# *The Design and Construction of a Contemorary American Gamelan*

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# The Design and Construction of a Contemporary American Gamelan

A thesis submitted in partial satisfaction of the requirements
for the degree Master of Arts
in Music

by

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1979

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University of California, San Diego
1979

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ABSTRACT OF THE THESIS

The Design and Construction of a Contemporary American Gamelan

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This paper comprises a procedure for the construction of an integrated ensemble of tuned percussion instruments modeled upon the traditional instruments of Indonesia.

In order to facilitate use in a contemporary Western musical environment, the instruments have been expanded from the traditional designs in terms of total range, intonational flexibility, and timbre.

## INTRODUCTION

The following comprises a procedure for the construction of an integrated ensemble of tuned percussion instruments modeled on the traditional gamelan orchestras of Indonesia.

For me, the basic impetus in building such an ensemble has always been a deep love for traditional Indonesian music coupled with a belief that a significant musical contribution could be made through the adaptation of some aspects of the traditional music and instruments to a contemporary western musical approach.

The designs set forth in the following pages have been created with a few guiding principles in mind. The designs should duplicate as close as possible both the sound and the playing techniques of traditional instruments. This is in the hope that persons trained on actual gamelan instruments will be able to relate to these American adaptations and that the instruments will be viable for the performance of traditional music.

Past this, the basic principle for these designs has been expansion. This has been done in a number of areas. To make the instruments more useful to contemporary western composers and performers, the ranges of most of the instruments have been extended (both above and below) beyond their traditional bounds. Additionally, wherever possible, the instruments are made with tunable keys and resonators so that a whole variety of intonational possibilities will be available (see discussion in the chapter on Intonation) on a single set of instruments. Since much of the interest in new instrument design and construction is centered on intonational problems, this seems a particularly important aspect.

The traditional timbres of the ensemble can be expanded through the use of a variety of materials. These plans utilize primarily brass and aluminum, but there is no reason why a set of instruments should not use other metals such as iron, steel, bronze, and any other of a large number of metals and metal alloys. It is best to use what is most readily available as this will provide the most latitude for experimentation. Most instrument builders are avid scavengers and spend a good amount of time frequenting junk yards, scrap metal yards, dumps, and garbage bins in industrial areas and construction sites. These are often the only affordable sources of what can often be quite expensive if bought new.

These plans may be used in a variety of ways. They may be executed simply as is. But I believe they will be more valuable and successful if they are used more as a rough guide for an instrument builder's own experiments. I see no reason not to diverge from my personal adherence to some of the limitations of the traditional instruments. I have tried to provide a basic conceptual framework for each design and its functional problems in the discussions which precede each set of instructions. As I emphasize in a number of places, these instructions are usually just one of many ways to approach the instrument or the sound.

I strongly encourage anyone using these plans to experiment, take chances, and not be afraid of wasting material in the exploration of some seemingly outlandish notion. All of these instruments originated at some point from just such a notion. As one works and begins to get a feel for the relationship between materials and sound, one's notions will probably begin to seem less outlandish.

The basic skill level required for these plans is no more than might have been acquired in a high school shop course in wood or metal working. The plans may be executed with a variety of tools. Ideally, one would have a band saw, table saw, and drill press, plus a variety of hand tools such as a hammer, wrenches, files, punches, t-square, and measuring devices. If one lacks the larger machine tools, one may substitute hand electric tools such as a sabre saw, circular saw, and hand drill. These will just require a bit more patience and precision on the part of the operator.

This work in what is now being called "American Gamelan" is the result of many years of work by many people. The designs encompassed in the following plans are not the result of a single person's work alone but are rather the present state of my work (at the completion of a gamelan built for the University of California San Diego Music Department) in the midst of a continual process of development and improvement of ideas and designs coming from a variety of persons working in this field.

First and foremost, I would like to acknowledge the debt to Lou Harrison and Bill Colvig who began this whole idea of "American Gamelan".

They have been a constant source of support, inspiration, and new ideas throughout my work with gamelan. I must also thank my colleague Dan Schmidt, particularly for his work with tunable resonators, and generally for our continual exchange of ideas and his knowledge of traditional Javanese music.

I must also give thanks to Brenda Hutchinson for her help in building and teaching on the University of California San Diego gamelan and to Robert Erickson for his support and inspiration in this past year. In my work on the gamelan in this past year I particularly want to thank Tom Rettig and William Brandt who have been ready and willing to help, both in the shop and the studio, on the shortest notice for long hours and without whose help much of the work on the gamelan would be incomplete.

On another level entirely (and perhaps the deepest level of all) I want to acknowledge the debt to the person and spirit of Harry Partch whose uncompromising diligence and vision made me believe long ago that this (and much more) was all possible.

INTONATION - Tuning the Ensemble

When one embarks upon the task of constructing an entire ensemble of tuned percussion instruments, one is immediately faced with a critical decision concerning the intonation system to be applied to the instruments.

It is certain that regardless of which system is utilized, it will have a very substantial influence upon the type of music which can be written and played on the instruments and on the sonic quality of that music.

One is actually faced with two decisions. The first regards the number of pitches per octave. The second regards the precise tuning of those pitches. These are potentially very broad questions and are not really within the scope of this study. However, the following considerations are suggested in making these decisions. While it is certainly advantageous to certain types of music to have many pitches per octave, these advantages are offset in varying degrees by both the increased difficulties for the performers in learning the system and in the increased size of the physical gesture required to play the necessarily larger instruments. The increased size of the instruments makes them more expensive and time consuming to build and difficult to transport.

If one has an interest in duplicating traditional Indonesian music, one should be aware that two very different tuning systems are in use in most of Indonesia, one with five tones, called slendro, which are roughly equidistant, and one with seven tones, called pelog, comprised of something like half-steps and thirds. In Central Java, most orchestras consist of two complete sets of instruments, one in each tuning. There will usually be one or two tones common to both systems. There is no standard tuning in Indonesia, in fact, gamelans are in part identified and known for their particular tuning.

In the West, the predominant tuning system is a twelve tone equal temperament. However much of the present interest in new instrument design is focused on different systems, such as those derived from the harmonic series or other equal temperaments, such as 19 or 31 tones per octave, which yield close approximations of just intonation.

The final decision on the number of pitches per octave and the precise tuning of those pitches will be a personal choice based on the type of music to be played, the ability of the potential musicians, and practical aspects such as time, money, and tranportation.

The following system is suggested as a potential middle ground in this question. The instruments in these instructions are generally built with seven tones to an octave, with each of these pitches variable (by means of the systems described below) over a total range of about a semi-tone. It is recommended that a number of these instruments be built in pairs so that the number of intonational possibilities can be greatly increased.

The advantages of this variable tuning system are as follows. The seven tones can be easily tuned to duplicate both traditional

Indonesian slendro and pelog scales and virtually any other seven tone mode that is derived from or is an alteration of a western diatonic scale, regardless of whether it is "just" or "equal" in temperament. If the instruments are built in pairs, the pairs may be tuned to different pitches yielding a potential 14 tones per octave. In addition, instruments in pairs may be easily tuned slightly out of tune creating (and giving precise control over) the precise beat frequencies which are such an important aspect of Balinese gamelan.

The seven tone instruments will not be unduly large and they bear a close relation (regardless of the precise pitches chosen) to both the physical and the conceptual formats to which most westerners are accustomed.

VARIABLE INTONATION CONTROL FOR TUNED METAL KEYS

Style One - for Sarons and pitches around middle C and above.

This system involves the use of movable rectangular weights attached to both ends of a metal key, which, when rotated, effectively shorten or lengthen the key's length thus changing its fundamental frequency. As the weights are rotated towards the center of the key, the pitch rises in frequency, as they are rotated out, the pitch lowers.

The larger the mass shifted in location, the greater the tuning effect. However, the amount of change is not based on mass alone but is also dependent on the change in the location of the mass in relation to the point of rotation. Thus a square, regardless of its size, rotating about its center would produce no pitch change. The most effective shape seems to be a rectangle, with about a 3/1 ratio of length to width, rotating about a hole drilled quite close to one of its ends.

To effect a proportional amount of pitch change in various registers, it is necessary to increase the mass of the rectangle with an increase of mass of the key. Thus a large brass key tuned to the same pitch as a smaller and lighter aluminum key would require a larger tuning weight to effect the same amount of pitch change. When working with a set of keys of the same material and thickness, the tuning weights get smaller as the pitches get higher.

There are a number of important practical considerations and limitations in utilizing this system. From various experiments, it seems evident that the addition of any weight to the ends of a key has a negative effect on the higher partials and on the sustain of the key. This loss is minimized to an acceptable degree if the size of the weight added is such that it yields about a semi-tone of total pitch change.

In theory, the optimum tuning weight would be quite long and narrow, thus yielding a greater ratio of mass location change to the mass itself and thus more pitch change with less of a timbre quality loss. However, such a weight either sticks out too far off the end of the key, making playing awkward, or else when turned sideways, necessitates large spaces between the keys, and when turned in, tends to damp the vibrations even more due to its length. It is also more likely to buzz against the key.

Another practical limitation is that the nodes move in proportion to the amount of pitch change. A pitch change greater than a semi-tone tends to move the nodes enough to require a different point of suspension for maximum sustain of vibrations.

The addition of the tuning weight will lower the pitch of the key about a whole step. It will also move the nodes. Thus it is necessary to add the basic tuning apparatus to a key before trying to tune it to a final pitch area and before drilling the nodal holes.

In using the weights, it is best to adjust them symmetrically in relation to each other. For example, if a slight lowering of the pitch is desired, it is best to turn both weights out a bit, as opposed to more of a turn on a single weight. This assures a more regular nodal line and an evenness of weight distribution on the key which effects sustain and partial structure. The effect of changes in the location of the tuning weight upon nodal location and shape can be easily demonstrated by dusting a small amount of salt, sand, or sawdust upon a key suspended horizontally and striking it a few times. The dusting will gradually line up on the nodal lines.

In order to minimize timbre quality loss by the addition of the tuning apparatus, it was found effective to work with thicker keys. Thus a set of keys which would have been made of ¼" aluminum, if non-variable in pitch, were made of 3/8" aluminum to alleviate timbre loss.

The basic procedure is as follows:

1) Drill a 3/16" hole in the widthwise middle of both ends of a key, 3/8" in from the end.

2) With a ¼" tapping tool, put threads into the hole. Insert a ¼" bolt and check to see if it is threaded properly.

3) Cut the rectangular tuning weights. For sizes for specific key length/thickness/pitch combinations, see the charts in the sections on the construction of specific instruments. Maintain about a 3/1 ratio of length to width on the tuning weight. This need not be very precise as it is actually possible to use about the same size weight over several pitches. One may cut a long strip of a particular thickness and width and then cut slightly varying lengths in relation to the key's length.

4) Drill a ¼" hole at one end of the tuning weight. Be sure this hole is full and clean or the bolt will not allow the weight to rotate independently of itself.

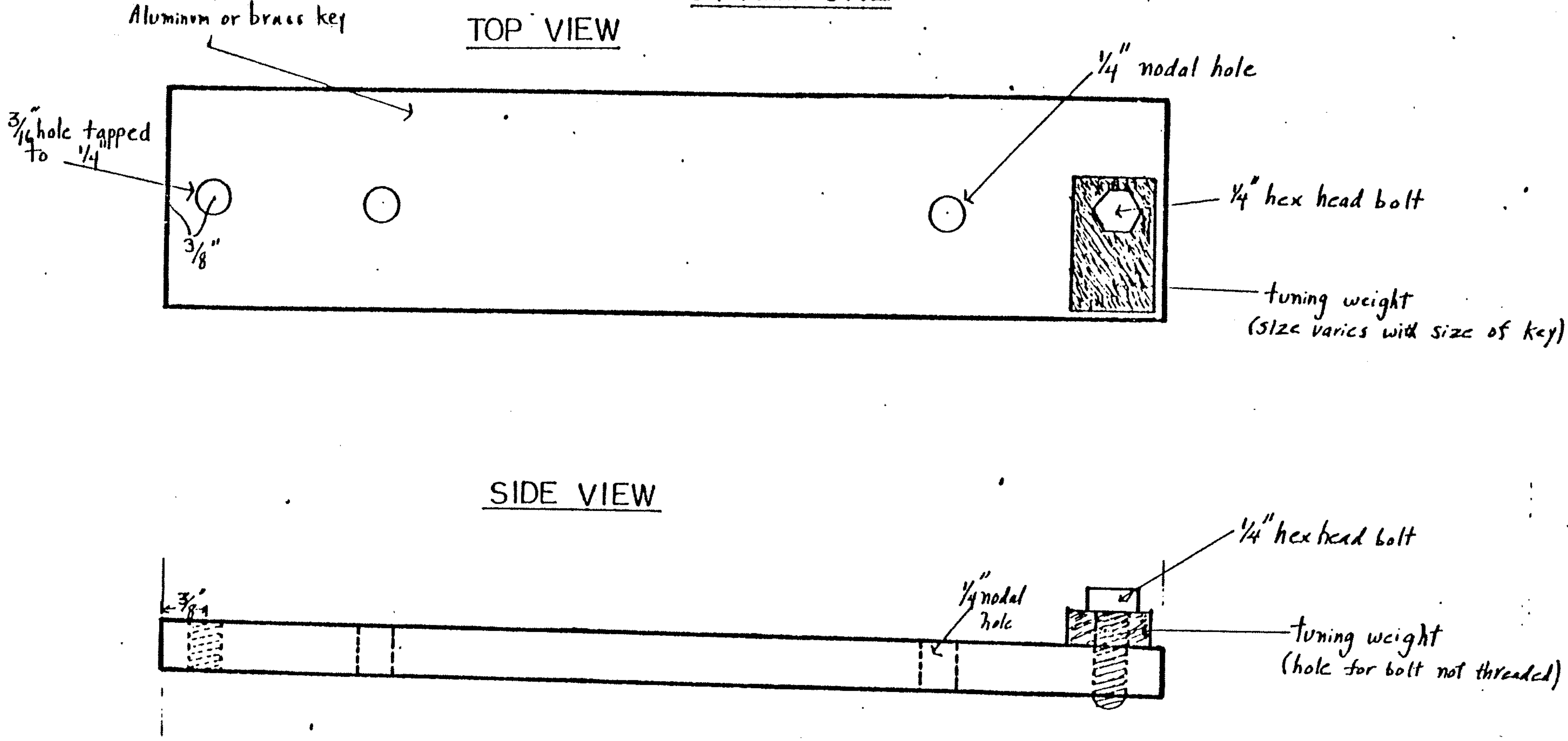
5) Bolt a weight tightly to the key on both ends. It should be long enough to go fully through the tuning weight and key. If a slightly lower pitch is at some point needed on a particular key, one may simply use a longer or heavier bolt.

