: A subminiature telephone jack, that accommodates the foot switch, or thumb switch which is used for stepping up/down the NOTE settings one semitone at a time. A foot switch is supplied as standard equipment, but any switch can be used for this purpose. The contacts must be the "normally open, momentary contact" type, and each time contact is made, the NOTE setting will advance by one semitone.

6. BAT CHGR: Used for charging the battery. DO NOT use battery chargers other than ones recommended for the Accu-Tuner, even when the plug is compatible with the SAT jack, the wrong voltage can damage the battery charging circuit in the SAT. (The Radio Shack model 273-1767, with a 2.1 mm barrel, negative on the inside, positive on the outside, is a compatible unit.) The battery will be fully charged after twelve hours.

BATTERY CHARGER INDICATOR

Accu-Tuners have a green LED above the battery charger jack which will light up when the battery charger is plugged in and is charging properly. If the LED does not light up, there is likely a faulty cable on the battery charger or a faulty electrical wall outlet. Try another wall outlet, if that doesn't help, replace the battery charger.

BATTERY CARE

NI-CAD
The standard battery used in the Sanderson Accu-Tuner is a Nickel-Cadmium (Ni-Cad) battery. The Ni-Cad will run the SAT for 40 to 60 hours, and can be recharged hundreds of times. To achieve the longest battery life we do recommend that the SAT be used until the "Lo-Bat" signal is displayed in the left LCD. Ni-Cad batteries do not benefit from nightly charging and will last longer if used to capacity before recharging.

TWO YEAR WARRANTY*

INVENTRONICS offers a 2 year warranty from date of purchase, on parts and labor. We will repair or replace the Accu-Tuner, as determined at the factory, should it be found defective. This warranty is not transferable, and applies only to the original purchaser of the equipment. Damage from the result of misuse, modification, or tampering with the equipment will void this warranty.

*The foot switch is not covered under this warranty.

APPENDIX A

Concise Step-by-Step Tables of Standard Routines

1. **Recalibration in Tune or Stretch Mode:**
SHIFT, CAL, release CAL, release SHIFT, CENTS up or down to stop lights, TUNE. You are at A4, 0.0 cents and calibrated to 440.00 Hz.

2. Recalibration in Memory Mode or FAC Mode:
SHIFT, CAL, release CAL, release SHIFT, CENTS up or down to stop lights, TUNE, NOTE up, NOTE down. You are still in the MEM mode, on the note where you left off, and recalibrated.

3. A. Measurement and Storage of FAC Stretch Numbers:
TUNE, NOTE=F, OCT=5, CENTS=0.0, tune F3 to stop lights, OCT up to 6, CENTS up or down to stop lights, SHIFT, STO-STRETCH. (NOTE=A, OCT=5, CENTS=0.0) Tune A4, OCT up to 6, CENTS up or down to stop lights, SHIFT, STO-STRETCH. (NOTE=C, OCT=6, CENTS=0.0) Tune C6. OCT up to C7, CENTS up or down to stop lights. SHIFT, STO-STRETCH. SHIFT, PAGE up to correct page, hold STRETCH, hold MEM, release STRETCH, release MEM. After 10 seconds you are at A0, NOTE up, NOTE down, and you are ready to start a stretch tuning.

B. Measurement and Storage of F4 Stretch Number:
TUNE, NOTE=F, OCT=5, CENTS=0.0, tune F4 to stop the lights, OCT up to 6, CENTS up or down to stop the lights, SHIFT, STO-STRETCH, press STRETCH button alone. You are at C3, ready to start tuning C3-F6.

4. Non-440 Calibration:
SHIFT, CAL, release CAL, release SHIFT, CENTS up or down to stop lights, TUNE, CENTS up or down to required offset (i.e., 8.0 cents = 442, 4.0 cents per Hertz), SHIFT, RST, release RST, release SHIFT. Your instrument is set for non-standard A, and the NOTE/OCTAVE window shows + or - to indicate sharp or flat. (This offset is used and changed by pitch-raise calculator).

5. Storing One Note in Memory:
Hold SHIFT button and press PAGE up or down to page number of desired piano. Then use the OCTAVE and NOTE buttons to get to the correct note on the piano. If you wish or need to change the partial: Press the TUNE button (then the partial will be displayed) and use the NOTE and OCTAVE buttons to display the desired partial, and finally use the CENTS button to get to the desired pitch. Then to store this, hold down the SHIFT button and press STO-MEM.

To check that proper note has been stored, press NOTE down, TUNE, to check partial's note, octave, and cents, then MEM to see piano's note octave, and page number.

6. Storing Consecutive Notes on Same Partial:
Set up the first note and store as described above. The SAT automatically goes to the next semitone keeping the partial relationship constant. To store the next note, press CENTS up or down to the new setting, SHIFT, STO-MEM. Repeat storing consecutive notes until you need to change the partial number.

