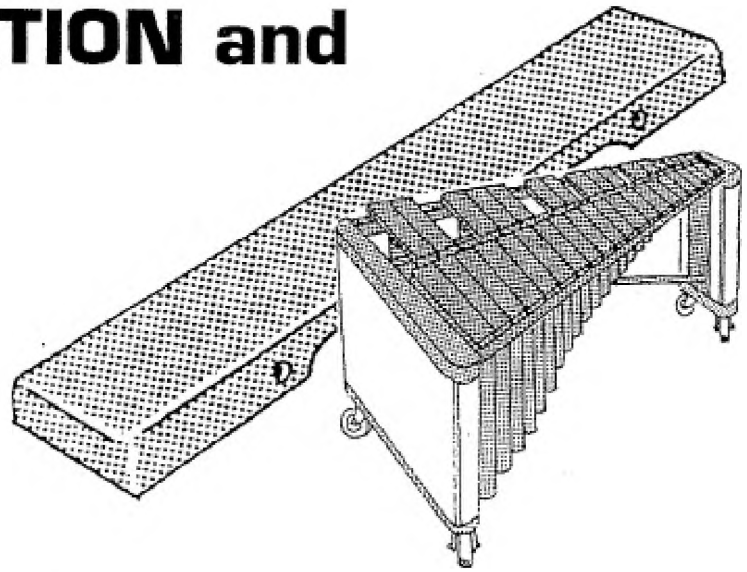
Marimba Bar Fabrication and Tuning

The step-by-step process of turning a piece of wood into a musical note suitable for melodic bar percussion

Chris Banta

MARIMBA BAR FABRICATION and TUNING



Christopher C. Banta

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To:

My wonderful wife Brenda and her son Ryan, and
my children Adrienne and Monica,
for their enduring patience with this
and all my projects.

CONTENTS

SECTION 5 BAR REPAIRS – THE ENVIRONMENT

SECTION 6 REFERENCES

TABLES

INTRODUCTION

Marimba Bar Fabrication and Tuning is a step-by-step handbook that will enable almost anyone to successfully fabricate and tune a marimba bar, bass marimba bar, or xylophone bar. It is organized in a systematic way to facilitate easy comprehension of the various steps involved. All the information is presented in the order that naturally transpires in processing a piece of timber from its raw state to a completely functioning musical note.

As the musical community becomes increasingly aware of their art form, some individuals will venture out on their own to actually design, build, and perform on their own *home-made* musical instruments. Some people have even been able to create businesses by selling some of their musical instrument projects.

While I was working on my bass own marimba projects, I became acquainted with several percussionists and musical innovators of varied talents and interests. Every individual, whom I've had the honor of meeting, has contributed to my understanding of the function of the marimba and all its intricate parts. They have provided me with the motivation and desire to continue learning about these wonderful mallet percussion instruments.

I am indebted to Del Roper, a master marimba builder, for his in-depth and seemingly endless knowledge on the subject of keyboard percussion. I am also grateful for having met Claire Musser, who is considered the *father of the modern marimba*. I give thanks to Emil Richards (Mr. World of Percussion) who knows how to play just about every modern and ethnic percussion instrument in existence, and with whom I have had the opportunity to build various instruments. I would also like to thank all the mallet percussionists and music institutions for having enough faith in my bass marimbas and in my technical awareness to have me work on their various instruments. The following is a partial list of those people and institutions:

Carl Rigoli	Rod Rozzelle
Joe Porcaro	Jules Greenberg
John Bergamo	Bob Zimitti
Alan Estes	Universal Studios, Stage 10
Gene Estes	Ron George
Ivor Darreg	Mike Fisher
Sinclair Lott	David Johnson
Jerry Williams	Julius Wechter
Jim Hildebrandt	Dan Greco
Francis Hookano	Don Williams
Dub Taylor	Chuck Burkinshaw
John Fitzgerald	Dale Anderson
Judy Chilnick	Mark Barnett
Victor Feldman	Paul Sternhagen
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Pinky Lee	David Ahlstrom
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Fred Raulston	Brian Hand
Dale Anderson	Atherton Baptist Homes

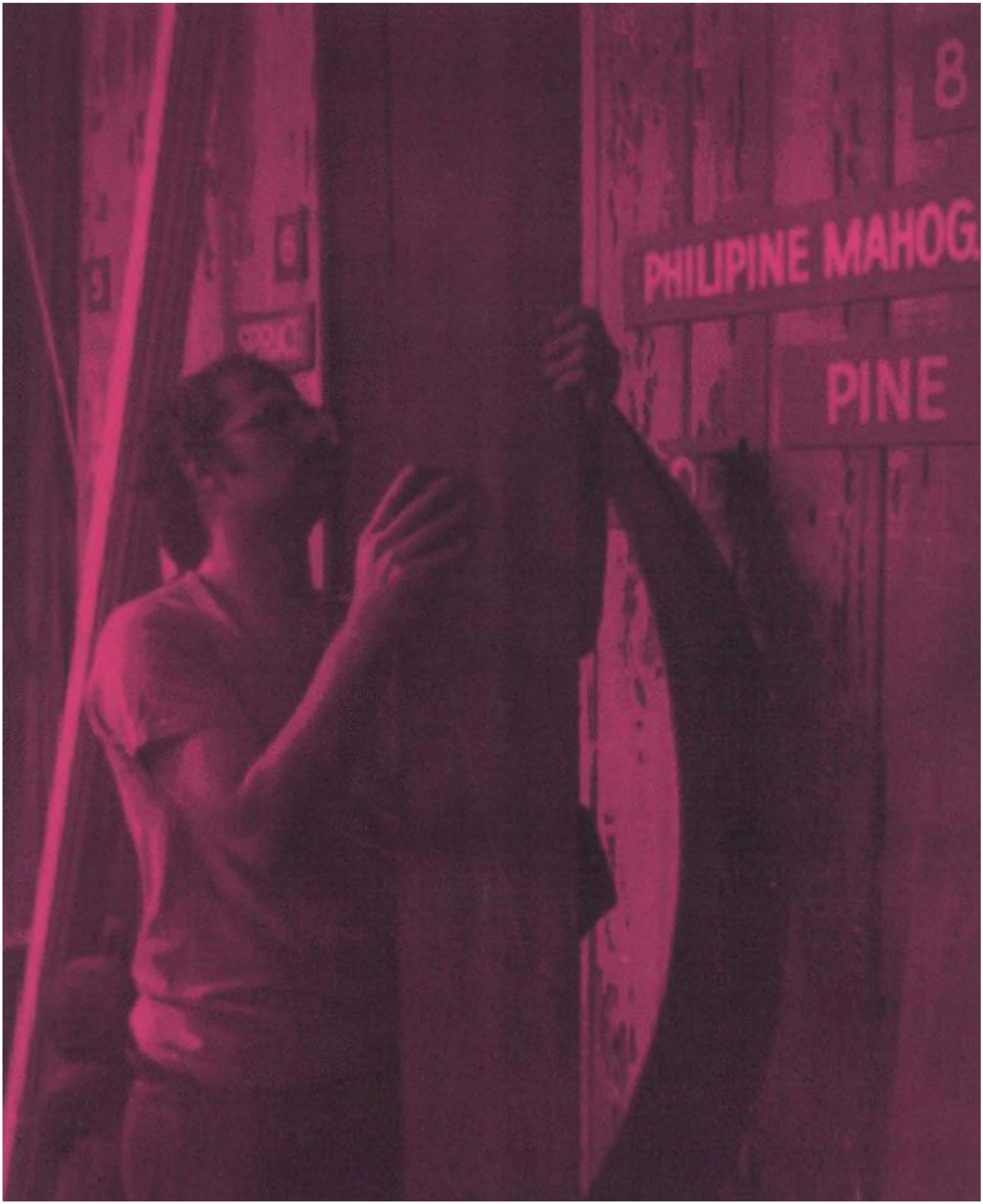
Tommy Vig
Wade Culbreath
Richard Sweet
Wayne DeBord
Steve Foreman
Dick Simonian
Terry Gibbs
. . . and many others

Cliff Hullings
Kidspace Museum, Pasadena
Pasadena High School (PHS)
California State University, Fullerton
Bob Szuch
Kurt Rasmussen
U.S. NAVY, Music School, Norfolk, VA

Christopher C. Banta

SECTION ONE

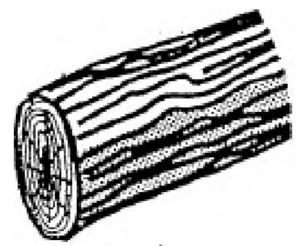
MATERIALS


8
PHILIPINE MAHOG.
PINE

Chapter 1

BAR MATERIALS

When designing and building *bar percussion* musical instruments, is it necessary for the designer to become fully acquainted with the physical properties of the materials used in the bar's construction. Since marimba, bass marimba, and xylophone bars are generally made out of wood (with the exception of certain instruments using synthetic, non-wooden materials), it is helpful to understand specific behaviors of wood so cost and time consuming mistakes associated with wrong material purchases, and can be minimized.



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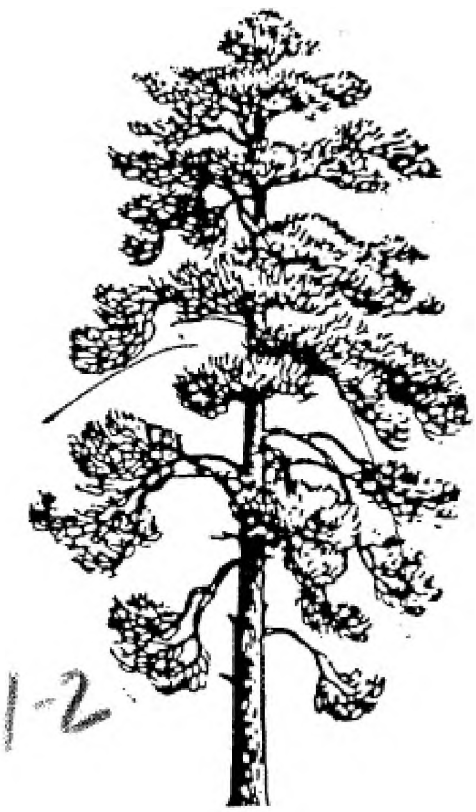
This chapter is divided into three classifications of materials; *Soft Woods, Hard Woods,* and *Synthetic Materials.*

NOTE:

The terms soft and hard are used to establish a basis of relative comparison rather than a quantitative comparison between the classifications of wood.

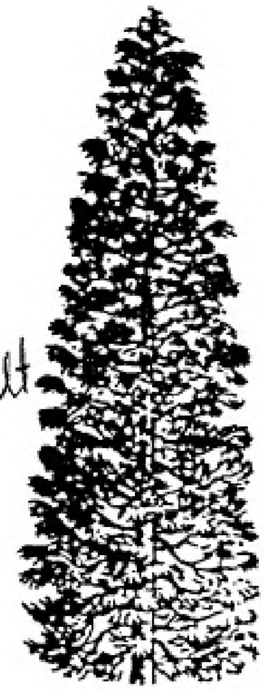
SOFT-WOOD CLASS



Soft-woods are characterized by being *lightweight, having moderate density and tensile strength, and are easy to shape in a way that tends to cause less wear and tear to saw blades and cutting tools than woods in the hard-wood class*. Some examples of soft-woods are; white pine, fir, white fir, spruce, cedar, even mahogany. One characteristic of soft-woods is their open or loose grain structure, as evident by the widened gap of organic trunk material between growth rings.

In some cases, soft-woods may be used for *indirect* musical purposes. For example, spruce is used for piano soundboards, and guitar and violin bodies. The wood is designed to vibrate as a secondary sound source, which is triggered by the transference of energy from a vibrating string. Another example is white pine, which is used extensively in organ pipe construction. In this case, the pine is fabricated to create the pipe's resonant column, which provides the boundary for the air to propagate within.

For marimba purposes, certain varieties of softwoods (such as; white pine and white fir) are great for bar-fabrication *learning* purposes. Wood supplies are abundant, relatively inexpensive, their vibrational characteristics are adequate, and the ease with which they machine saves time. This helps beginning marimba builders to grasp the bar's behavior during the early learning stages of bar tuning.



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HARD-WOOD CLASS

Hard woods are characterized by being *heavy and relatively dense, having a high tensile strength, and are generally tougher to shape than woods from the soft wood class.* Some examples in the hard-wood class are; walnut, birch, ash, oak, maple, macacauba, shedua, teak, and bubinga. Hard woods have a tighter grain structure which contributes to their density and added weight.

Many types of hard-woods are found in cabinetry work. They contain character marks and swirls that look particularly attractive on furniture. Although visually appealing for furniture, they are generally not conducive to the vibrational characteristics required in bar percussion.

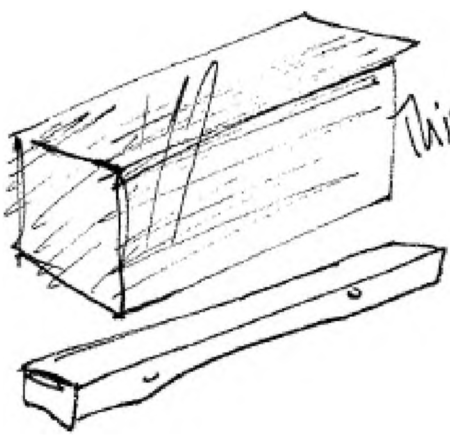
1-4

When a hard-wood grain structure is absolutely straight it can be a good candidate for primary vibrational sound sources, such as the marimba bar. (*See Chapter 2 for bar percussion wood grain straightness criteria.*) For visual appeal and additional structural considerations, hard woods can also be used as secondary musical instrument components. For example, the dark and rich wood

ebony is used in clarinet, oboe, and piccolo bodies.

Hard-woods are generally more durable than soft woods, which makes them ideal for bar percussion. Most hard woods have good vibrational characteristics and are fairly rugged. African Padouk, Macacauba, Bubinga, Rosewood, and Purple Heart are examples of woods that may qualify for bar percussion. Some will be heavier than others, some will be easier to obtain than others, and some will be more costly than others.

SYNTHETIC MATERIALS



As the availability of hard woods dwindles or becomes increasingly more expensive, certain types of synthetic materials may be a desirable alternative. One such synthetic is called a *polycarbonite*, which is a manufactured fibrous plastic that is extremely resilient. The sound quality or timbre from a polycarbonite marimba bar has a distinctly different character than wood, depending on the likes and dislikes of the performer or listener. The sound has been described to occur somewhere between wooden and metallic.

Synthetic materials have three distinct advantages over wood. First, they are not plagued with varying densities and organic inconsistencies associated with wood—a direct result that may contribute to differing sustain times and tonal quality. Second, synthetics are less affected by weather. The grains of wooden bars can make them susceptible to humidity absorption, which may affect sustain time. And finally, synthetics are tougher than wood, which makes them able to resist damage and splintering from repeated and hard mallet blows, and from rough handling.

You may then ask, "why use wood?" The answer lies partly in the fact that many performers and listeners still prefer the warm and natural sound of wooden percussion.

A NOTE ABOUT SEASONED WOODS:
Stay away from wet or so-called "green" woods in marimba bar fabrication. As the wood dries there will most likely be shrinkage, warpage and cracking along with the possibility of a change in pitch after the bar has been tuned. When at the lumber supplier, be sure to inquire as to how long the timber has been in stock, where it came from, and if they know when it was cut down. If the stock has been sitting in covered environments for six-months or longer, it is probably sufficiently dry.

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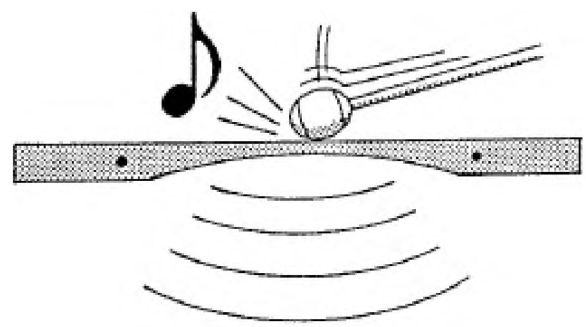
Chapter 2

FUNCTIONAL CHARACTERISTICS AND GRAIN STRUCTURE OF WOOD

There are three characteristics that affect the functional qualities of a vibrating wooden bar; *density, hardness,* and *grain structure.*



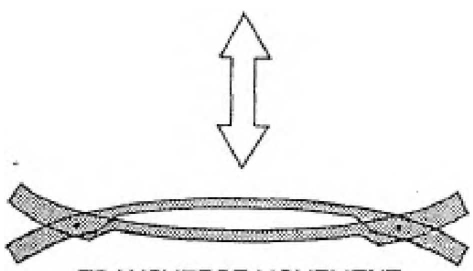
Density is the mass that contributes to the sustain qualities of the material. In general, materials with heavy masses will sustain longer than materials with lighter masses. (Hardwoods have higher densities than softwoods.) Sustain time is desirable for marimba bars. The longer the bar sustains, the longer it will continue to transfer energy into a resonator. The result is a longer-lasting, full-sounding, highly resonant note. Bars with short sustain times have a rapid tapering-off sound when struck—similar to a bump or thud.

Hardness is the durability of the wood and its ability to withstand continued mallet blows without damage. Since xylophones are played with harder mallets, bars must be made from a harder variety of hardwood.

Grain Structure is the internal pattern or direction of fibers within a piece of wood. During vibration, grain contributes to the resiliency and restorative force which eventually causes the bar to come to rest.

The marimba bar is a precision mechanical structure. When struck with a mallet, the bar vibrates with extreme regularity, and should maintain it's vibration or frequency for many years. Density, hardness, and grain-structure are responsible for transferring the bar's vibrational energy into the immediate environment. With the aid of a resonator, to amplify the bar's energy, the ear will hear this *boosted* energy as an audible frequency or tone.

LENGTH-WISE GRAIN


TRANSVERSE MOVEMENT

Length-wise grain is responsible for the *transverse* motion of the bar. Absolutely *straight-grain*, that lays in parallel direction, is required for optimizing transverse movement. (Figure 2A)

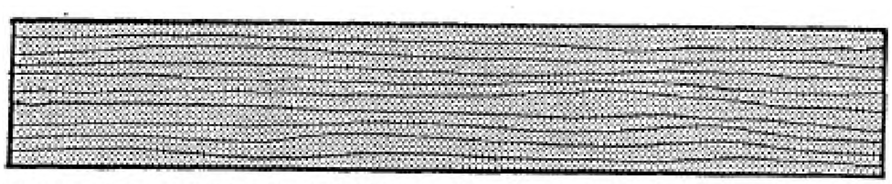


FIGURE 2A (TOP VIEW) - STRAIGHT GRAIN

A slight change is grain direction may be acceptable. But this won't be known until the bar is tuned and its sustain qualities can be evaluated. (Figure 2B)

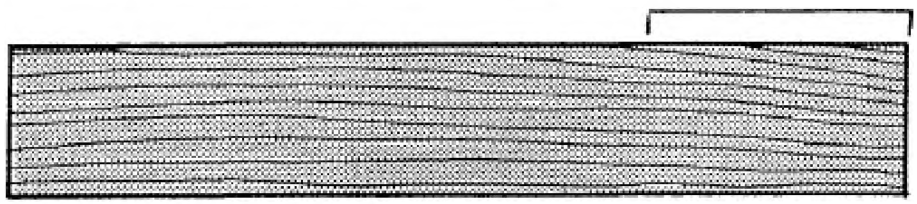


FIGURE 2B - SLIGHT CHANGE

If a piece of wood with a change in grain direction is used, the change should not occur until after the three-quarters point of the bar's length. (Figure 2C) Avoid this if possible

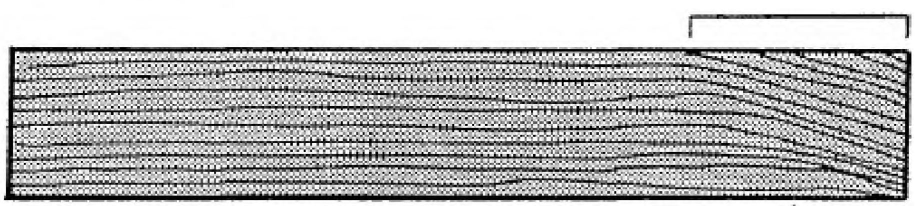


FIGURE 2C - NOTICEABLE CHANGE

Radically curved grain hinders the bar's movement which makes it unusable for musical purposes. (Figure 2D)

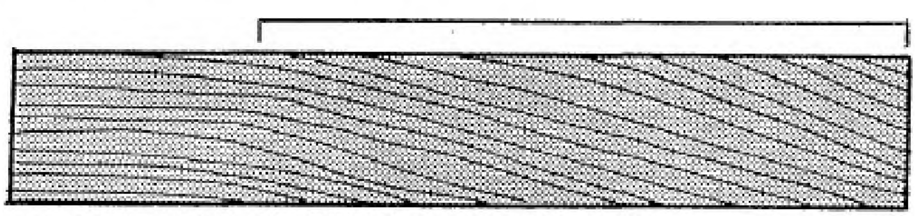


FIGURE 2D - RADICAL CHANGE (CONTRARY GRAIN)

Hindered vibration is immediately evident when the bar is struck. Its motion is severely limited and any vibration would cease instantly. *Contrary* grain is bad because it prevents transverse motion from occurring.

A bar with a radical departure from straight grain, might be put to better use. It is possible to sub-divide and recut the bar into pieces that utilize the straight portions of the grain. (Figure 2E)

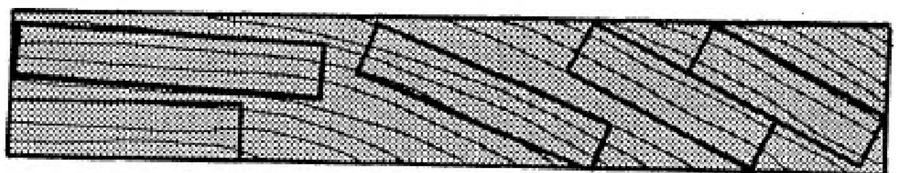
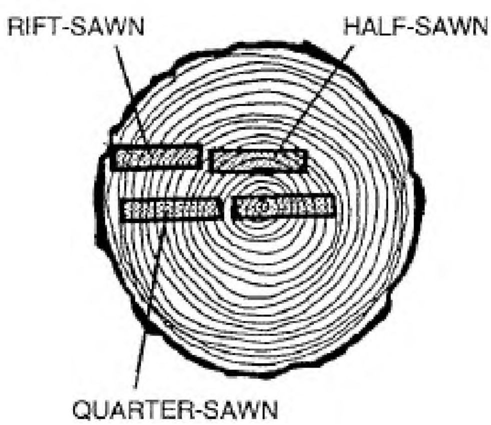


FIGURE 2E



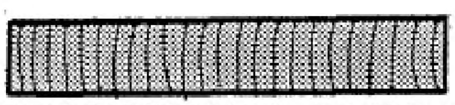


FIGURE 2F (END VIEW) - QUARTER-SAWN

END GRAIN

End grains are less critical than the length-wise grains. However, in the interest of quality musical instrument construction, there is an optimal cut from the tree. The best end grain cut (for vibrational purposes) is *quarter-sawn*. (Figure 2F) This cut maximizes the bar's movement and can be detected by it perpendicular lines to the bar's width.

Unfortunately, quarter-sawn end grains can only be located after sorting through piles of lumber. Patient visual inspection of each board will yield the best quality.

Most quality lumber is *rift-sawn* which is similar to quarter-sawn in that the grain lines are more oblique and less perpendicular. (Figure 2G)

FIGURE 2G - RIFT-SAWN

Standard grades of lumber are *flat* or *half-sawn*. (Figure 2H) Since half-sawn cuts are not symmetrical like the quarter-sawn variety, the transverse energy is not as vibrant and sustain times tend to be shorter in duration.

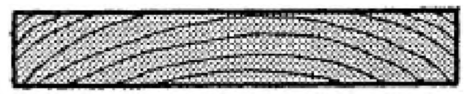


FIGURE 2H - FLAT OR HALF-SAWN

End grains that contain the center of the tree are totally unsuitable for bar percussion. (Figure 2I)

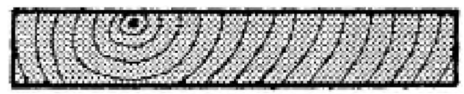


FIGURE 2I - TREE'S CENTER

KNOTS

The ideal piece of wood should not have knots anywhere within the grain structure. However, sometimes they are unavoidable. Small *pin-hole* knots, in small quantities, are acceptable. (Figure 2J)

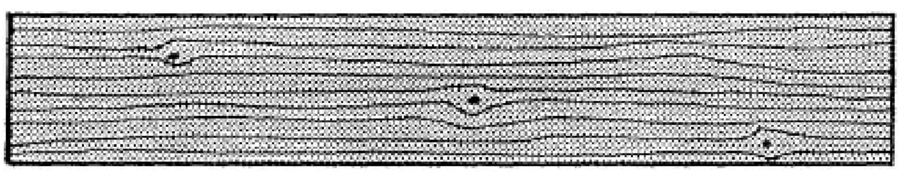


FIGURE 2J (TOP VIEW) - PIN-HOLE KNOTS

Large knots that break up the grain's continuity, are unacceptable for bar percussion. (Figure 2K)

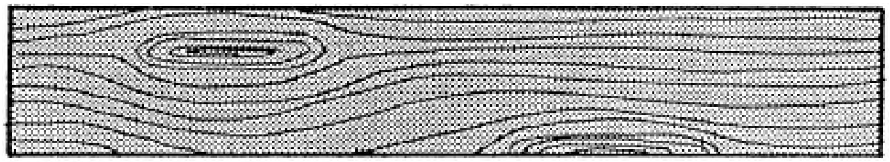


FIGURE 2K - LARGE KNOTS

SHRINKAGE

Shrinkage occurs when moisture in the wood dissipates into the air. Since dissipation is a natural process, do not use wet or so-called "green" woods in marimba bar fabrication. As the wood dries, it may warp or crack along with the possibility of the pitch changing after the bar has been tuned. While at the lumber supplier, be sure to inquire as to how long the timber has been in stock, where it came from, and if they know when it was cut down. If the stock has been sitting in covered environments for six-months or longer, it is probably sufficiently dry.

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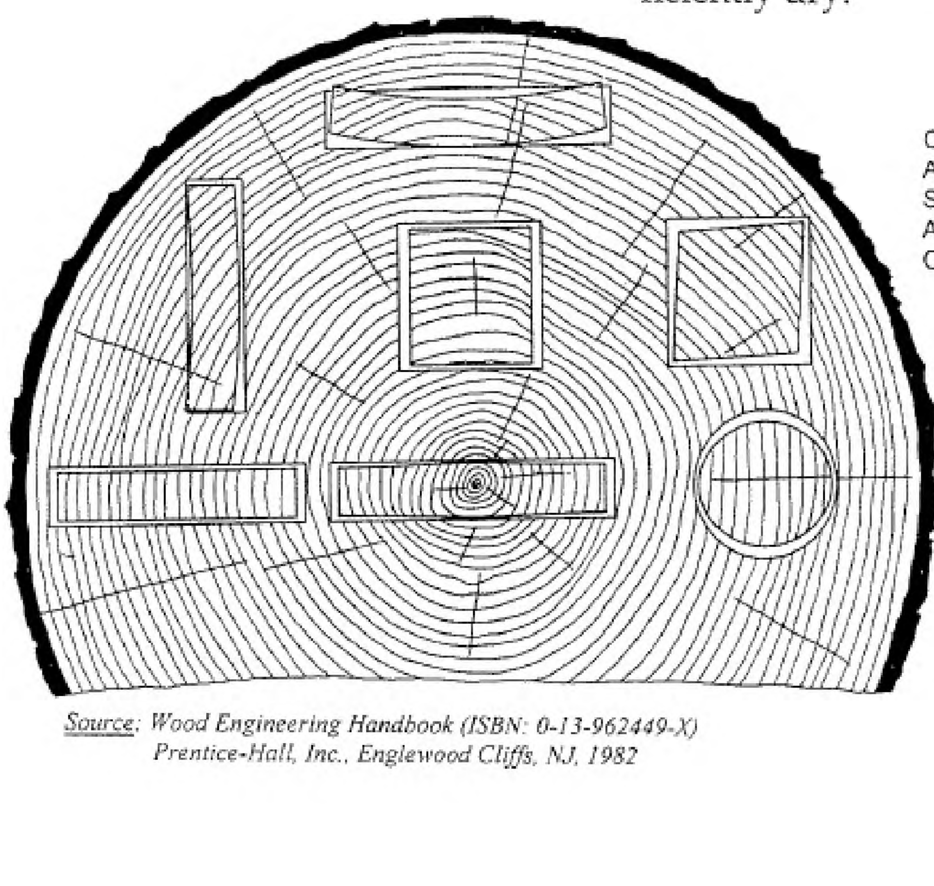

CHARACTERISTIC SHRINKAGE AND DISTORTION OF FLATS, SQUARES, AND ROUNDS AS AFFECTED BY THE DIRECTION OF THE ANNUAL RINGS.

Source: Wood Engineering Handbook (ISBN: 0-13-962449-X) Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982

Chapter 3

MUSICAL QUALITIES OF WOOD

The following is a partial list of commonly known woods. Each wood contains a simple description as to its suitability in bar percussion instruments.

***African Padouk** - Sometimes called *vermilion* because of its brilliant orange-red color. This wood has an outstanding fundamental sustain with powerful overtones. Recommended as an excellent replacement to Honduras Rosewood.

Birch - Looks good on coffee tables and kitchen cabinets, but has a dull sound with a medium sustain time. Overtones are weak.

Brazilian Rosewood - Don't let the word *rosewood* fool you. Commonly found in ethnic flutes and whistles from South America. Not much better than Birch.

NOTE:
The asterisk (*) indicates the wood is acceptable for use in both marimba and bass marimba construction.

***Bubinga** - Very rare, therefore costly. If located, grab it! Very good fundamental and overtone characteristics. Very resilient to repeated mallet blows.