6) The final tuning of a key can take place from either its highest, lowest, or its center pitch, depending upon what intonational limits are important to the particular key.

Because the tuning apparatus requires a hole drilled near both ends of a key, all rough tuning of a key must take place in a downward pitch direction. This is because the usual procedure of raising a key's pitch by cutting material off the end is limited by the close proximity of the hole to the end. Small rises in pitch can still be accomplished by grinding of mass from the underside of the key near the ends. (See separate pages on the tuning of aluminum keys). Thus it is recommended that the basic key be constructed sharp of the desired pitch and then down to pitch by cutting in the center underside of the key.

Once tuned to a general intonational area, particular points of intonation can be indicated by marks on the key indicating the tuning weight's location.

# VARIABLE INTONATION SYSTEM FOR TUNED METAL KEYS
## STYLE ONE



Variable Intonation - Style 2 for kempul and gongs

This system involves the construction of a pair of brackets which are placed over both ends of a key. It operates on the same principles as the rotating weights, i.e., the pitch changes with the shift in mass in relation to the nodal points.

This method involves the addition of substantially more mass in the adjusting apparatus than in the first style. It seems most effective on tones below middle C and functions well to the bottom of the audible spectrum. One of its main advantages is that it allows a tuning range of a whole tone to a minor 3rd on a given key. This may be particularly useful in the gong range where one may not have a full collection of keys and resonators for all pitches of the scale.

There is a substantial high frequency timbre loss with this system but since these lower pitches are usually played with soft mallets in order to minimize higher partials, this loss is generally not noticed nor lamented.

This system functions particularly well with brass keys because their greater mass withstands the bracket's potential damping effects. Thus a brass key's sustain may be only inconsequentially affected. An aluminum key, depending on its thickness, may be more detrimentally affected in terms to sustain, but it may also have the advantage of a greater tuning range.

The nodes will move substantially with the addition of the tuning brackets. However, with brackets of the specifications given in the charts, the amount of nodal shift when the brackets are moved to either extreme is not a problem. One should always determine the location of the nodal holes from the central pitch area on a key with it's brackets attached to a center position of the key.

The addition of the tuning apparatus to a center position on the key tends to drop the pitch of an unbracketed key about a whole step, and the nodes tend to move towards the ends about 1/4"-3/8". If the bracket is moved up very close to the nodal holes, the pitch approaches the unbracketed pitch of the key.

Besides the potential timbre loss, there are two main disadvantages to this system in relation to the first style. First, it requires the use of four bolts (instead of two) per key, making tuning adjustments a slower process. Since it's tuning range is greater, fine tuning is more difficult and thus slower.

A second disadvantage, for certain instrument designs, is that the tuning apparatus protrudes out about ½" on either side of the key. On instruments where the keys are lined up next to each other, this causes an additional inch of space between each key, making playing potentially more difficult and the instrument larger. For slentem and gender, this may be a real problem and thus Style 1 tuners are recommended. For gongs and kempul, there will be no problems.

The basic procedure for each key is as follows:

1) Cut four strips of aluminum, 5/8"-3/4" wide, about the thickness of the key to be bracketed, and of a length about one inch longer than the key's width. For thin brass keys (1/8"), it may be advantageous to use a thicker bracket for reasons given below.

2) On all four strips mark a point 3/16"-¼" in from each end and in the widthwise center of the strip.

3) On two of these strips, drill a ¼" hole at these points.

4) On the other two, drill a 3/16" hole and then tap (thread) this hole with a tapping tool.

5) Connect the two strips with a ¼" bolt. This bolt should be at least 1/8" longer than the sum of the thickness of the key and the two strips.

6) Slip a bracket over each end of the key. Place them symmetrically in relation to the ends of the key, about halfway between the nodal area and the end of the key. They should also be perpendicular to the length of the key. Tighten the bracket against the key. Be careful not to make it too tight as the threads in the bottom half of the bracket may become stripped. If this becomes a problem, one may need to use a thicker strip. Be sure also that there is a small space between the side of the bolts and the side of the key. Only the strips should touch the key. If the bolts should pinch the key, adjustments will be rather difficult.

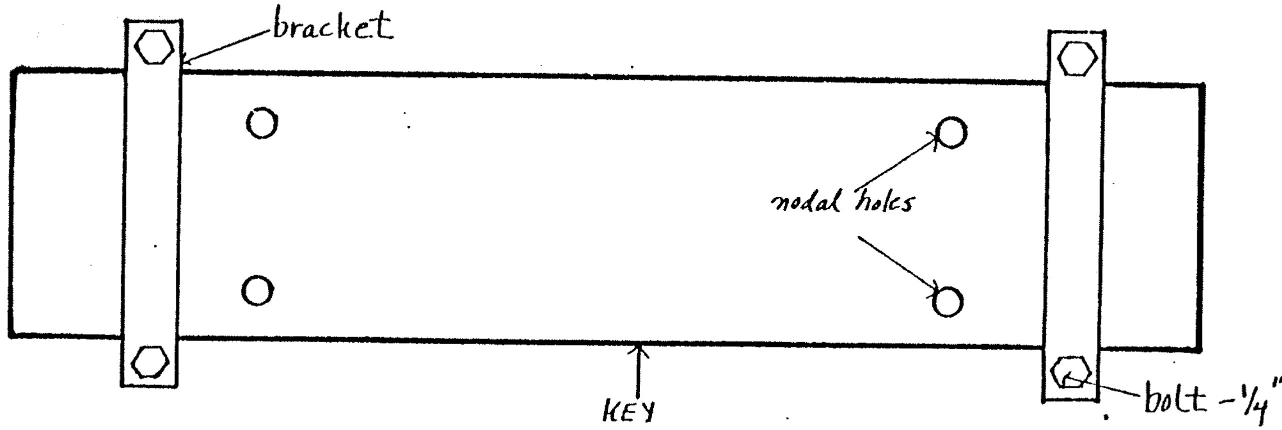
7) Tighten the brackets at the center point between the key's end and its nodes and check the pitch. It should be very near the center pitch one wishes for that key. If it is not, the key may be tuned by the usual methods, lengthwise shortening for raising the pitch, making it thinner in the center for lowering. Then check the tuning range necessary for the key by adjusting the brackets to either extreme, near the nodes and near the end. If the range of pitch change is not enough, the bracket used must be thicker and/or wider (i.e., it must have more mass). If you must go to a larger bracket, keep in mind that the center pitch of the key will drop in proportion with the additional bracket mass. Do not drill nodal holes until the key is center tuned and has the correct tuning range.

8) Determine the location of the nodal holes by the usual dusting method. It is suggested that before drilling, the extremes of nodal variation with bracket adjustment be determined. Find the nodes at three points of the brackets location, at the end of the key, the center, and next to the nodes. There should not be more than about 1/8" variation on each side of the center location. The center point of nodal location should also be the central pitch area. This is where the nodal holes should be drilled.

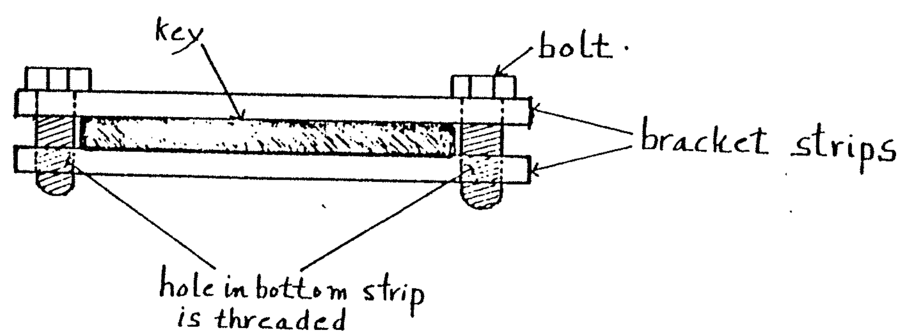
9) For keys which are going to be suspended from above over individual resonators (gongs, kempul, and slentem), it is best to drill two holes in each nodal line. This gives much more stability to the key and keeps it from flopping around when played. These holes should be drilled about 1/6 of the width in from both sides on both nodal lines. Thus there are four nodal holes in each key.

# VARIABLE INTONATION SYSTEM — STYLE TWO

## TOP VIEW




## END VIEW



## SARON-DEMUNG, SARON-PEKING WITH TUNABLE KEYS

The saron family of the traditional Javanese gamelan is a group of three trough resonated metallophones called (from low to high in pitch) demung, saron, and peking. Basically, each has the range of a single octave plus an additional note or two, usually extending the range upward. However, in adapting these instruments for western use, it seems advisable to extend the range of an individual instrument to two full octaves. Thus the traditional three instruments now become two, one with the range of demung and saron and one with the range of saron and peking. If the instruments are to be used for traditional Javanese music, there may be two musicians at each instrument, one in each octave. This also has the advantage of doubling the number of musicians in the saron range, a practice common in Java. Of course, there is no reason why an instrument with a larger range should not be built. There is however a limit to a trough resonator's ability to effectively resonate pitches lower than the traditional demung range. The specifications here are for an instrument with a two octave range, seven tones per octave, with a relatively large trough resonator which enhances the fundamental pitch, particularly in the demung range, somewhat more than the traditional instruments. If a more traditional sound is desired, the resonator need merely be made shallower.

In the interests of expanding intonational possibilities, the specifications for the keys and resonator width are for tunable keys. See the separate instructions under Intonation for making tunable keys.

SARON-DEMUNG

Materials

1) 5/8" particle board or plywood, surface area about 2 feet by 4 feet.

2) Aluminum keys

a. 70" of 3/8", 2" wide

b. 105" of 3/8", 1-3/4" wide

3) Tuning weights:

a. 20" of ¼" aluminum, 3/4" wide

b. 30" of ¼" aluminum, 5/8" wide

4) Soft neoprene or similar material, ¼" thick, two strips, ¼" wide, 36" long each.

5) Pins for holding keys to the trough, 30 3d finishing nails, wrapped with duct tape, surgical hose, or similar material.

6) Glue and nails for assembling case.

7) 30 hex head machine bolts, 5/8" in length, ¼" diameter.

MAKING THE KEYS

It is essential that the complete key set be constructed and rough tuned before the case is assembled as the case must precisely fit under the nodal points of the keys. Cut the lengths of 2" and 1-3/4" wide, 3/8" thick aluminum into the lengths in the chart below. The tuning weights are all ¼" thick. All dimensions are in inches.

| PITCH AREA | LENGTH | WIDTH | TUNING WEIGHT/ LENGTH | TUNING WEIGHT/ WIDTH |
|---|---|---|---|---|
| C | 15" | 2" | 1-3/4" | 3/4" |
| D | 14½" | 2" | 1-3/4" | 3/4" |
| E | 14" | 2" | 1-3/4" | 3/4" |
| F | 13½" | 2" | 1-3/4" | 3/4" |
| G | 13" | 2" | 1-3/4" | 3/4" |
| A-440 | 12½" | 1-3/4" | 1-5/8" | 3/4" |
| B | 12" | 1-3/4" | 1-5/8" | 5/8" |
| C | 11½" | 1-3/4" | 1-5/8" | " |
| D | 11" | " | 1-5/8" | " |
| E | 10½" | " | 1½" | " |
| F | 10" | " | 1½" | " |
| G | 9½" | " | 1½" | " |
| A-880 | 9" | " | 1-3/8" | " |
| B | 8½" | " | 1-3/8" | " |
| C | 8" | " | 1-3/8" | " |

Please note that the term "pitch area" is used to emphasize that each of the indicated lengths can be tuned to a relatively wide range of pitches through the process of undercutting. Thus, a 14" length may just as easily be tuned to E flat as E natural. See separate instructions called Variable Intonation Control for Tuned Metal Keys for directions on drilling, tapping, and assembling keys and tuning apparatus.

Drill the nodal holes as in instructions.