7. Changing the Partial Number in Memory Mode:
Press TUNE, then NOTE up or down to pitch of new partial, OCT up or down to pitch of new partial, CENTS up or down to pitch of new partial, SHIFT, STO-MEM. You have stored one note at the new partial number, and may proceed with storing consecutive notes until the partial number changes again.

8. Storing an F4 Stretch Tuning on a Page in Memory:
Measure and store F4 Stretch Number as described above (3B). Then SHIFT, PAGE up or down to correct page number. Then hold down STRETCH button and roll over to MEM button.

APPENDIX B

Cents Tables for some Non-equal Temperaments

Pythagorean Temperament.

A	0.0		Dd	-15.6		F#	5.9
A#	13.7		D	-2.0		Gb	-17.6
Bb	-9.8		D#	11.7		G	-3.9
B	3.9		Eb	-11.7		G#	9.8
C	-5.9		E	2.0		Ab	-13.7
C#	7.8		F	-7.8			

The usual practice is to use only the above flats.

Meantone Temperament

A	0.0		Dd	27.4		F#	-10.3
A#	-24.0		D	3.5		Gb	30.8
Bb	17.1		D#	-20.5		G	6.8
B	-6.8		Eb	20.5		G#	-17.1
C	10.3		E	-3.4		Ab	23.9
C#	-13.7		F	13.7			

The usual sharps and flats are C#, F#, G#, Bb, and Eb.

Marpurg's Temperament 1.

A	0.0		C#	0.0		F	0.0
A#	5.9		D	5.9		F#	5.9
B	3.9		D#	3.9		G	3.9
C	2.0		E	2.0		G#	2.0

Werkmeister III, Correct Temperament No. 1

A	0.0		C#	2.0		F	9.8
A#	7.8		D	3.9		F#	0.0
B	3.9		D#	5.9		G	7.8
C	11.7		E	2.0		G#	3.9

Kirnberger III, Corrected Temperament

A	0.0		C#	2.0		F	9.8
A#	7.8		D	3.9		F#	2.0
B	0.0		D#	5.9		G	7.8
C	11.7		E	-2.0		G#	3.9

Young's Temperament No.1

A	0.0		C#	-3.9		F	3.9
A#	2.0		D	2.0		F#	-5.9
B	-3.9		D#	0.0		G	3.9
C	5.9		E	-2.0		G#	-2.0

Vallotti or Fairchild Temperament

(REF: Piano Technicians Journal, Oct. 82, p.20.)

This temperament was independently developed in 1982 by Steve Fairchild while looking for a temperament to smooth out the simple keys on small pianos. It greatly reduces the harshness caused by excessive inharmonicity, and for that reason could also be called the "Piano Teacher's Delight" temperament.

A	0.0		C#	0.0		F	7.8
A#	5.9		D	2.0		F#	-2.0
B	-3.9		D#	3.9		G	3.9
C	5.9		E	-2.0		G#	2.0

Cents Offset for Hz at A4

Frequency of A4	Cents Offset
446	23.5
445	19.6
444	15.7
443	11.8
442	7.9
441	3.9
440	0.0
439	-3.9

Frequency of A4	Cents Offset
438	-7.9
437	-11.8
436	-15.8
435	-19.8
430	-39.8
420	-80.5
415.3	-100.0
415	-101.3

Formula for calculating cents offset of A4 at 420Hz: Log(420/440,2)*1200 = -80.54

APPENDIX C

Aural and Visual Tuning (The best of both worlds)

By J. Coleman, Sr.

The definitive work on temperaments and tuning was written by Owen Jorgenson. In his book "Tuning the Historical Temperaments" he traces the natural progress of aural tuning systems from the Pythagorean and Just Intonation systems through several meantone temperaments to the Well temperaments and the Equal temperament. It is this last system in which most piano technicians are engaged. The basis of this system is the need or desire to be able to play in all keys with equally out of tune parallel intervals. This need was borne out of the practice of composers who became far-ranging in their tonalities of a particular composition.

The earliest popular approaches to tuning the equal temperament involved tuning a series of twelve 4ths or 5ths such that each 5th was narrowed slightly and each 4th was widened slightly in such a way that they were all equally out of tune. The difficulty with this approach was that it took 12 steps before one could tell if he was doing alright.

More recent approaches to equal temperament involve one or two test intervals for each step taken in the tempering system. More care is being given to insure that each interval (such as the minor 3rds, major 3rds, 4ths, 5ths, minor 6ths, major 6ths) is equally tempered and is compatible with all its parallel similar intervals. Some of the more popular recent temperament systems are by George Defebaugh, Bill Stegeman, Dr. Al Sanderson (2 octave A-A temp) James Coleman (F-A temp) and Mark Peele (10th temp). These may be seen demonstrated at various Piano Technician's Guild Institutes, Conferences and Seminars.