Eastern Indian Rosewood - Again, don't let the word *rosewood* fool you. This wood looks pretty, but that's about all. Has minimum sustain time. No relation to Honduras Rosewood.

***Honduras Rosewood** - The all-time industry standard for bar percussion instruments. Has excellent sustain and overtones, and is resistant to repeated mallet blows. Somewhat difficult to obtain and is costly. Quality appears to be less than the wood from thirty years ago, sometimes requiring large quantities of scrap to yield small amounts of choice wood.

***Macacauba** - Sometimes called *macawood.* Outstanding fundamental sustain with strong overtones. Comes in long straight-grained lengths which makes it a good choice for bass marimbas. Machines extremely well and takes a beautiful finish.

Oak - As always, a tough wood to saw and shape. Fair sustain. However, better suited for that roller-top desk.

Pau Ferro - Totally dead for vibrating bars! This is probably due to its extreme sap content. In fact, this wood is heavier than the specific gravity of water, thus unable to float. Gives off a sickeningly sweet odor when machined.

Philippine Mahogany - Not bad for a softer wood. Works moderately well on bass marimba notes, even with a slightly hindered sustain time. However, no good for the middle and upper registers on marimbas due to the softness. Very easy to machine and shape.

Purple Heart - Has good sustain qualities. But, fabrication is difficult. This wood tends to burn when sawing and planing, which might be caused by its sap content. Brilliant purple finish.

Shedua - A so so wood probably better suited for furniture use.

Spruce - A wide-grained wood used primarily for secondary resonation components such as piano sound boards, guitar bodies, and organ pipes. **Sitka Spruce** is the denser variety that has been used on bass marimba notes by instrument builder Harry Partch.

***Teak** - Excellent overtones and good fundamental sustain. The only problem is that this wood contains small grits within its grain that tend to dull saw and planer blades. Very oily. A good bass marimba replacement alternative in the absence of honduras rosewood, padouk, or macacauba.

Walnut - Similar to Birch.

White Pine - Too light and soft for bar percussion. However, is great for bar fabrication learning purposes and prototype work. Excellent for column resonators and organ pipes. Very easy to machine.

BAR PERCUSSION QUALITIES OF WOODS

The tables on pages 29 and 30 provide some quantitative data on the woods listed above. This may be helpful when selecting wood types, their sustain and overtone qualities, durability, and the types of [wooden] bar percussion instruments they are most suited.

TABLE 1A: MUSICAL QUALITIES OF WOOD USED IN BAR PERCUSSION (Alphabetical Order)

CODES:

4 = Excellent	M = Marimba
3 = Good	B = Bass Marimba
2 = Fair	X = Xylophone
1 = Poor	-- = Not recommended

WOOD TYPE	SUSTAIN QUALITY	OVERTONE QUALITY	DURABILITY	USE
African Padouk	4	4	3	M, B
Birch	2	2	3	--
Brazilian Rosewood	2 1/2	2	3 1/2	--
Bubinga	4	3 1/2	4	M, B, X
Honduras Rosewood	4	4	4	M, B, X
Macacauba	4	4	3	M, B
Oak	2 1/2	2	4	--
Pau Ferro	1	1	3 1/2	--
Philippine Mahogany	2	2	2	B
Purple Heart	3	3	3 1/2	M, B
Shedua	2	2	3	--
Spruce	2 1/2	3	2 1/2	B
Teak	3 1/2	4	3	M, B
Walnut	2	2	3	--
White Pine	1 1/2	2	1	--

TABLE 1B: MUSICAL QUALITIES OF WOOD USED IN BAR PERCUSSION (Order of Quality)

CODES:

4 = Excellent
3 = Good
2 = Fair
1 = Poor

M = Marimba
B = Bass Marimba
X = Xylophone
-- = Not recommended

WOOD TYPE	SUSTAIN QUALITY	OVERTONE QUALITY	DURABILITY	USE
Honduras Rosewood	4	4	4	M, B, X
Bubinga	4	3 1/2	4	M, B, X
African Padouk	4	4	3	M, B
Macacauba	4	4	3	M, B
Teak	3 1/2	4	3	M, B
Purple Heart	3	3	3 1/2	M, B
Spruce	2 1/2	3	2 1/2	B
Brazilian Rosewood	2 1/2	2	3 1/2	--
Oak	2 1/2	2	4	--
Walnut	2	2	3	--
Birch	2	2	3	--
Shedua	2	2	3	--
Philippine Mahogany	2	2	2	B
White Pine	1 1/2	2	1	--
Pau Ferro	1	1	3 1/2	--

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Chapter 4

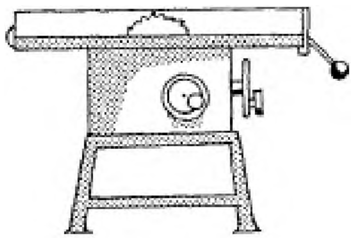
TOOLS USED IN FABRICATION

Tools used in marimba bar fabrication must be capable of shaping a piece of wood into its final *marimba bar* form, which includes; cutting, smoothing, and finishing. Fabrication of the bar with only hand tools may prove to be an exercise in futility. The work will be very time consuming and may try the worker's patience. The author firmly believes in the use of stationary power tools to accomplish most fabrication operations. Hand power tools are effective for those operations not requiring high levels of accuracy, such as rough cutting and sanding. This chapter is divided into two sections; *stationary power tools* and *hand power tools*.

STATIONARY POWER TOOLS

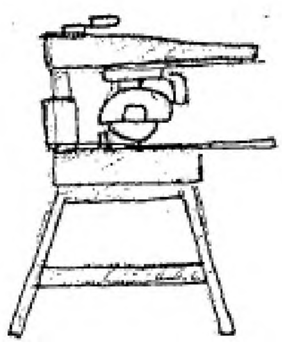
Due to their structural integrity, rigidness, and overall weight, stationary wood power tools generally provide a higher level of accuracy than their hand held power tool counterparts. Operator shakiness and error are reduced when movements associated with material or tool *lifting* are removed.

Table Saw



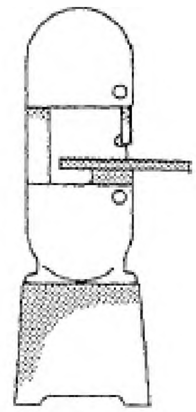
The table saw is a standard wood shop tool. It performs two basic functions; *ripping* and *cross-cutting*. Ripping (with the grain) reduces larger pieces of wood into narrow pieces with the aid of the ripping fence. Cross-cutting (against the grain) reduces the narrow pieces into shorter lengths with the aid of a cross-cut or miter-gauge. Wood, in either case, is pushed against a rotating blade while being guided and supported by the saw's table and the rip-fence or miter-gauge.

Radial Arm Saw



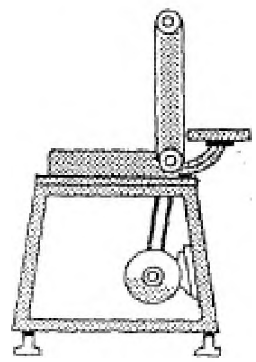
The radial arm saw can perform all of the functions of the table saw plus a few additional cuts because of its swivel head. Instead of the blade-motor assembly being permanently attached to the table, the radial arm saw's blade-motor assembly is capable of movement. For example instead of adjusting the rip fence some distance from the blade, the blade on the radial head is moved away from a stationary fence. Ripping of long boards are pushed into the rotating blade just like the table saw. For cross-cut operations, the blade is moved (back-&-forth) while the board remains in a fixed position. The arm of the saw is capable of being positioned at angles to accommodate angular cutting. The swivel also adjusts so the blade can make compound and angular cuts.

Band Saw



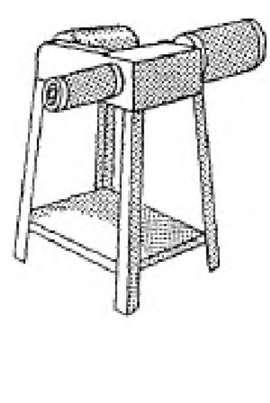
The band saw was designed to perform secondary cutting operations known as *re-sawing*. Due to is blade length, it has the ability to cut through greater thicknesses of wood than the table or radial arm saws. Since the width of the blade is narrow, it can perform curved cutting in the wood. This makes it ideal for removing the arch portion of the marimba bar. (See page 76)

Belt Sander

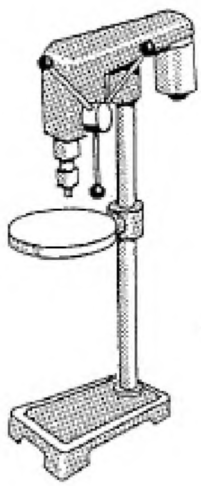


The belt sander provides a power sanding capability which smoothes-out saw blade cut marks on the wood. The rounded part of the belt sander can be used for removing material from the arch area during tuning operations. (See page 95)

Inflatable Drum Sander



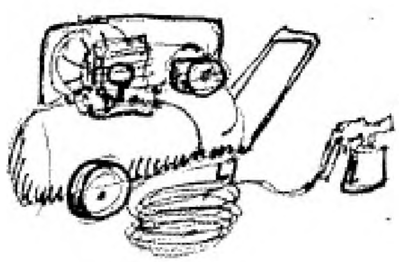
The inflatable drum sander holds sand paper drums in place with air-filled cylindrical-shaped bladders. By varying the air pressure within the bladder, the sanding drum will yield more or less to conform to the shape of the sanded object. Low pressure allows the drum to conform to rounded shapes and corners which give them a buffed appearance when using a fine-grit sanding drum. High pressure provides less give so the drum removes greater quantities of ma



terial. This can be helpful when sanding out splinters and dents. (See page 89)

Drill Press

As per its name, the drill press is used to drill holes. This tool provide a small support table, 90° to the drill bit, that serves to stabilize the material being drilled. (See pages 83, 84)



Air Compressor

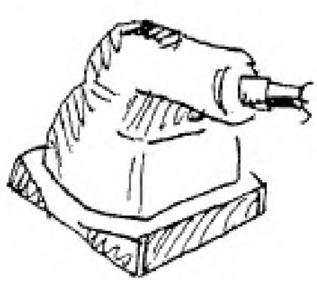
The air compressor provides a regulated air source for spray paint guns. Air pressure is used to siphon paint from a canister into a special nozzle system that controls the flow or paint or spray onto the work. (See pages 90, 91)

HAND POWER TOOLS

Router

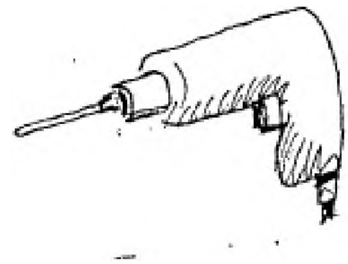
The router is a high-speed tool used for shaping the corners of wood. It uses specially shaped cutting bits to create a radius, cove, or a complex pattern on the wood. (See page 71)

Orbital Sander



The orbital sander is used to prepare the wood for eventual finishing. Its orbital (swirling) action removes tooling flaws and marks caused by larger grit sanding papers. (See page 89)

Electric Drill



In addition to creating holes, the electric drill can also be used to countersink the holes that were made by the drill bits. Countersinking provides a wider entryway into the hole. (See pages 86, 124)

Airless Paint Gun

Used to apply paint onto the work in spray fashion. However, this system does not rely on air pressure to force paint into a spray gun. Rather, it uses a reciprocating piston to create the pressure against the paint and direct it through the spray nozzle.

NOTE:
See Table 4 (page 67) for a listing of bar fabrication operations and the recommended tools.

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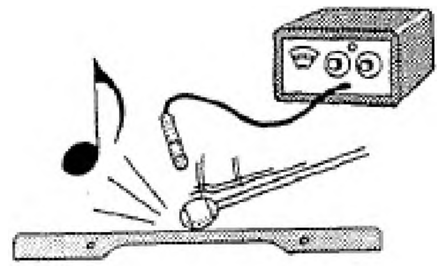
Chapter 5

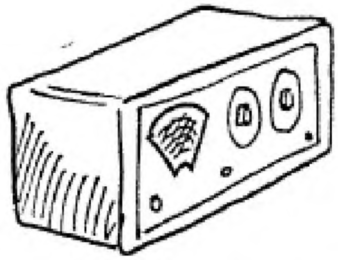
TUNING DEVICES

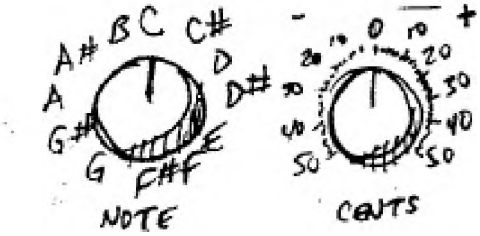


Accurate tuning is only possible with the aid of an accurate tuning device or instrument. A tuning device is superior to the ear because it is designed to make distinctions between small interval distances, which is necessary for precise tonality

All tuning instruments have a *pitch display* mechanism which is triggered by a burst of energy, such as; a plucked string, trumpet blast, or a marimba bar that is struck by a mallet. These instruments are designed to display and indicate an instantaneous reading that provides the user with immediate visual feedback of the musical instrument's frequency or pitch.

NOTE: Due to changing technologies, this chapter will not attempt to identify nor describe all types of tuning devices that are available on the market.

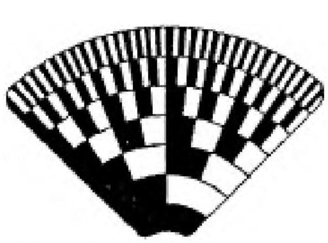




TYPES OF TUNING DEVICES

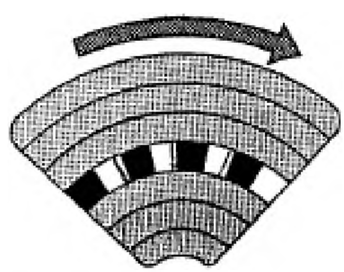
Stroboscopic

The stroboscopic or strobe tuner has a translucent rotating disc attached to a motor which is controlled be two dials. One dial is marked with every step in the chromatic scale, and the other dial provides continuously variable settings (marked in cents*) between each of those steps. The rotating disc contains a printed pattern of lines (in varying widths) each corresponding to a specific octave. Behind the disc sits a neon bulb which flashes on and off with every pulse or vibration of the sound source's frequency. These pulses are picked up by a microphone connected to the device. During operation, the neon flashes through the disc causing stroboscopic imaging.

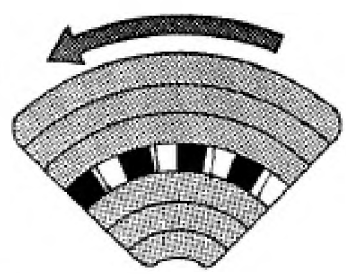


DISC STANDING STILL

When the frequency of the sound is sharp, in respect to the dial settings, the strobing image will move to the right. If flat, the image moves to the left. When the frequency is correct, the image stands perfectly still.



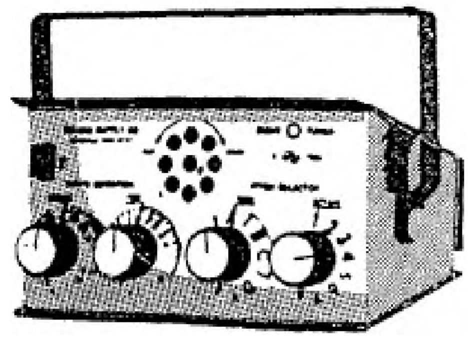
SHARP OF PITCH



FLAT OF PITCH

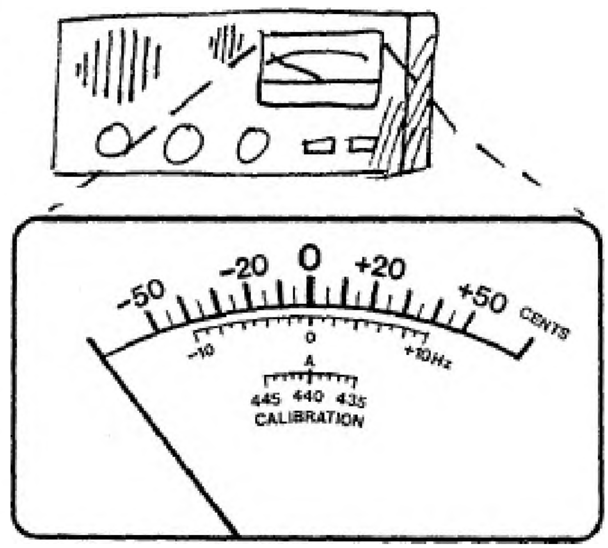
** In the 12-note chromatic scale, each half-step is subdivided into one hundred equal parts – called cents. Since there are twelve half-steps to the octave, the total number of cents per octave equals 1200.*

Some strobe tuners require calibration to compensate for temperature and instrument warm-up, Others do not require calibration because they are crystal-controlled.



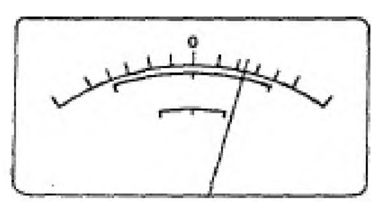
Light Emitting Diode (LED)

The LED type device has many similar features as the strobe tuner with the exception of its display mechanism. A microphone is coupled to electronic circuitry which activates the LED's. They blink on and off in a circular fashion. Clockwise represents a sharp pitch, and counter-clockwise a flat pitch. When the LED's light up but do not blink or rotate, then the sound source frequency is correct with respect the notes and cents dial settings.

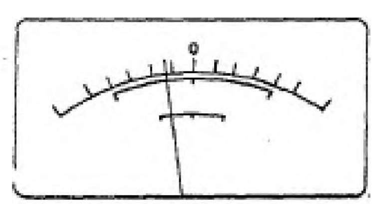


Analog Meter

This tuning device also utilizes electronic circuitry and selector switches. However, the visual indicator is a meter with a zero mid-scale mark. To the right of zero indicates sharp pitch by varying degrees. To the left, flat pitch. The zero position represents correct pitch. Some meters contains an internal loudspeaker for providing audible tones. This is sometimes useful for direct comparisons to the sound source's frequency. Metered tuners are usually portable hand held devices which makes them great for on the spot tuning. However, since



SHARP OF PITCH



FLAT OF PITCH

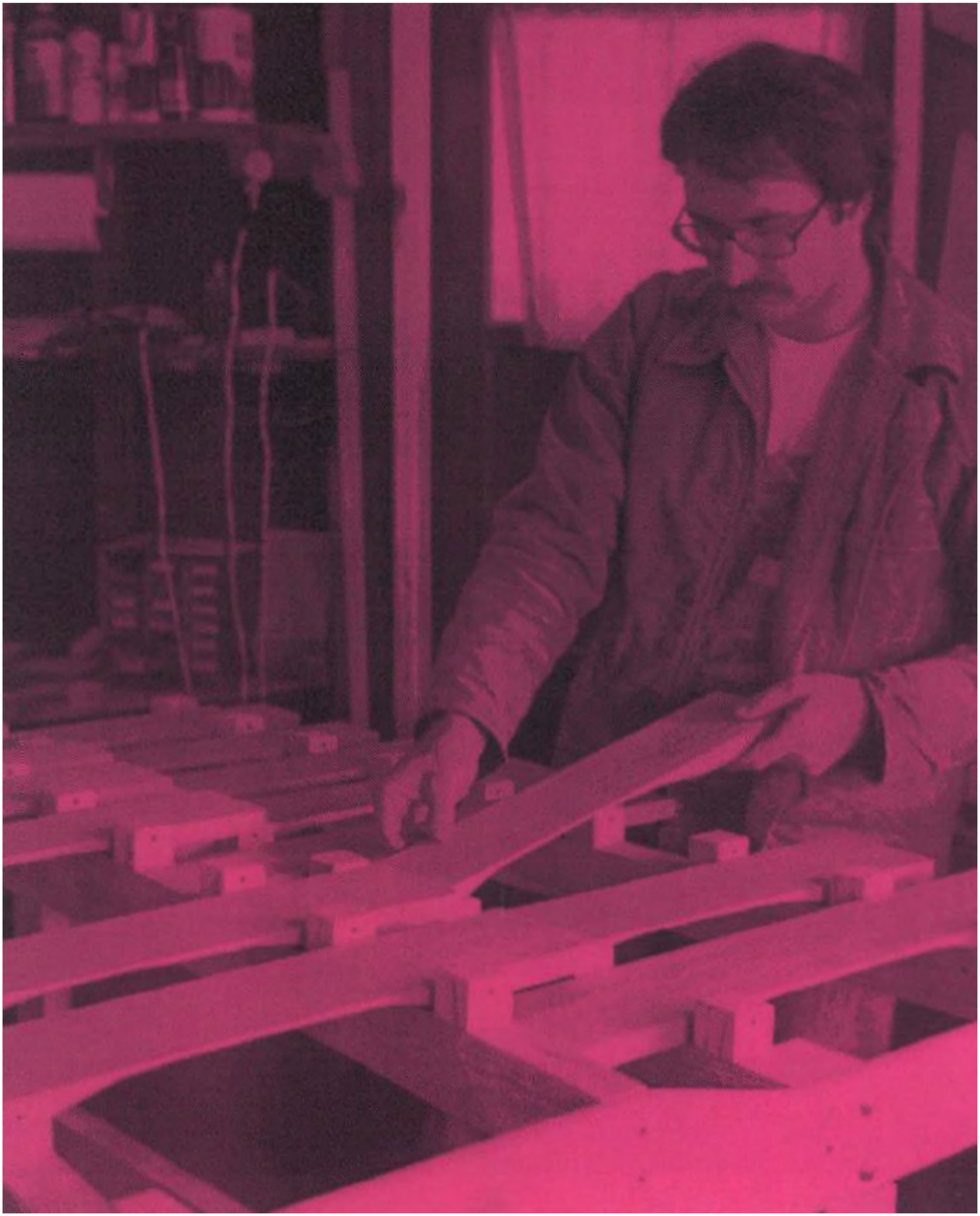
the meter is small, it is difficult to discern one-cent resolution. (This does not mean the metered tuner is any less accurate. It just means that it may be difficult to read, for example, the distinction between a D plus 13 cents and D plus 14 cents.)

Digital Display

Some tuning devices utilize An *alphanumeric* readout accompanied by a minus sign and a number which indicates the amount of cents deviation from zero. For example, if the display read A - 14, this would represent a pitch that is 14 cents flat of A. A display that reads F 37, would be a pitch that is 37 cents sharp of F. Double zero would indicate an *at pitch* setting. These units aid the musician in quick accurate tuning, thus minimizing some of the complexities of the other tuners.

SECTION TWO

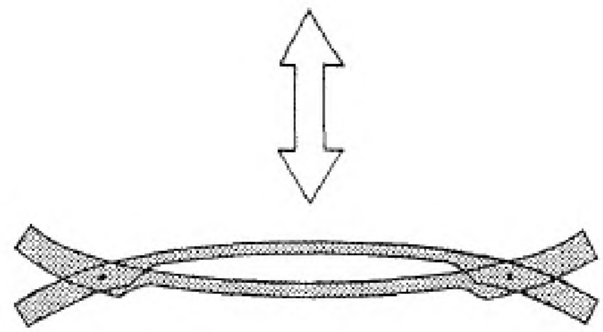
DESIGN CONSIDERATIONS



Chapter 6

MODES OF VIBRATION

All sound is produced by *vibration*. The speed of this vibration determines frequency which is called *pitch*. High frequencies equate to high pitches and low frequencies to low pitches. The marimba bar, like a string, has several *modes* of vibration. These modes are individual segments of movement, all of which occur simultaneously and which contribute to the bar's overall *quality* of sound.

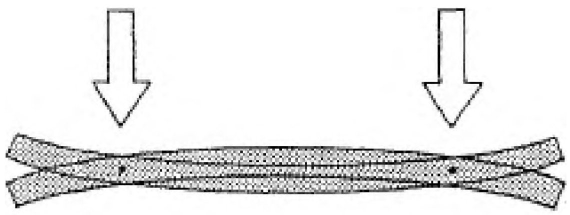


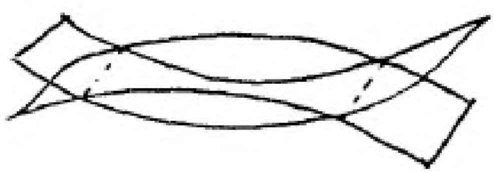
DESCRIPTION OF MODES

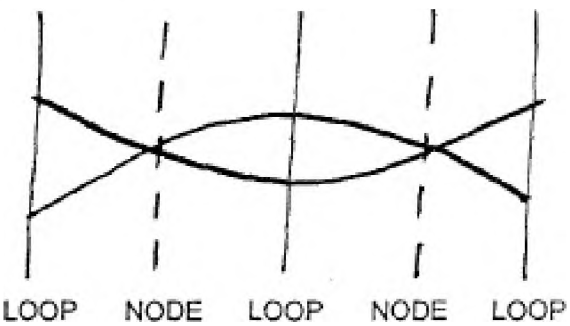
Since the marimba bar is a rectangularly shaped body, there are three modes of vibration that occur along the length-wise plane of the bar. The exact location of these modes determines how the bar is to be tuned. These modes are respectfully referred to as *first, second,* and *third* modes of vibration.

First Mode of Vibration

The first mode of vibration represents the *fundamental* or primary pitch of the bar, and is sometimes referred to as the *first harmonic.* This mode occurs from a single vibrational pattern known as; loop-node-loop-node-loop. The first mode of vibration has a mathematical value or ratio associated with it, which is the ratio of 1:1.







The illustrations herein have the bar depicted as a "lined" figure to show where the modes occur more clearly.

The first mode has the greatest degree of freedom, thus giving off the greatest amplitude. This is why the fundamental pitch is the most predominate tone, and that which is heard on every musical note on bar percussion instruments.

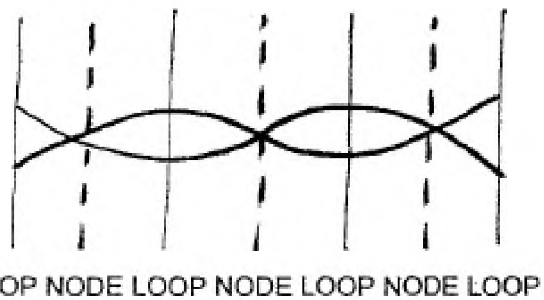
Helpful Definitions:

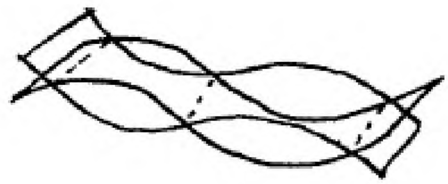
Loop: The low pressure area in the body that vibrates with maximum intensity.

Node: Is the opposite of a loop in that it is the high-pressure area that contains little or no vibration.

Second Mode of Vibration

The second mode of vibration provides the secondary pitch or second harmonic, and has four loops and three nodes, as illustrated:

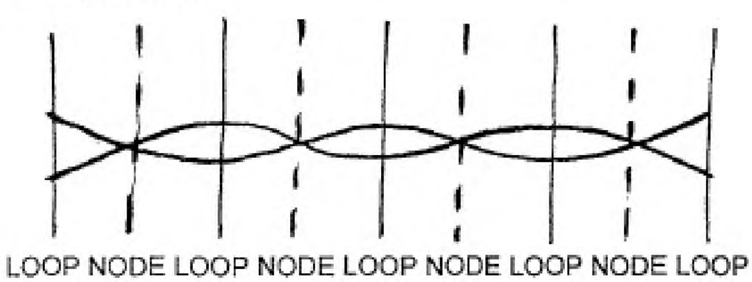


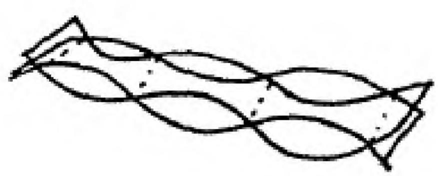


The frequency of the second mode occurs two-octaves above the fundamental frequency (first mode). For example, if the fundamental frequency is 100 Hz, then the frequency associated with the second mode would be 400 Hz. This relationship represents a ratio of 4:1.

Third Mode of Vibration

The third mode of vibration provides the third pitch or third harmonic, and has five loops and four nodes, as illustrated:





The frequency of the third mode occurs three-octaves and a third above the fundamental frequency. If the fundamental were 100 Hz, and the second harmonic is 400 Hz, then the third frequency associated with the third mode would be 1000Hz. This relationship represents a ratio of 10:1.

It should be mentioned that these three modes result from careful tuning of the bar (as discussed in Chapter 16), but do not exist in raw material bar stock. When the harmonics are not tuned, the bar will not sound musical or harmonious. Rather, it will have a non-musical *clang* or *clunk* sound when struck with a mallet or dropped onto a hard surface.

NOTE: In the bar percussion community, the terms "second" and "third" are often brought up during discussions of bar tuning. For example, a marimba whose bars are only tuned with the fundamental and the second harmonic, are said to have "harmonic" or "second harmonic" tuning. Instruments with all three modes tuned are said to have "third harmonic" tuning, thus creating a distinction between the two tuning configurations.

THE XYLOPHONE BAR

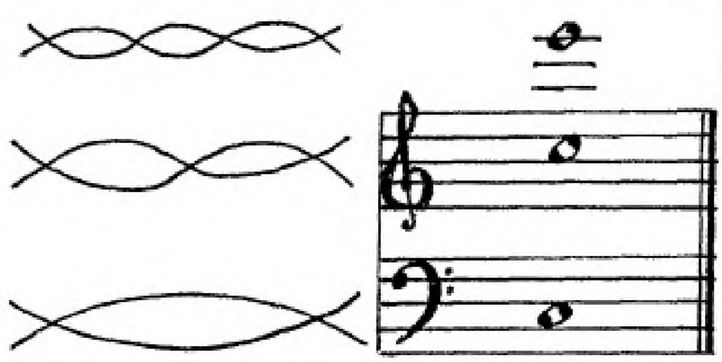
The mode of vibration for the xylophone bar results when the second harmonic (4:1) is lowered a perfect fourth. This places the secondary harmonic pitch of the xylophone bar an octave and a fifth above its fundamental pitch (or the 3:1 ratio), and is what gives the xylophone it's characteristic tone. In our example, if the xylophone bar fundamental is 100Hz, then the harmonic would be 300Hz. See Chapter 18 for the xylophone bar tuning process.