When laid out in order, the nodal holes should fall into two relatively straight lines. Space the keys such that no two keys will hit each other regardless of which position the tuning weights are in. There should be about 1/8"-1/4" between the keys. To minimize this distance turn all tuning weights on the bottom end of the keys in one direction and the weights on the top end in the opposite direction.

Before proceeding to make the case, check to see if the key set will fit properly on the case size in the instructions, both in terms of length and width. If it does not, one must make adjustments in the case size. The following instructions are for a trough which will fit with keys made to the previous key specifications.

MAKING THE TROUGH RESONATOR

1) Take a 36" by 12" piece of 5/8" particle board and on one of the 12" sides, mark a point 3" from the bottom. On the other 12" side, mark a point 9" from the bottom. Draw a line connecting these points and cut along this line. These will be the sides of the trough and should be identical in size.

2) Cut one piece of particle board 9" by 9½" and another piece 5½" by 9". These will be the ends.

3) To cut the bottom, take a rectangular piece of particle board 9½" by 36½". Mark a point in the center of one of the 9½" sides. Mark a point 2-3/4" on both sides of this center point. Draw and cut on the lines connecting each of these two outer points to the respective opposite corner.

4) Hold up the sides against the sides of the bottom piece to determine the angle and direction to adjust the ends of the sides. This should be about 5-7 degrees and may be done by filing, sanding, or a slight careful recut. This adjustment is necessary for the proper joining of the ends and the sides.

5) Using 3 or 4d finishing nails and glue, connect the ends and sides by nailing through the ends into the sides.

6) Take the bottom piece and lay it into place between the ends of the side-end assembly. If the bottom is too long, trim the ends slightly at an angle so that they will properly abutt to the ends. Nail and glue into place.

7) Let the glue dry. Sand the case to remove excess glue and uneven joints. Fill any gaps in the joints on the inside of the trough with putty or other sealer.

FINAL ASSEMBLY

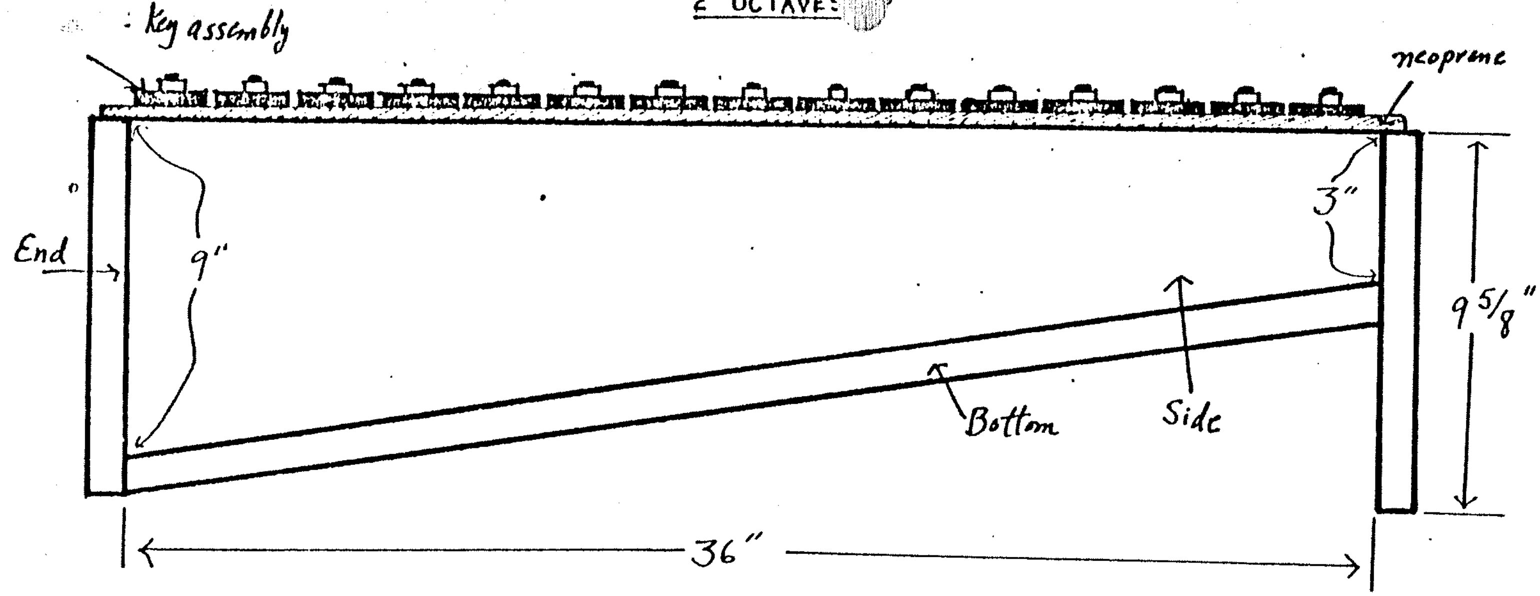
1) Cut two ¼" wide strips of ¼" soft neoprene or other similar material and lay them over the entire length of the top of the sides of the trough.

2) Lay the keys over the neoprene strips and position the keys and the neoprene so that the neoprene is directly under the nodal holes, and that the nodal holes are as close to the center of the sides' thickness as possible. Space the keys with 1/8"-1/4" between them.

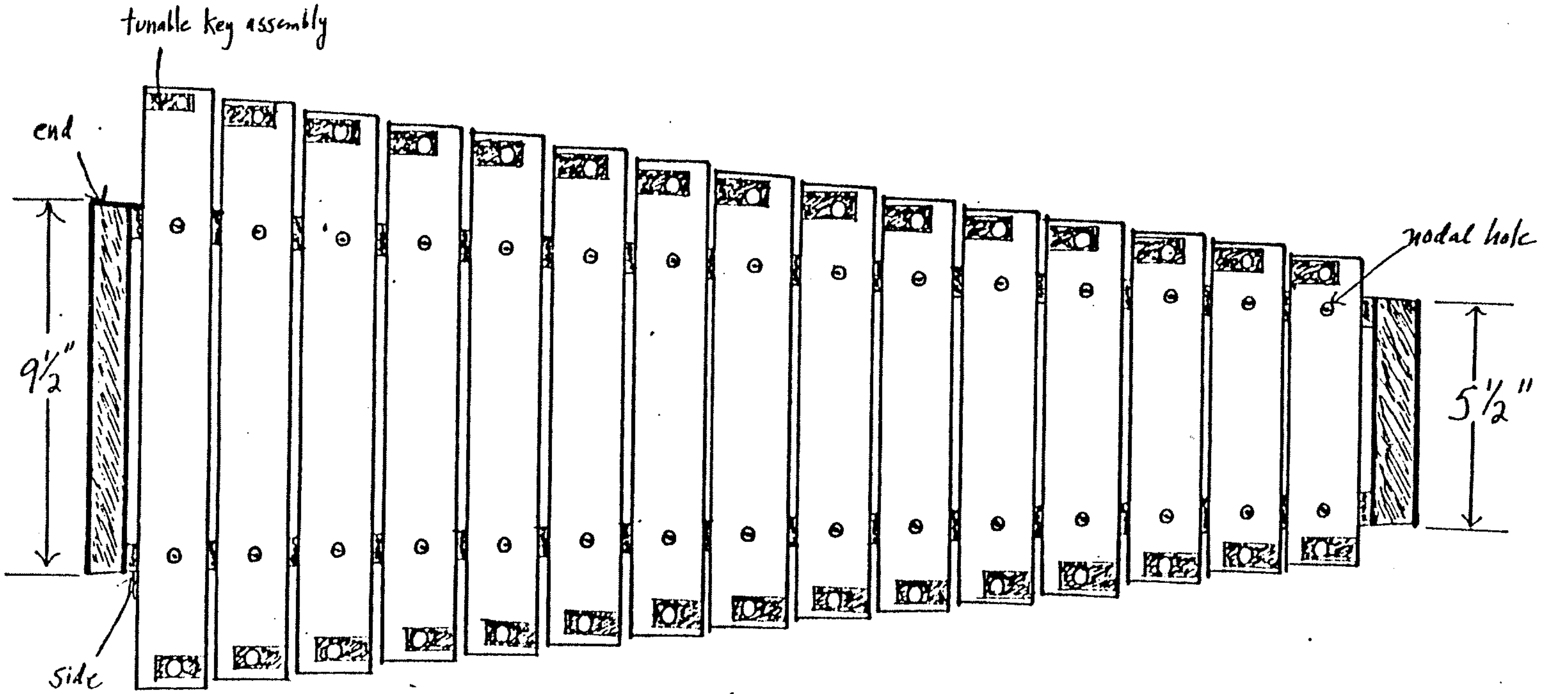
3) Using 2 or 3d nails, put a nail through the center of the nodal hole through the neoprene so that the nail protrudes no more than about an 1/8" above the key.

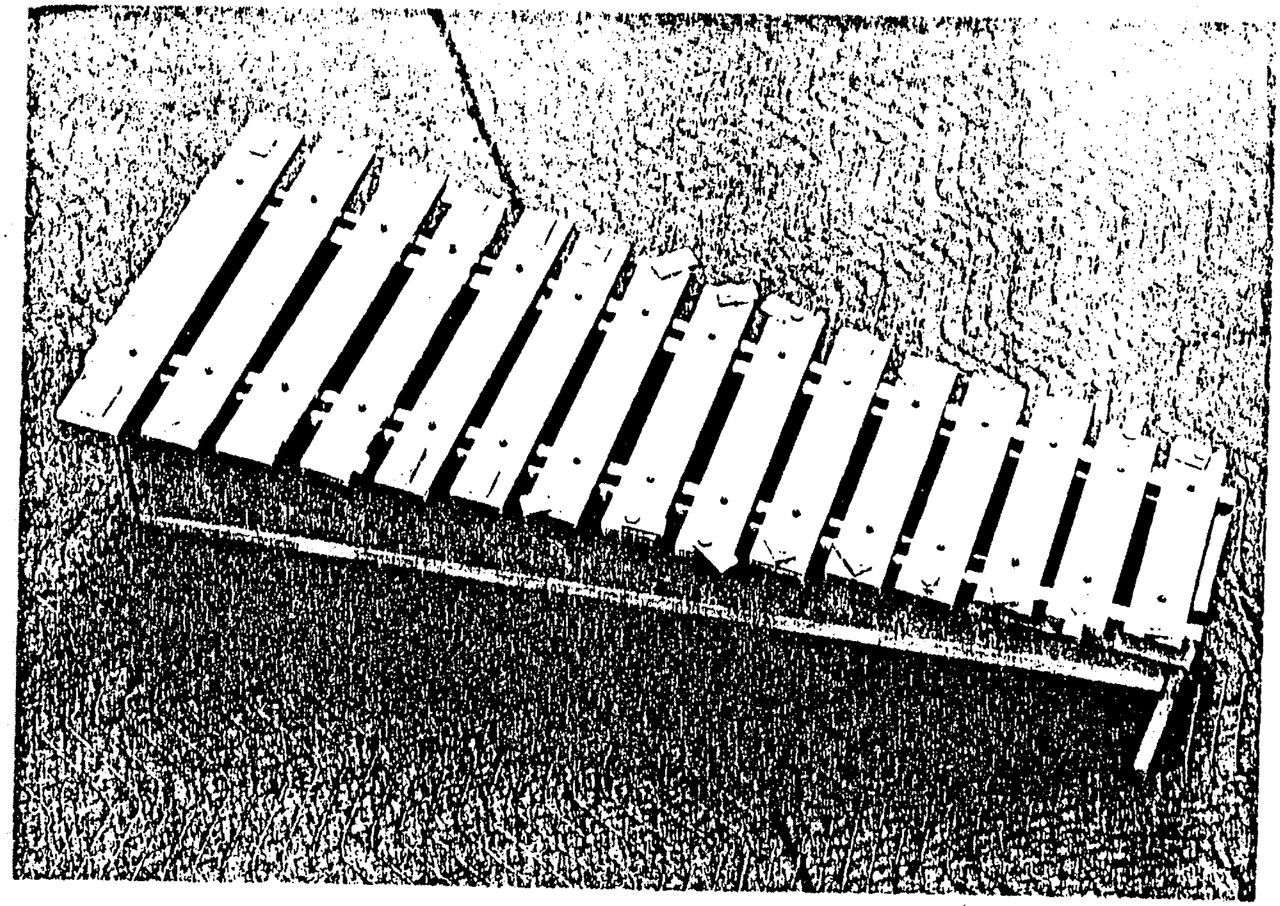
4) Remove the key(s) and cover the portion of the nail above the neoprene with a small wrapping of duct tape or surgical hose. This should be of small enough diameter to not be tight against the nodal hole when the key is put back on. The nails may be bent slightly to better allow free movement of the keys.

## SARON DEMUNG — SIDE VIEW
### 2 OCTAVES




## TOP VIEW





SARON DEMUNG WITH STYLE ONE TUNING APPARATUS

## SARON-PEKING

### Materials

1) For the sides, 5/8" particle board or plywood, 2 pieces, 32" long, 6½" at one end and 2" at the other.

2) Ends, one piece 4" by 6½", one piece 7½" by 6½".

3) Bottom, cut from a rectangle 32¼" long, 7½" wide.

4) Aluminum keys, 130" of 3/8" thick, 1-3/4" wide.

5) Soft neoprene, ¼" thick, ¼" wide strips, 2 pieces each 32" long.

6) Tuning weights, see chart, all are 5/8" wide.