Since the Stretch Calculator tunings involve the accurate tuning of the 4th partial of each note in the F-F temperament, all the intervals which involve the 4th partials will be beautifully tempered (such as major 3rds, 4ths). Other intervals such as minor 3rds, major and minor 7ths which are involved with higher order partials will also be beautifully tempered. Since the greatest irregularity in partial alignments occur in the 1st, 2nd, and 3rd partials, there may be some slight unevenness heard in the octave and 5ths.

Now, by the simple practice of playing certain test intervals while tuning with the Stretch Calculator mode, one can have a double check on his aural test as well as assuring that the visual judgements are more accurate. If one tunes the stretch tuning system from top to bottom or at least from C5 down, when the 4th 1/2 step down is achieved, a major 3rd aural test is available without the upper note interfering with the LED display. In arriving at the seventh 1/2 step down, a 5th is available for aural judgement without LED interference from the upper note of the interval. This 5th interval can be followed on down to C3. One may notice a slight variation in the sound of the 5ths especially as one approaches the lower area of the scale. Sometimes this is merely due to the slipping or instability of the previously tuned upper note of the 5th. But, with the shorter scaled pianos, irregularity of the lower partials may cause the beat frequency to be greater than expected. At this point one may make a decision to alter the lower note to smooth out of the 5th interval (which of course may change the beat rate in other intervals based on this lower note). By doing this judiciously one can have a better tempering than can be had with either aural or visual methods alone.

APPENDIX D

What are Partials and Beats?

By J. Coleman, Sr.

A piano string has a series of partials (sometimes erroneously called harmonics) which are approximately whole number multiples of the fundamental frequency (first partial). For example the 3rd A on a piano (counting from A0, A1, A2) has a theoretical frequency of 110 cycles per second (or Hertz). If it is multiplied by 2, you have 220 Hz (2nd partial). If one places his finger lightly on the middle of a string, he can force it to vibrate at its 2nd partial. If A2 is lightly touched at a distance of 1/3 the length from one end after the note is played, the string will be forced to vibrate at its 3rd partial (approximately 330 Hz which is 3 times the fundamental pitch). One can continue to divide the string by 1/4, 1/5, 1/6, 1/7, 1/8, etc. This will cause the string to sound at its 4th, 5th, 6th, 7th, and 8th partials respectively.

In order to further clarify, let me say that when a string is forced as above to vibrate in three parts by touching it at the 1/3 point, we say that this is the 3rd partial because one can see the string breakup into 3 parts with 2 nodal points in between. At the same time one notices that the pitch jumps one octave plus a 5th (19 half-steps above).

One should learn the note location for the partial series for each note of the chromatic scale. Here are the notes that correspond to the locations of the first 12 partials of the note Middle C.

C4 C5 G5 C6 E6 G6 Bb6 C7 D7 E7 F#7 G7
Oct 5th 4th 3rd 3rd 3rd 2nd 2nd 2nd 2nd half

When one is listening to various tempered intervals, there is at least one particular area where one can hear the beat phenomenon between coincident partials of the two notes. For example: when listening to the 5th (F3-C4), these 2 tones have partials which occur in close proximity to the note C5 (the 3rd partial of F and the 2nd partial of C). These are called the first of lowest coincident partials. If there is a slight difference in the pitch of the two coincident partials, one can hear a slight waver in the tone. This is called the beat phenomenon at the pitch of C5. It is the difference of frequency or Hz of these two partials. One can calculate the beat speed if one knows the cents reading of each of these two partials. The following formula is helpful to convert cents difference to beats per second!

Beats=ref. note Hz x 2 raised to (upper cents deviation/1200) minus ref. HZ x 2 raised to (lower cents dev./1200).

The reference note frequency can be found in charts, but it is so easy to calculate using the 1/12 root of 2 which is the half step ratio. If we need to know the Hz of C5 we merely multiply A440 times 1.0594631 three times to get 523.2251. In the process we find A# at 466.164, B 493.883. If we wish to find Hz below A440 we divide by 1.0594631. G# equals 415.305, G=391.995 etc.

Now let's use the formula above to find the beat rate of the interval F3-A3 (Major 3rd). The 5th partial of F3 is at the note location of A5. The 4th partial of A3 is also near A5. When properly tuned, on most pianos they will create a beat rate of approximately 7 beats per second. Let's say that the 4th partial of A3 reads +3.7 cents and the 5th partial of F3 reads -10 cents at the reference note of A5 (880 Hz). At A5, -10 cents is the same as G# +90 cents since we have 100 cents per half step. Now, taking the higher reading first, we have
Ref Hz 880 x (2 raised to (3.7/1200)) = 881.883
Ref Hz 830.61 x (2 to (90/1200) power) = 874.932
This leaves us with a difference of 6.95 Hz which is the beat frequency of the lowest coincident partials of these two notes.