TABLE OF MODES

Table 2 below, provides a brief glimpse of the modes and their relationship to the music staff.

TABLE 2: MODES OF VIBRATION - BAR MECHANICS

TUNING	RATIO	MODE	SAMPLE PITCH
3RD HARMONIC	10:1		
2ND HARMONIC	4:1		
1ST HARMONIC (Fundamental)	1:1		



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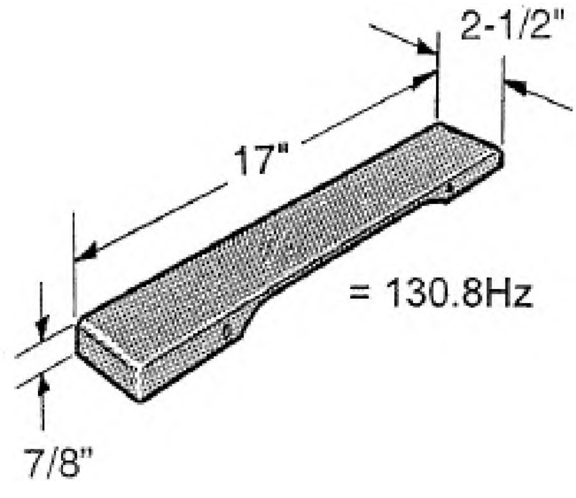
Chapter 7

DESIGN CONSIDERATIONS:
BAR SIZE vs. PITCH

The marimba, bass marimba, and xylophone each use different sized bars that are designed specifically for their respective instrument's range and percussive sound. Bar size is proportional to it's pitch. In general, lower frequencies require longer bars, and higher frequencies require shorter bars.

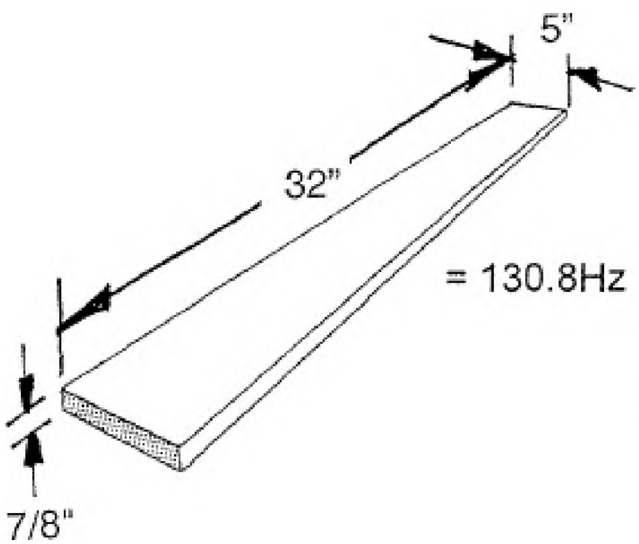
BAR SIZE vs. PITCH

What is optimum size relative to pitch? This is determined by certain factors. One such factor is the *frequency* the bar is required to produce. To illustrate this, we take a tenor C marimba bar, which measures 2-1/2 inches wide by 17 inches long, and is 7/8 of an inch thick. This particular bar has a certain amount of wood removed from its undercut arch so it vibrates 130.8 times in one second.



Bar Too Large

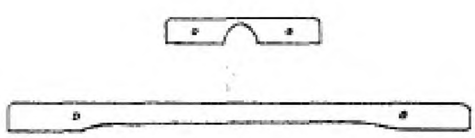
Lets say we locate a piece of precut timber that doesn't require much, if any,



wood to be removed from its underside. It already vibrates at about 130 cycles per second. However, this plank of wood measures 5 inches wide by 32 inches long, which is substantially larger than the 17 inch marimba bar. One advantage to this larger bar is that it is capable of moving more molecules in the air thus making it louder than the smaller bar. However, there is a trade-off. An instrument utilizing timber of this magnitude would be huge! The performer would have to dash from note-to-note and be able to stretch impossibly to reach distant notes. Very impractical. It is because of this, that a compromise in bar sizing must be made for ease of the performer.

Another factor is that large pieces generally do not work for higher pitches. That is, they are unable to vibrate rapidly enough due to their excessive mass and length. Larger pieces should be reserved for the lower registers.

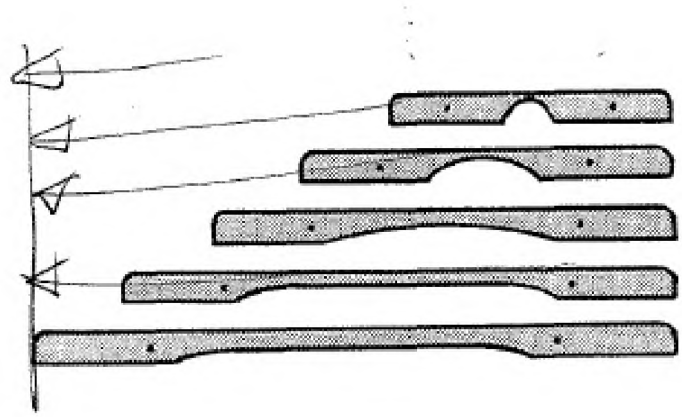
Bar Too Small



If we decide to go the other way, that is create a 130.8 Hz bar using a smaller piece of wood (say 7 inches), we will encounter two problems. First, smaller pieces of wood are physically stiffer in proportion to their larger counterparts. Much of the small bar's underside (at the arch center) would have to be removed to cause it to vibrate at a slower rate. In fact, so much wood must be removed that the bar becomes extremely thin at the top of the arch. Such thinness would reduce the bar's restoring force, therefore causing it to vibrate with less vigor.

In conclusion, the 17 inch bar represents a workable compromise between the 32" and 7" bars.

Depth of Undercut Arch

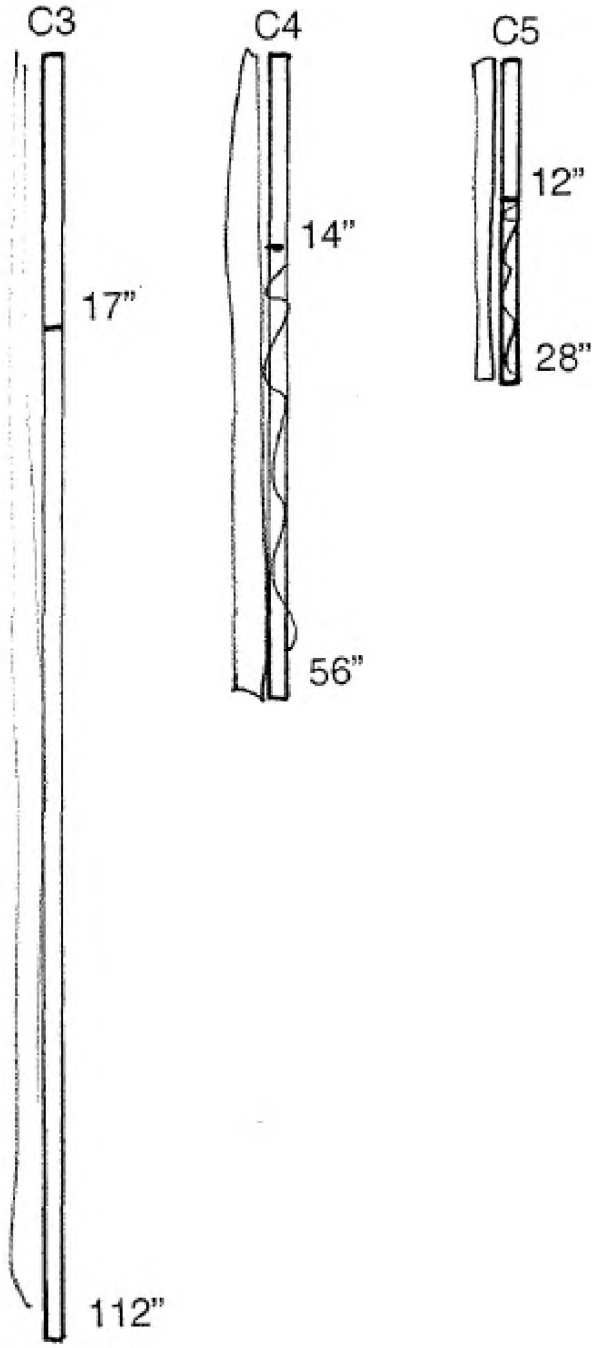


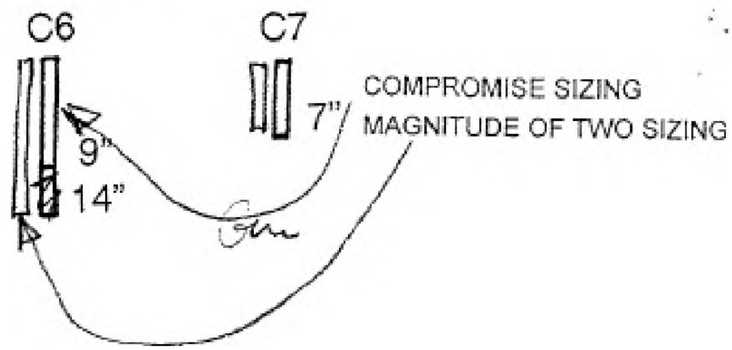
The basic guideline for the undercut arch is to **not** cut it so deep (by trying to obtain an unrealistically low pitch) that the bar becomes susceptible to breakage. Small low-pitch, thin-in-the-middle, bars give off a warbling swishing sound. This sound occurs from the thin portion of the bar flapping during vibration, similar to the shaking of a piece of sheet metal.

The bar should have sufficient material thickness at the arch center so the wood fibers will not breakdown and weaken through continued playing.

As stated earlier, the marimba is an instrument consisting of compromised bar sizing in regards to their pitch, and the marimba must cover a five-octave, or greater, range. But, the bar's dimensions only represent a fraction of their mathematical proportion.

Theoretically if the length of the top C (C7), of our five-octave marimba, were 7," C6 should be 14," C5 should be 28," C4 should be 56," and C3 should be 112" long! This doubling of the bar's length at each octave would be impossible to play for an individual performer.





There is no set rule for establishing the sizes of marimba bars except that their sizing *must* be able to accommodate the player. The crux of the problem in size vs. pitch centers around *acquiring a relatively substantial sound from a relatively small piece of wood.*

BAR SIZING

What is the correct sizing for marimba bars? Modern marimba companies have determined a range of bar sizes that suit the performers playing on their instruments. In fact, the sizing between bars of each instrument is very close with little or no difference among them.

Table 3 provides a workable range of sizes at the octave. However, Appendix 3 may be helpful in providing the length and width dimensions of bars similar to those found on standard marimbas.

TABLE 3: BAR SIZING AT THE OCTAVE

NOTE: Using the larger dimension, on both length and width, will yield a more powerful bar than the smaller dimension.

OCTAVE	LENGTH RANGE	WIDTH RANGE
BASS MARIMBA		
C1 (BASS C)	30" TO 36"	5" TO 7-1/2"
C2 (CELLO C)	22-1/2" TO 24"	3-3/4" TO 4-1/2"
C3 (TENOR C)	18" TO 19"	3" TO 3-1/2
MARIMBA		
C3 (TENOR C)	16" TO 17"	2 1/4" TO 2-3/4"
C4 (MIDDLE C)	13-1/2 TO 14-1/4"	2" TO 2-1/4"
C5	11" TO 11-7/8"	1-3/4" TO 1-7/8"
C6	9" TO 9-1/2"	1-5/8" TO 1-3/4"
C7	6-3/4" TO 7-1/4"	1-1/2" TO 1-5/8"
XYLOPHONE		
C5	15" TO 17"	1-1/2" TO 1-5/8"*
C6	11-1/2" TO 13"	1-1/2 " TO 1-5/8"
C7	7-1/2" TO 9"	1-1/2" TO 1-5/8"
C8	4-3/4" TO 5-1/2"	1-1/2" TO 1-5/8"

*Xylophone bars are the same width throughout the range of the instrument.

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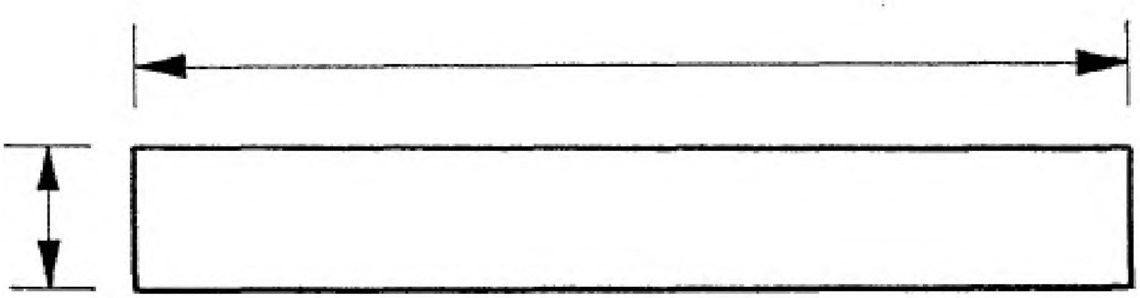
Chapter 8

DESIGN CONSIDERATIONS:

BAR PROPORTIONS

Bar size is a major factor when designing a keyboard percussion instrument. Generally, the register and instruments range determine the bar's proportions. Bar proportion can be expressed as a ratio, which is the bar's *length* vs. its *width*. Either percentage (%) or the colon (:) can be used to express the ratio. For example, if we have a marimba bar that measures 16 inches in length by 2 inches in width, the width would equal 12.5 % of its overall length. As a ratio, the width would be either one-eighth to one (1/8 : 1) , or one-to-eight (1:8).



FORMULAS

Ratios and percentages can be figured using the following formulas:

Ratio

RATIO = LENGTH / WIDTH

Example: If we have a bar whose dimensions are 17" by 2-1/4", what is the width to length ratio?

Ratio = L/W
= 17 / 2.25
= 7.5
Ratio = 1:7.5

Percentage

PERCENTAGE = WIDTH X 100 / LENGTH

Example: If we have the same bar whose dimensions are 17" by 2-1/4", what percentage of the length is the width?

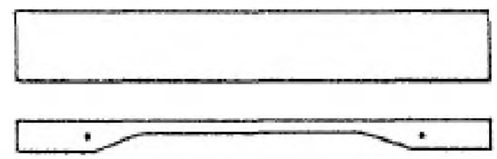
Percentage = W x 100 / L
= 225 / 17
= 13.2
Percentage = 13.2%

PERCUSSION INSTRUMENT RATIOS

The follow information discusses basic ratios for the marimba, bass marimba, and xylophone.

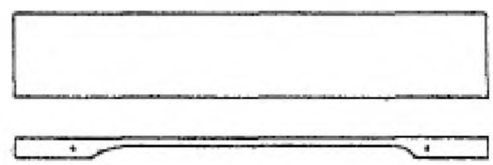
Marimba

A standard marimba bar runs a width to length ratio of approximately 1:7.5, or width to length percentage of 13.2%. This relationship is apparent from middle C (C4) and below. For example, a tenor C (C3) bar measures approximately 2-1/4" by 17". The ratio in the upper range changes because the bars width remains constant.



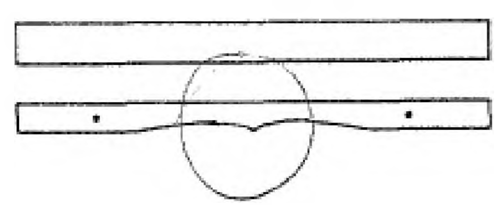
Bass Marimba

Bass marimba bars are wider which may range from 16.6% or 1:6 to 25% or 1:4. For example, the bass marimba's tenor C (C3) bar may measure 18" by 3" (1:6), Cello C (C2) may measure 20″ by 5″ (1:5), and Bass C (C1) may measure 36″ by 9″ (1:4). The wider bar is necessary so it will move more air molecules to compensate for human hearing which is less sensitive at low frequencies.



Xylophone

The length-width ratio of the xylophone is less consistent than the standard and bass marimbas. The width of the xylophone bar is the same throughout the instrument's range. If the lowest note of the xylophone (typically F4) is 15 inches long, its width is about 1-1/2 inches wide.



(This represents a ratio of 1:10 or 10%.) If the length of the top note is 5-1/4 inches long, with the same width, then the ratio changes to 1:3.5 or 28.5%.

The same width attribute on xylophones is necessary because this is primarily an upper-register instrument, which has no problem in carrying over the sound of a large ensemble.

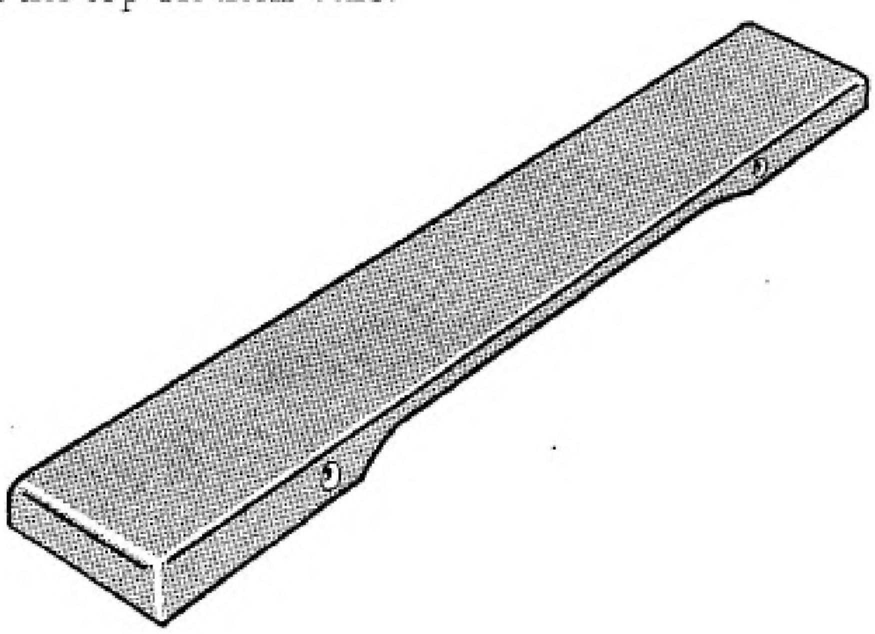
❑

Chapter 9

DESIGN CONSIDERATIONS:
BAR APPEARANCE

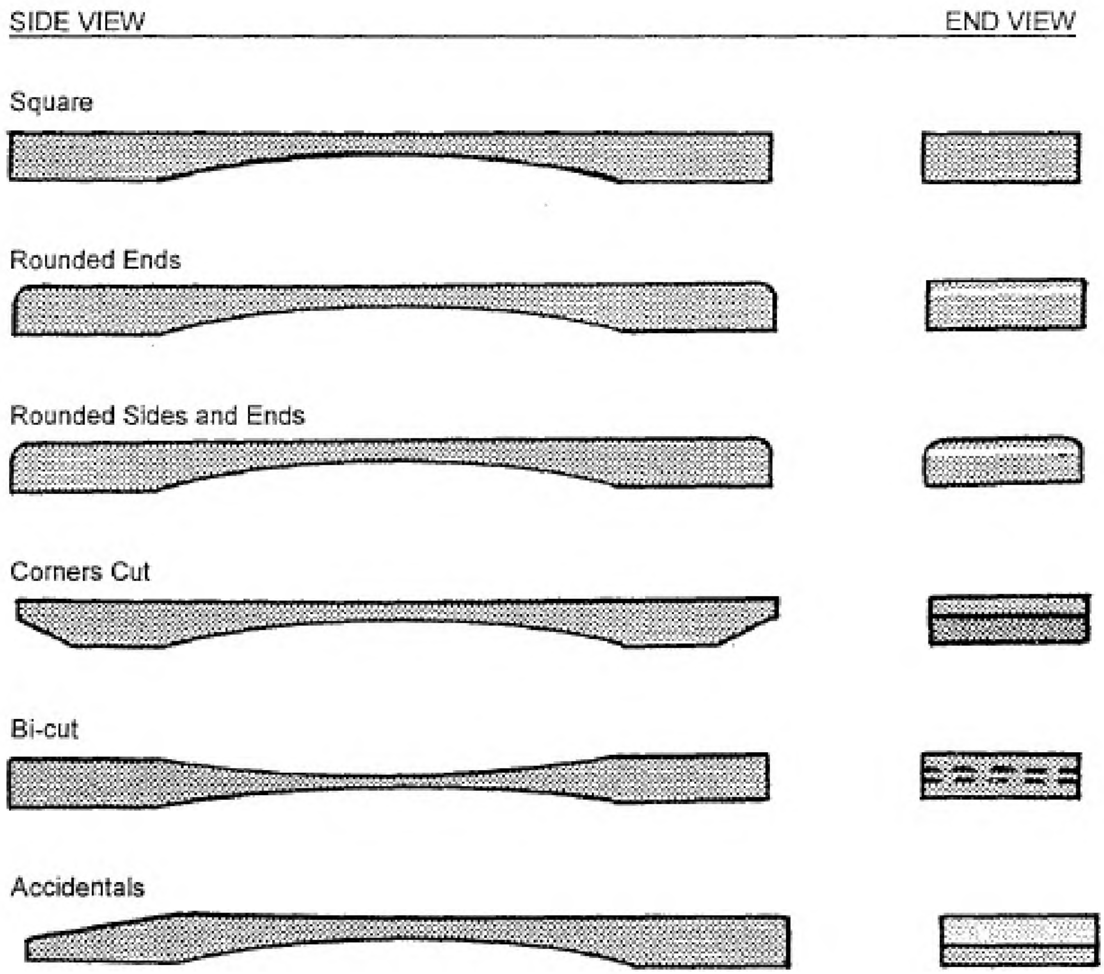
There are numerous refinements that can be utilized on [rectangularily configured] marimba bars. Every design conforms to either the physical confines of the instrument frame or the visual appeal of the overall instrument. Physically, the bar's appearance has no affect on the bar's function when a resonator is used. The quality of the wood is the primary factor in performance.

Most manufacturers of standard marimbas use rounded corners where the sides meet the top on their bars.



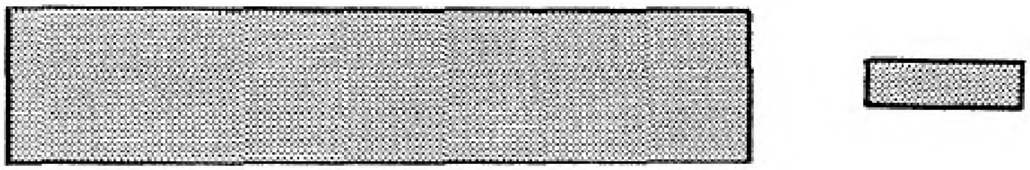
VARIETIES OF BAR APPEARANCE

The following are examples of shapes that have come from different bar percussion instruments

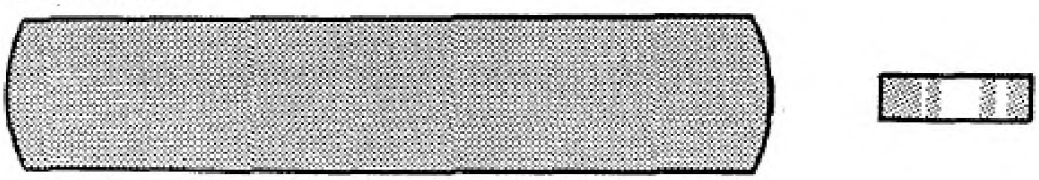


TOP VIEW END VIEW

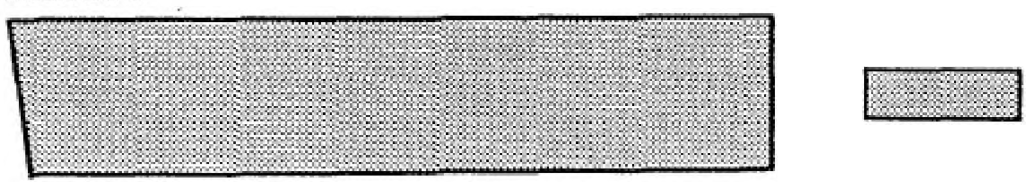
Standard



Ends Rounded



Guatamalan



SECTION THREE

FABRICATION

Chapter 10

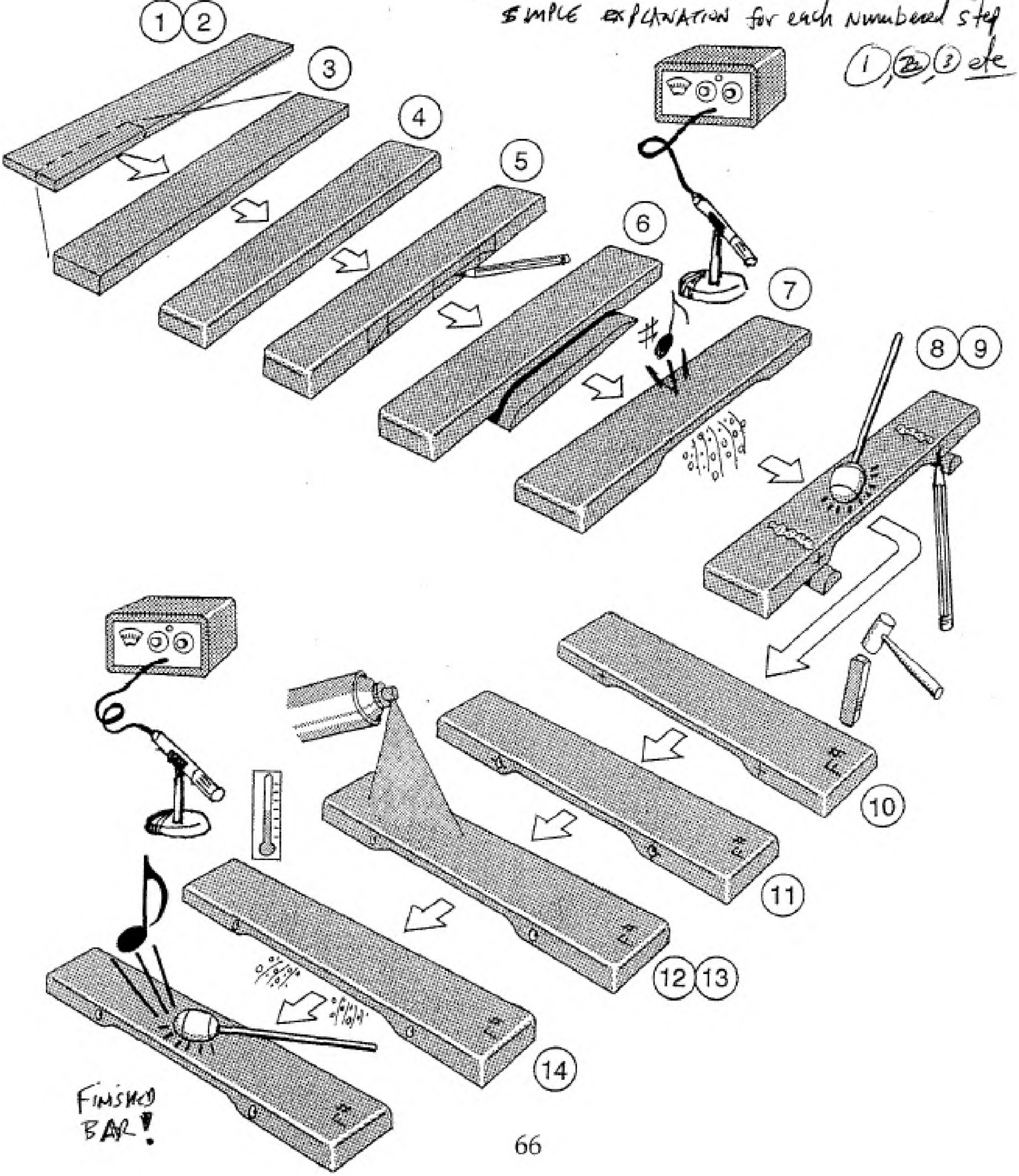
FABRICATION:
PROCESS OVERVIEW

Once the size and shape of the marimba bars have been determined and the tools have been allocated, fabrication is the next step. The following series of steps should enable the designer to successfully fabricate either a single marimba bar or a complete marimba bar set. Chapters are referenced when greater detail is required.

The illustration on page 66 represents the visual flow of the the bar's fabrication process in step-by-step ~~manner~~. Table 4, on the page 67, lists the fabrication steps, that correspond with the numbered circles in the illustration, along with the applicable chapters and tools.

FASHION

(*) IDEA! ENLARGE TO CREATE POSTER
"BASIC STEPS IN CREATING A MARIMB BAR"
SIMPLE EXPLANATION for each numbered step
1, 2, 3 etc



FINISHED BAR!