7) 30 hex head bolts, 5/8" length, ¼" diameter, for attaching tuning weights.

8) Nails and glue as in saron-demung instructions.

### KEY SPECIFICATIONS

All dimensions are in inches, for 3/8" aluminum.

| PITCH AREA | LENGTH | TUNING WEIGHT/ LENGTH | TUNING WEIGHT/ THICKNESS |
|---|---|---|---|
| C | 11½ | 1-5/8 | ¼ |
| D | 11 | 1-5/8 | " |
| E | 10½ | 1-5/8 | " |
| F | 9-3/4 | 1½ | " |
| G | 9¼ | " | " |
| A-880 | 8-3/4 | " | " |
| B | 8¼ | " | " |
| C | 8 | " | " |
| D | 7-5/8 | " | 3/16 |
| E | 7 | " | " |
| F | 6-3/4 | " | " |
| G | 6½ | 1¼ | " |
| A -1760 | 6¼ | " | " |
| B | 6 | " | 1/8 |
| C | 5½ | " | 1/8 |

For constructing the trough, follow the basic directions for the saron-demung, substituting the sizes given in the saron-peking materials list and the drawings.

KEY SPECIFICATIONS for saron-peking, brass 7/16" thick, 1-3/4" wide. All dimensions are in inches.

| Pitch Area | Length | Tuning Weight/ Length | Tuning Weight/ Thickness | Tuning Weight/ Width |
|---|---|---|---|---|
| C | 10" | 1-3/4 | ¼ | 5/8 |
| D | 9½" | 1½ | " | " |
| E | 9 | 1½ | " | " |
| F | 8½ | 1½ | " | " |
| G | 8 | 1¼ | " | " |
| A-880 | 7-5/8 | " | " | " |
| B | 7¼ | " | " | " |
| C | 7 | " | " | " |
| D | 6-5/8 | " | " | ½ |
| E | 6¼ | " | " | " |
| F | 6 | " | " | " |
| G | 5½ | " | " | " |
| A-1760 | 5-3/8 | " | 3/16 | " |
| B | 5¼ | " | 3/16 | " |
| C | 5 | 1 | 1/8 (brass) | " |

Tuning Aluminum Bars (before the addition of a variable tuning apparatus)

To determine the general size of a bar for a particular pitch, refer to the charts at the end of the paper. To tune a bar higher in pitch, one cuts material off the ends, shortening the bar. To lower the pitch, one cuts material out of the center on the underside of the key. This should be done evenly across the bar's width. A bar should never be cut deeper than half its total thickness as this will substantially weaken the bar, eventually causing it to bend. Several smaller cuts may be made rather than a single deep cut. The amount of material removed and the depth of the cut will have an effect on the relative amplitudes of the bar's partials. A sort of fine timbre tuning can be achieved this way, but lacking information about this in relation to a variety of materials, it is recommended that one's own experiments be undertaken to determine the timbre desired.

All these alterations to the key should be made before nodal holes are drilled, regardless of whether tuning apparatus will be added later. Don't forget that the addition of the tuning apparatus will lower the pitch of the key.

Adjustments to the width of a key will have virtually no effect on the pitch of the key, though it may affect the timbre.

Locating and Drilling Nodal Holes on Unaltered Bars

On any bar which has been altered with the addition of the tuning apparatus, the nodes must be located by sprinkling dust or sand on the bar and striking the bar until the sand forms a line at the lines (2) of no vibration.

On a straight, unaltered bar, the nodes may be found 22.5% in from both sides. To determine this point, multiply the total length of the key by .225. The result will be the distance in from each end one must measure to find the nodal lines.

Keys for trough resonated instruments need only one hole in each nodal line. However, for instruments in which the keys are suspended from above (surrogate gongs and kempul) it is best to have two holes in each nodal line to prevent the key from rocking sideways and hitting the resonator or cradle. These holes should be located about 1/6 of the width in from both sides on the nodal lines.

## SURROGATE GONGS AND KEMPULS

The technology for the construction of gongs of the traditional Indonesian design is virtually unavailable to most western instrument builders. These designs will offer a few alternatives which provide acceptable sound in these extremely low registers for tuned percussion instruments. All these designs operate on the single principle of a metal key coupled with a resonator tuned to the precise pitch of the key.

There are a number of possible resonator designs, each has its own advantages and weaknesses. The resonators may be made from a large variety of materials, virtually any rigid, encloseable material will work. Excellent resonators have been built from plastic pipe, plywood boxes, cardboard mailing tubes, corrugated pipe, and ceramic pipe. Whether the inside of the resonator is square, rectangular, circular, or elliptical seems to have little effect on the ability of the container to resonate. What is essential is an absolute seal on all joints; there should be no openings except for the single intended opening for coupling with the key (or in the case of an "open" resonator, the second opening at the opposite end of the resonator. Any crack or other unintended opening will almost certainly reduce the resonator's effectiveness).

There are three basic types of resonators which will be illustrated in these instructions. These are closed or stopped (single opening), "Helmholtz", and open (at both ends) resonators.

### Closed or Stopped Resonators

This design may be made in a number of sizes and shapes. It is probably the most practical and effective design given here in terms of sound. This is the type of resonator which is used in the west on vibraphones and marimbas. The designs given here are for rectangular, long boxes of plywood or particle board.

A stopped resonator's frequency is dependent almost entirely on its length. When the length is doubled, the resonance drops an octave. The width has virtually no effect on the resonant frequency, however it does have an important effect on the amplitude of a given key. In general, the lower the note, the wider the resonator should be to effectively resonate a pitch. Of course, there is a wide range of frequencies which can be effectively resonated by a resonator of a given width, but generally, when the length exceeds the width by a ratio of six or seven to one, the amplitude at that frequency is substantially weaker than would be possible with a wider resonator.

The first design given here is for a resonator with a tunable resonant frequency by means of an internal sliding piston. This tunable design affords great flexibility in operation because a wide range of pitches may be resonated (one at a time) by a single resonator merely by adjusting the piston to the point of best effectiveness, in terms of loudness and sustain.

One may wish to build the entire set of gongs and kempuls with tunable resonators and thus have complete tuning flexibility with any resonator. If one is using tunable keys, some tuning mechanism on the resonators will be useful for maintaining maximum resonance. A given length can resonate pitches in a range of approximately a major 2nd around its fundamental frequency but effectiveness drops off rapidly. (Other fine tuning mechanisms will be discussed subsequently). If one is using fixed pitches, one may wish to build a single tunable resonator in 2 or 3 width/length combinations so as to determine the best size for a particular pitch. One may then build a resonator exactly for that single pitch. The most flexible system in working with tunable keys is to build the resonators just long enough to resonate only the range of pitches obtainable by the particular key(s) with which it will be used. This reduces the materials used and the size and weight of the instruments to a functional minimum.

It is suggested that the resonators, whether tunable or not, be built in a variety of widths (or diameters in the case of tubular materials). The following sizes are suggested for the following pitch areas;

| Inside Crossectional Width | Maximum Length (Closed, piston design) | Approximate lowest Pitch Range |
|---|---|---|
| 4" | 24" | D (below middle C) |
| 6" | 42" | F (12th below middle C) |
| 8" | 56" | C (two octaves below C) |
| 12" | 84" | F (two octaves and 5th below C) |

CLOSED TUNABLE RESONATOR WITH MODULAR KEY ASSEMBLY

These instructions will be for a closed resonator with a 6" internal width. The process for constructing other sizes will be identical with only the substitution of the different sizes.

1) Cut two lengths of 5/8" particle board or plywood 6" wide and 42" long. These are the sides.

2) Cut a length of board 7¼" wide (inside width plus two thicknesses) and 42" long. This is the bottom.

3) Cut another length of board 7¼" wide and 35¼" long. This is the top.

4) Cut one piece of board 7¼" wide and 6-5/8" tall. This is the end piece.

5) Building a Gluing Alignment Tool - For the piston to operate smoothly, it is absolutely essential that the inside width of the box be uniform throughout. To insure this it is best to use a gluing alignment tool like the one described below.

a. Cut two identical 6" squares of 5/8" or 3/4" board.

b. Locate their centers and drill a 5/8" diameter hole through that point, perpendicular to the plane of the square.

c. Insert a 5/8" dowel through both pieces. They should move easily but not loosely.

6) Nail and glue one side to the bottom. Using the gluing alignment tool, nail and glue the opposite side to the bottom. Slide one of the tool's squares into position near the next nail location and be sure both sides abut the square before nailing.

7) Leaving the tool inside the resonator, nail the top to the sides, again sliding a square into place where one is nailing.

8) Pull out the alignment tool and thoroughly clean off all excess glue and drips from inside the resonator. Any excess glue will make the piston difficult to operate.

9) Nail and glue end piece to the end which will be open on

the top for coupling with the key.

MAKING THE PISTON

The basic problem with the piston is achieving a good seal between the outer edges of the piston and the inside walls of the resonators. This seal must be tight enough to achieve a good resonance but it must also be loose enough to slide the piston without too great a force. A variety of materials for achieving this seal are possible, among them are felt, cork, neoprene, and a variety of weather strippings. The most effective materials are those which are easily compressed but retain their tendency to expand. They must also be able to withstand the friction of repeated sliding within the resonator. For this I have found certain types of hard neoprene and a particular door stripping to be very effective. The door stripping has the advantage of having a tacking strip edge which can be used for fastening it to the piston. These plans will utilize this material.

1) Cut two identical squares of any material 5/8" or thicker. These must be ¼" smaller than the inside of the resonator. A resonator with a 6" inside would have a piston with a 5-3/4" side.

2) Locate the center of each square and drill a 1/2" or 5/8" hole at that point.

3) Cut pieces of the weather stripping or neoprene such that they cover the entire perimeter of the above square and protrude ½" beyond all edges. Be sure to leave enough material on the square and then tack the material to one of the squares.

4) Lay one square on top of the other with the material sandwiched in between the two pieces. Align their sides precisely and nail the pieces together.

5) Take a length of dowel the same size as the center hole, insert and nail and glue in place. The length of the dowel will depend on the length and intended use of the resonator. The dowel should not protrude beyond the opposite side of the piston from which it enters.

6) Insert piston into the resonator's open end (this may take some force) and move it back and forth. If it is too tight, one may trim off a bit of the sealing material. If it is too loose, one will either have to make a larger piston or leave more sealing material protruding over the sides of the squares. It is difficult to give an exact prescription in this area because each sealing material responds differently to the pressures of compression or pressure.

Constructing the Modular Key Cradle

This design is modular in two ways. One, it may be transferred easily onto resonators of the same size, if the resonators are made precisely. Two, the keys themselves may be easily interchanged onto a single cradle.

The specifications given here are for a cradle to be coupled with a 6" inside width resonator. The exact process may be used for different size resonators by appropriately changing the dimensions of the pieces.

1) Cut two rectangles of 3/4" plywood or particle board 11½" x 3".

2) On both rectangles, measure 2" in from each end and mark a line perpendicular to the length. Between these two lines mark a line (parallel to the length) 1½" in from either edge.

3) Cut out the smaller inscribed rectangle. These are the sides. (See drawings)

4) Cut two pieces of 3/4" thick lumber, 1½" wide and 16" long. These are the sides.

5) On one lengthwise edge of both of the sides, drill ½" to 3/4" deep holes one inch and three and a half inches in from either end. (Each side has four holes).

6) Stand up on edge both of the end pieces with the rectangular cut-out facing up. Measure the exact width of the resonator and space the ends accordingly. Place the sides in the cut-out area and butt them against the ends. Center the sides between the two ends. The same amount of the sides should hang over the ends at all four corners.

7) Drill through each end piece and side at the above contact points. Make sure that the distance between the ends stays the same as the width of the resonator. Use a ¼" drill. The holes drilled in the edges of the sides must face up.

8) Bolt the ends to the sides at these four points with a ¼" x 3" hex-head bolt. Use washers on both sides and put the hex-head on the inside, between the two sides.

9) Place the cradle on top of the resonator. If it fits too tightly, sand the sides of the resonator until it fits properly. If it is too loose, the insides of the cradle may be lined with a fabric such

as felt, velour, or other thick material to shim it to a proper fit. It is actually a good idea to line all points of contact between the cradle and the resonator with some soft material because this cuts down on attack transients being amplified by the resonator and it also eliminates buzzes and bouncing between the cradle and resonator.