With the aid of a scientific calculator one can easily compute the beat rate of any interval. Dr. Sanderson has an excellent set of notes on how to tune a beautiful 2 Octave Temperament by carefully measured intervals using either aural principles or machine techniques. You may find it interesting to measure your resulting interval widths after setting a careful machine tuning or vice versa, you may find it more interesting to measure interval widths after very carefully tuning by ear. (See Appendix E)

APPENDIX E

The Two-Octave "A" Temperament

By Dr. A.E. Sanderson

The two-octave A temperament is probably the first temperament designed to take into account the inharmonicity of pianos strings. Inharmonicity not only changes the beat rates from their theoretical values for all intervals on a piano, it also creates impossible tuning conflicts as well. The simple octave splits up into different kinds of octaves, depending upon which pair of coincident partials are tuned to zero beat. Even the single, double, and triple octaves are incompatible intervals on a piano, and can only be tuned to sound "as good as possible," not perfect, because inharmonicity makes perfection literally unattainable.

The two-octave A temperament is tuned from the "outside in." That is, the wide intervals, two octaves and the double octave, are tuned first. This is done so that octave tuning problems with a piano will show up at the earliest possible stage when they are relatively easy to correct with small compromises. Many pianos have, unfortunately, incompatible tuning requirements, and by tuning the three A's first, we can establish a double octave and two octaves that fit as well as is possible both with each other and with the scale of the given piano.

Next we subdivide this wide interval into six equal parts by tuning six contiguous major thirds that fit between the three A's perfectly. Finally, with every fourth note already tuned, we fit the three missing notes within each major third primarily by tuning a pattern of thirds and fourths.

Tuning wide intervals first, and then subdividing them has important advantages over the usual methods of building up wide intervals by tuning a succession of narrow ones. In the first place, it guarantees that the wide intervals will be as harmonious as possible, and that the narrow intervals will be adjusted or forced to be compatible with them. Secondly, small errors in tuning narrow intervals cannot add up to become large errors in the wide intervals, no matter how difficult the scale of the piano. This not only leads to greater accuracy on well-scaled pianos, but also greatly reduces the number of problems associated with tuning poorly scaled pianos.

Direct-Interval Tuning

Direct-interval tuning is a way of using the Sanderson Accu-Tuner™ that exactly simulates the way fine aural tuners tune by ear. Each interval is tuned by setting its width to a specified number of cents, which is verified by a direct measurement. Hence the term "direct-interval tuning". The sequence of intervals followed is circular, just as in aural tuning, and this makes it quite easy for the tuner to check each interval aurally as it is tuned. (If you are not familiar with measuring the width of intervals in cents, refer to the section entitled "Measuring the Width of Musical Intervals").

First, two single octaves and the double octave are tuned using direct-interval measurements. Second, the double octave is subdivided in six equal parts with a set of contiguous major thirds that mathematically fit this span perfectly, as determined by direct interval measurements. This leaves every fourth note tuned, and the three untuned notes within each major third are then tuned with fourths and thirds, again by direct interval measurements. Follow the step by step procedure below, and be sure to check all intervals aurally as you tune:

Step 1. Tune A4 to zero cents, and A3 from A4 as a 2-4 octave 1 cent wide. (Refer to Appendix H if you are not familiar with the different kinds of octaves.)

Step 2. Tune A2 from A3 as a 3-6 octave 1 cent wide. Check the A2-A4 double octave, and if it is more than 4 cents wide, divide the excess by three and narrow both octaves by this amount. (E.g., if double octave is 5.5 cents wide, 5.5-4 is 1.5, divide by 3, and narrow both octaves .5 cent.)

Step 3. Tune three major thirds of equal cents width between A2 and A3. You must first guess how wide to tune them, then see how the guess works out and revise it if necessary. A good first guess is 13.5 cents. So tune F3 from A3 13.5 cents wide, then C#3 from F3 13.5 cents wide. Measure the width of the A2-C#3 third. If it is also 13.5 cents wide, you were lucky and these three thirds are the correct width on the first guess. If you were not so lucky, average the three thirds (two of which were 13.5 cents wide), and tune all three to this average value by retouching C#3 and F3.

Step 4. Now tune C#4 from A3, and F4 from C#4, as thirds of this same value. You have now tuned five contiguous thirds all the same width, a width that fits exactly the A2-A3 octave. To see whether this width fits the A3=A4 octave, measure the width of the last third, F4-A4. If this agrees with the other thirds, you were lucky again and these six thirds are all tuned. If you weren't lucky, take the discrepancy of the last F4-A4 third, divide it by 3, and move F4 by this amount in the direction that will reduce the discrepancy. (E.g., if you had five thirds at 13.5 cents, and the last was 12 cents the discrepancy is 1.5 cents. Take one-third of this, 0.5 cents, and move F4 flat by this amount. This leaves you with four thirds at 13.5, one at 13, and one at 12.5. This is quite reasonable on that "inharmonic instrument," the piano).