TABLE 4: BAR DESIGN AND FABRICATION CHECKLIST

✓	FABRICATION STEP	WHERE-TO-GO	APPLICABLE TOOL(S)
☐	1 Select wood	Chapter's 1, 2, 3, & 11	-
☐	2 Determine bar size	Chapter's 7 & 8, Appendix 3	-
☐	3 Cut bar blank	Chapter 11	Table saw or radial arm saw
☐	4 Shape bar	Chapter 11	Router
☐	5 Determine arch contour	Chapter 12	-
☐	6 Remove arch	Chapter 12	Bandsaw
☐	7 Tune bar (to 1/2-step sharp)	Chapter 16	Tuning instrument
☐	8 Locate node points	Chapter 13	-
☐	9 Determine drilling locations	Chapter 13	-
☐	10 Identify bar	Chapter 13	Letter punch set or transfer lettering
☐	11 Drill mounting holes	Chapter 14	Drill press or electric drill
☐	12 Prepare surface for painting	Chapter 15	Sander
☐	13 Apply finish	Chapter 15	Paint application equipment
☐	14 Tune bar (to final pitch)	Chapter 16 &/17	Tuning instrument

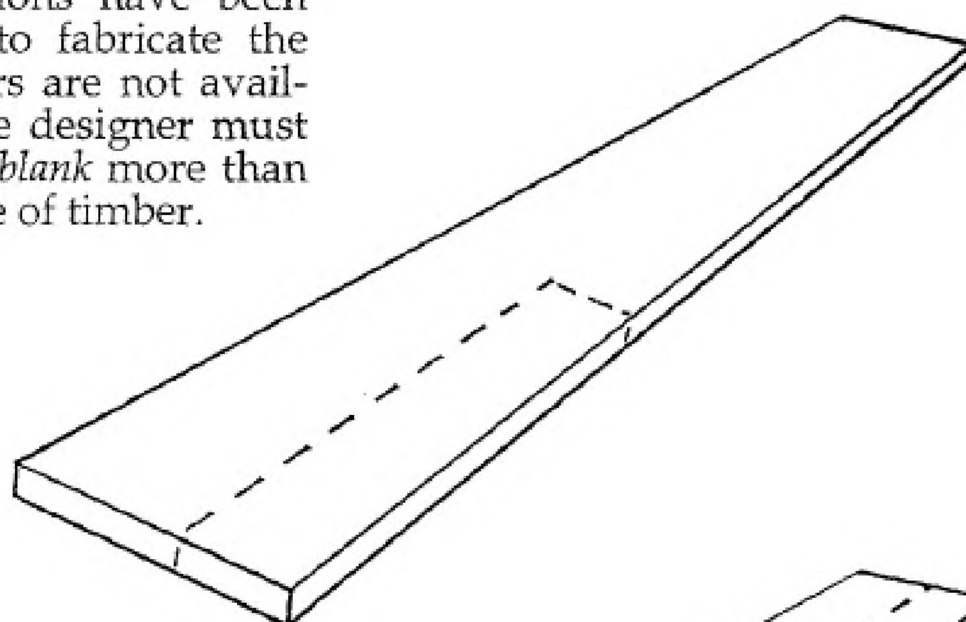
☐

Chapter 11

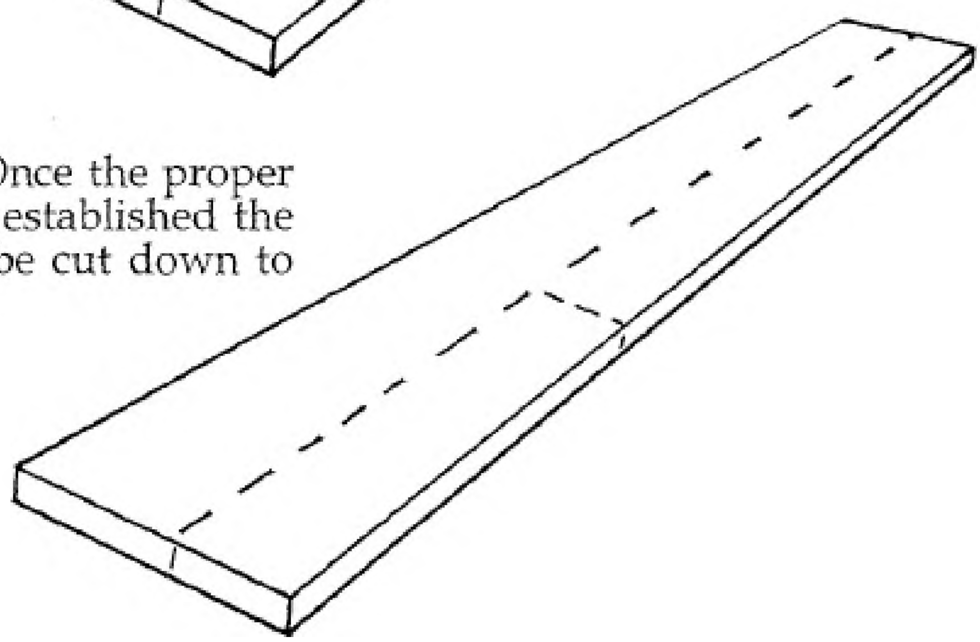
FABRICATION:

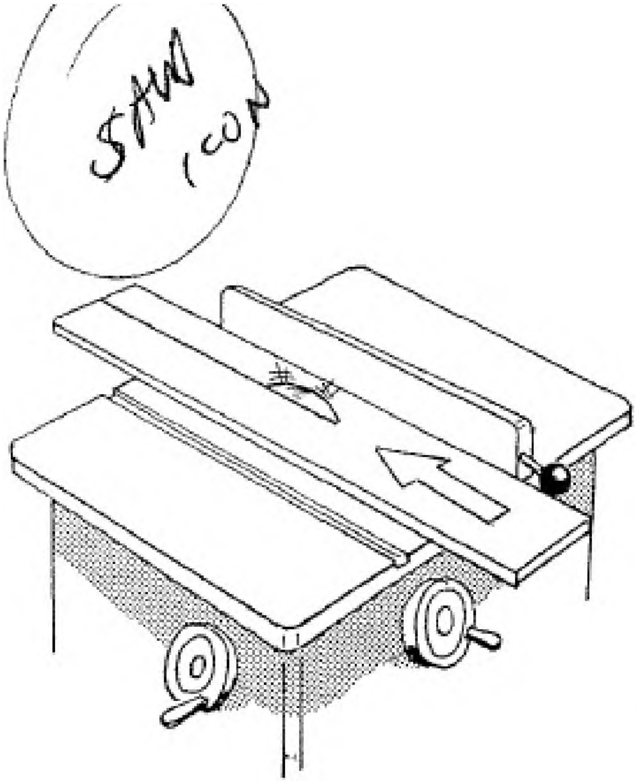
CREATING THE BAR BLANK

Once the bar's dimensions have been established, it is time to fabricate the bar. Since marimba bars are not available in pre-cut sizes, the designer must create a correct size *bar blank* more than likely from a larger piece of timber.



Bar Blank Fabrication - Once the proper grain direction has been established the *larger* board is ready to be cut down to size.



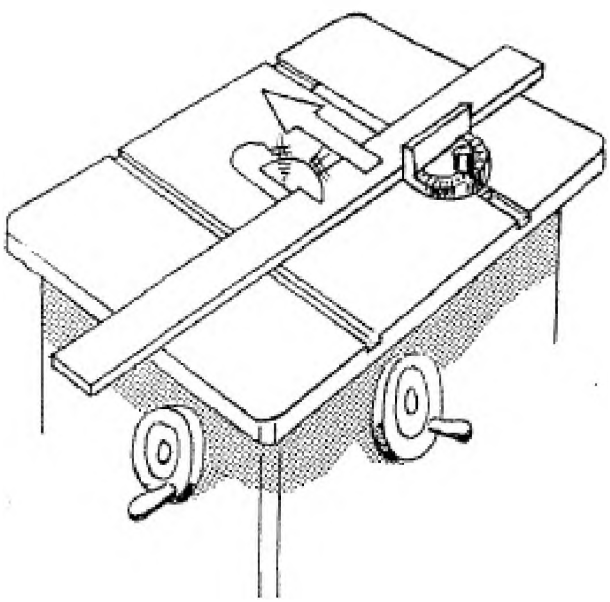


CUTTING TO SIZE

STEP 1 - Rip Stock To Correct Width

Using the table (or radial arm) saw, *rip* the longer piece into the correct **width** of the bar. (A slight bit oversized is acceptable since the bar will require clean-up sanding.)

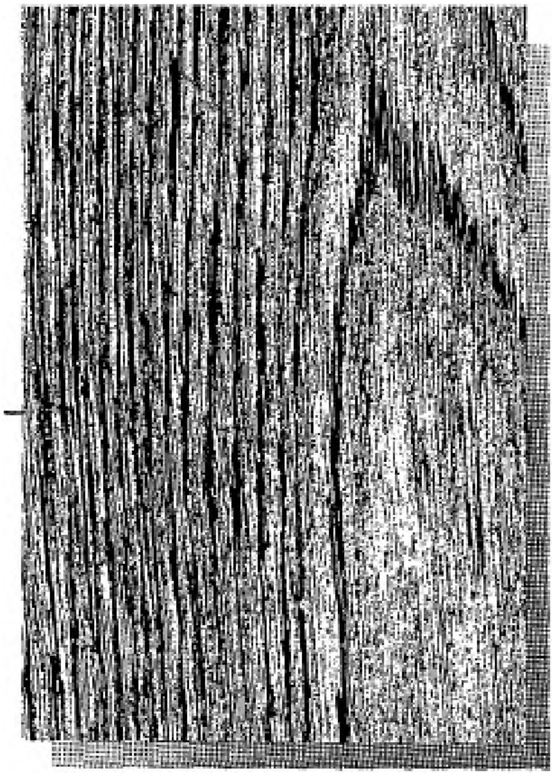
Measure this dimension to make sure it is correct!



STEP 2 - Cross-Cut the Stock To Correct Length

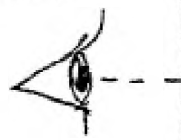
When the length of timber has been cut to the correct width, the bar's **length** can be *cross-cut* using the saw's miter-gauge attachment.

Measure this dimension to make sure it is correct!



SHAPING THE BAR BLANK

Shaping is the process of smoothing out the *hard-cornered* look of the bar so it takes on a softer appearance. The router can be used for rounding bar corners to create smooth transitions at the bar's right-angles.

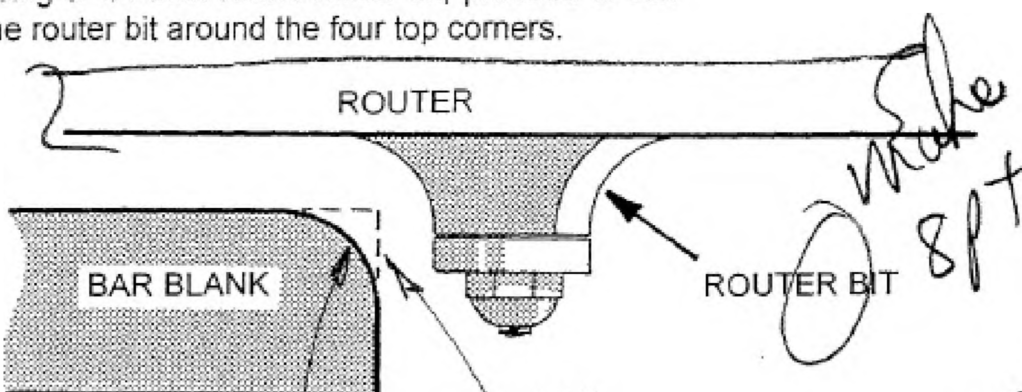


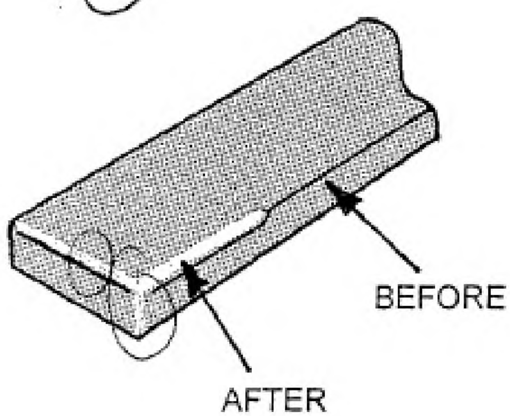
STEP 1 - Select the Best Playing Surface

Select the surface that looks visually pleasing, since this will eventually become the playing surface.

STEP 2 - Round the Corners

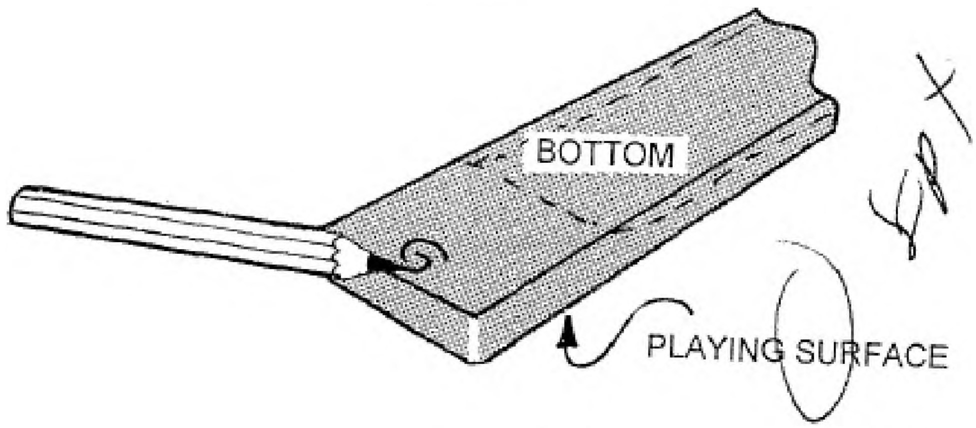
With the selected playing facing upward and using a 1/4-inch round router bit, proceed to run the router bit around the four top corners.





STEP 3 - Identify the Bar Blank

As a temporary means of identication, write down the bar's pitch, opposite the playing surface, with a pencil.



The bar blank is now ready for removal of the undercut arch.

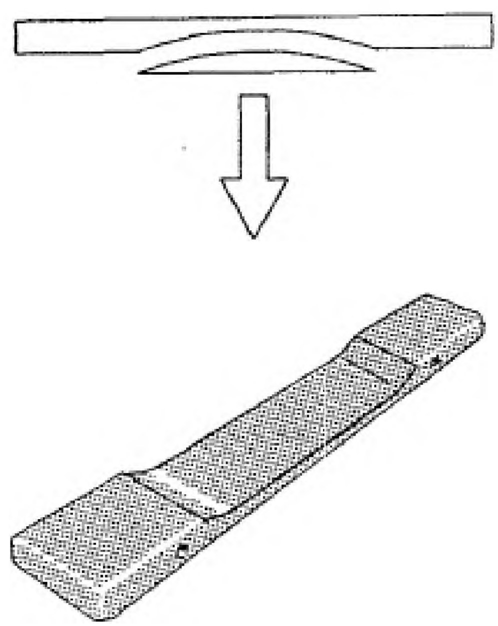
❑

Chapter 12

FABRICATION:

THE UNDERCUT ARCH

When designing for proper pitch, it is necessary to remove wood from the underside at the bar's center. This action is responsible for lowering the pitch and aids in tuning control. If the arch is cut too deep, the pitch may drop below the desired pitch. Conversely, if the arch isn't cut deep enough, the pitch will sharp of the desired pitch, and additional wood must be removed. The final amount of wood removed will be addressed during tuning in Chapter 16.

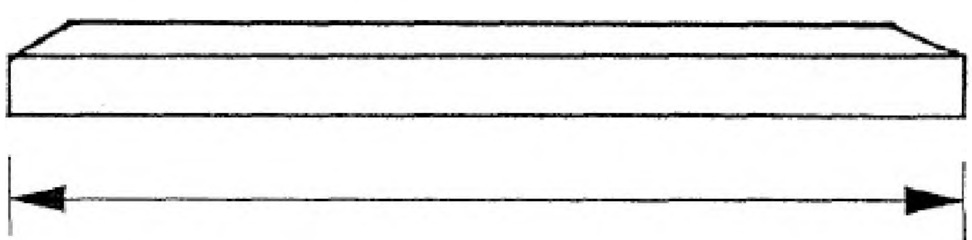


ARCH CONTOUR (LOW REGISTER)

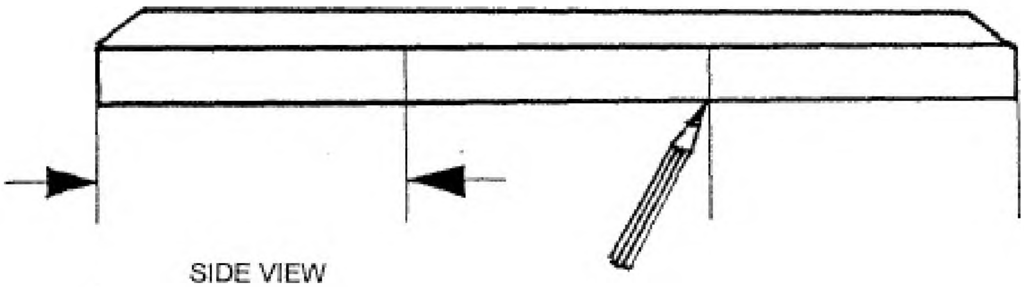
Use the following steps for designing the arch contour.

STEP 1 - Take a bar blank, with its corners already routed.

STEP 2 - Measure the overall length of the bar blank.

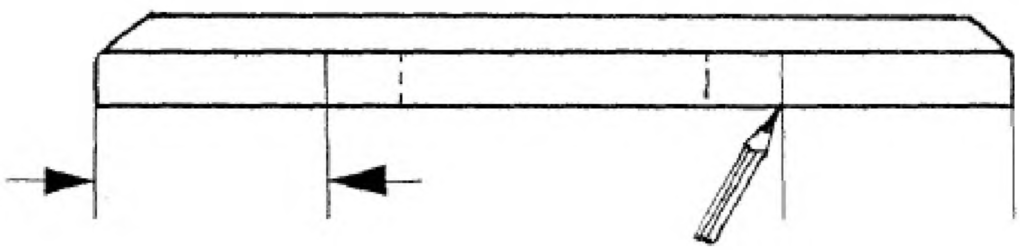


<u>STEP 3</u> - Locate one-third (33.3%) the bar's length and make two marks, one from each end. (*For example: If the bar is 16" long, the dimensions can be figured by multiplying the length times .333. Therefore, 16 x .333 = 5.28".*)

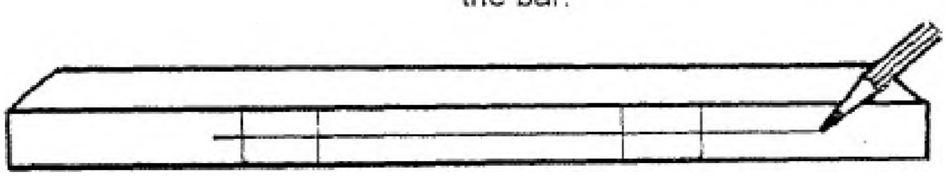


SIDE VIEW

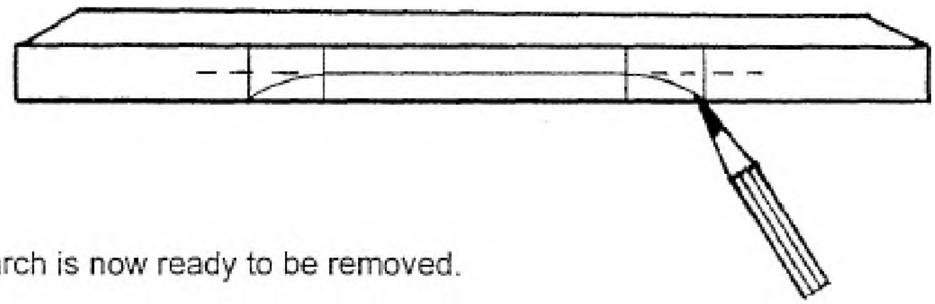
<u>STEP 4</u> - Find one-quarter (25%) the bar's length and make two marks, one from each end. (*Just like before, except multiply the length times .25. Therefore, 16 x .25 = 4.00".*)



<u>STEP 5</u> - Draw a line that halves the thickness of the bar.

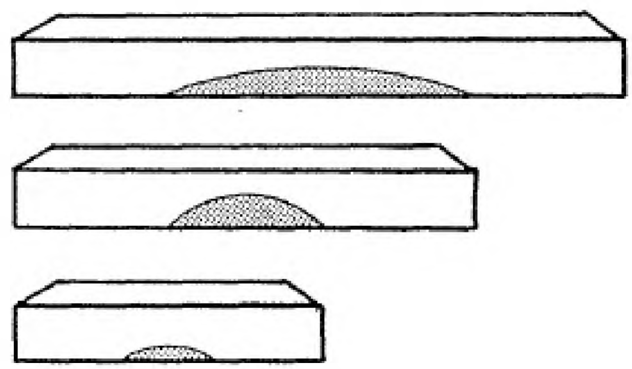


STEP 6 - Complete the arch contour by drawing two slightly curved lines from the straight middle line tapering down to the two one-quarter lines.



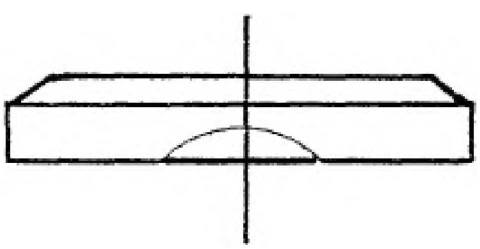
STEP 7 - The arch is now ready to be removed.

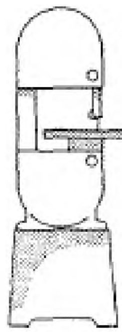
ARCH CONTOUR (UPPER REGISTER)



As pitch ascends, the bar's length becomes shorter. At this point, the arch will diminish in both length and depth. The arch may not even be necessary in the extreme high register of an instrument like the xylophone.

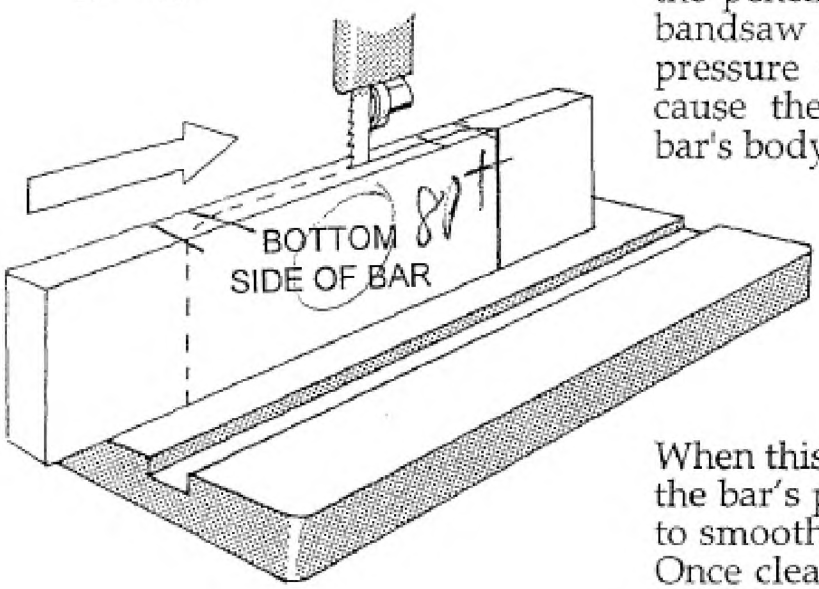
On these shorter bars, simply divide the length in the middle. Then saw away a small arch right at the center of the bar.



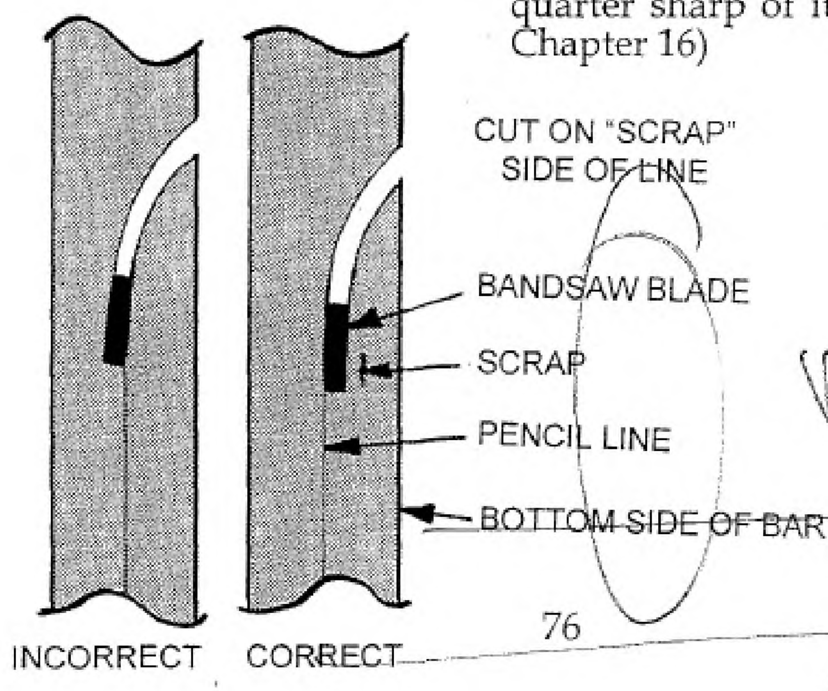


CUTTING OUT THE ARCH

Once the surface shape has been established, the arch can be removed. The bandsaw is best tool for removing the arch. Lay the bar on its side. Following the pencil line, gently feed bar into the bandsaw blade. Slow even pushing pressure will yield a smooth cut and cause the scrap to separate from the bar's body. Use a sharp blade!

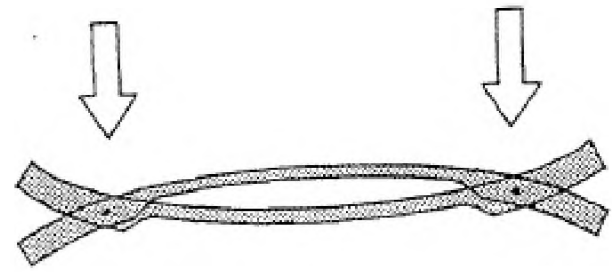


When this sawing operation is complete, the bar's playing surface may be sanded to smooth out any saw or router marks. Once cleaned up, the bar is ready to be rough tuned to approximately one-quarter sharp of its destiny pitch. (See Chapter 16) ❑

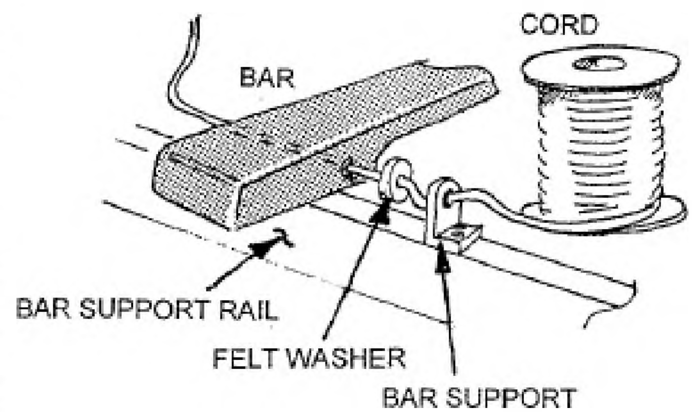


Chapter 13

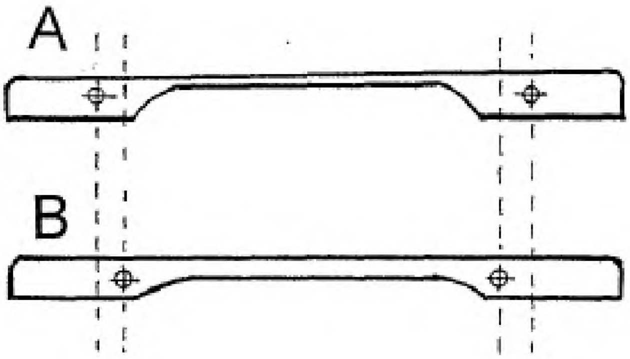
FABRICATION:
LOCATING THE NODE POINTS



Since there is no movement at the fundamental node points, this presents an ideal opportunity for mounting the bar. The manufacturers of keyboard percussion instruments usually run a line or cord through holes drilled at the nodes to hold the bar permanently in place. The *suspended* bar can vibrate at maximum amplitude without interference.



Some literature explains that the fundamental node points fall somewhere between one-quarter and one-fifth the bar's length. In an attempt to more accurately quantify it, others claim that the distance is 22.5% from the bar's end. Unfortunately these are mathematical assumptions which may be different than the bar's *true* node point positions. There is a better way of determining where the two fundamental node points exist on any rectangular-shaped body. However, the pitch of the bar must be rough tuned so that it is approximately one-quarter step sharp of its destiny pitch. If the bar is not tuned, it's higher pitch will causes the node points to be closer together than they would be when tuned to a lower pitch. This creates a false indicator as to how far apart the bar support rails need to be from each other.



NODE POINTS AND PITCH

To illustrate node point location and pitch, we have two bars with the exact same dimensions. If we tune bar A lower than bar B, the node points of bar A will be farther apart in comparison to bar B.

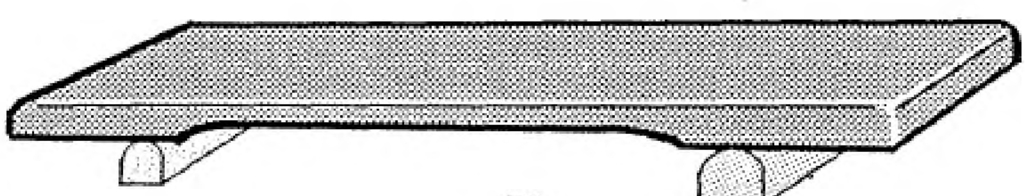
As material is removed from the middle of the bar, to create the lower pitch, the mass in the bar shifts towards the ends. On the higher pitched bar there is more material in the arch area to distribute the mass towards the bar center. The node points will be closer together.

LOCATING THE FUNDAMENTAL NODES

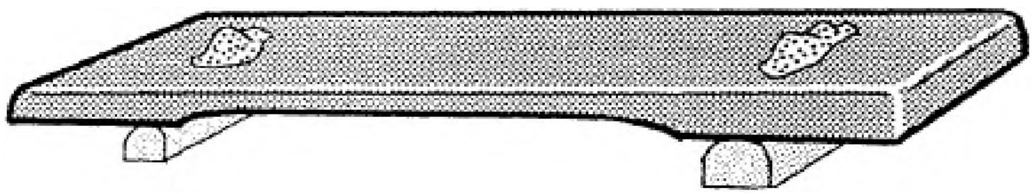
Check the node point locations only when the bar has been rough-tuned to a ¼-step sharp of its destiny pitch!