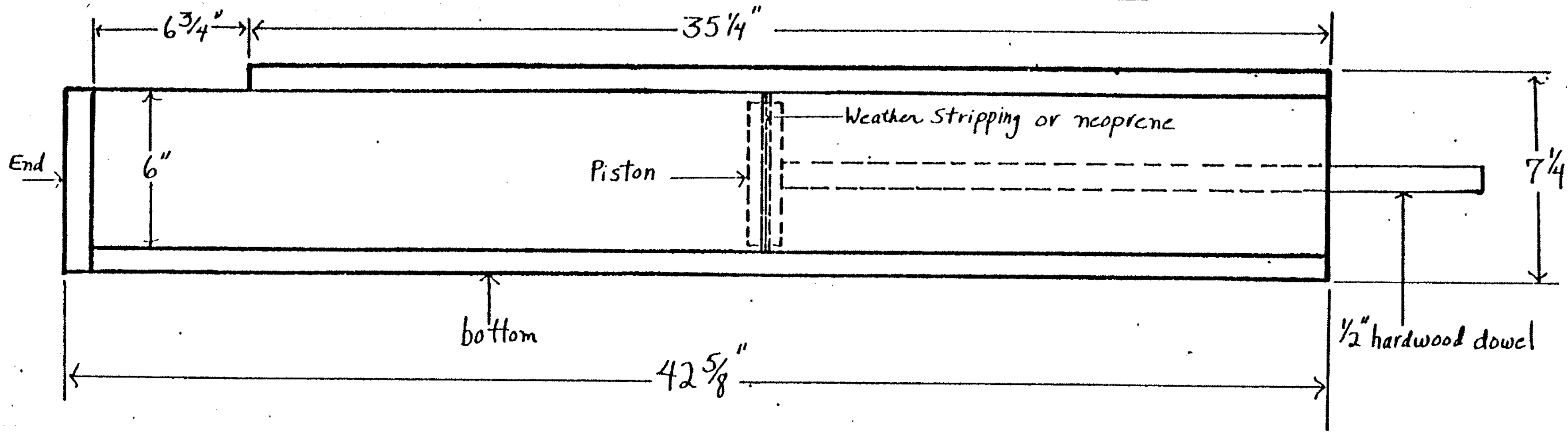
10) Cut four pieces of ½" dowel, each 1½" long. With a saw, cut a notch about 3/32" wide and ½" deep into one end of each piece.

11) Take the intended key and insert nylon cord through its nodal holes. Lay the key in the cradle and insert the notched dowels into the holes on top of the cradle's sides which most accurately allign with the keys' nodal holes.

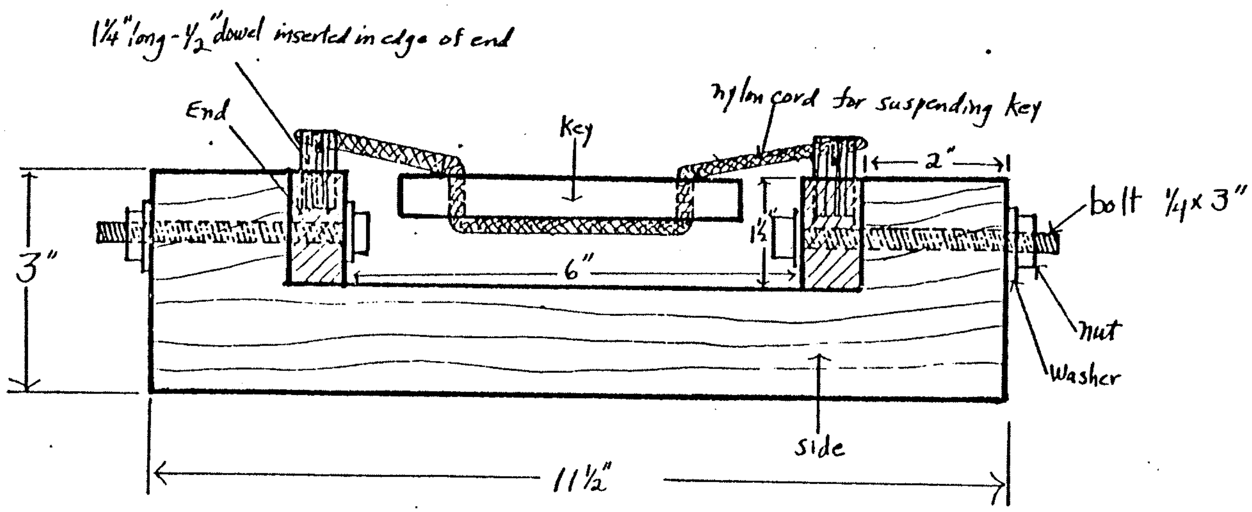
12) Loop the string through the notches in the dowels and adjust the height of the key for best resonance. To prevent the cord from slipping out of the notch, it is a good idea to tie a knot in the cord keeping the key at the proper height. If different keys are intended for a single cradle, it is best to have a set of notched pegs and cord for each key. This is by far the easiest and quickest way of changing keys.

## TUNABLE RESONATOR—KEMPUL AND GONGS

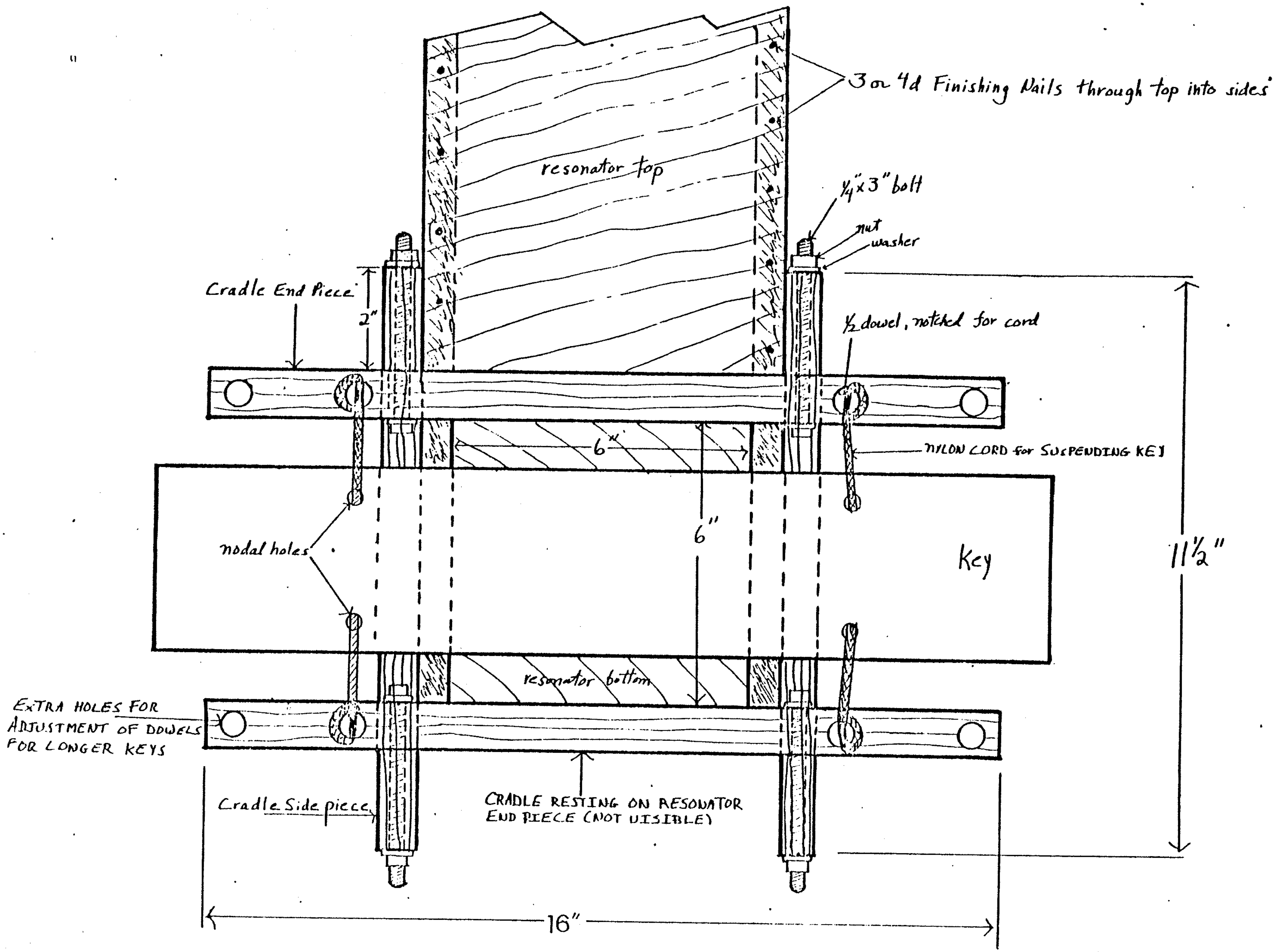
SIDE VIEW—WITHOUT KEY AND CRADLE




## CRADLE WITH KEY—SIDE VIEW



# CRADLE AND RESONATOR—TOP VIEW



## HELMHOLTZ RESONATORS

The Helmholtz resonator derives its name for the great 19th century physicist who first documented this type of resonator in the west. A Helmholtz resonator is one in which the pitch is determined by the volume of the container and the size of the opening which couples the resonator with a vibrating key. The resonator will only amplify when it is tuned to the same pitch as the vibrating key. The larger the volume, the lower the resonant frequency; the larger the opening, the higher the resonant frequency.

The chief advantage of a helmholtz resonator is one of size. The resonant frequency of any closed resonator (box, tube, or whatever) may be substantially lowered simply by closing off part of the opening (and thus turning it into a Helmholtz resonator). This is extremely useful for instruments in which the resonators are suspended vertically below a key. Without helmholtz resonators, these instruments could be extremely tall. The Javanese use the principle for this reason on a number of instruments such as slentem, gender, and gong kemodong.

The primary disadvantage of this type of resonation is a loss of amplitude. A substantial lowering of the resonant frequency (by reducing the size of the opening) can be obtained with only a gradual loss of amplitude, but at a certain point (which varies with the size and shape of the resonator) the loss will become quite noticable. This point is generally when the size of the opening is less than a 1 to 4 or 5 ratio with the width or diameter of the container.

The resonator is tuned by increasing or reducing the opening which couples the resonator to the key. (There should be no other opening). The resonator is most effective when the opening is circular and falls directly under the center of the key. This is important to keep in mind as one adjusts the tuning of the resonator. Small adjustments (enough for the variations in tuning of the keys described here) may be made easily by having a rotating flap which may be adjusted to cover a portion of a larger circular hole in the top of the resonator.

To obtain different ranges of resonant frequencies, one merely builds different size boxes and varies the size of the opening. Any particular size of box has quite a large range of resonant frequencies with a variable opening, usually well over a 5th.

A simple and adequate design for a box is as follows:

1) Cut four rectangular or square pieces of 3/4" thick material. These will be the top, bottom, and two sides.

2) Cut two additional pieces of the same material. The dimensions of these are as follows:

a. the height is equal to the height of the sides;

b. the width is equal to the width of the top less the thickness of the two sides. These will be the other two sides.

3) Using 3 or 4d nails and glue, join the four sides, being sure the two sides with the shortened widths are inside the two other sides.

4) Nail on the bottom and let dry.

5) After the glue has dried, seal all corners with wood putty or caulking.

6) Glue and nail on the top.

7) Cut a small hole in the top of the box and check the pitch by blowing across the hole or tapping the box. A small hole in a large box will give a very low pitch. Gradually increase the size of the hole until the desired pitch is reached. The easiest tool for this job is a sabre or hand jig saw. Test the resonant pitch by suspending the key over the hole, setting the key on foam rubber strips under its nodal points.

One may also wish to begin tuning the resonator by cutting a relatively large hole in the top of the resonator and suspending the key over the hole. Tàke a piece of thin material and partially cover the hole. With the key vibrating, one may tune the resonator through increasing and decreasing the size of the opening by sliding the thin material. There will be a sharp increase in amplitude as the resonator comes in tune.

The resonator may be made variable in pitch simply by loosely bolting a flap of thin material to the top of the resonator such that it may be rotated to cover whatever portion of the opening that is necessary.

The key may be suspended in a cradle of the same design as was described in the previous section. One need merely adapt the cradle size to the dimensions of the box.

## OPEN AND MODIFIED OPEN RESONATORS

The final resonator design to be illustrated is known as an open resonator. This resonator operates in a similar fashion to the closed resonator in that its resonant frequency is determined by its length. However, the resonant frequency of an open resonator is exactly one octave higher than the resonant frequency of a closed resonator of the same length.

The main advantage of this system is that when an open resonator is properly tuned to a key (or the key to the resonator), the resonator seems to have a stronger amplifying effect than an equally tuned closed resonator, both in terms of amplitude and even dispersion of the sound. This may be because the sound waves are emanating from two openings instead of one. The main disadvantage in comparing an open resonator to a closed or helmholtz resonator is size. A set of open resonators for a given set of pitches will have to be twice as long as a set of closed resonators. This difference will become quite substantial in terms of materials and space required when one is resonating pitches in the lower registers.

Another disadvantage to a purely open resonating system is that the resonant frequency is fixed and therefore not particularly useful for more than a narrow pitch area. To solve this problem, a modification may be made to the resonator by the addition of a hinged flap which can close or partially close the open end.

This system has a number of advantages. First, the flap is an effective tuning mechanism. As a flap moves towards the closed position, the resonant frequency drops. The tuning range of a resonator of a given length with a flap is not as much as with a piston design, but it is at least a 5th which is more than enough for most actual applications.

The second advantage is one of size. Open resonators modified with a flap need not be as long as a fully open resonator. The size for a given pitch is generally about halfway between the open and closed lengths for a given pitch.

A third advantage is one of sound quality. A key which has a modified open resonator tuned such that the flap is almost closed (about a 10-20 degree angle of the flap off of vertical) generally has the largest amplitude of all the systems discussed here. This is perhaps due to an upward deflection of the sound into the room by the flap. (It is possible that each of the three resonating systems illustrated here may function more or less effectively in various acoustical environments such as outdoors, rooms with high or low ceilings, large or small rooms, partially enclosed outdoor spaces, or areas defined by absorbent or reflective surfaces.)