Step 5. Now every fourth note is tuned from A2 to A4. Fill in the missing notes between F3 and C#4 to get a nine-note mini-temperament. You must now take a guess at the width of the fourths, try it on the mini-temperament, and revise it as necessary to make the fourths fit with the thirds, whose width you already know. A good first guess for fourths is 2.5 cents. Tune up a fourth from F3 to A#3 down a third from A#3 to F#3, up a fourth from F#3 to B3 and stop. Now tune down a fourth from C#4 to G#3, up a third from G#3 to C4, down a fourth from C4 to G3 and stop. You have filled in the six missing notes of the mini-temperament, now you can tell whether your guess on the width of the fourths was correct from the width of the G3-B3 third, which is the check interval.

Step 6. Measure the width of the G3-B3 third and compare it to what it should be. If it is smaller than the other thirds, your fourth guess was also too small, and vice versa. The size of the error in the fourths equal one-quarter the error in the G3-B3 check interval because four fourths were tuned to get to the check interval.

Step 7. Retune the mini-temperament as in Step 5 with the new correct value for the widths of the fourths. Check it aurally to see that you have five perfectly rising thirds, and four equally good fourths. This result can always be achieved even on the most poorly scaled piano, since we have not been asked to make any compromises up to this point.

Step 8. Tune outwards from the mini-temperament with major thirds down to A2 and up to A3. The thirds tuned downwards are constant width but the thirds tuned upwards may have to be calculated if their width varies. Use straight-line interpolation based on the three known thirds in the A3-A4 octave, to get numbers for the missing thirds. (E.g., in Step 4 these three thirds, A3-C#4, C#4-F4 and F4-A4 were 13.5, 13, and 12.5 cents, respectively. Straight-line interpolation gives values of 13.4, 13.3, and 13.1 for A#3-D4, B3-D#4 and C4-E4, and 12.9, 12.8, and 12.6 for D4-F#4, D#4-G4 and E4-G#4, respectively).

Step 9. The electronic tuning of the two octaves A2-A4 is now complete. A very careful aural check is advisable at this point. Pay particular attention to the fourths, which are wider than theoretical owing to the effects of inharmonicity. The fifths are purer than theoretical for the same reason, and rarely cause any trouble.

Aural Tuning

The two-octave "A" temperament may be tuned aurally with exactly the same note-tuning sequence. This makes it easy to check an electronic tuning aurally at every step--very helpful in avoiding errors. Aural tuners can study and possibly improve their tuning by using the SAT to measure the width of tuned intervals after setting this two-octave temperament very carefully by ear.

Step 1. Tune A4 to 440 Hz. Use F2 as test note, 17th to fork should beat same as 17th to A4. Tune A3 from A4 as a 2-4 octave, 1\2 beat wide. That is, the tenth should beat 1\2 beat per second (bps) faster than the third.

Step 2. Tune A2 from A3 as a 3-6 octave 1\2 beat wide. That is, the major sixth should beat 1\2 bps faster than the minor third.

Step 3. Check the double octave, a 1-4 interval to be less than 1 beat wide. That is, the 17th beat should be less than 1 bps faster than the third. If the double octave is too wide, compromise both octaves slightly to get and acceptable double octave.

Step 4. Divide the A2-A3 octave into three equal parts by tuning C#3 and F3. These thirds can be tested very accurately with the contiguous thirds test. This test states that two contiguous thirds must have relative beat rates in the ratio of 4 to 5, that is 4 beats of the lower one require the same amount of time to complete as 5 beats of the upper one. This test then does not require knowledge of beats per second, only a good sense of rhythm or tempo. In this case, C#3 and F3 are correctly tuned when 4 beats of A2-C#3 occur at the same tempo as 5 beats of C#3-F3, and in addition, 4 beats of C#3-F3 occur at the same tempo as 5 beats of F3-A3.

Step 5. Now tune C#4 and F4 to divide the A3-A4 octave into three equal parts with thirds. You may have to taper the width of the thirds downwards slightly in the upper octave on account of the inharmonicity of the piano.

Step 6. Check that the three major tenths formed on the seven notes tuned so far also in the ratio of 4 to 5. Also check the C# and F octaves with both the third-tenth and minor-third-sixth tests. Scale problems will show up at this stage, and it may be necessary to compromise slightly the perfectly rising thirds to get satisfactory octaves and tenths.

Step 7. Fill in the six untuned notes between F3 and C#4 to get a nine-note mini-temperament, but be sure not to change already tuned notes. Tune up a fourth from F3 to A#3, down a third from A#3 to F#3, up a fourth from F#3 to B3 and stop. Then tune down a fourth from C#4 to G#3 , up a third from G#3 to C4, down a fourth from C4 to G3 and stop. Check the G3-B3 third, which is the test interval for this tuning. If it is too small, you must expand your fourths, and vice versa. With just nine notes to worry about, it is always possible to get five perfectly rising thirds and four matched fourths no matter how poorly scaled the piano may be. The beat rates may not be very close to theoretical, but they will be right for the given piano and its inharmonicity characteristics. So tune the piano, and let the beat rates fall where they may!