The following steps will locate the true nodal centers on any length of wood..

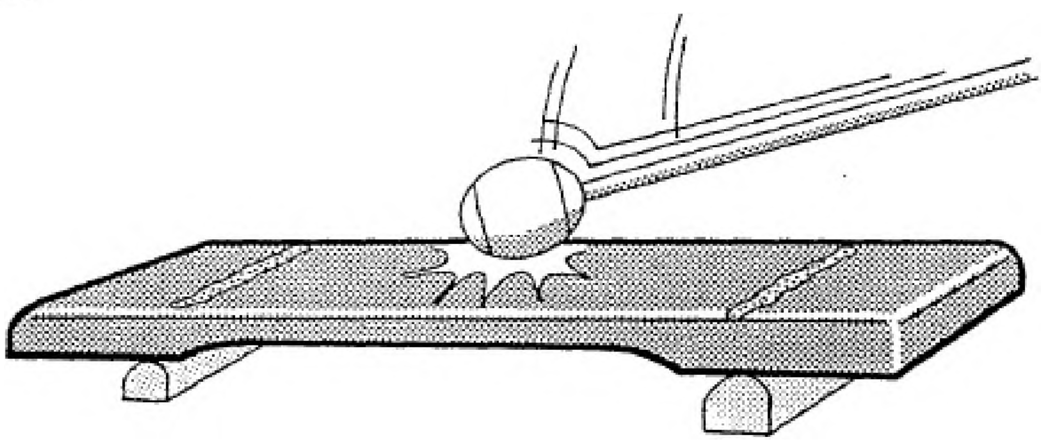
STEP 1 - Support the bar on top of two small foam blocks approximately one-quarter the bar's length from each end.



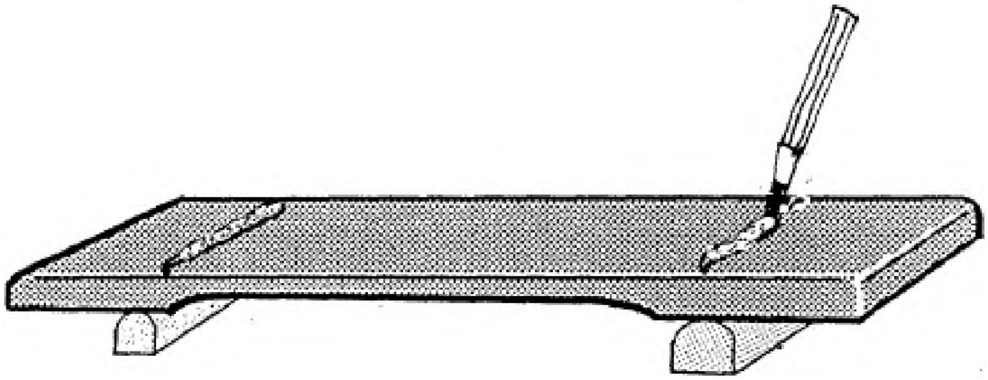
<u>STEP 2</u> - Sprinkle salt or fine saw dust on the bar's surface immediately above the foam. (Do not use sugar or any powder that becomes sticky from handling.)



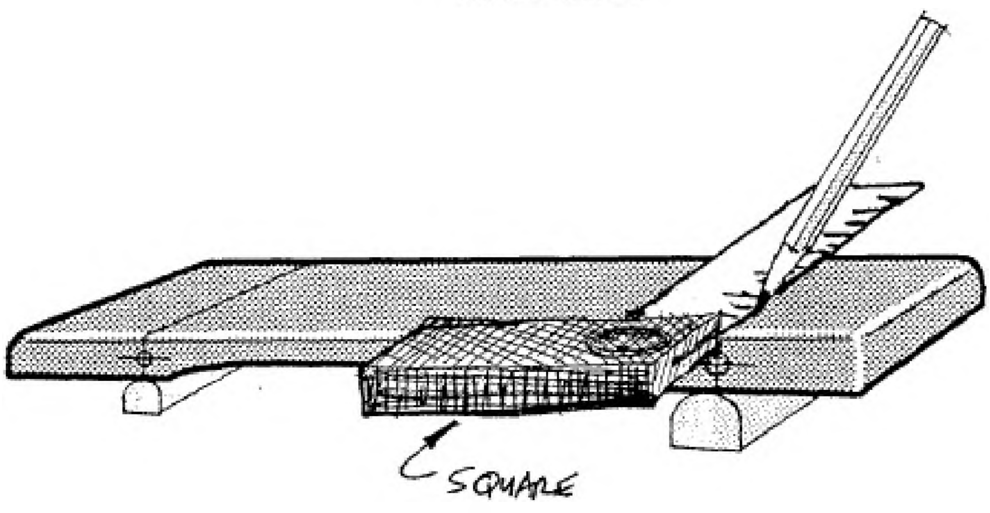
<u>STEP 3</u> - Lightly tap the bar in the middle with a marimba mallet to cause vibration. The salt will gather at the node points on the bar where no movement occurs.



STEP 4 - Place a mark at both node point areas where the salt has gathered.

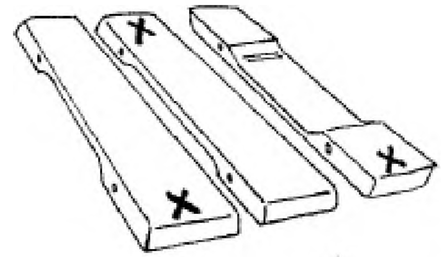


STEP 5 - Transfer each mark to the bar's side using a 90° square or at an angle to match the angle of the bar support rail. (See page 82) This indicates where the future mounting holes will be drilled.



BAR IDENTIFICATION

Once the bar is rough tuned and the node points have been located, it is a good idea to identify the bar.

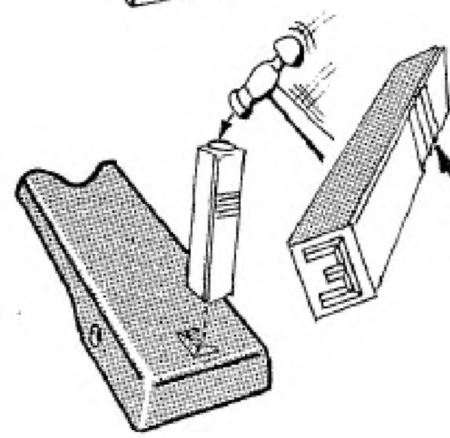


Identification Location

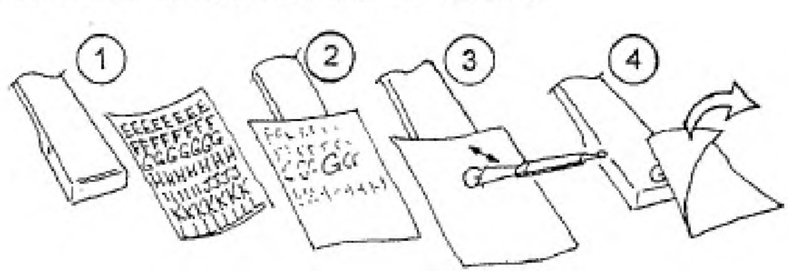
There are three locations where the bar's pitch can be placed; top front, top back, or underneath.

Identification Methods

Steel Punch - The bar's pitch letter can be inprinted into the wood by means of a steel punch. If unfamiliar with using punches, it helps to practice on a piece of scrap wood to ensure proper letter orientation and consistency of letter location is maintained. (Use a no-give surface like concrete so bar won't bounce when struck.)



Press-on Lettering - Press-on letters are burnished onto the surface with a smooth blunt object such as a burnishing tool or a dull-pointed pencil. However, it is recommended that a coat or two of the finish be applied to the bar prior to adhering the lettering. Once burnished in place, subsequent coats of the bar's finish should be added.



1) PRESS-ON LETTERING SHEET
2) ALIGN LETTER ON BAR
3) BURNISH LETTER ONTO BAR
4) PEEL BACK SHEET

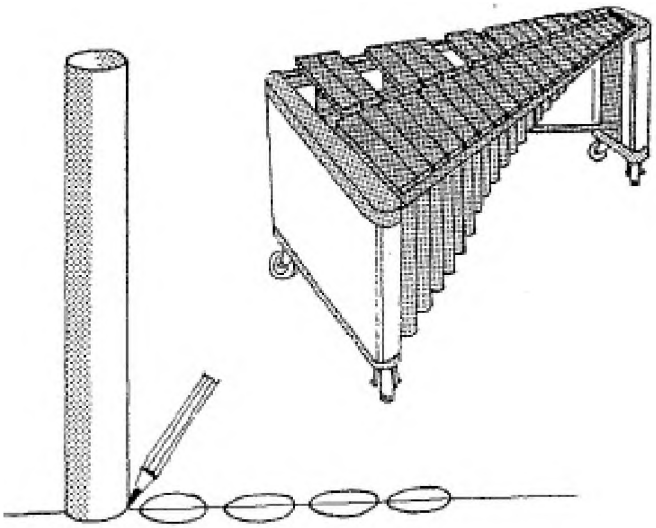


FIG 1

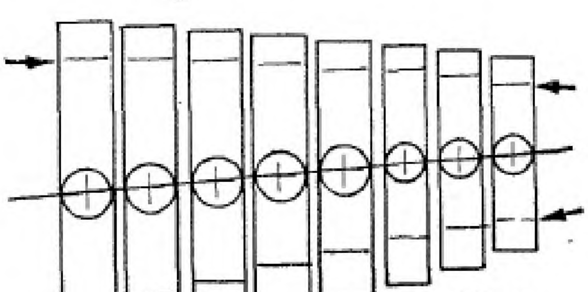


FIG 2

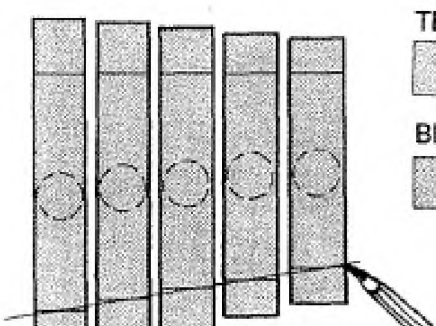


FIG 3

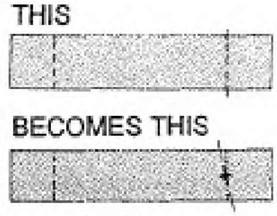


FIG 4

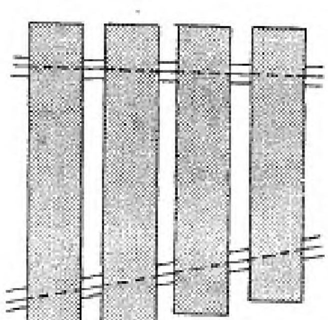


FIG 5

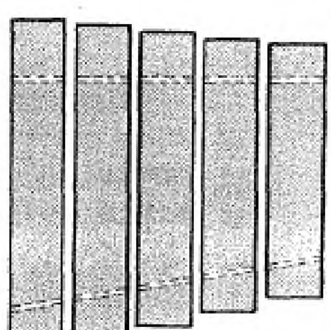


FIG 6

LAYING OUT BAR SETS

When designing a set of bars that must be interconnected to each other, the relationship with their individual resonators must be established. The cross-sectional diameter of each resonator can be used to create a *resonator centerline template* which is necessary for bar node point positioning.

Bars must be tuned and their node point locations identified first! After drawing a straight line, trace the diameter of each resonator tube side-by-side each other. (Figure 1) Be sure to allow for spacing of the bar supports between bars. By laying the center of each bar over its corresponding circle (that represents each resonator), the collective node points of all bars will become apparent. (Figure 2)

All the designer need do is draw an interconnecting line across all the node-point center locations to establish the bar support rail location. (Figure 3) Notice that this new line will cause the perpendicular node line to become slightly skewed. (Figure 4) This small angular variation will not interfere with the bar's vibration.

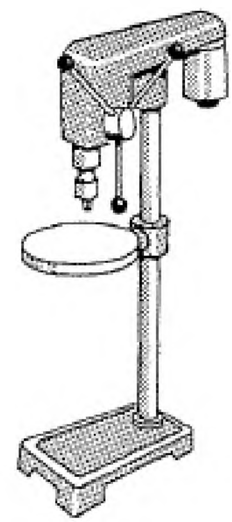
Since the bar support rail must follow the collective node point line (Figure 5), the mounting holes must also be drilled to following that same line. (Figure 6) Bar support hardware should align with holes between bars.

❑

Chapter 14

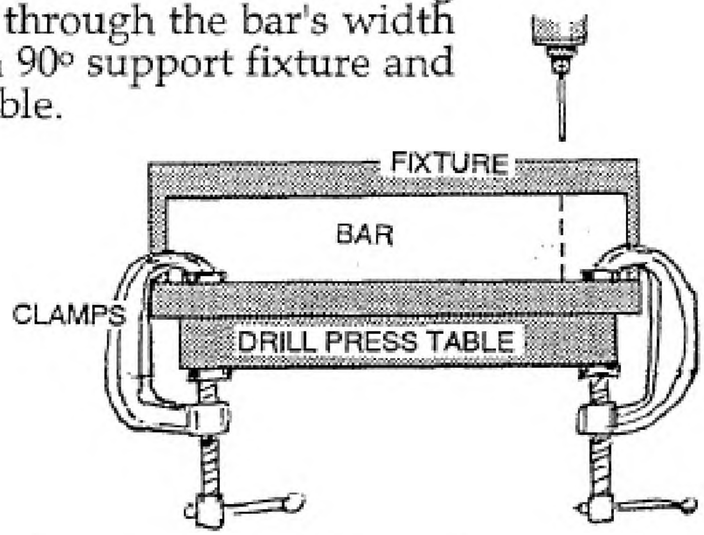
FABRICATION:
DRILLING THE MOUNTING HOLES

Since the suspension cord is the preferred method for anchoring the bar onto the instrument frame, holes must be accurately drilled at the node points.

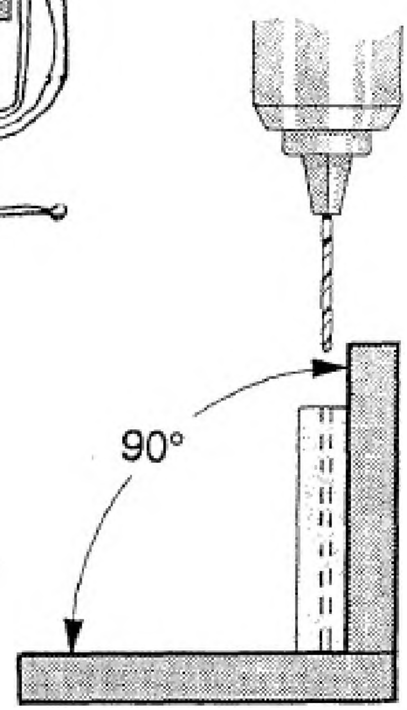


THE BAR SUPPORT FIXTURE

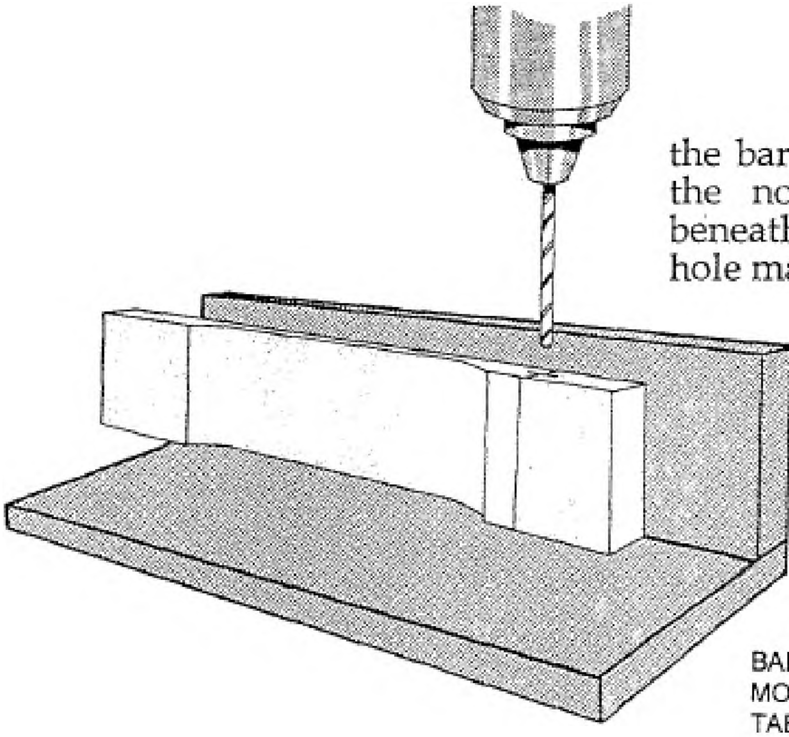
There is an accurate method for drilling mounting holes through the bar's width with the aid of a 90° support fixture and the drill press table.



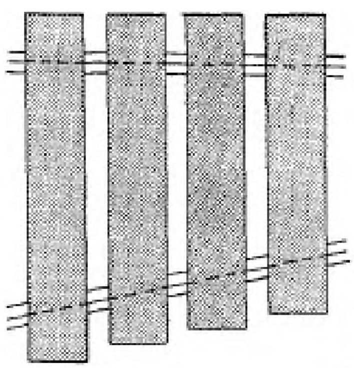
The fixture consists of two pieces of wood butt jointed together at a 90° right-angle. By clamping the fixture onto the drill press table, the drill bit can be aligned to one-half the bar's thickness from the fixture's vertical fence. When



the bar is placed against the fence with the node-point marking immediately beneath the drill bit, a perfectly straight hole may be drilled.



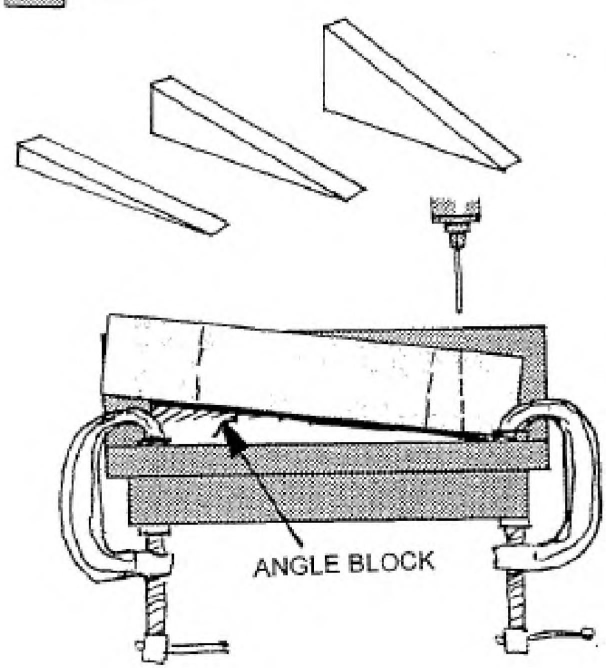
BAR SUPPORT FIXTURE MOUNTED TO DRILL PRESS TABLE



It is important to drill the hole from both directions (by flipping the bar over) so the drill bit can enter from the opposite edge. As the drill works its way into the material, it will eventually meet the partially drilled hole from the other side.

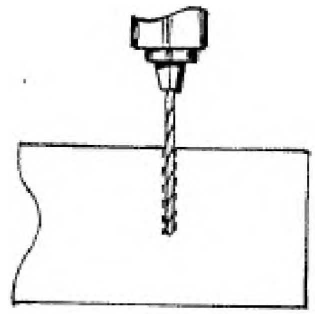
DRILLING AT ANGLES

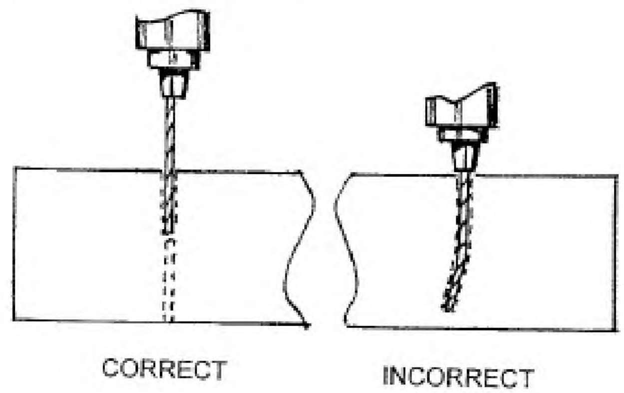
Since the node points of the complete bar set are skewed at an angle correlating to the bar support rail, the holes in each bar must be drilled to conform to that angle. Angle blocks, that change the 90° hole angle, are helpful when drilling at different angles. They are placed between the bar and the support fixture.



Helpful tips on drilling holes:

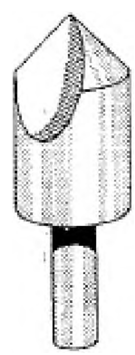
- Drill the hole a slight bit larger than the diameter of the mounting cord for ease of insertion.
- Use sharp drill bits! This keeps the bit from wandering within the wood.
- Do not drill long holes in one continuous movement. Back the drill bit out often to clear the chips, and to minimize the chance of the bit binding inside the wood.
- Drill long holes from both sides to avoid breaking through at the wrong spot.
- Depending on the bar's width, use six or twelve inch "aircraft" bits to provide enough length when drilling through wide bass marimba bars.

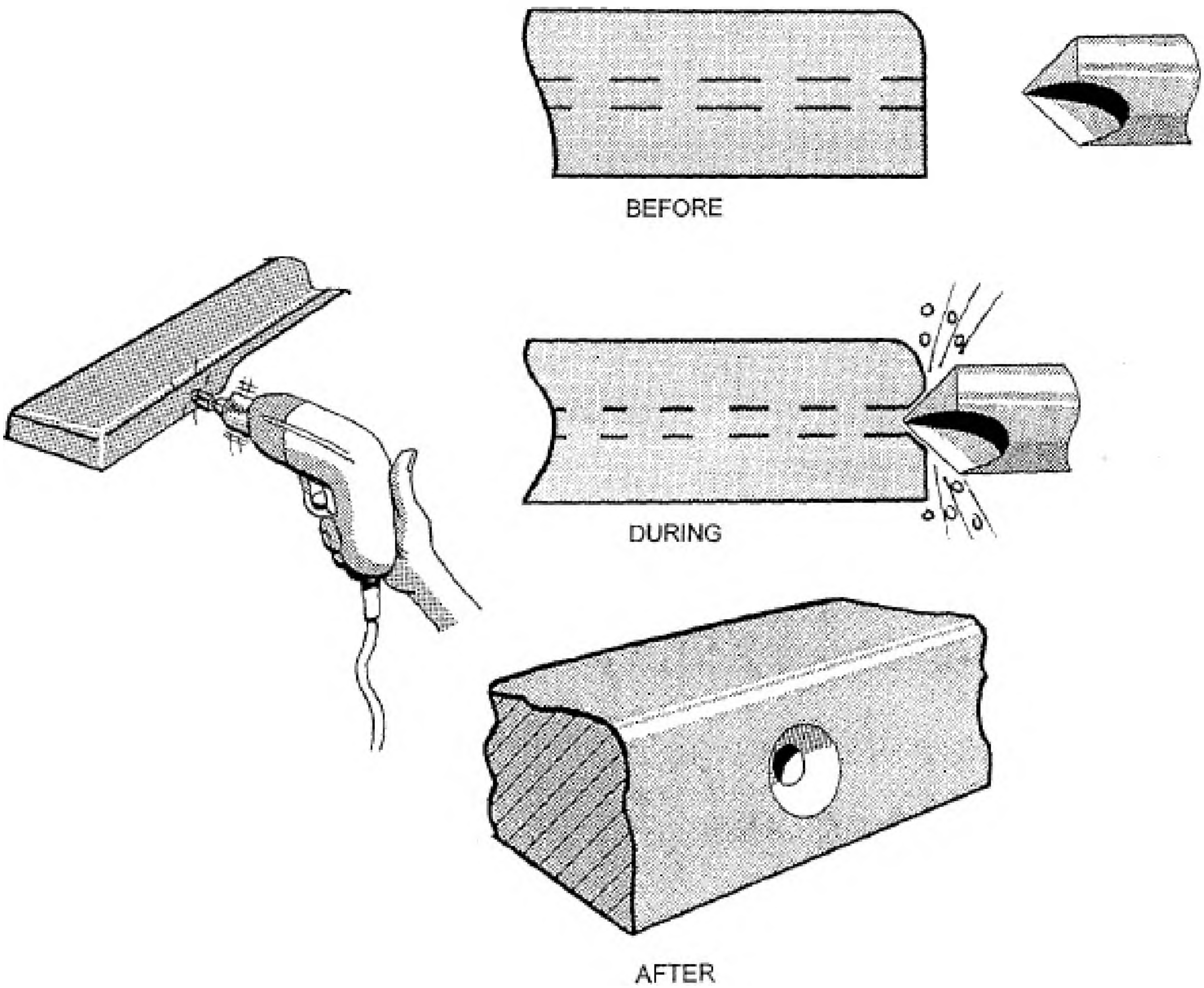




THE COUNTERSINK

A countersink is designed to create a tapered entry way into the hole. This not only cleans up the holes appearance but provides easier access when inserting the mounting cord.




BEFORE
DURING
AFTER

Chapter 15

FABRICATION:
FINISHES

The exposed surface on a wooden bar requires protection from the elements as well as repeated mallet blows. Therefore, a durable, scratch-resistant paint is necessary to provide this protection. In addition, the playing surface will be less susceptible to denting and chipping that may occur from hard mallets or from reckless transportation of the instrument.

TYPES OF FINISHES

There are basically two types of finishes: *Natural* and *Synthetic*.

Natural Finish

A natural finish is the category of varnishes, lacquers, and shellacs utilizing natural base elements. Unfortunately, natural finishes tend to yellow with age, and over a period of years may develop small hair-line cracks which is what happens when the base element loses its pliability.

Synthetic Finish

Synthetic finishes are the urethanes, varithanes, or your so called "liquid plastics" which have a polymer base compound.

Two excellent choices of finishes are *Varithane*™ made by Flecto and *Urethane* ™ made by Deft, which are available in gloss, semi-gloss, and satin. (Most percussionist prefer the satin finish since it tends to lesson the reflectivity of over head spot-lights during live performances.) These varithane products adhere to wood extremely well. Testing has shown that should a dent occur on the finish, the finish actually conforms to the contour of the dent in the grain without chipping out. Moisture cannot

Finishing Materials Not Conducive to Vibrating Bars:

Polyester Resin - Do not finish the bar with resins such as those used in the fiber-glass lay-up process, which require a catalyst for curing. When cured, these resins don't flex over short distances, and could chip or crack by trying to resist the flexing movement of the wood.

Wood Oil - Also stay away from wood oils. Such oils, while looking great on furniture, are made to penetrate the wood fiber which may dampen or reduce its vibrational intensity.

While looking good on bar tops and contours, Very well Vibrating a bar's penetrate through the finish to the wood and best of all, they are highly resistant to scratching.

SURFACE PREPARATION

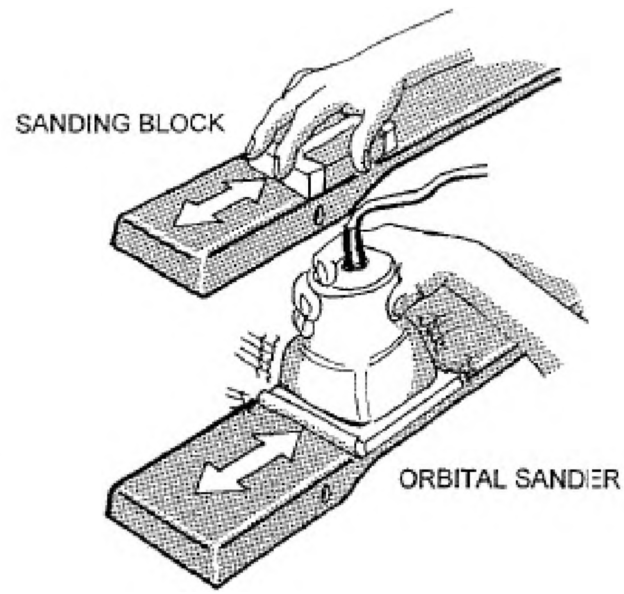
The quality of finish is directly proportional to the quality of surface preparation. Use the following steps when preparing the wood's surface:

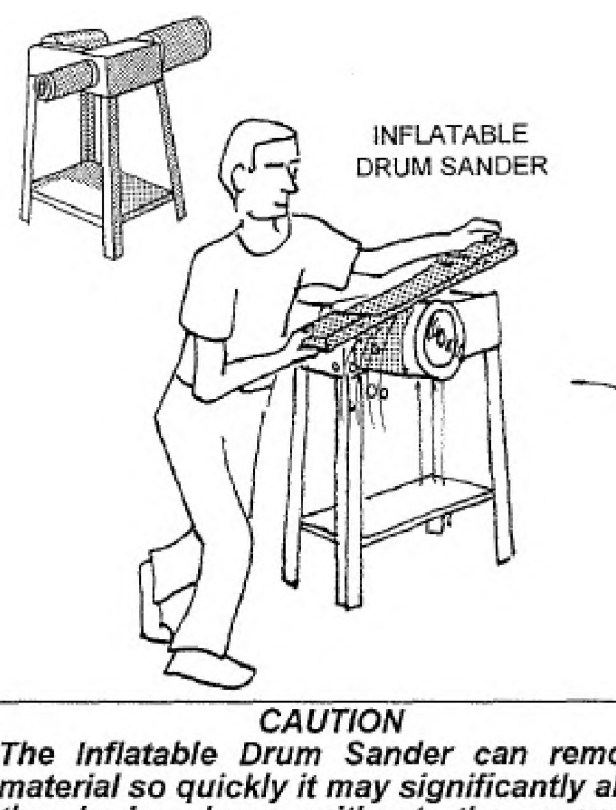
STEP 1 - Start with a medium rough sandpaper (100 or 120 grit) for removing unsightly saw marks. [Tools: Hand Sand, Orbital Sander, or Inflatable Drum Sander]

STEP 2 - Then switch to a medium fine sandpaper (220 grit) to remove scratching caused by the rougher grit.