An additional smaller advantage is the ability to use the flap to control a kind of "amplitude vibrato." Rapidly moving the resonator in and out of tune with the flap (while the key is vibrating) produces a strong alternation of loud and soft dynamics quite similar to the "beating" effects in Balinese music. This system has the advantage in that the speed of "beats" is entirely up to the performer, limited only by their ability to control the flap. The system has an added advantage over beats produced by two keys slightly out of tune because the speed of beating is variable within the duration of the note, which can be quite long on a thick brass key.

The basic resonator designs for the closed, open, and modified open resonators are identical. Both the long box and cradle are the same. For an open resonator of fixed pitch, one need only omit the piston and then cut the resonator to the proper length for the desired pitch. This length may be determined with a piston adjustment of a closed resonator tuned to the same key. The length must then be doubled for the open resonator.

For a modified open resonator, a flap must be hinged onto the open end of a resonator. The following method is suggested.

1) Obtain a regular door hinge with a removable pin. Since it is necessary for the flap to stay in whatever position it is set at, the hinge must be quite stiff. If the hinge moves freely or easily it is necessary to remove the pin and bend it in a number of directions. Most likely it will have to be driven back into the hinge with a hammer. Even if it is quite tight, the leverage of the flap will probably be sufficient to move it when necessary.

2) Cut a flap from wood in the shape of a square the same dimensions as the outside cross-section of the resonator. (7¼" in the case of a resonator 6" on the inside and made of 5/8" particle board.)

3) Screw the hinge onto the flap. Be sure the pivot point of the hinge will be on the outside of the box and flap.

4) Hold the flap and hinge onto the open end of the resonator and screw the other half of the hinge onto the outside and bottom surface of the resonator. This way, the flap will deflect sound upward

into the space. This is also the easiest position from which the flap may be adjusted, for whatever reason.

The exact height of the key from the opening in any type of resonator will greatly affect the sustain time and timbre of the key. Too close will frequently produce a loud but short-lived sound, which may be desired in some instances. Too far away will produce a thin tone with little fundamental.

MALLETS - for Gong and Kempul

Gong Mallets

Materials:

1) 4 inch length of 4 X 4, fir or redwood

2) 12" length of 3/4" dowel, soft or hardwood

3) A large ball of fairly light, soft string

4) Piece of soft fabric, such as flannel or felt of size 12" X 24".

Instructions:

1) Take the 4" length of 4 X 4, and trace a circle of 3½" diameter on the top of it. Cut this out on a band saw.

2) In the center of the bottom, bore a 3/4" hole, 2" deep. Using glue, insert the 12" length of dowel into the hole. Round off the exposed end of the dowel with sandpaper or a file.

3) Take the ball of string and wrap it around the circumference of the 3½" circle, placing substantially more in the center and little at the edges. Wrap it rather tightly. Enough string should be put on such that the diameter of the circle is increased to at least 5½" at the center.

4) Tie the two ends of string together.

5) Take the fabric and wrap it around the circle. Tack or staple it to the top and the bottom of the circle, not on the face of the circle. Pull it tight and try to avoid creases and folds wherever possible.

6) The end of the material should be pasted with white glue to keep it from fraying away.

Kempul Mallets

One possible mallet for the kempul follows the same design as for the gong with the following changes.

Design One:

1) The head should be only 2" high and have a diameter of about 2½".

2) Drill the hole only about 1½" into the head.

3) Substantially less string will be needed for wrapping the outside. It will also require less fabric.

4) The finished diameter should be about 4".

Design Two:

An excellent mallet may be made from a la crosse ball, which can be found in most sporting goods stores. Other athletic balls may also make good mallets for different size keys or sounds. Super balls also make excellent mallets for relatively low notes.

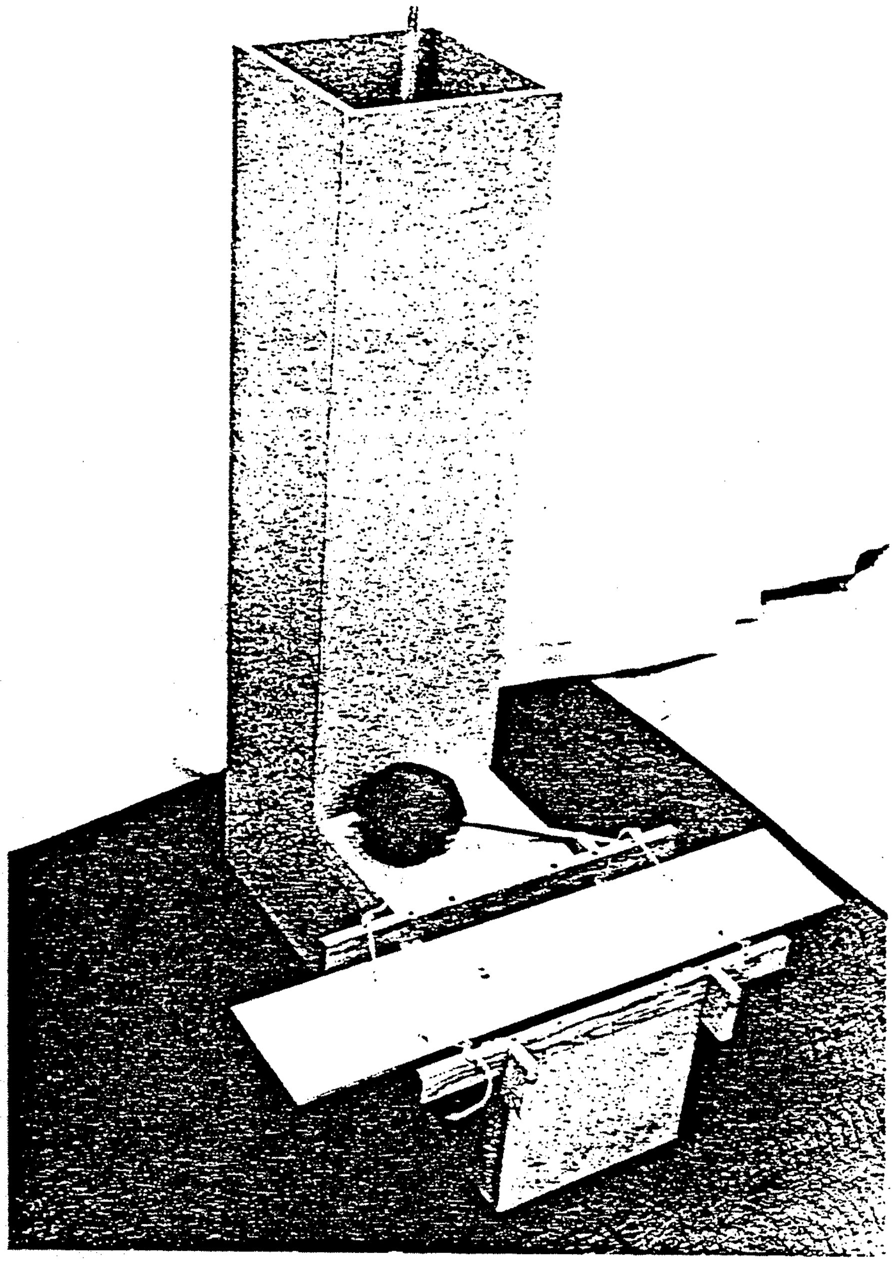
1) Drill a ½" hole 3/4 of the way through the ball, being sure the hole goes through the center of the ball.

2) Cut a 12" length of ½" dowel and glue it into the hole in the ball.

3) Cover the ball with a thin layer of contact cement or similar adhesive and then wrap the entire surface of the ball with two or three layers of cotton string. Wrap circularly from top to bottom, gradually rotating the ball. Each wrapping of the string should pass over both the top and bottom (where the dowel inserts) of the ball.

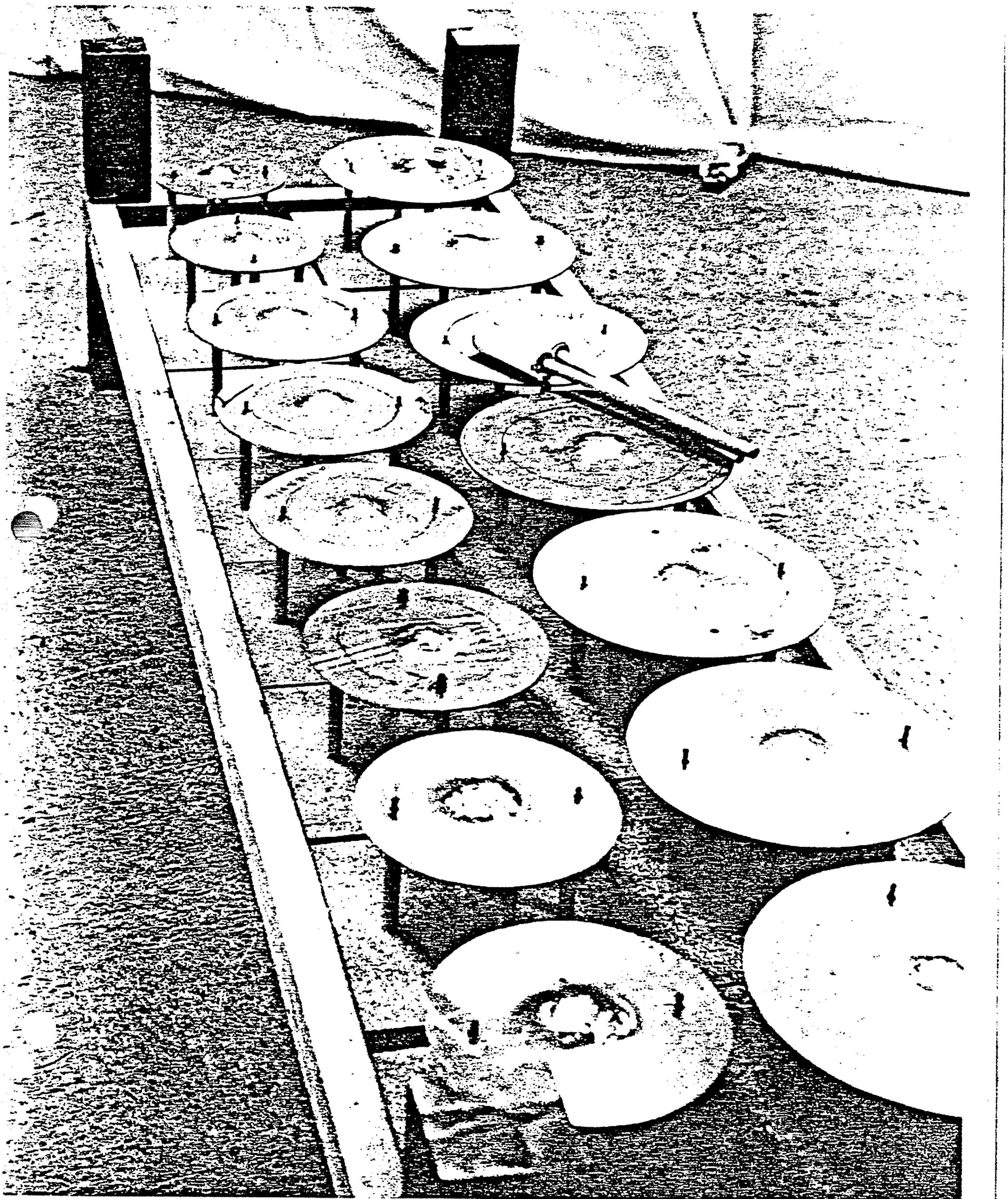
4) Cover the string with another thin layer of adhesive and wrap 2 or 3 more layers of cotton string as described above.

5) To prevent string from unraveling from either the top or bottom areas, seal the top and bottom areas with a quantity of white glue worked into the string.