Step 8. Tune down to A2 and up to A4, and use the contiguous third test to place each note initially. Check each note with the fourth and fifth, and then the major sixth and octave as they become available. The final result should be two octaves tuned with rising thirds all the way, with all fourths quite even and acceptable, and with all fifths nearly pure.

APPENDIX F

Contiguous-Interval Tuning Tests for Electronic Piano Tuners

By Dr. A.E. Sanderson

Two contiguous musical intervals are intervals that touch each other, in other words, share the note in the middle. Tests that use contiguous intervals are easy to learn and use, and tell the tuner explicitly which notes are at fault and what to do to correct them.

Contiguous major thirds will beat in the ratio of four to five because the major third itself consists of two notes whose frequencies are in the ratio of four to five. Displacing any interval up the keyboard will speed it up theoretically in the ratio of the frequencies of the two root notes involved. Therefore two contiguous major thirds should beat in the ratio of four to five, two contiguous minor thirds in the ratio of five to six. Similarly, two contiguous fourths should beat in the ratio of three to four and two contiguous fifths in the ratio of two to three. However, on the piano this theoretical relationship holds well only for the major and minor thirds. The fourths and fifths are so strongly affected by inharmonicity that these contiguous intervals beat at almost the same speeds.

Using the above facts, we can develop a test for one note of the piano at a time. Take C4 for example. Play down a third and up a third G#3-C4 and C4-E4, keeping time at the rate of four beats of the lower one, and then at five beats of the upper one. Think of it as four beats to the measure, followed by five beats to the measure. The tempo of the two kinds of measures should agree. If the upper beat rate is too fast, it indicates that C4 may be flat, and vice versa.

Before moving C4, we need more evidence. Play down a fourth and up a fourth, G3-C4 and C4-F4, and listen for near equality of the beat rates, or an upper beat rate just slightly faster than the lower. If C4 is flat the upper fourth will be faster than the lower, and vice versa. If both the fourth test and the third test indicate the C4 is flat, this is very strong evidence that C4 should be moved. But to nail down your decision, you can add a contiguous fifth test as well.

To check contiguous fifths, play down a fifth and up a fifth, F3-C4 and C4-G4. If C4 is flat, the lower fifth will beat faster than the upper.

In our example, we have now used three tests, and six other notes to check up on one note. If all the tests indicate that C4 is flat, then it is a good idea to move C4. If some tests say flat and some say sharp, then leave C4 where it is and go on to test other notes. Eventually you will find the main culprit or culprits, the notes for which all three tests say the same thing. Move these notes without hesitation. Your temperament will improve steadily as you find and correct each note that fails all three contiguous tests.

The range of this contiguous-interval test is at least from C3 to C5, a two-octave span. After tuning the whole piano, unisons and all, start applying this test at C3. Move up one semitone at a time, and correct any note that fails all three tests before moving on. Go up to C5 this way. If you like, you may make a second pass from C3 to C5 and polish your tuning even more. Eventually you will reach the point where no notes can be improved upon, and at that point you will have an extremely fine tuning. A supertuning if you will!

APPENDIX G

Octave Tuning
By R. Baldassin

Tuning octaves with the Accu-Tuner can be directly related to tuning octaves aurally with specific interval tests. These interval tests and electronic setting instructions have been included here for three primary reasons: 1) So that aural tuners will know which SAT settings correspond to the interval tests they have been using. 2) So that SAT users may expand their aural tuning abilities by checking aurally with interval tests, and 3) To raise in general the level of knowledge relating to octave tests, electronic setting instructions, and their use in piano tuning.

Knowing that there are several types of octaves, aural tests and electronic setting instructions are necessary to insure that the appropriate type is being tuned in a given area of the piano. Since only one type is in tune at a time, and so rare is the exception, the tests and setting instructions for one type only should be used at a time. The exception, of course, would be in a transitional area, changing from one type to another.

Two different aural tests along with the electronic setting instructions have been provided so that the findings may be double checked. Since the aural tests employ the use of intervals for comparison, both expanded and contracted, and either the upper note or lower may be the reference to which we are tuning, four classifications of aural tests result. Be sure to note the Classification for each test so as to correctly interpret the findings and make the proper adjustments in tuning the octave.

CLASS A: Lower note is the reference note. If the beat rate between the test note and the upper note is *too slow* as compared to the beat rate of the test note and the reference note, *raise the upper note*. If the beat rate with the upper note is *too fast, lower the upper note*.