STEP 3 - Finally, use a fine sandpaper (400 grit) to create a satin smooth finish prior to adding the protective coat.

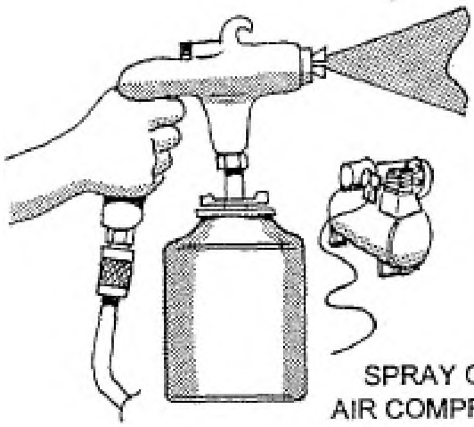
Always *sand with the grain.* Never sand across the grain, with the rougher grit sandpaper's, otherwise the wood fibers might tear. Wood tearing can cause a mild sponging effect which may lead to a rough finish rather than a smooth finish.

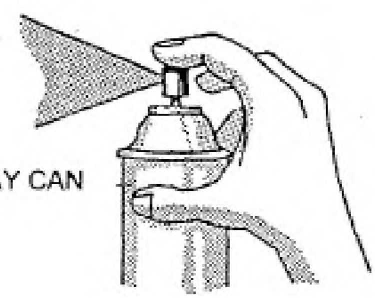




CAUTION

The Inflatable Drum Sander can remove material so quickly it may significantly alter the bar's shape without the operator knowing it. Also, watch your knuckles!





FINISH APPLICATION

The finish may be applied in different ways; by *spray*, *brush*, or *sponge*.

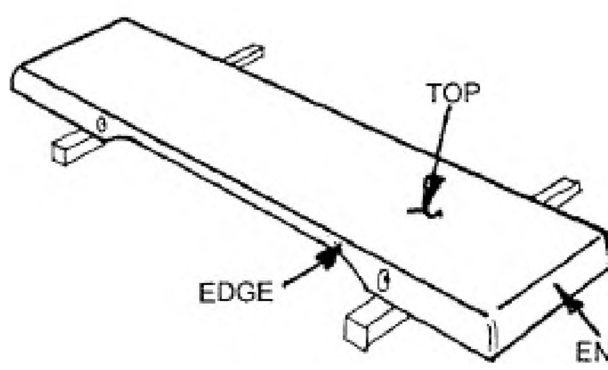
Spray Application

Spray painting is ideal, either by an air compressor/spray gun combination, spray can, or from an airless paint sprayer. The *spray gun* technique is preferable because it provides the greatest degree of control over *spray pattern*, *quantity* of paint, and *velocity* of paint. Clogging is also minimized when compared to the spray can type.

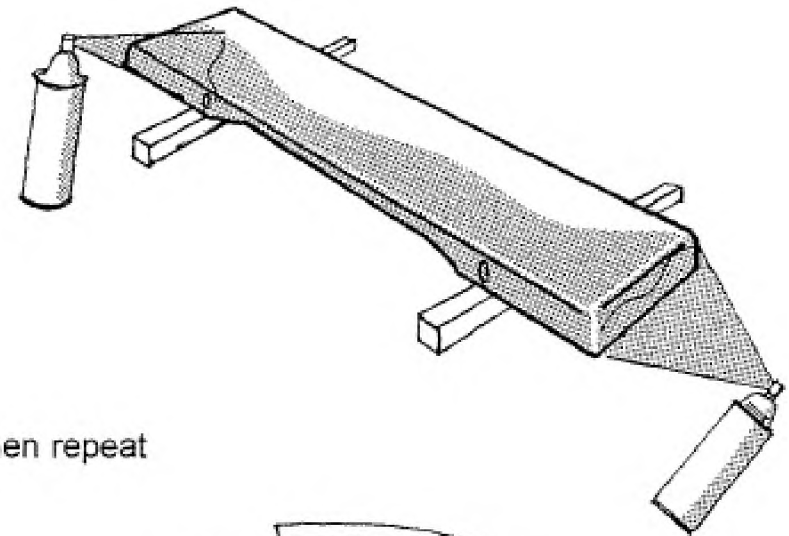
When spraying paint onto the surface, always spray in light, even coats. Build up the protective coat gradually, rather than shooting it all at once. This minimizes the chance of drips and sags.

Use following steps to cover the entire bar with an even coat:

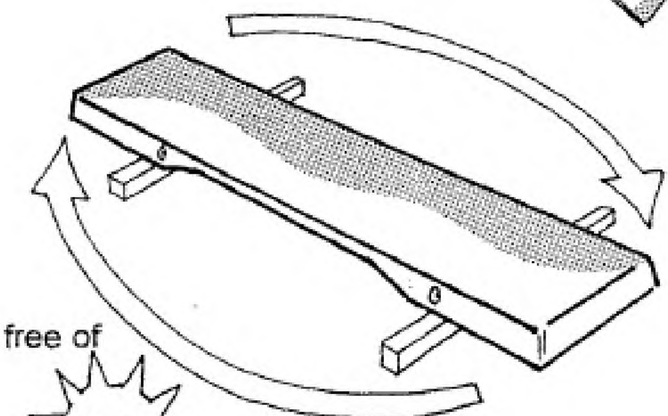
STEP 1 - Lay bar on support blocks so the playing surface is face up.



STEP 2 - Spray top, edge, and end with an even coating.



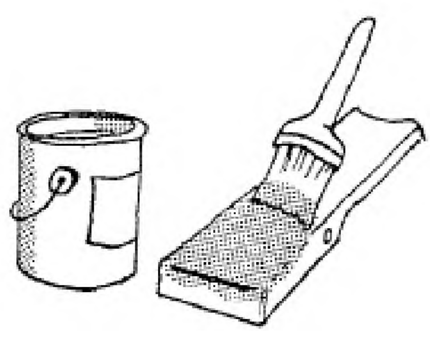
STEP 3 - Turn the bar around 180°, then repeat step 2.

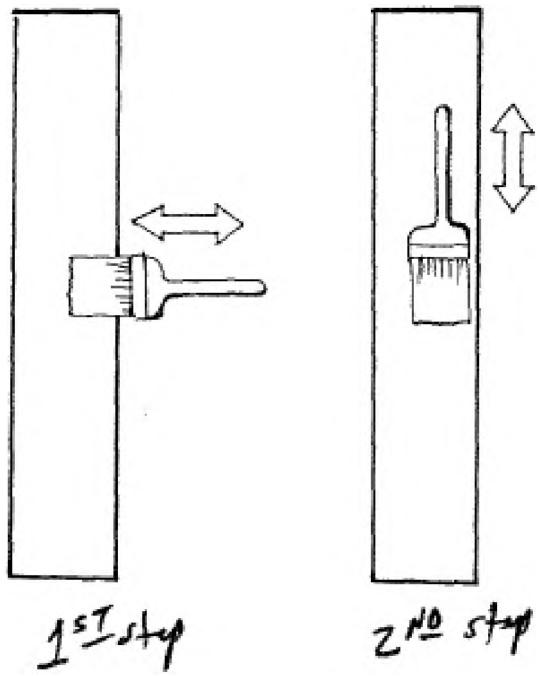


STEP 4 - Move bar to a warm drying area free of dust.

Brush Application

Brushing the paint will work if, first, brushed against the grain, then second, brushed with the grain to smooth-over the coating.





Sponge Application

Dipping a sponge into the paint and then applying it to the wood like the brush application works well. Be careful to cover all exposed areas

DRYING

Apply paint in warm temperatures. Warming the wood prior to painting also helps. In addition, the warmth of the wood encourages the coat to lay evenly as well as lessening the drying time.

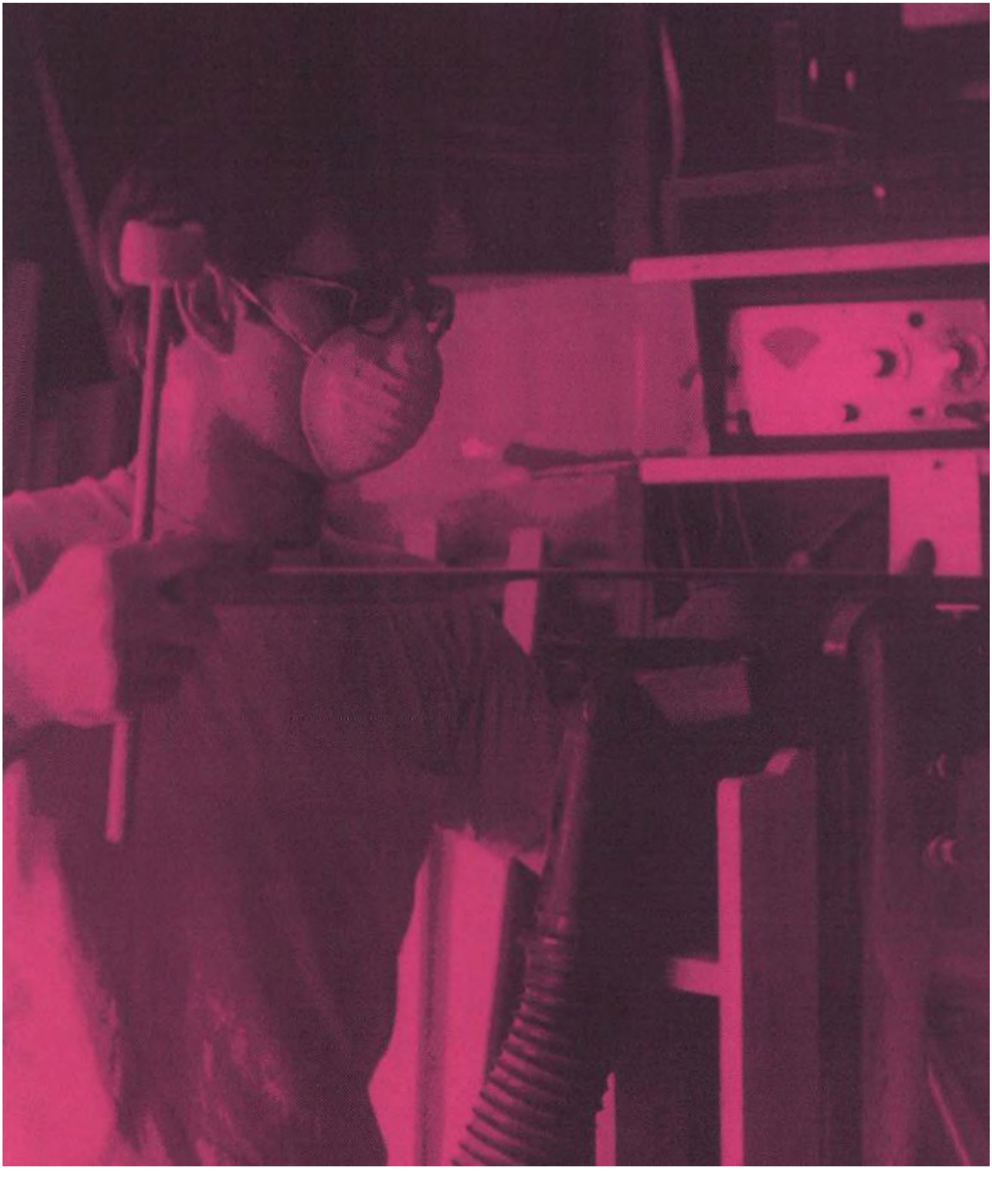
Avoid applying paint in cold, humid climates if possible. Unfortunately, these adverse painting conditions cause the paint to dry much slower which increases the chance of dust settling on the wet/tacky surface.

Sometimes, when the paint is drying, there may be small air pockets within the grain that may rise through the coating to cause a bubble to form. During drying, bubbles may pop and create a crater-like formation. When dry, a light sanding between coats smoothes out bubbles and bits of dust that may have settled. The light sanding ensures the final coat will be quite smooth.

❑

SECTION FOUR

TUNING



Chapter 16

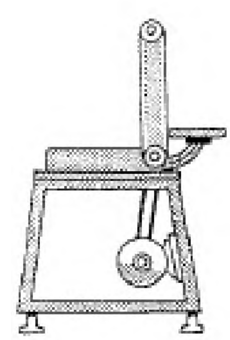
TUNING:
MARIMBA BAR

Once the bar has been cut to size, shaped, and the undercut arch removed, it is ready for tuning.

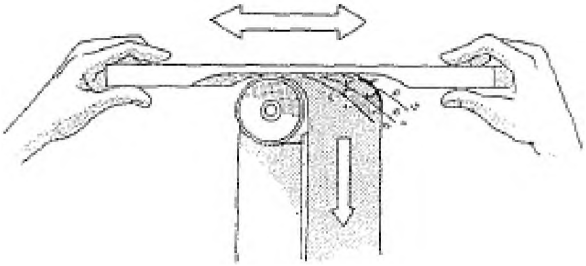
THEORY OF BAR TUNING

Tuning of bar percussion instruments is straight forward once a simple rule is understood and followed. *All bar percussion tuning is accomplished by the flattening of sharp pitches.* This is the removal of mass, from certain locations within the arch area, that will result in the lowering of frequencies corresponding to the modes of vibration. What must be learned and practiced is *where* the material is to be removed, as well as *how much* to remove.

MATERIAL REMOVAL TECHNIQUE



A simple yet very controlled way of removing additional material from the arch is through the use of the belt sander. The roller, at the belt tracking



mechanism, should be approximately three inches in diameter which is perfect for the bar's arch. By moving the bar back-and-forth, the material is removed in a very controlled manner. Light pressure removes small amounts of material, while heavy pressure removes greater amounts.

A Word of Caution: PRACTICE FIRST!

For learning purposes, the novice bar builder should use inexpensive woods, such as white pine or fir. It is a sure thing that first time attempts at bar tuning will yield a bar whose pitch has dropped far below the desired pitch. When the amount of wood removal becomes more predictable and controlled, the builder can changeover to the *vibrational* class of woods, used in bar percussion instruments, and tune with a higher-level of confidence.

TYPES OF TUNING

The remainder of this chapter is divided into three parts; *Fundamental Tuning* which provides steps in tuning the fundamental or 1st harmonic only. This is an *introductory* section that will help the novice to understand what happens to the bar's fundamental pitch when material is removed from the arch area. *2nd Harmonic Tuning* provides steps in tuning not only the fundamental, but the 2nd harmonic as well. *3rd Harmonic*

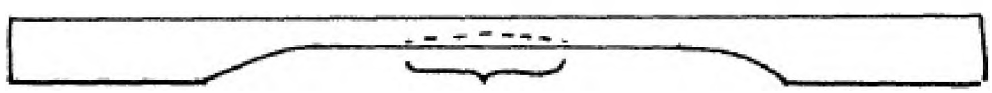
Tuning which provides steps in tuning fundamental, 2nd, and 3rd harmonics.

Fundamental Tuning (1st Harmonic)

The following steps will yield a marimba bar whose fundamental pitch will be in perfect tune.

<u>Step 1</u> Saw out undercut arch per Chapter 12.

<u>Step 2</u> Check the fundamental pitch of bar with tuning device. (Depending on how much of the arch was originally sawed out, the pitch could be anywhere from two to five half-steps sharp of pitch.)

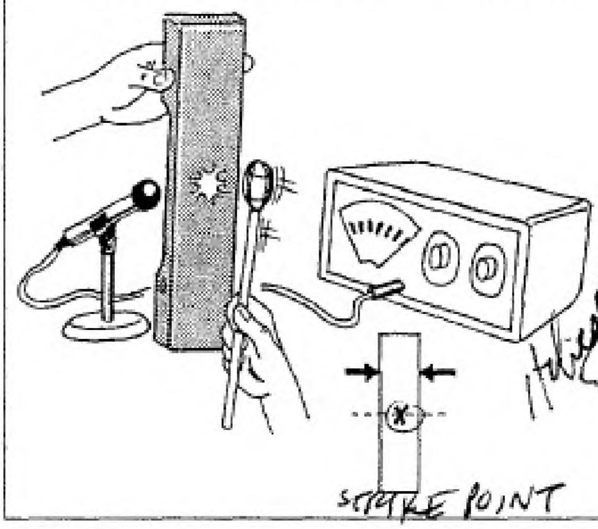


A

<u>Step 3</u> To flatten the pitch, remove wood from point A in small amounts. (Do not stay localized at point A against the sanding surface. Strive to transfer material removal over a wider area thereby minimizing thin spots.)

NOTE: On pitches C6 and above, employ stretch-octave tuning per Chapter 17.

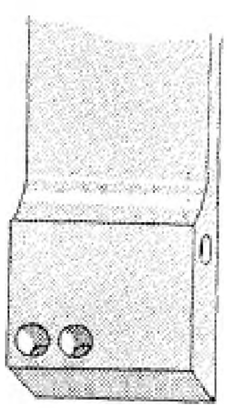
HOW TO CHECK THE FUNDAMENTAL (OR 1ST HARMONIC) PITCH



To check the fundamental pitch, simply hold the bar widthwise at the fundamental node point. Place the undercut close to the tuning device's microphone. Then strike the opposite side with a mallet. At that instant, observe the reading on the tuning device display. NOTES: (1) Friction, ~~caused by the sanding~~, will make the bar's pitch to read flat. (2) Allow the bar to cool down prior to ~~measuring~~ pitch.

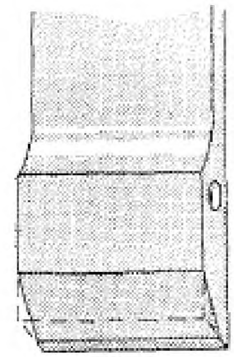
Fundamental Too Flat

When too much material is removed, the bar's pitch will flatten below the desired pitch. The only way to correct flat pitches is to raise the pitch of the bar. The following methods may be helpful in raising the pitch of the bar. However, the amount of pitch raising depends on how flat the bar has gone.



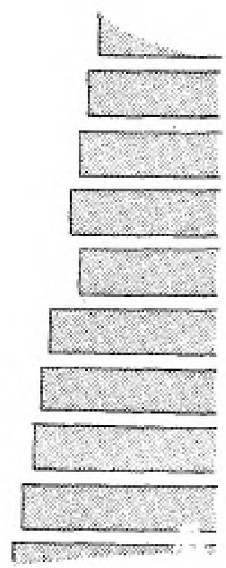
To Raise Pitch:

<u>1 to 10 Cents Flat</u> - For pitches that range from 1 to 10 cents flat, drill partial holes from the bar's ends to remove mass. This method will not affect the external appearance of the bar. ***CAUTION! Be careful not to drill through the bar!***



10 to 30 Cents Flat - For pitches that range from 10 to 30 cents flat, remove amounts of mass underneath each bar end without shortening the bar's length.

More than 30 Cents Flat - (Not Recommended) For pitches that are flat by 30 cents or more, shorten the bar's overall length equally from both ends. Unfortunately this method destroys the visual continuity of the bar with its surrounding notes, as well as shifting the fundamental node points closer together (page 78). In some cases, it may not be possible to retrieve the pitches of extremely flat bars. It is better to start with a new bar.

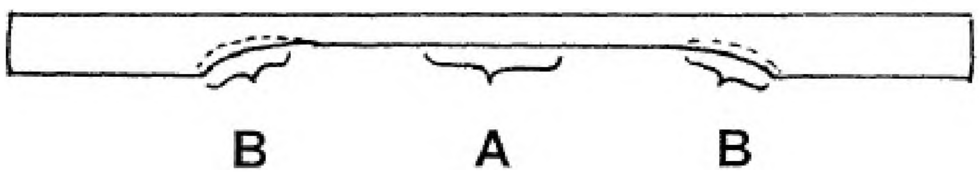


2nd Harmonic Tuning

Why second harmonic tuning? Harmonic tuning is necessary for the marimba's lower pitches. As the marimba notes descend in pitch, the whole harmonic structure lowers as well. On lower notes, the 2nd harmonic becomes quite noticeable if it is not tuned two octaves above the fundamental. The harmonics of higher pitches are less of a problem since they are masked by the dominant fundamental pitch and, as a result, cannot be heard as well.

2nd harmonic tuning has the same tuning characteristics as fundamental tuning, with one exception, additional effort is required in controlling the 2nd harmonic along with the fundamental pitch.

The 2nd harmonic is flattened by removing wood from points B.



The following steps will yield a marimba bar whose fundamental and 2nd harmonics are in perfect tune.

<u>Step 1</u> Saw out undercut arch per Chapter 12.

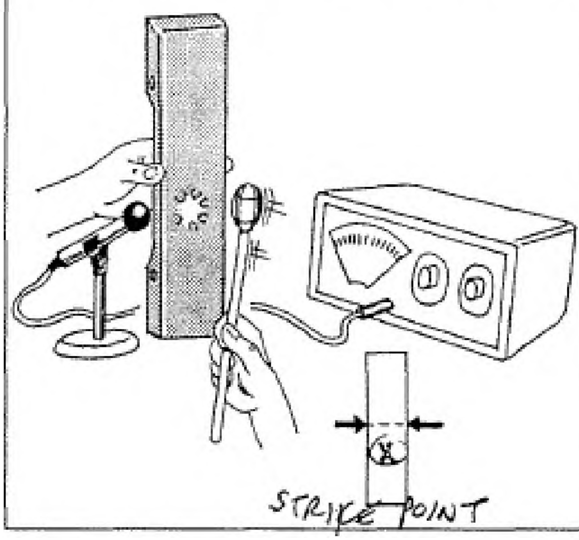
<u>Step 2</u> Locate 2nd harmonic pitch with tuning device. (See following page to check for 2nd harmonic.)

<u>Step 3</u> After taking note of the 2nd harmonic, locate the fundamental pitch. At this point, the 2nd harmonic could range from an octave and a third to an octave and a fifth above the fundamental.

Step 4 Lower the *fundamental* first by removing wood from point A until it becomes a unison two octaves below the 2nd harmonic. At this point, both fundamental and 2nd harmonic should be sharp of the desired pitch.

Step 5 Flatten both fundamental (point A) and the 2nd harmonic (point B) in gradual amounts until the desired pitch is met.

HOW TO CHECK THE 2nd HARMONIC



When checking the 2nd harmonic, hold the bar by pinching it widthwise in the middle. Holding the bar in this manner dampens the movement of the fundamental mode causing the 2nd mode to ring forth. Place the undercut close to the microphone, then strike the opposite side between the middle and the bottom with a mallet. When reading pitch on the tuning device, the sustain time of the 2nd harmonic will decay rapidly. Tap the bar many times as necessary until the 2nd harmonic is thoroughly located. Use a slightly harder mallet to help bring out the 2nd harmonic.

2nd Harmonic Too Flat

The following steps may be used to correct a flat fundamental and/or a flat 2nd harmonic.

Fundamental FLAT/ 2nd Harmonic OKAY

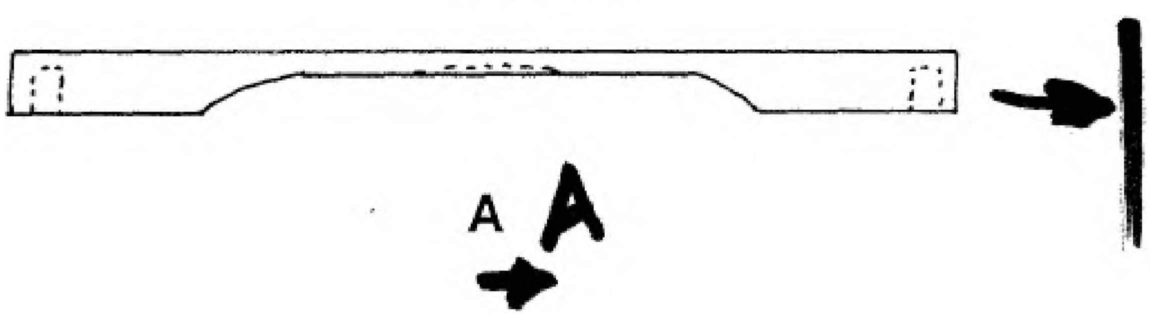
Step 1 Remove wood from underside of the bar ends, as specified under Fundamental Too Flat, to raise the fundamental to pitch and sharpen the 2nd harmonic above desired pitch.

Step 2 Remove wood from points B to flatten 2nd harmonic which should bring it down to unison with the fundamental.

Fundamental OKAY/ 2nd Harmonic FLAT

Step 1 Remove wood from underside of bar ends to sharpen the fundamental above pitch and to raise the 2nd harmonic to the desired pitch.

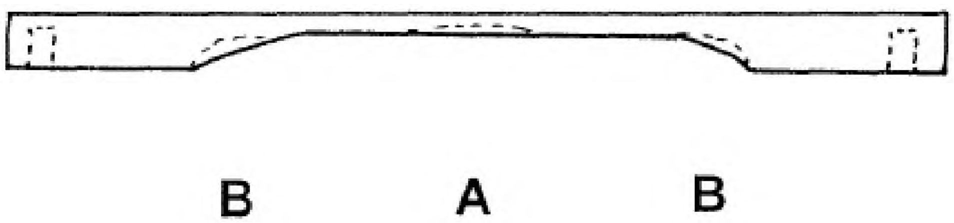
Step 2 Remove wood from point A to flatten fundamental.



Both Fundamental and 2nd Harmonic FLAT

Step 1 *Remove wood from underside of bar ends to sharpen both pitches.*

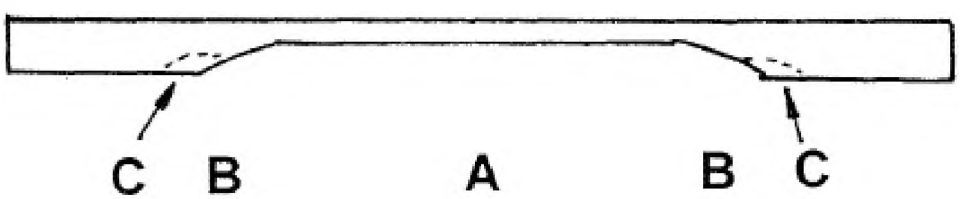
Step 2 *Remove wood from points A and B as necessary to flatten both pitches until the desired pitch is met.*



3rd Harmonic Tuning

Why third harmonic tuning? 3rd harmonic tuning is a continuation of 2nd harmonic tuning in that it gives the lower notes of the marimba a more harmonius sound.

The 3rd harmonic is flattened by removing wood from points C.



The following steps will acquaint the reader with the basics of controlling the 3rd harmonic, 2nd harmonic, and the fundamental pitch all at the same time.

Step 1 Saw out undercut arch per Chapter 12.

Step 2 Locate 2nd harmonic pitch with tuning device.

Step 3 After taking note of the 2nd harmonic, locate the fundamental pitch. At this point, the 2nd harmonic could range from an octave and a third to an octave and a fifth above the fundamental.

Step 4 Lower the fundamental first by removing wood from point A until it becomes a unison two octaves below the 2nd harmonic. Both fundamental and 2nd harmonic should be sharp of the desired pitch.

Step 5 Flatten both fundamental (point A) and 2nd harmonic (points B) until they are approximately a major second or third above the desired pitch.

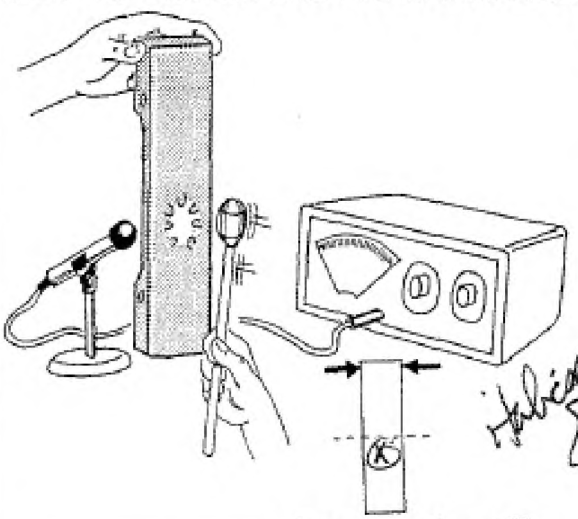
Step 6 Locate 3rd harmonic. The 3rd harmonic usually occurs about an octave plus a third (or fourth) above the 2nd harmonic.

Step 7 Flatten the 3rd harmonic, by removing material from points C, until the 3rd harmonic becomes a tenth (octave and a major third) above the 2nd harmonic. (NOTE: Be cautious. Flattening the 3rd may flatten the 2nd due to their close proximity to each other.) Table 5 provides unison pairs of the fundamental and 2nd harmonic, and their corresponding notes at the third (or tenth) interval position.

Step 8 The Fundamental may become sharp of 2nd harmonic unison. Remove material from point A to flatten fundamental to maintain the [fundamental and 2nd harmonic] unison pair.

Step 9 Flatten all three harmonics in gradual amounts until the fundamental is approximately 50 cents sharp of its *destiny* pitch. (This sharp pitch state is to allow for painting of the bar and drilling of the mounting holes.) After these other operations, complete the tuning process to bring the bar down to its final pitch.)

HOW TO CHECK THE 3rd HARMONIC



When checking the 3rd harmonic, pinch the bar width-wise at the very top. This will dampen both the fundamental and 2nd harmonic and allow the 3rd to ring forth. While facing the undercut toward the microphone, tap the opposite side at the bar's center with a xylophone mallet. Do this repeatedly until the 3rd harmonic is located. NOTE: This is where the stroboscopic type tuners are especially helpful. They can display momentary tones with accuracy that easy to discern by the eye.