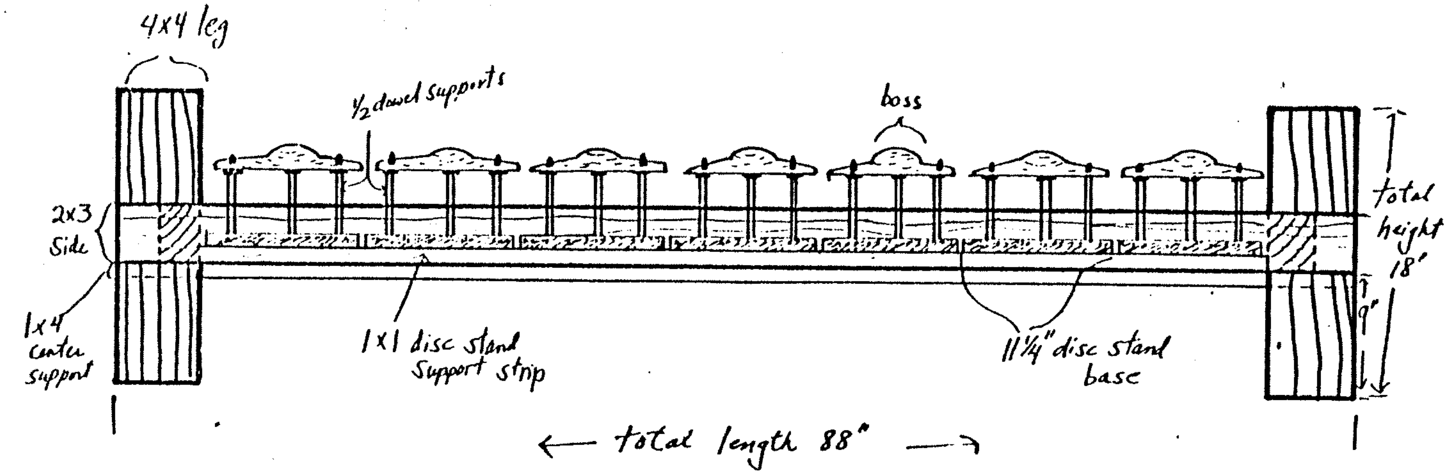


GONG - CLOSED 12 INCH RESONATOR WITH PISTON
RESONATOR IS FOLDED UP TO OCCUPY LESS SPACE

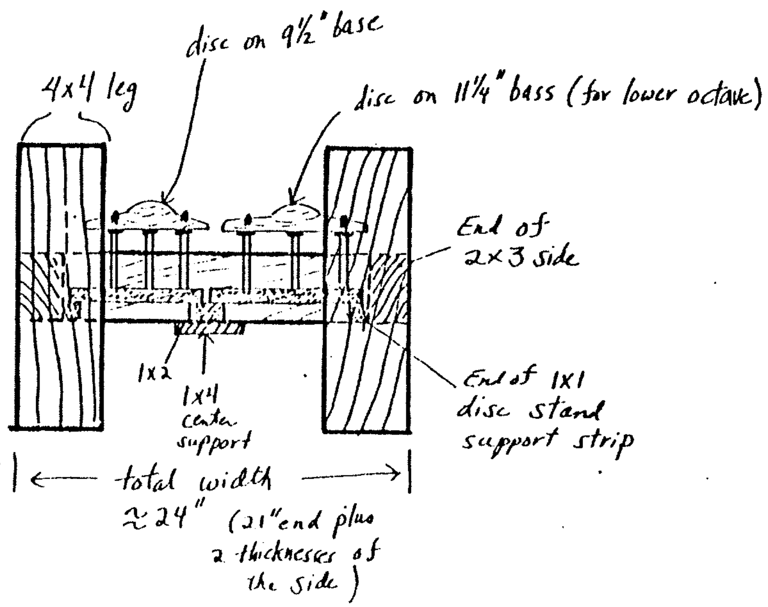
BONANG BARUNG



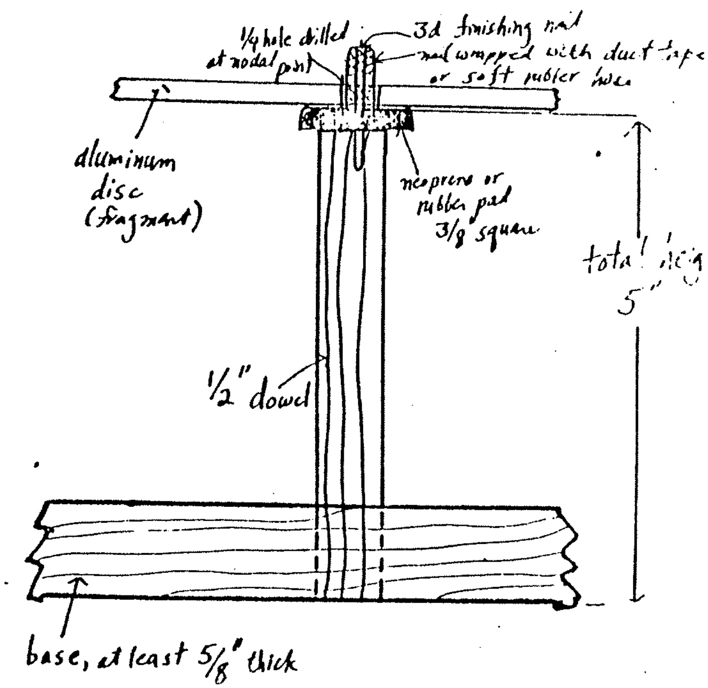
# BONANG VIEW




## END VIEW

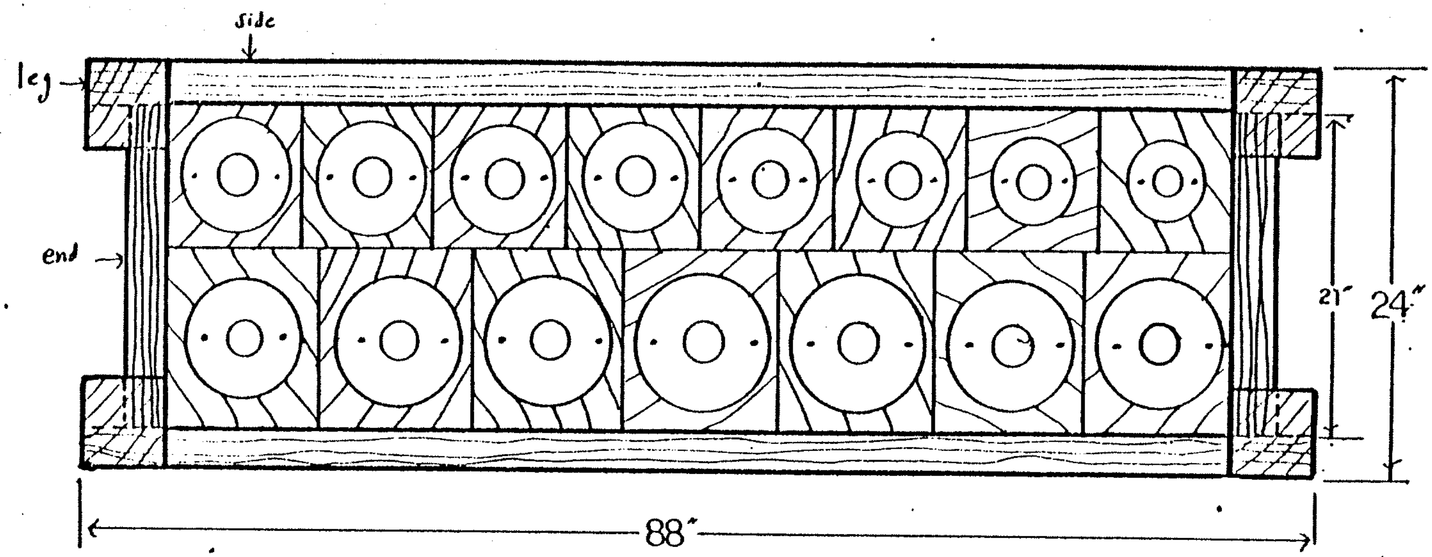



## DISC STAND ASSEMBLY

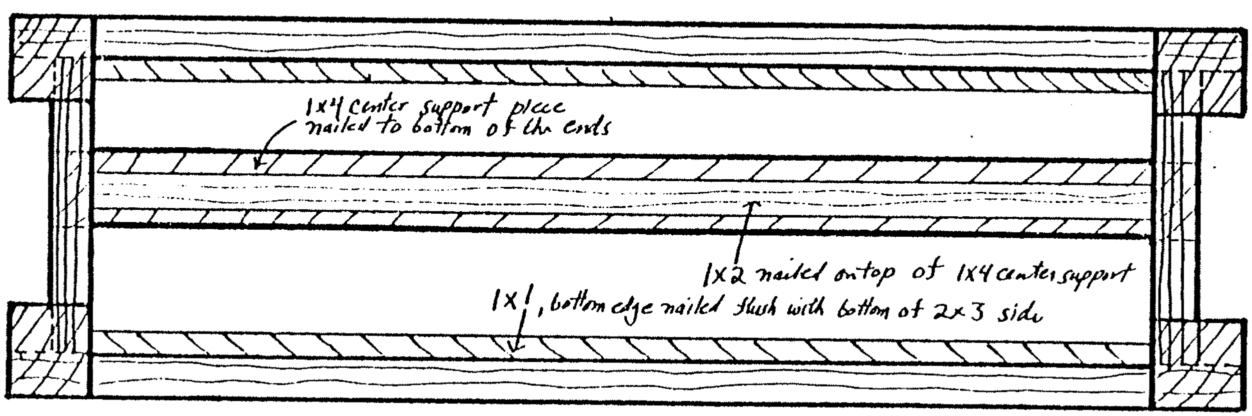


# BONANG [illegible] VIEW

WITH DISCS




WITHOUT DISCS



BONANG FAMILY

The bonang family of instruments in Java functions generally as the primary group of instruments for the elaboration of a nuclear or trunk melody. The instruments have a two octave range, though usually only five tones per octave are used, even in pelog. In Java, there are two or three instruments of different ranges in this family, and there is one of each in both the slendro and pelog tuning systems. These are, from low to high in pitch, bonang panembung, bonang barung, and bonang panerus. Each adjacent instrument has an overlap of one octave with its neighboring instrument. There is only one of each range of instrument in the orchestra, and sometimes one of the three will be omitted, usually the bonang panembung.

In design, the individual pitches are essentially small gongs, but instead of being suspended vertically, they rest on their edges and look like a collection of kettles. They are essentially modular in design, as the individual kettles may be arranged in any order to suit the particular piece to be played.

In these designs, aluminum discs will be substituted for these kettles since the technology for making these kettles in the Javanese fashion is virtually unavailable in the west. The following designs are an adequate duplication of both the timbre and the playing technique for these instruments. These designs will be for instruments with seven tones per octave. The case specifications will be given only for the bonang barung. For the other instruments one may follow the identical processes of construction, merely substituting the different dimensions required by the various sizes of the discs.

BONANG MATERIALS

Materials for the bonang barung case

1) Sides - two pieces of 2X3, 88" long.

2) Ends - two pieces of 2X3, 21" long.

3) Legs - four pieces of 4X4, 18" long.

4) Disc stand support strips - two pieces of 1X1, 81" long.

5) Center support - one piece 1X4, 84" long.
one piece 1X2, 81½" long.

6) 8d finishing nails, 4d finishing nails, glue.

Materials for the disc stands

1) Seven squares of any wood material at least 5/8" thick, side of square 11½". Eight squares with a side of 9½".

2) 27 lineal feet of ½" hardwood dowel.

3) One square foot of ¼" soft neoprene or similar material

4) 3d finishing nails.

5) Duct tape or other high quality tape, or rubber hose which fits snugly around a 3d nail.

6) Approximately 200 inches of strips of neoprene or foam rubber for padding the disc stands and the case.

Materials for aluminum discs - See following charts

SPECIFICATIONS FOR ALUMINUM DISCS

These charts present one possibility for a set design, many others are possible.

For Bonang Barung

| Pitch Area | Width of Disc | Thickness of Disc |
|---|---|---|
| C | 11 | .090 (3/32") |
| D | 10-3/4 | .090 |
| E | 11 | .110 (7/64") |
| F | 10½ | .110 |
| G | 10½ | .090 |
| A | 10-3/8 | .090 |
| B | 10-3/4 | .090 |
| C | 9 | .090 |
| D | 9 | .110 |
| E | 8½ | .090 |
| F | 8½ | .110 |
| G | 8¼ | .090 |
| A | 8-3/16 | .110 |
| B | 7½ | .125 (1/8") |
| C | 7 | .125 |

Bonang Panerus

| | | |
|---|---|---|
| C | 9 | .110 |
| D | 8½ | .090 |
| E | 8 | .100 |
| F | 7-3/4 | .100 |
| G | 7½ | .100 |
| A | 7¼ | .110 |
| B | 7 | .110 |
| C | 6½ | .125 |
| D | 6¼ | .125 |
| E | 6 | .125 |
| F | 5-3/4 | .125 |
| G | 5½ | .125 |
| A | 5¼ | .125 |
| B | 5 | .125 |
| C | 5 | .125 |

One can easily see from the variety of irregularities both within and between the charts that a particular pitch may be obtained from a variety of combinations of disc diameter and thicknesses.

TUNING ALUMINUM DISCS - The theory

There are a few general criteria which affect the pitch of a particular disc.

1) Diameter - the greater the diameter, the lower the pitch.

2) Thickness - the thicker the disc, the higher the pitch.

3) Height and diameter of the boss (the nipple pounded into the center of the disc) - the higher the boss the higher the pitch the greater the diameter, the lower the pitch.

4) Arch of the top of the disc - the more the arch (usually the result of pounding the boss), the higher the pitch. The reverse effect (inverting the arch or dishing from the rim to the boss) also produces a rise in the pitch.

5) The useable tuning range of a disc of a given diameter and thickness is easily a 5th and sometimes as much as an octave. The extremes of a disc's range are usually marked by a thin tone, strong irregular partials, or a short sustain. There is generally a smaller pitch area in which the disc is particularly resonant.

6) The charts given previously were taken from one set of instruments. Many other ways to achieve the same pitches are possible so it is unnecessary to attempt to duplicate the charts exactly. It is better to work with the materials which are most available. (One may also want to choose on the basis of aesthetic criteria such as timbre between two discs of the same pitch but different dimensions.)

TUNING ALUMINUM DISCS - The practice

1) Take a large block of wood and at its center carve or bore a hole about 2" deep and 2-3" in diameter. This piece will be used in forming the boss in the pounding process.

2) On a band saw, cut out the aluminum discs to the various diameters. Take care to make the discs relatively circular.

3) Take a disc and place its center over the center of the bored piece of wood. Starting at its center pound, with a ball peen hammer, a nipple or boss into the disc. This process is very loud so one should plug one's ears. The depth and diameter of the bas to a large extent determine the pitch of the disc. The boss diameter generally varies from 1¼" to 2½".