CLASS B: Upper note is the reference note. If the beat rate between the test note and the lower note is *too slow* as compared to the beat rate of the test note and the reference note, *raise the lower note*. If the beat rate with the lower note is *too fast, lower the lower note*.

CLASS C: Lower note is the reference note. If the beat rate between the test note and the upper note is *too slow* as compared to the beat rate of the test note and the reference note, *lower the upper note*. If the beat rate with the upper note is *too fast, raise the upper note*.

CLASS D: Upper note is the reference note. If the beat rate between the test note and the lower note is *too slow* as compared to the beat rate of the test note and the reference note, *lower the lower note*. If the beat rate with the lower note is *too fast, raise the lower note*.

The object in each case is to obtain an equal beat rate between the upper and lower notes of the octave, and the test note. Each test is given a name corresponding to the intervals employed in the test. In naming the intervals, "P" denotes a so-called "Perfect" interval, "M" denotes a "Major" interval, "m" denotes a minor interval, "A" denotes an "Augmented" interval, and "d" denotes a "diminished" interval. It must be noted that some of these intervals are very hard to hear in the bass region of the piano. These checks, however, are still valid. To make use of these checks, hold down one of the octave notes and the test note without playing them. (You may have to use the sostenuto pedal in some cases). Play the strike note with a staccato blow. Repeat this procedure with the other octave note and the test note. When the two beat rates are the same, the type of octave which has been tested for will have been tuned. The strike note in all cases is the note listed in the electronic setting instructions for that particular type of octave.

APPENDIX H

DUAL SYSTEMS FOR SMOOTHING OUT THE STRINGING BREAK

By J. Coleman, Sr.

Often we encounter a piano with wound strings in the tenor section. In older piano design where inharmonicity was not considered, the highest wound strings had much lower inharmonicity than their neighboring plain strings, which usually had very high inharmonicity. This has always caused some difficulty in achieving smooth interval beat speeds. There is a way to help out this situation by tuning the lowest plain strings a little flatter than usual and tuning the upper wound strings a little sharper.

For an example: A spinet piano might have wound strings on F3 and F#3 and then have plain steel strings from G3 on up. The difference between the 4th and 8th partials of F3 and F#3 may be something like 8 or 9 cents whereas the difference between the 4th and 8th partials of G3 and G#3 might be somewhere from 18 to 14 cents. If all of these notes are tuned by their 4th partials to any smooth curve pattern, the major 3rds based on F3 and F#3 will beat faster than normal and the major 3rds based on G3, G#3 and A3 will beat slower than usual. This is due to the differential of inharmonicity between the upper and lower note of the intervals. This is how it works: A string with lower inharmonicity has less difference between its 4th and 5th partials. The opposite is true of a string with higher inharmonicity. If each note is tuned on the basis of keeping the 4th partials on a smooth curve, then when the lower note of a major 3rd has less relative inharmonicity than the upper note does, the smaller distance between the 4th and 5th partials causes the interval to have a slightly faster beat. This is more easily understood by the fact that the lower note was tuned by its 4th partial, but its 5th partial is the cause of the beat with the 4th partial of the upper note. With the 5th partial of F3 being closer than normal to the 4th partial of F3, this makes the 5th partial of F3 flatter in respect to the 4th partial of A3 than it would have been in a more normal situation.

When you look at the situation of the greater inharmonicity of the upper note (A3), since it is tuned by its 4th partial, its 4th partial is right where it belongs according to the stretch curve being used. However, the beat speed of F3-A3 could be helped some if the A3 were tuned slightly flatter. In fact several of the intervals involved with plain strings vs. wound strings which occur in the tenor section can usually be helped by lowering the upper plain strings on a graduated basis. One way to tell if some correction is helpful is to look at the tenor bridge to see if it flares out like the end of a hockey stick. If it does, then some lowering to the pitch starting where the "hockey stick bend" begins will help. In the past, this has been done rather arbitrarily. Now with the advent of FAC stretch numbers on the newest SAT's, one can let the computer in the SAT do the figuring. Here's one way to do it: If during the measuring of the F3 plain string stretch, you notice that it is unusually high (such as 14-25 cents), you can increase the stretch number by 1 to 2 cents before storing it in the usual fashion (your call). This will keep the beat rates from slowing down too much as the 3rds descend from C4 down to F3. When the lower notes of the plain string section have a relatively higher inharmonicity (more distance between the 4th and 5th partials of F3) the sharper 5th partial of F3 decreases the beat produced with the 4th partial of A3, the upper note.

In similar fashion one can cause the upper wound strings to be tuned slightly sharper by selecting a stretch number that is slightly lower than what was measured.

Here is the beauty of this system. You can use 2 pages of memory and do both things.