TABLE 5: 3RD HARMONIC INTERVAL

UNISON PAIRS FUNDAMENTAL	2ND HARMONIC	3RD HARMONIC
C	C	E
C#	C#	F
D	D	F#
D#	D#	G
E	E	G#
F	F	A
F#	F#	A#
G	G	B
G#	G#	C
A	A	C#
A#	A#	D
B	B	D#

3rd Harmonic Too Flat

When too much material is removed from point C the 3rd harmonic will be flat of desired pitch. The 3rd harmonic is very difficult to raise without almost totally destroying the bar. What this means is, removing wood from the underside bar end has little or no effect on the 3rd harmonic. It tends to stay flat. If the 3rd harmonic is ~~only about~~ 5 ~~ten~~ cents flat, the bar's pitch may be able to be raised until the 3rd is sharp of the final pitch. (At this point the fundamental will sharpen considerably.) Remove material only from points B since this area of the bar affects the 3rd harmonic. Points C need not *be touched. As a rule, if the 3rd harmonic is more than 10 or 15 cents flat, it is best to start with a new bar.* blank.

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Chapter 17

STRETCH OCTAVE TUNING

One characteristic of human hearing is that it tends to hear high frequencies a slight bit flat of true pitch. When these upper frequencies are accurately tuned they are not really flat, but just perceived as flat.

There is a method of adjusting the higher pitches, on wooden bar percussion, so they sound more in tune. This adjustment also makes the instrument sound brighter than normal thus giving it a more brilliant tone. [illegible] The methods we speak of is called *stretching* the upper octaves. (Piano tuners and technicians have been utilizing such a method for years.)

NOTE
It is not advisable to expand the upper octave(s) on metal bar percussion, such as the vibraphone or orchestra bells. Metal bars sustain for a much longer duration (than wood). Attempting this technique would cause the upper octave unisons to have noticeable beating when played simultaneouly.

The stretching process is actually opening up the distance between adjacent notes as you ascend up the scale in the upper register of a bar percussion instrument. This can be accomplished by *adding one cent per note* above a pre-determines pitch. A tuning device with one cent resolution is absolutely necessary for this operation.

PROCESS FOR STRETCHING THE OCTAVE

The lowest note for the stretching operation, on both the marimba and xylophone, is C6. (See illustration on page 112.) To add the appropriate number of cents per note, proceed in the following manner:

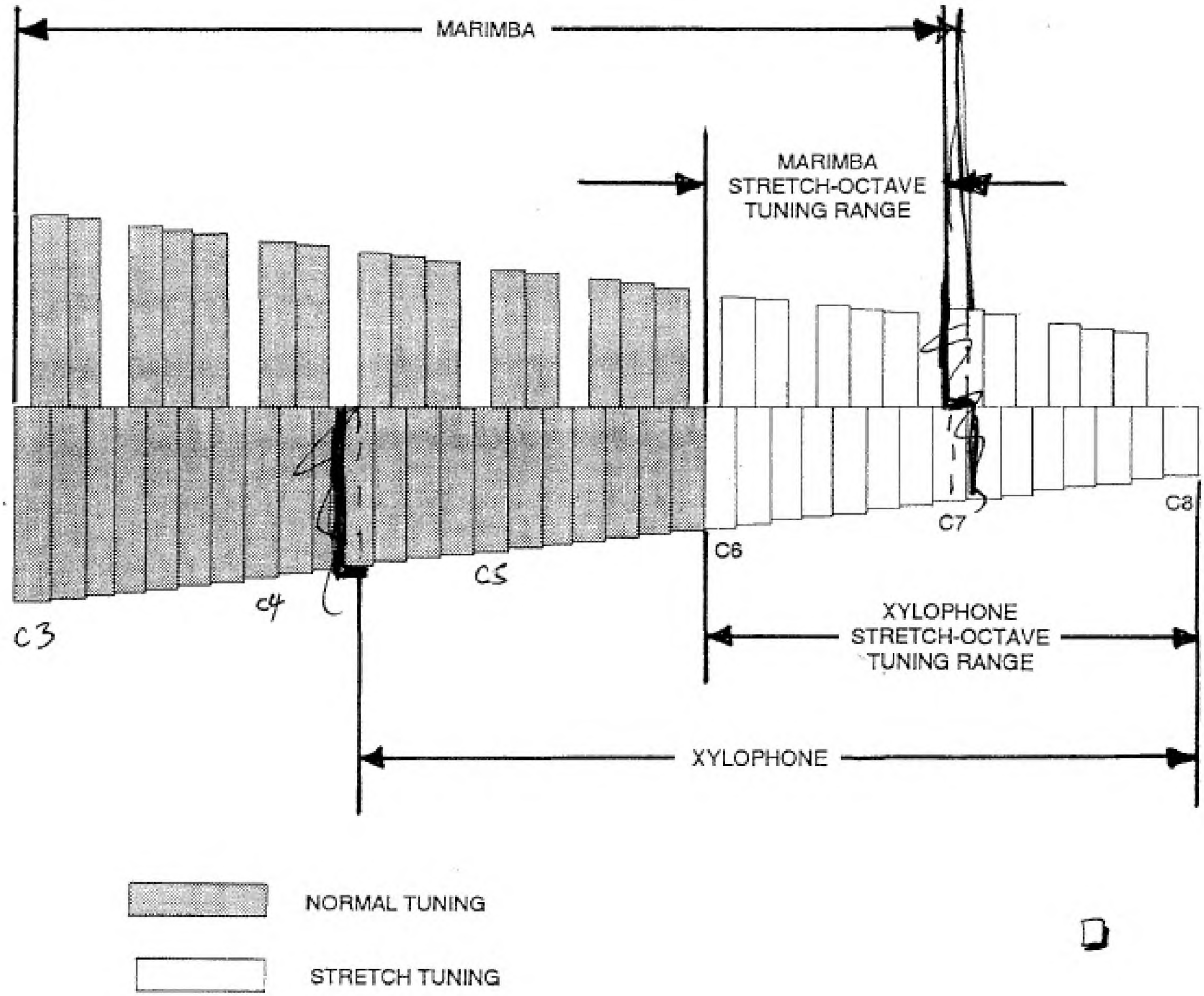
Starting with the pitch of "C" (C6), set the cents dial/indicator (on the tuner) to the *zero* position. On the next note (C#), adjust the cents dial to plus one (+1). Set the dial, for D, to +2 cents, D# to +3, an so forth. Progress upward until all notes have been properly expanded. The top note on the marimba (C7) will be at +12 cents. The xylophone's top note (C8) will be at +24 cents.

TABLE FOR STRETCHING PITCHES

The table ~~on the next page~~ may be used as a guide for stretching upper register pitches.

TABLE 6: AMOUNT OF DEVIATION FOR STRETCHED PITCHES

PITCH	CENTS
C6	0
C#	+1
D	+2
D#	+3
E	+4
F	+5
F#	+6
G	+7
G#	+8
A	+9
A#	+10
B	+11
C7	+12 (MARIMBA - HIGHEST NOTE)
C#	+13
D	+14
D#	+15
E	+16
F	+17
F#	+18
G	+19
G#	+20
A	+21
A#	+22
B	+23
C8	+24 (XYLOPHONE - HIGHEST NOTE)


MARIMBA
MARIMBA STRETCH-OCTAVE TUNING RANGE
C3
C4
C5
C6
C7
C8
XYLOPHONE STRETCH-OCTAVE TUNING RANGE
XYLOPHONE
NORMAL TUNING
STRETCH TUNING

Chapter 18

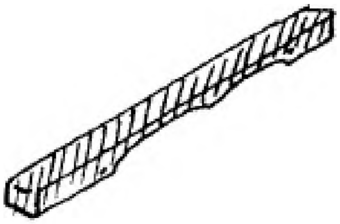
XYLOPHONE TUNING

Xylophones have a distinctive sound that is somewhat different than their marimba counterparts. There is an upper harmonic in the xylophone bar that is an octave and a fifth above the fundamental, which represents a ratio of 3:1. Another characteristic of the xylophone is that each bar is the same width throughout the instrument's range. That is, the width of the low notes is the same as the width of the high notes.

NOTE

A hardwood is necessary for xylophone bars since they are generally played with harder mallets, such as: rubber, hard rubber, plastic, or wood. Metal mallets, such as brass or aluminum, are more suitable for orchestra bell and glockenspiel type bar percussion. These mallets should never be used on wooden bars because they will tear up bar's surface.

(See TABLE 7, pg 116)



3:1 HARMONIC BAR SHAPE

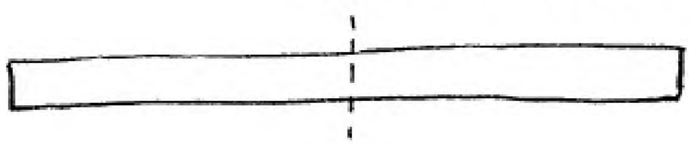
When fabricating and tuning a xylophone bar, the idea is to lower the 4:1 harmonic down a perfect fourth to 3:1. To accomplish this, the arch is cut in a slightly different shape than the conventional ~~percussion~~ marimba bar. It is this shape that helps to express the 3:1 harmonic.

SIDE VIEW

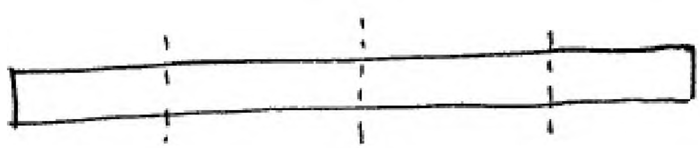
XYLOPHONE BAR TUNING PROCESS

Tuning the 3:1 harmonic can be accomplished using the following steps:

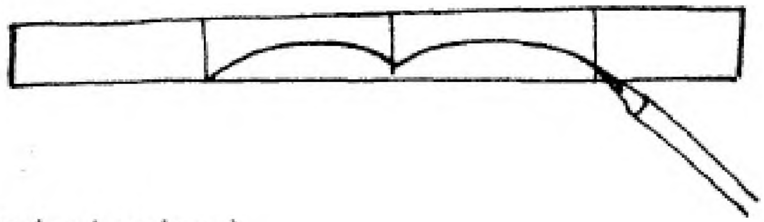
<u>Step 1</u> Take a bar blank and divide it in half.



<u>Step 2</u> Divide both halves in half.



Step 3 Draw two *shallow* contour arch lines as shown.



Step 4 Remove arches (using bandsaw).

Step 5 Check the fundamental pitch and make ~~a~~ note. (See page 98 for how to hold bar during tuning.) Employ stretch octave tuning per chapter 17. on pitch C6 and above,

Step 6 Locate the 2ND harmonic pitch and make note. Table 7 on page 116 shows where the harmonic will eventually need to be in respect to the fundamental. (See page 101 for how to hold the bar ~~during tuning.~~) to hear the 2ND harmonic pitch.)

Step 7 Remove material in small amounts from points B to cause the harmonic pitch to flatten. (This will more than likely pull the fundamental down with it.)

Step 8 If needed, Remove material from point A to flatten the fundamental.

Gradually

Step 9 Lower both pitches down to their final pitch. (Remember to keep pitches slightly sharp to accommodate finishing and hole drilling processes. They can receive final tuning afterwards.)

NOTE
When tuning xylophone bars, the tuning device must be switched back and forth between the fundamental pitch and the fifth to constantly monitor tuning progress.

TUNING TABLE

TABLE 7: XYLOPHONE BAR HARMONIC INTERVAL

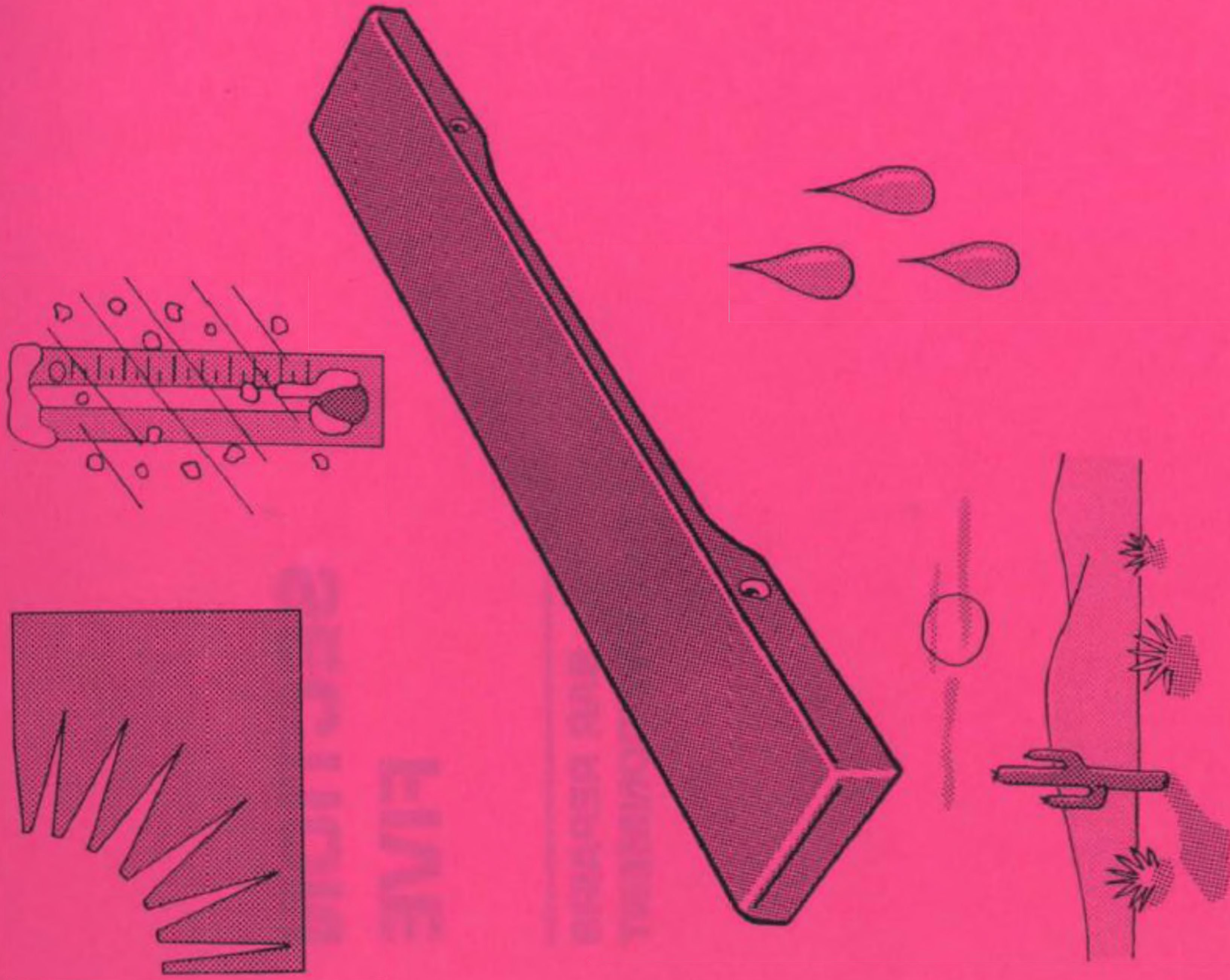
|← ONE OCTAVE AND A FIFTH →|

FUNDAMENTAL	HARMONIC
C	G
C#	G#
D	A
D#	A#
E	B
F	C
F#	C#
G	D
G#	D#
A	E
A#	F
B	F#

❑

SECTION FIVE

BAR REPAIRS
THE ENVIRONMENT



Chapter 19

BAR PROBLEMS AND REPAIRS

It is amazing that wooden bar percussion instruments last as long as they do. Unfortunately, this type of musical instrument lends itself to many potential problems. After all, a piece of material that is continually struck and beaten is bound to eventually weaken or breakdown in one way or another. Whether this weakening occurs from constant pounding or from age, it is the percussive nature of the beast.

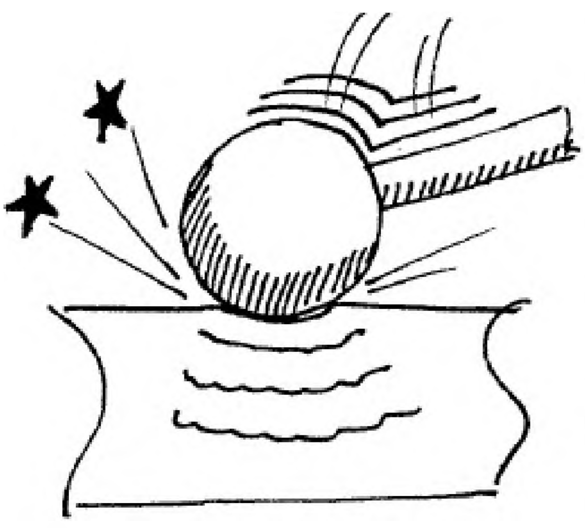
A certain amount of preventative maintenance can be performed to minimize down time. However, some repair work to the bars or finish may be required. It is important for the percussionist to understand the instrument and its limitations to increase its life. Playing with the properly designed mallets along with graceful execution will ensure the instrument is around for while. There are, of course, certain problems that affect older instruments that are beyond the performer's control that can be repaired.

The following chapter is divided into six potential problem areas -- *Deadness, Dents, Splintering, Chipped Finish, Cracks and Splits,* and *Breakage.*

DEADNESS

Deadness may result from many years of excessive vibrational movement, perhaps caused by hard playing. This causes the grain structure at the thinnest point to break down or fatigue. The bar's ability to recover in vibrational movement is lost, thus resulting in a flattening or lowering of the pitch and/or loss of sustain time (deadness).

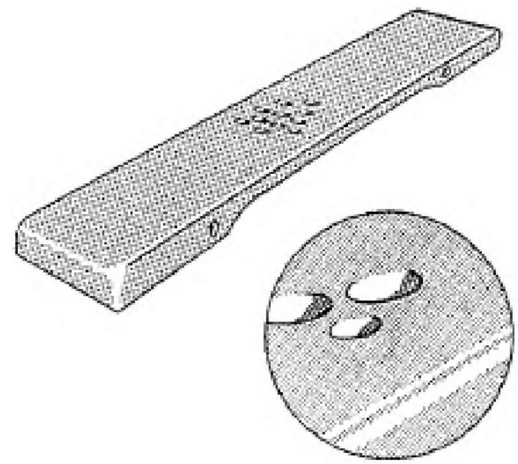
Flattened pitch can be corrected by retuning the bar. A *loss of sustain* may or may not be noticeable unless compared with the surrounding notes. If a bar sounds too dead, there will be no way to restore its original sustain time. Replacement is necessary.



DENTS

Dents are not considered detrimental to the overall performance of the bar, but depending on the degree of damage, they can be quite unsightly. Dents are caused by unnecessarily hard playing with extremely hard mallets, such as; hard rubber, plastic, wood, and heaven forbid -- metal!

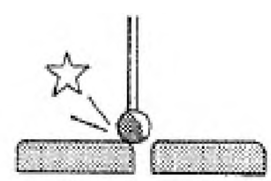
Dents cause the wood to conform to the shape of the object creating the dent, such as a mallet head, and may cause the wood fiber to break.



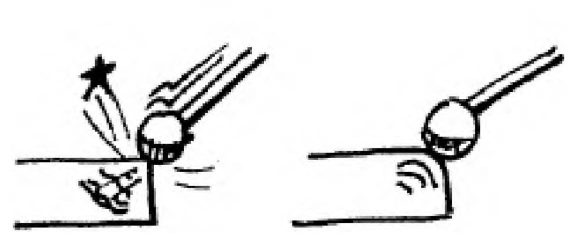
When dents aren't too deep, a sanding off the old finish, an application of a new protective finish, and a retuning are usually in order. Broken fibers may require additional sanding to smooth out the surface for restoring the bar's appearance. Unfortunately, this sanding operation runs the risk of further flattening of the pitch by reducing the bar's overall thickness.

Broken fibers may not be able to take a new finish because of the roughened surface. This condition causes the applied coat to be *sponged* or absorbed into the wood. Excessive coatings build up may help.

SPLINTERING



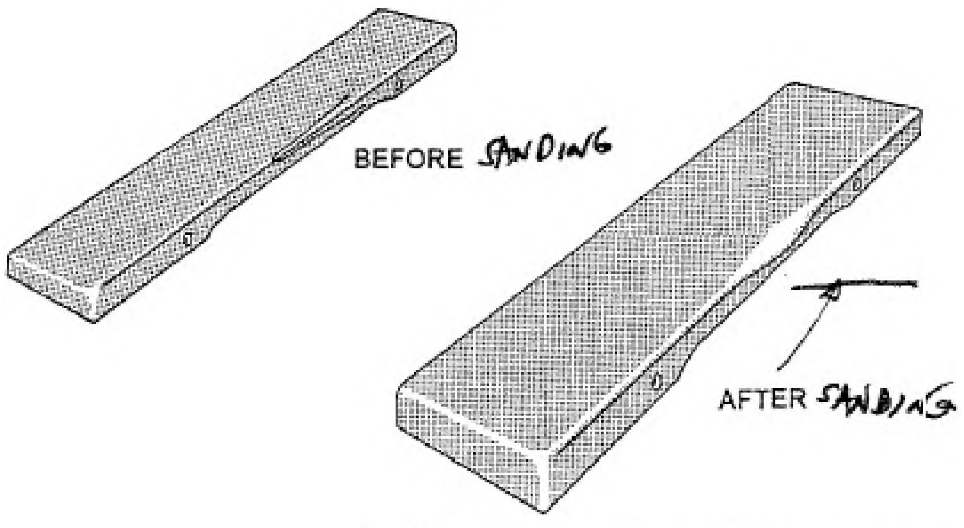
The majority of splintering seems to occur on the bar's corner, where the playing surface meets the bar's side or end. Splintering may be caused by constant glissandos up and down the paying surface or a struggling percussionist who keeps missing the bar's center.



NOTE:
Rounded corners will help to discourage splintering.

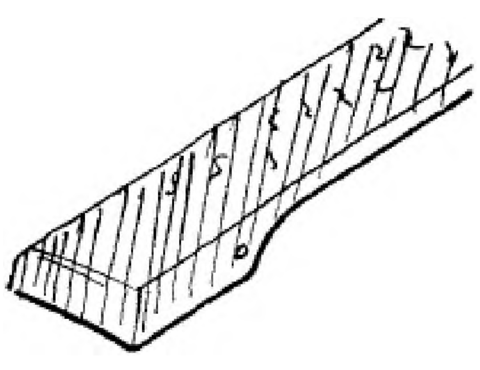
The splintering problem occurs mostly in the higher registers where harder mallets are required. Xylophones are especially plagued with this problem.

If splintering does not run too deep, it can be sanded out and blended into the rest of the bar.



A long running splinter may require gluing to keep it from springing back up. Sand, refinish, then retune if necessary.

CHIPPED OR CRACKED FINISH

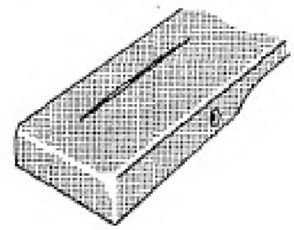


A chipped finish may either appear as little hair-line cracks in the finish or portions of the finish that have actually fallen away or chipped out. This type of defect is noticeable on old bars, with aging finish. Sometimes chips result from several applications of new paint over an improperly prepared old finish.

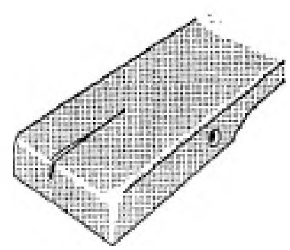
Cracks and/or chips may be treated like dents.

CRACKS OR SPLITS IN THE BAR

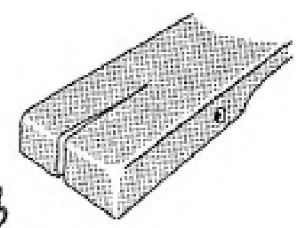
A crack or split is the actual parting of the grain from itself within the bar's structure. Correction of this type of problem can be very delicate because the bar's performance is not always guaranteed.



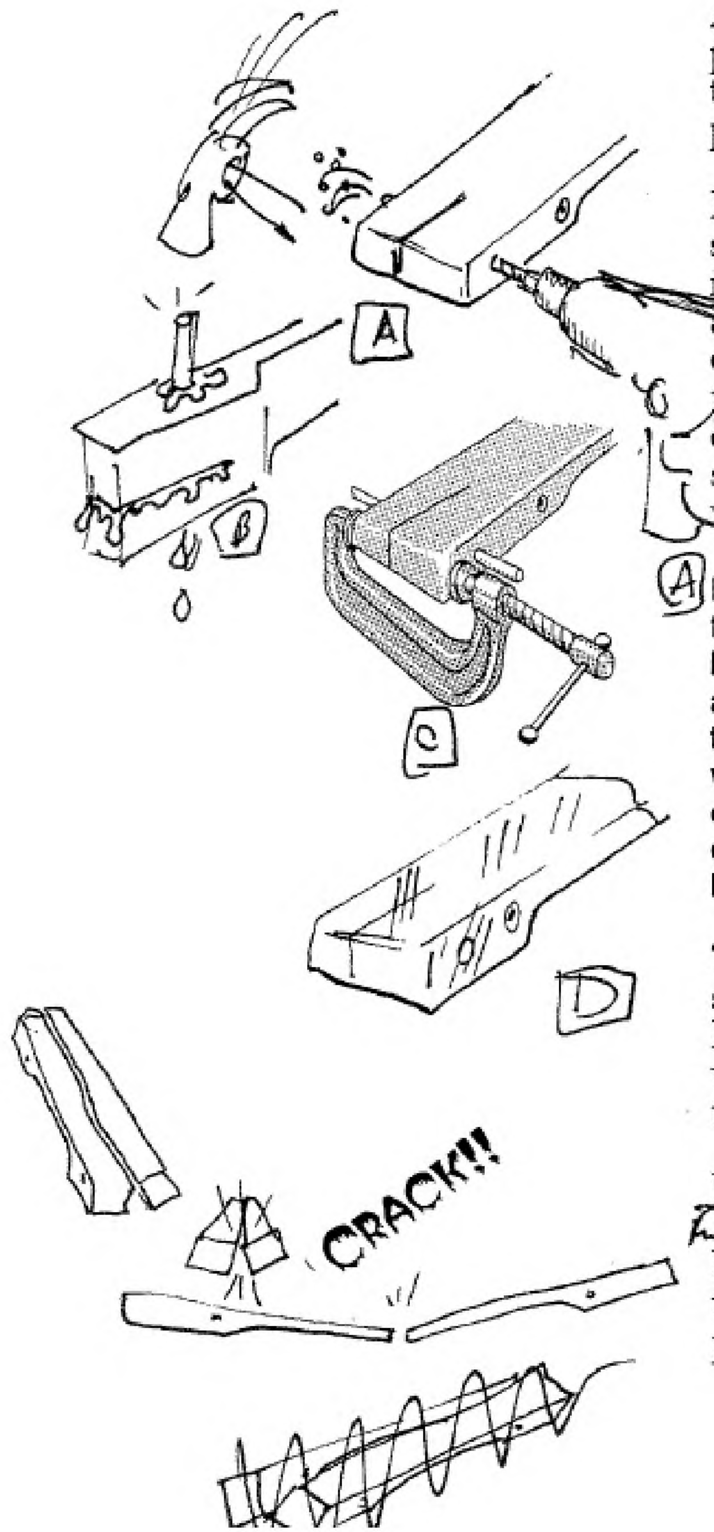
A crack or split can occur by; (1) extreme changes in temperature or humidity, (2) striking the bar too hard with an improper mallet, or (3) external damage caused by cartage, such the careless passing of the instrument through a narrow doorway and jamming one of the bars into the cord support.



A crack may occur anywhere within the bar. The crack may only be a fraction of the bar's thickness deep or may go completely through it, especially at the thinnest part of the bar-arch center.



Short or shallow cracks may be treated with a small amount of Aliphatic resin (yellow carpenter's glue) or epoxy by forcing it into the crack with a finger tip. (A stream of compressed air may force the glue deeper into the crack.)



Add a moderate amount of clamping pressure to force the crack to close. If the glue does its job, the crack will probably not split any further.

It may be tough to repair long or deep splits with glue. This is because the bar is subject to a combination of vibration and mallet impacts, and the glue could eventually pull apart or chip out. A better solution is to physically add a mechanical cross-member within the grain structure. There is a method that works well for splits at the end of the bar:

Drill a 3/16" diameter hole through the width of the bar right through the split. Pour glue into the hole then drive a length of 3/16" diameter dowel all the way through the hole until it protrudes through the other side. Pinch the bar (width-wise) with a clamp or vise overnight. When dry, carefully saw off both dowel ends and sand down until they are flush with the surrounding bar material.

The bar should be as mechanically sound as a non-split piece of wood. Placing the dowel at the end of the bar will not interfere with the bar's vibrational modes..

BREAKAGE

Breakage length or width-wise is an extremely unfortunate situation since replacement is almost always necessary.

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Chapter 20

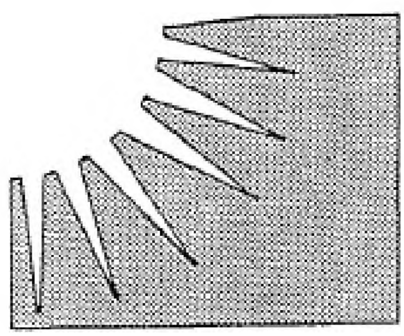
THE EFFECTS OF TEMPERATURE AND CLIMATE

The conditions of *hot, cold, damp*, and *dry* are responsible for affecting the behavior of all materials. ~~Just as humans are affected, so is wood~~.

TEMPERATURE

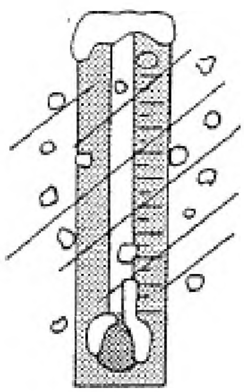
Temperature is the one element that has the most profound effect on musical instruments. Most problems that arise from temperature can be remedied by removing the instrument from the adverse condition to a ~~desired environment~~. After a short time, the instrument will have adjusted and stabilized to the change.

Heat



The effects of heat causes the marimba bar to read flat, ~~which is apparent when taking readings from the tuning instrument~~. When tuning the bar, the friction caused by the sanding, on the under-cut arch, will cause the wood to warm up. It is therefore necessary to allow the wood to cool prior to [redacted] measuring [redacted] ~~pitch;~~ preferably at [redacted] temperature it will be played. Hot environments, such as sunny days, will also warm the bar causing the pitch to flatten.

Cold



Cold marimba bars read [redacted] opposite of warm bars [redacted]. ~~It is not recommended to tune~~ marimba or xylophone bars after they have been expose to the cool night air.

Marimba bars will read even sharper in much colder temperatures. The reason for this is that the cold tends to stiffen and elasticity in the wood which causes the wood to vibrate faster than when in temperatures ~~around the 70 degree F range~~.

NOTE:

Some marimbas have a resonator height adjustment feature for compensation in mild temperature changes. The idea is that in warm temperatures the pitch of the bar flattens while the pitch of the resonator sharpens. (In resonators, warm temperatures cause the speed of sound to increase.) By raising the resonator so it becomes closer to bar, this partially blocks the resonator's opening which causes it's pitch to flatten. The flattened pitch, of the raised resonator, will more closely resemble the flattened pitch caused by the warm bar. However, in colder temperatures the bar does the exact opposite and sharpens in pitch. The resonator flattens in pitch because of the speed of sound slowing as well. Unfortunately, lowering the resonator will not bring the bar's pitch down to match that of the resonators. Idealistically, the instrument should be maintained and played at room temperatures with 65 to 75 degrees F.

HUMIDITY

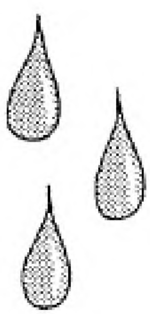
Humidity is basically the water content or dampness of the air. Bar percussion instruments tend to function best within human comfort range of 25% to 40% humidity.

Musical instruments are actually climatized to humidity - whether the humidity level is High (damp) or low (dry). Instrument exposure to radical and abrupt changes in humidity is not recommended.

A musical instrument, whether it be a piano or a marimba, will require some degree of adaptability (stabilization) to its surrounding climate. If after a period of time an instrument is moved to a radically different climatic environment, problems may occur (such as the transporting of an instrument from a damp humid climate like the Florida Everglades to the extremely dry environment found in the Arizona Desert). The instrument might have its material dry-out with a potential for irreparable damage, such as shrinkage, warpage, or splitting of critical sound producing components and support structures.

On the other hand, instruments brought from dry environment to the damp climate will have a tendency to swell thus altering the characteristics of their components. and structures. It is therefore necessary to maintain relatively constant ~~temperature and~~ humidity levels so the instrument itself can remain stable.

Dampness

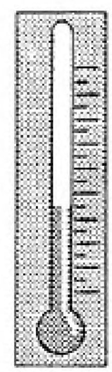


Excessively damp climate (60% and greater) generally causes instruments with absorptive components to swell. High humidity finds its way into everything and the marimba bar is no exception - especially when it has not been properly finished. Excessive and constant humidity exposure will cause the bar to absorb moisture and lose it's sustain, punch, and vibrancy. It may be possible to dry the wood over a period of time. But, restoration of its full sustain capabilities are not always guaranteed.

Dryness

Excessively dry climate (10% and less) will manifest itself by causing wood to shrink, warp, and split. Such problems are noticeable and tend to manifest themselves within the expose portions of the bar resulting from worn out or chipped finishes.

TEMPERATURE STABILIZATION



Before and during the tuning operation, the marimba bar must be temperature stabilized to ideally match that of the room it will be played. As stated in the note above, the optimum temperature range is between 65 and 75 degrees F.

If a set of marimba bars is allowed to sit in the house and temperature stabilize all night, they should be ready for tuning the next day. (In colder temperatures it will be necessary to keep the bars in a warmer environment. To suit this purpose, the bars can be wrapped in an electric blanket or placed near a heating vent.

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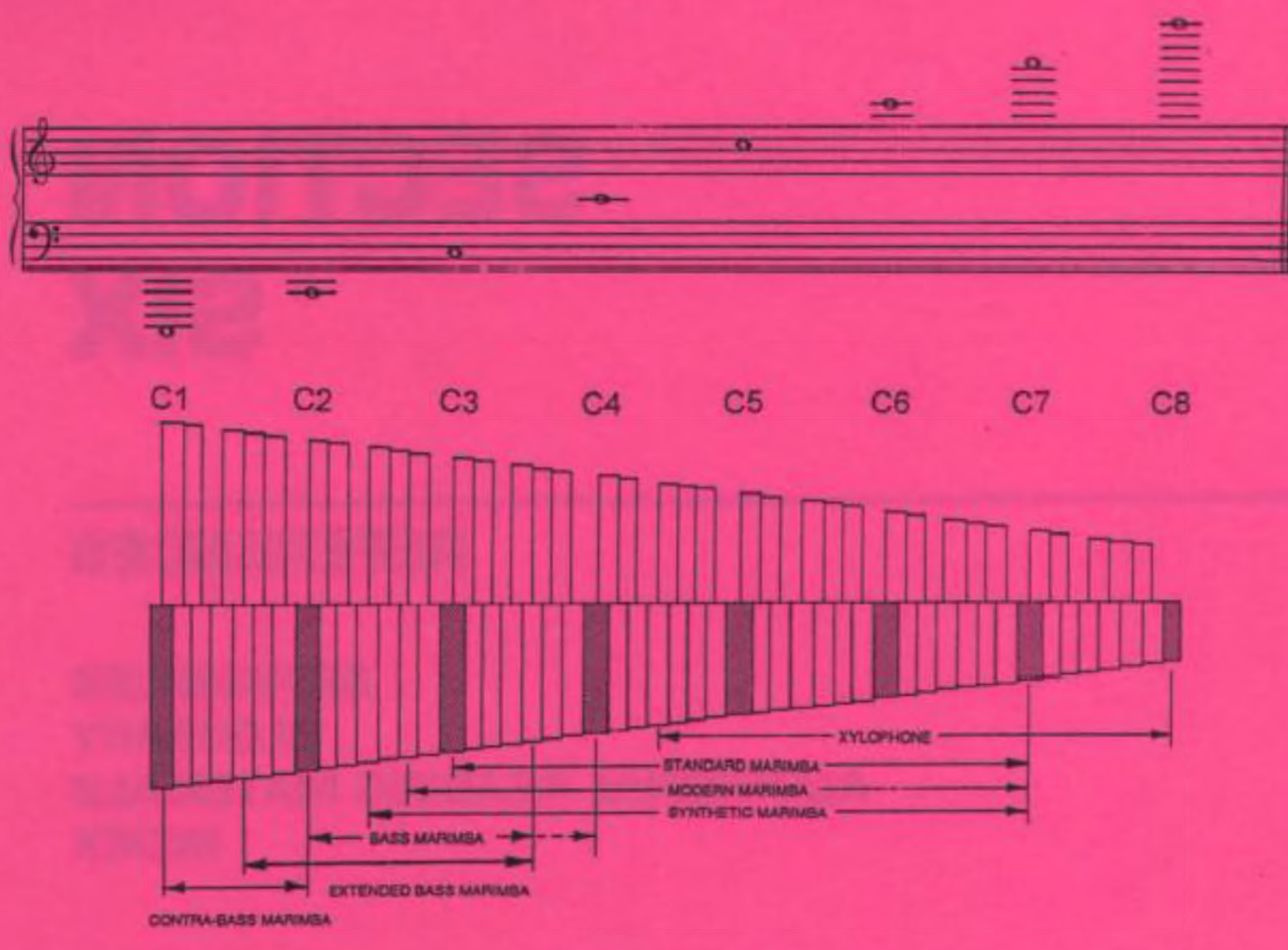
SECTION SIX

REFERENCES

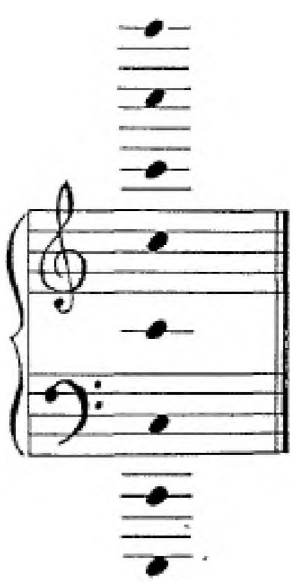
APPENDICES
GLOSSARY
ADDITIONAL READING MATERIALS
INDEX

APPENDIX 1 - General Ranges of Keyboard Percussion Instruments



APPENDIX 2 - Notation Identification Systems

OCTAVE NAME	CORRESPONDING FREQUENCY (Hz)	Notation System		
		PIANO	PIPE ORGAN	MARIMBA/ XYLOPHONE
Bass C	32.7	C4	CCC	C1
Cello C	65.4	C16	CC	C2
Tenor C	130.8	C28	C	C3
Middle C	261.65	C40	c1	C4
Alto C	523.3	C52	c2	C5
Soprano C	1046.6	C64	c3	C6
Sopranino C	2093.2	C76	c4	C7
High C	4186.4	C88	c5	C8



C8 *Highest note on xylophone and piano*

C7 *Highest note on marimba*

C6

C5

C4 [Middle C]

C3 *Lowest note on standard marimba*

C2 *Lowest note on orchestral cello*

C1 *Lowest C on piano*

APPENDIX 3 - Marimba and Bass Marimba Bar Dimensions

Standard Marimba

	PITCH	LENGTH	WIDTH
130.81Hz	C3	17.00"	2.50"
	C#	16.78	2.45
	D	16.56	2.41
	D#	16.34	2.36
	E	16.12	2.32
	F	15.91	2.28
	F#	15.70	2.24
	G	15.49	2.19
	G#	15.29	2.15
	A	15.09	2.11
	A#	14.89	2.08
	B	14.69	2.04
261.63Hz	C4	14.50	2.00
	C#	14.30	1.99
	D	14.10	1.98
	D#	13.90	1.97
	E	13.71	1.96
	F	13.52	1.95
	F#	13.33	1.94
	G	13.14	1.93
	G#	12.96	1.92
	A	12.78	1.91
	A#	12.60	1.90
	B	12.42	1.89
523.25Hz	C5	12.25	1.875
	C#	11.99	1.86
	D	11.74	1.85
	D#	11.50	1.84
	E	11.25	1.83
	F	11.02	1.82
	F#	10.79	1.81
	G	10.56	1.80
	G#	10.34	1.79
	A	10.12	1.78
	A#	9.91	1.77
	B	9.70	1.76
1046.5Hz	C6	9.50	1.75
	C#	9.35	1.74
	D	9.18	1.73
	D#	9.03	1.72
	E	8.88	1.71
	F	8.73	1.70
	F#	8.58	1.69
	G	8.44	1.68
	G#	8.29	1.67
	A	8.15	1.66
	A#	8.02	1.65
	B	7.88	1.64
2093.0Hz	C7	7.75	1.625

Bass Marimba

		(Medium-Scale)*		(Wide-Scale)*	
	PITCH	LENGTH	WIDTH	LENGTH	WIDTH
32.70Hz	C1	30.00"	6.00"	34.00"	9.00"
	C#	29.37	5.83	33.03	8.63
	D	28.75	5.66	32.08	8.27
	D#	28.14	5.50	31.16	7.94
	E	27.55	5.35	30.27	7.61
	F	26.97	5.19	29.41	7.30
	F#	26.40	5.05	28.57	7.01
	G	25.85	4.90	27.75	6.73
	G#	25.30	4.76	26.95	6.46
	A	24.77	4.63	26.18	6.20
	A#	24.25	4.49	25.43	5.96
	B	23.74	4.37	24.71	5.72
65.41Hz	C2	23.24	4.24	24.00	5.50
	C#	22.75	4.12	23.43	5.25
	D	22.27	4.00	22.88	5.02
	D#	21.80	3.89	22.33	4.80
	E	21.34	3.78	21.81	4.59
	F	20.89	3.67	21.29	4.39
	F#	20.45	3.57	20.78	4.20
	G	20.02	3.47	20.29	4.02
	G#	19.60	3.37	19.81	3.85
	A	19.19	3.27	19.34	3.69
	A#	18.78	3.18	18.88	3.53
	B	18.39	3.09	18.44	3.39
130.81Hz	C3	18.00	3.00	18.00	3.25

*Bass marimbas designed in medium-scale will have sufficient strength in sound for use in small acoustic ensembles. Bass marimbas designed using wide-scale bar sizing will have greater amplitude and carrying power than the medium-scale instrument. However, the trade-off for power is an increase in physical size, added weight, and material cost. For a simple comparison test in loudness and prior to actual instrument construction, the designer should build two bass notes - each tuned to the same pitch. (Cello C [C2] or D2 will work) One note should utilize the dimensions from the medium-scale and the other from the wide-scale. Let your ears by your guide.

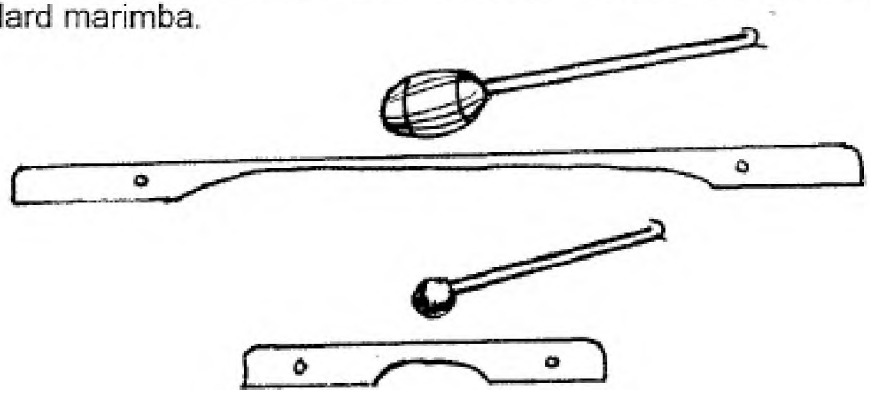
APPENDIX 4 - Frequencies of the Equal-Tempered Scale Based on A-440Hz as the Pitch Standard

	PITCH	FREQUENCY (Hz)		PITCH	FREQUENCY (Hz)	PITCH	FREQUENCY (Hz)
Bass	C1	32.70	Middle	C4	261.63	C7	2093.0
	C#	34.65		C#	277.18	C#	2217.5
	D	31.71		D	293.66	D	2349.3
	D#	38.89		D#	311.13	D#	2489.0
	E	41.20		E	329.63	E	2637.0
	F	43.65		F	349.23	F	2793.8
	F#	46.25		F#	369.99	F#	2959.9
	G	48.99		G	391.99	G	3136.0
	G#	51.91		G#	415.30	G#	3322.4
	A	**55.00**		**A**	**440.00**	**A**	**3520.0**
	A#	58.27		A#	466.16	A#	3729.3
	B	61.74		B	493.88	B	3951.1
Cello	C2	65.41		C5	523.25	C8	4186.0
	C#	69.29		C#	554.37		
	D	73.42		D	587.33		
	D#	77.78		D#	622.25		
	E	82.41		E	659.26		
	F	87.31		F	698.46		
	F#	92.50		F#	739.99		
	G	97.99		G	783.99		
	G#	103.83		G#	830.61		
	A	**110.00**		**A**	**880.00**		
	A#	116.54		A#	932.33		
	B	123.47		B	987.77		
Tenor	C3	130.81		C6	1046.5		
	C#	138.59		C#	1108.7		
	D	146.83		D	1174.6		
	D#	155.56		D#	1244.5		
	E	164.81		E	1318.5		
	F	174.61		F	1396.9		
	F#	184.99		F#	1479.9		
	G	195.99		G	1567.9		
	G#	207.65		G#	1661.2		
	A	**220.00**		**A**	**1760.0**		
	A#	233.08		A#	1864.7		
	B	246.94		B	1975.5		

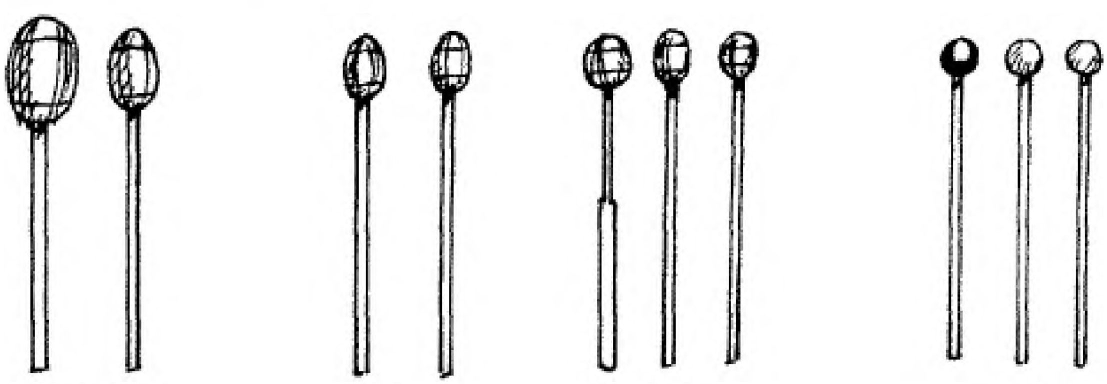
APPENDIX 5 - **Mallet Size vs. Timbre**

Mallet size and type is responsible for the timbre or tone quality of a bar percussion instrument.

LARGE/SOFT mallets cause more fundamental with weaker overtones. These types of mallets are used for *wide* bars such as those in the bass marimbas and lower registers of the standard marimba.



SMALL/HARD mallets bring out the overtones and less of the fundamental. These types of mallets are used on *narrow* bars such as those on the xylophone and the upper registers of the marimba.



APPENDIX 6 - How to Determine the Length of Marimba Resonators

A marimba resonator is a quarter-wavelength column. Quarter-wavelength means one end of the column is closed-off with the opposite end open. It is the open end that sits directly beneath the bar's arch. Proper resonance can only occur when the resonator vibrates at the same frequency as the bar's. (See Appendix 4 for frequencies.)

Column Length - The length of the column can be figured using the following formula:

$$L = \lambda / f / 4$$

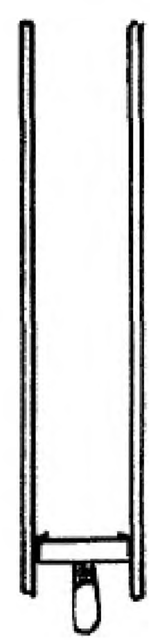
Where: L = Length of column (from opening to opposite end) in feet.
λ = Speed of sound. (1129 ft per second @ 70° F)
f = Frequency of desired pitch in Hertz.
4 = Quarter-wavelength factor

Sample Problem: *How long does a resonator need to be to resonate at 150 Hz?*

L = λ / f / 4
L = 1129 / 150
L = 7.53 / 4
L = 1.88 ft long

To convert from feet to inches, multiply length by 12.

1.88 x 12 = 22.56 inches long



Column Width - The diameter of the column should as wide as the bar's width.

Column Materials - The column may be fabricated out of aluminum tube stock (of 1-1/2", 2", or 2-1/2" diameter) with a 1/16" wall thickness. PVC (Poly-Vinyl Chloride) tubing will also work, except diameters may be limited to non-fractional single inch dimensions; 1", 2", 3", 4", and so forth. Cardboard tubing will work even with its limited durability. Resonators, for pitches below Tenor C [C3], should be fabricated in the form of square tubes using 1/4" to 1/2" thick white pine - similar to that of organ pipes.

Stopper - The stopper is an adjustable plug that closes off one end of the tube. One method for round columns is to cut out a round piece of wood with a handle attached to it. The perimeter of the wood can be covered with felt for an air-tight fit when inserted into the column.

GLOSSARY

AMPLITUDE - The maximum or extreme departure from the value of intensity or loudness from its average value. Generally, the more energy, the more amplitude.

ATTENUATE - To lessen or decrease in amplitude or loudness.

CENTS - A minute unit of pitch measurement. 1/1200th of an octave, or 1/100th of a semi-tone.

FUNDAMENTAL - The basic or primary tone of a pitch. Sometimes referred to as the first harmonic.

FREQUENCY - The number of complete cycles or vibrations occurring in a given unit of time.

GRAIN - The structural makeup of wood in the arrangement or direction of fibers or layers.

HARMONIC - A harmonic is obtained by multiplying the fundamental frequency by the number of the desired harmonic. Example: If the fundamental frequency is 100 Hz, then the seventh harmonic would be 700 Hz.

HERTZ - A term that has replaced *cycles per second.* After German physicist Heinrich Rudolph Hertz (1857-1894) the term is now an international unit of measurement for frequency. Can be abbreviated as Hz.

MODE - A pattern of wave motion. *Mode of vibration* would be the specific pattern unique to its frequency.

NODE - A point in a vibrating body where little or no vibration occurs. (A *loop* or *anti-node* is the point where maximum vibration occurs.)

OVERTONE - One of the secondary sounds of a fundamental tone or pitch

PITCH - The property of a musical tone determined by its frequency and intensity.

RESONATOR - A hollow body, such as a cavity or tube, that responds to the vibrations of a frequency producing device, such as a marimba bar. Used for *amplifying* a sound source by resonance.

SEMI-TONE - 1/12th of an octave. Equal to 100 cents or a half-step.

TIMBRE - (pronounced *taam-burr*) The quality of a sound or tone that distinguishes it from other sounds of the same frequency and loudness.

TONE - A sound wave capable of exciting an auditory sensation (hearing) by its regularity of frequency or vibration.

TRANSVERSE MOTION - The perpendicular movement to a length of material, such as bar or rod, during vibration.

VIBRATION - A periodic motion of particles or oscillations of an elastic body alternating back and forth in opposite directions from a position of equilibrium. (*Equilibrium* is the state of balance or equality between opposing forces.)

ADDITIONAL READING MATERIALS

Material on marimba bar fabrication and tuning seems to be rare. However, the books listed below address bar fabrication and/or the vibrating bar in varying levels of detail.

Marimba Bar and Marimba Fabrication

Banek, Reinhold, and Scoville, Jon,
SOUND DESIGNS, A Handbook of Musical Instrument Building (ISBN: 0-89815-011-6),
Ten Speed Press, Berkeley, California, 1980

Banta, Christopher,
Basic MARIMBA BAR Mechanics and RESONATOR Principles,
Funhouse Press, Agoura Hills, CA, 1982

Banta, Christopher
THE BASS MARIMBA
Volume 2: A Guide to Instrument Design and Fabrication, (ISBN: 0-942742-09-5),
Funhouse Press, Agoura Hills, CA, 1996
- See inside back cover for description -

McCallum, Frank,
The Book of the Marimba,
Carlton Press, New York, 1969 (Out of Print)

Moore, James Ph.D.,
The Acoustics of Bar Percussion Instruments,
Permus Publications, Columbus, Ohio, 1978

Design Software

Banta, Christopher,
Engineering Design Environments for Low-Frequency Bar Percussion,
Funhouse Press, Agoura Hills, CA, 1996
- See inside back cover for description -

About Marimbas in General

Banta, Christopher,
THE BASS MARIMBA
Volume 1: The Romance of Instrument Design, (ISBN: 0-942742-02-8),
Funhouse Press, Agoura Hills, CA, 1996
- See inside back cover for description -

Chenoweth, Vida
The Marimbas of Guatemala,
The University of Kentucky Press, Lexington, 1974

Diagram Group, The,
Musical Instruments of the World, 1980

Fine Hardwoods/American Walnut Association,
Fine Hardwoods Selectorama, Indianapolis, (no date)

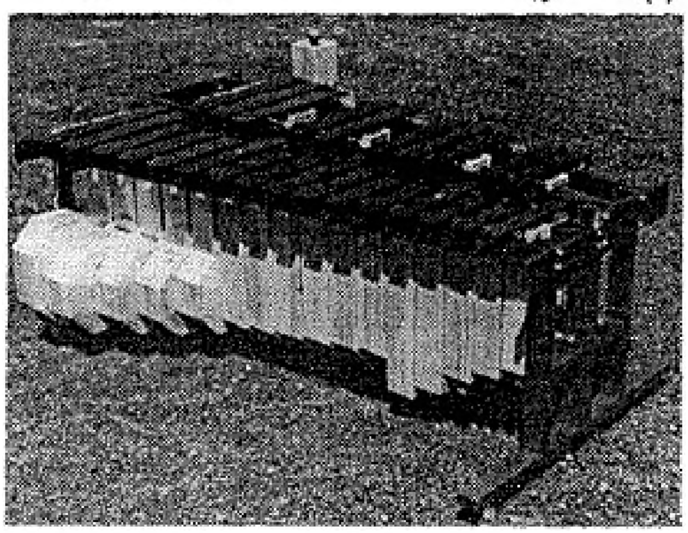
INDEX

NOTES

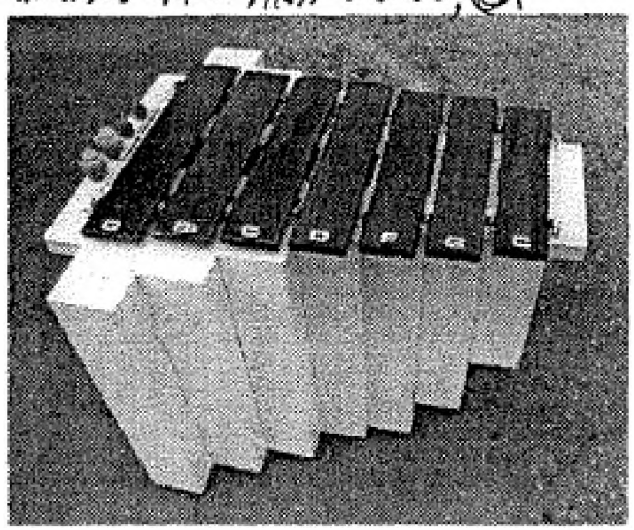
NOTES

PARTIAL LIST OF CCBANTA BASS MARIMBA PROJECTS

INSTRUMENT	NO. OF NOTES	YEAR	CLIENT
Bass Marimba	8	1973	Composer: David Alhstrom
Contra-Bass Marimba	5	1974	Experimental
Bass Marimba (Ver 1)	13	1979	Bus: Frank's Drum Shop, Chicago, IL
Sub Contra Bass Marimba	2	1979	Experimental
Bass Marimba (Ver 1)	13	1980	Bus: Yamaha International, Japan
Bass Marimba (Ver 1)	13	1980	Bus: Yamaha International, Japan
Extended Bass Marimba (Ver 1)	25	1980	Musician: Emil Richards
Extended Bass Marimba (Ver 1)	25	1980	Composer: David Ahlstrom
Contra-Bass Marimba	13	1980	School of Music: Cal-Arts, Valencia, CA
Semi Contra Bass Marimba	25	1985	School of Music: Univ of So. Calif (USC)
Extended Bass Marimba (Ver 2)	25	1986	School of Music: US NAVY, Norfolk, VA
Rhythmic Bass Marimba	3	1990	Bus: Kidspace Museum, Pasadena, CA
Rhythmic Bass Marimba	7	1990	Bus: Kidspace Museum, Pasadena, CA
Rhythmic Bass Marimba	11	1991	School of Music: Univ of So. Calif (USC)
" "	13	1991	Thousand Oaks High School, CA

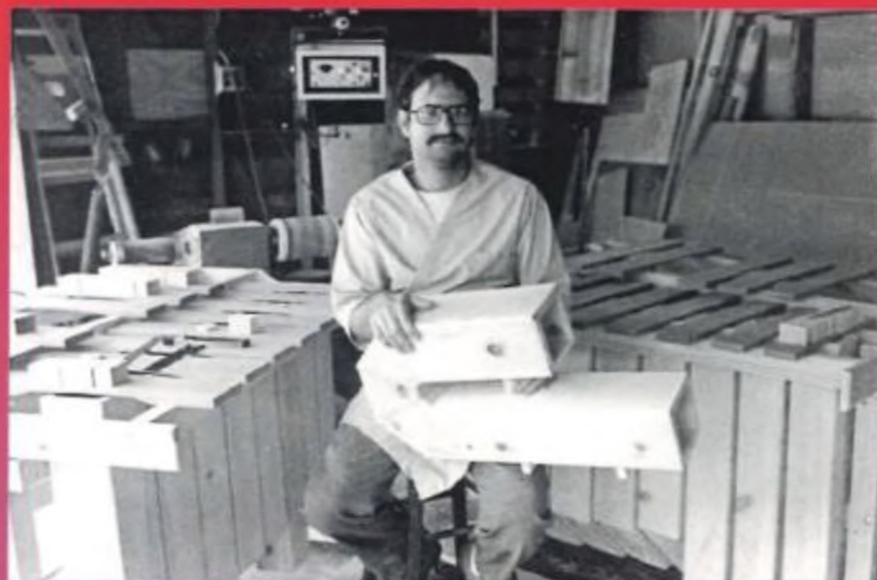


SEMI CONTRA BASS MARIMBA, 1985



RHYTHMIC BASS MARIMBA (7-NOTE), ~~1991~~ 1990

Marimba Bar Fabrication and Tuning is a workbook that provides in-depth information of how to turn a piece of wood into a musical note suitable for melodic bar percussion. This work covers the aspects of wood, bar design, fabrication tools and techniques, the tuning process, finishes, bar problems and solutions, and the effects of the environment on the bar.



CHRIS BANTA IN HIS WORKSHOP

Christopher C. Banta has spent over 20-years designing and building bass marimbas, and tuning bar percussion instruments for percussionists all over the United States. His instruments are used by Emil Richards (Mr. World of Percussion), Steve Traugh (Supercussion), John Bergamo (Repercussion), California Institute of the Arts (Cal-Arts), the University of Southern California (USC), the US NAVY, and many others. Chris' bass marimbas can be heard on such motion pictures as; Sho-Gun, Poltergeist, The Equals, and The Color Purple.

Marimba Bar Fabrication and Tuning

ISBN: 0-942742-08-7

ISBN 0-942742-08-7

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