Let's say that the stringing break comes between E3 and F3. You measured stretch for F3 at 13.0 cents. Add another .5 cents before storing, then complete the measurements for A4 and C6 in the normal manner. Select page 1 in memory, roll over from STRETCH to MEM to compute and store this on page 1. Now go back to re-measure for F3 except set up the machine to E5 at 0.0, tune E3 (wound string), then jump up to E6 and measure the stretch for E3. Let's say it measures 3.7 cents. Add .3 cents (your guess), then change the note to F6 keeping the 3.7 + .3 =4.0 cents in the right window. Use SHIFT-STO-STRETCH to change the value for F3. Leave the previous readings in there for A4 and C6. Select page 2 of memory. Roll over from STRETCH to MEMORY to compute and store this second set of stretch numbers on page 2.

Tune up from F3 to C8 using page 1. Tune down from E3 to A0 using page 2. This will keep a more even progression across the stringing break as far as major 3rd and major 6ths are concerned. It will also avoid tuning the entire Bass section flatter than needed just because of the higher inharmonicity of the lower plain strings. Sometimes it even helps the octave relationships. The minor 3rds will still have a little irregularity, but it will keep the 5ths from being on the wide side in the lower plain string area.

If you are tuning a piano which has the break between F#3 and G3, you could take the usual FAC measurements and store on page 1, then take a measurement on G3 (the lowest plain string) and transfer that reading to F6 in order to compute and store on page 2. In this case all of the plain string notes would be tuned from page 2 and all of the wound strings would be tuned from page 1.

SANDERSON ACCU-TUNER™
SPECIFICATIONS

NOTE RANGE:
9 Octaves. C1 through B9 (A4 = 440.00 Hz).

CENTS RANGE:
-198 cents, to +160 cents with ±0.04 cents accuracy throughout the scale.

CALIBRATION ACCURACY:
Built-in 440.00 Hz crystal frequency standard for self-calibration, accurate to ±0.01 cents.

DISPLAYS:
Liquid-crystal displays (LCD) for NOTE, OCTAVE and CENTS.

Rotating light-emitting-diode (LED) display for analog FLAT or SHARP tuning indicator.

STRETCH CALCULATOR:
Built-in stretch calculator with automatic selection of NOTE, OCTAVE and CENTS settings.

MEMORY MODE:
The SAT II comes standard with the ability to memorize sixty 88-note tunings. (The SAT comes standard with forty piano memories). Additional Piano memory can be purchased for a maximum of 206 piano memories in each unit.

MEASURE MODE:
Computer measures unknown pitch of a note automatically and displays cents deviation.

MICROPHONE:
Built-in high-fidelity electret microphone. No external microphone required.

TEMPERATURE DRIFT:
Less than ±0.01 cents in temperatures from 40°F to 100°F.

BATTERY:
Rechargeable Nickel Cadmium (NiCad) battery with 40 to 60 hours of operation per charge. Will recharge in 12 hours and have a life expectancy of up to 8 years. SAT may be battery operated or plugged into an AC line. Automatic shut down to conserve battery power.

INPUT/OUTPUT JACKS

AUDIO IN: Input for high-level audio signals from electronic pianos and organs.

MAG IN: Input for low-level audio signals, from magnetic pickups and similar devices.

FLTR OUT: Filtered audio output at pitch selected by NOTE, OCTAVE and CENTS settings.

OSC OUT: Oscillator output for broadcasting an oboe-like tone at pitch selected by NOTE, OCTAVE and CENTS settings. (Use Speaker/Amplifier listed below.)

NOTE SWITCH: Input for foot pedal or thumb switch used to advance NOTE setting by one semitone.

BAT CHGR: Input for battery charger plug.

SIZE & WEIGHT: 7 1/2" wide, 4 1/2" high and 5 1/2" deep.
Weight 1.8 lbs.

ACCESSORIES

ALUMINUM CASES:
SMALL 12.75" X 9.75" X 5.25"
MEDIUM 15.25" X 9.25" X 6.5"
LARGE 17 1/2" X 12.25" X 6.25"

MAGNETIC PICKUP:
A microphone that magnetically attaches to the plate of the piano and picks up the signal directly from the strings without interference from room noise.

SPEAKER/AMPLIFIER:
The speaker/amplifier allows the user to listen to the tone instead of using the display in the SAT and is especially useful for chipping pianos.

PROGRAM OPTIONS

PTG TUNING EXAM OPTION:
A modification of the standard SAT to make it possible to score or practice for the PTG exam with the Accu-Tuner alone.

MIDI (MUSICAL INSTRUMENT DIGITAL INTERFACE):
Standard with the SAT II or as an optional modification to other SAT's. Makes it possible to transmit or receive stored tunings to a computer.

PIANO LIBRARIAN:
An Inventronics program for storing and cataloging piano tunings in conjunction with computers running Windows 95 or newer operating systems. Please call for current operating system compatability.

PATENTS:
U.S. Pat. Nos. 3,789,313; 3,968,719; 3,982,184; 3,983,473; 4,014,242; other patents pending; plus foreign patents.