4) The more one pounds, the higher the pitch. Make the boss symmetrical around the center of the disc. The boss acts to give a coherent tone to the disc. It seems to function well between a height of around ¼" to 1", at which point the aluminum may crack or strange partials may creep in. Keep the bulk of the rise of the boss within about a 3" diameter about the center of the disc. The whole disc will tend to cup towards the boss and this also greatly raises the pitch. However, if the cupping becomes too great, the disc may warp which gives a strange sound indeed. One must then pound the warp out or discard the disc, unless one wishes to utilize that sound.

5) To lower the pitch, simply turn the disc over and pound around the circumference of the boss. The pitch goes down very fast as one removes the cup shape from the disc. However, if one pounds so far that the cup is inverted (while still retaining the original

nipple), the pitch goes up again rapidly.

6) The discs are quite sensitive to tuning. A correctly placed stroke (generally near the edge of the boss) may raise or lower the pitch a third. Strokes on the boss itself are less sensitive and are thus more useful for fine tuning.

7) At present no adequate method of making individual discs tunable, in a similar fashion to the instruments with keys, has been discovered. The only method known so far is the pounding described above and this is clearly not a useable method in a performance situation. Thus, if one desires a similar sort of tuning flexibility as one has with the instruments with keys, it is suggested that replacement discs be made and tuned to the desired pitches. These may be quickly substituted for another pitch.

LOCATING NODAL POINTS IN BOSSED DISCS

There is no strict formula for determining the location of the nodal points since the disc is stressed unevenly due to pounding of the boss.

The best method is to construct a testing suspension system and find the actual nodal points of each disc.

Constructing a Testing Suspension System for Bossed Discs

1) Cut two 12" squares of 3/4" plywood or particle board. Nail and glue these together.

2) Connect the corners with two diagonal lines and mark points every 5/8" out from the intersection of the lines. The lines must be perpendicular to each other.

3) Beginning 1¼" out from the intersection point, drill a ½" hole at each mark on each line to a depth of halfway through the joined pieces of wood.

4) Cut four pieces of ½" dowel, each 5" long.

5) Cut 4 pieces, 3/8" square of ¼" thick soft neoprene or similar material.

6) With a tack (not a nail), tack a neoprene square on to an end of each 5" length of dowel. Drive the tack far enough such that it compresses the neoprene at that point and sits recessed well below the top of the neoprene square.

<u>Finding the Nodes with the Suspension Device</u>

1) Center a pounded and tuned disc over the stand. Insert the four dowels into the hole in each line which falls about ¼ to 1/5 of the diameter in from the edge of the disc.

2) Center the disc on top of the four dowels and sprinkle a small amount of sawdust, or salt on top of the disc. Lightly and repeatedly strike the boss part of the disc with an appropriate mallet (see section on mallets below) until the dust lines up at the points of no vibration. This will roughly approximate a circle in shape and be located about ¼ to 1/5 of the diameter in from the edge.

3) Draw this circle on top of the disc and note the areas which give the clearest nodal line. In most instances, some areas give a clear line and some give a vague or fuzzy line.

4) Mark a point on this circle in one of the clear areas. Draw a line through this point and the center of the disc and mark where the line crosses the other side of the circle.

5) Drill a ¼" hole through the disc at each of these two points on the circle.

On the smallest discs, such as the top octave of the bonang panerus, it is difficult to get a clear circle with the sawdust or salt. In these instances the following method is recommended. This method will also work for the larger/lower discs.

1) Mark a point ¼ to 1/5 of the diameter in from the edge of the disc. Do the same 180 degrees opposite on the disc (on the same side).

2) Set the disc on top of a single dowel at one of these two points. Pinch the other point between the thumb and a finger at the point on the opposite side. Repeatedly strike the disc while moving one's pinching point and the point of suspension on the dowel until the maximum sustain time is obtained. Mark these points on the disc, being sure that they are still 180 degrees opposite each other. Drill the two nodal holes at these points.

MAKING THE DISC STANDS

1) Cut the 15 disc stand basses, seven squares with an 11¼" side, and eight squares with a 9½" side.

2) Take each individual finished aluminum disc with the nodal holes drilled and pair it with an appropriate base. The seven lowest pitches will be on the 11¼" bases, the higher 8 will be on the 9½" squares.

3) Center the disc in the center of the square and mark the disc's nodal points on the base. Place the disc such that the line between the nodal holes is parallel to two of the base's sides.

4) Although only two holes are necessary to anchor each disc, the disc will be further stabilized by an additional two posts which require no nodal holes in the disc but are located under the nodes. Their placement is determined as follows:

a. Draw a line on the base connecting the points of the disc's two nodal lines;

b. From the center of that line, draw a line perpendicular to the first line;

c. Measuring out along this line on each side of the center, mark a point the same distance that the original two nodal holes are from the center.

5) Bore a hole at each of these four points.

6) Cut four 5" lengths of ½" hardwood dowel for each square and glue them into the four holes in the square. Set the disc on top of the dowels to make sure the dowels are in straight and even in height. Always keep a disc and its respective stand together because a disc will fit only on the stand made for its particular nodal holes.

7) With a razor blade or sharp strong scissors, cut the ½" neoprene into squares with a 3/8" side. When the dowels have dried into the bases, take a 3d finishing nail and drive it through the neoprene into the top of the dowel. Place the disc over it and find the point on the opposite dowel where the nail should be driven. This should be as close to the center of the dowel as possible. Drive the nail through the neoprene square leaving the top of the nail protruding about 3/8" above the neoprene square.

8) Cut 3/8" strips of duct or gaffers tape and wrap about a 3/4" section of the tape around the exposed nail. This will prevent buzzing between the nail and the disc.

9) Take a tack (not a nail) and tack a neoprene square to the other two dowels. Be sure to drive the tack deep enough so that it is recessed far enough in the neoprene that it will not come into contact with a disc resting on top of it. These two dowels just provide support from underneath but do not anchor the disc in place.

10) Place the disc over the four posts. It should rest freely, without pressure between any two nails. If there is contact, try bending the nail (there should be enough flexibility for this), until the disc sits freely. Any tension between the nails will mute the tone of the disc.

<u>RESONATORS FOR THE BONANG</u> (optional)

The lowest few notes of the bonang are often a bit thin in sound and it has been found that the addition of the most rudimentary form of resonator can substantially enhance the volume of the fundamental pitch. This resonator can be placed directly under the disc and be attached to the base. Actually, one must be careful of having too good a resonator here for it can easily result in a booming tone with a short duration. If this problem is encountered, one may wish to cut out the area on the base under the resonator. One can also trim portions of the resonator's sides to eliminate this problem.

The resonator can be a square made from plywood or particle board which fits between the supporting dowels on the base and has a height of about one inch less than the bottom of the disc. If the resonator is too close to the disc, it will also give a booming tone with short duration.

CONSTRUCTING THE BONANG CASE

For other sizes of bonang, substitute dimensions based on the size of the disc stands used. The length and width will change but the height will remain the same.

1) Cut two pieces of 2 X 3, each 88" long. These will be the lengthwise sides.

2) Cut two pieces of 2 X 3, each 21" long. These are the ends and should be only slightly more than the sum of the two disc stand sides. In the case of the bonang, it is a bit more than 11½" plus 9½".

3) Cut four pieces of 4 X 4, each 18 inches long.

4) Mark two lines on two adjacent sides of each 4 X 4, perpendicular to the length, 9 inches from the bottom end. Measure the exact width of the 2 X 3 (should be about 2-5/8") and mark another two perpendicular lines (one on each face) that distance above the first lines. Measure the thickness of the 2 X 3 (about 1-5/8") and cut out the wood between the lines on both faces to that depth. The cutting may be done on a table saw with dado blades, band saw, or with a hand saw, chisel, and file. Cut inside the lines to be sure the inserted piece will fit tightly. Repeat this operation on all four legs.

5) Using 8d finishing nails, glue and nail the sides to the 4 X 4 legs. Be sure the ends of the sides are flush with the legs.

6) Nail and glue the ends to the side/leg assemblies. Be sure the ends abut the inside of the sides on all four corners.

See drawings.

7) Take the two 81" 1 X 1 strips and nail and glue them on the inside of the sides, one surface of each being flush with the bottom of the side.

8) Nail and glue the 84" 1 X 4 on the bottom of the ends so that it will be under the joint between the two rows of disc stands. Its center should be about 12-7/8" in from one side.

9) Nail the 81½" 1 X 2 on top of the center of the 1 X 4, between the two ends. The top of this 1 X 2 should be at the same height as the top of the 1 X 1 strips. Its center should also be under the joint between the two rows of disc stands.

10) Cut thin strips of foam rubber or neoprene and line the top of the two 1 X 1 and the 1 X 2 strips. Attach them with staples or tacks. Be sure the staple or tack is well recessed below the top of the foam material. This padding helps reduce the "clunk" of striking the disc from being transferred to or amplified by the case.

11) Place the completed disc and stand assemblies into the case and arrange them in the order desired.

BONANG MALLETS

1) Cut a ½ or 5/8 inch length of dowel 13" long. This will be the handle.

2) Cut a 4" length of 1" thick hardwood dowel. This will be the head.

3) Drill a 2" deep hole the diameter of the handle in the center of one end of the head. Make this hole as parallel to the length of the head as possible.

4) Put glue in this hole and fully insert the handle. Let dry.

5) Cover the entire surface of the head with a thin layer of glue.

6) Take a length of soft cotton rope, about 3/16" to ¼" in diameter and wrap a single layer evenly around the head completely covering the wood. With a small tack, fasten the two ends of the rope to the head. Let dry.

One may wish to make different sets of mallets to obtain different sounds. One may vary the hardness or thickness of the rope. One may also use an additional layer of rope on the head or cover the head with a fabric. It is difficult to prescribe exactly which combination yields what sound. One must simply experiment to determine the sounds that one desires.

## CHARTS

The following charts give specifications for general pitch de-- termination for untuned metal slabs. In using these charts, it is best to cut the material a bit longer than the specified length as variations in the condition of the metal will cause pitch variations between two slabs of identical dimensions. If the resulting pitch is too low, the bar may always be shortened. Gaps in the charts result from a lack of precise information about that specific pitch. (This lack of information is the result of a lack of funds with which to experiment to determine these lengths). In most cases a reasonably close length may be interpolated from information on either side of the missing data. The width of a key for a specific length is best kept in the area of a 5 or 6 to 1 ratio of length to width.

Chart for 1/4 inch aluminum

| Octave in Hz. | 1047-523 | 523-262 | 262-131 | 131-65.4 |
|---|---|---|---|---|
| C | 7 | 10 | 14-1/8 | 20 |
| B | 7-1/8 | 10¼ | 14½ | 20-5/8 |
| A# | 7-3/8 | 10-9/16 | 15 | 21-3/8 |
| A | 7-9/16 | 10-3/4 | 15½ | 21-7/8 |
| G# | 7-3/4 | 11¼ | 16 | 22-3/8 |
| G | 8 | 11-5/8 | 16½ | 23 |
| F# | 8 | 12 | 17 | 23-5/8 |
| F | 8¼ | 12¼ | 17½ | 24-3/8 |
| E | 8-3/4 | 12-5/8 | 18 | 25 |
| D# | 9 | 13 | 18½ | |
| D | 9¼ | 13-3/8 | 19 | |
| C# | 9-3/4 | 13-5/8 | 19½ | |
| C | 10 | 14-1/8 | 20 | |

Chart for 3/8 inch aluminum

| Octave in Hz. | 4186-2093 | 2093-1047 | 1047-523 | 523-262 | 262-131 | 131-65 | 65-33 |
|---|---|---|---|---|---|---|---|
| Pitch Area | | | | | | | |
| C | | 6 | 8-3/4 | 12½ | 17½ | | 34½ |
| B | | 6¼ | 9-1/8 | 13 | 18 | | |
| A# | | 6-3/8 | 9¼ | 13-3/8 | 18¼ | | |
| A | | 6½ | 9½ | 13-3/4 | | | 38½ |
| G# | 4-3/4 | 6-11/16 | 9-3/4 | 14-1/8 | | | |
| G | | 7 | 10 | 14½ | | | |
| F# | | 7¼ | 10-3/8 | 15 | | | |
| F | | 7-5/8 | 10-3/4 | 15-3/8 | | | |
| E | | 7-13/16 | 11 | 15-3/4 | | | |
| D# | | 8 | 11-3/8 | 16 | | 31½ | |
| D | 5-11/16 | 8¼ | 11-3/4 | 16½ | | | |
| C# | 5-7/8 | 8½ | 12 | 17 | | | |
| C | 6 | 8-3/4 | 12½ | 17½ | | 34½ | |

Chart for 3/16 inch brass

| Octave in Hz. | 523-262 | 262-131 | 131-65.4 |
|---|---|---|---|
| Pitch Area | | | |
| C | | 9¼ | |
| B | | 9½ | |
| A# | | 9-3/4 | |
| A | | 10 | |
| G# | | 10-3/8 | |
| G | | 10-3/4 | |
| F# | | 11 | |
| F | 8-1/8 | 11-3/8 | |
| E | 8-3/8 | 11-3/4 | |
| D# | 8-5/8 | 12 | |
| D | 8-3/4 | 12½ | |
| C# | 9 | | 18 |
| C | 9¼ | | |

These keys are generally 2½ inches wide. The style two tuning bracket should be about 3¼" long, 5/8" wide, and 3/16" thick, It is of aluminum, not brass.

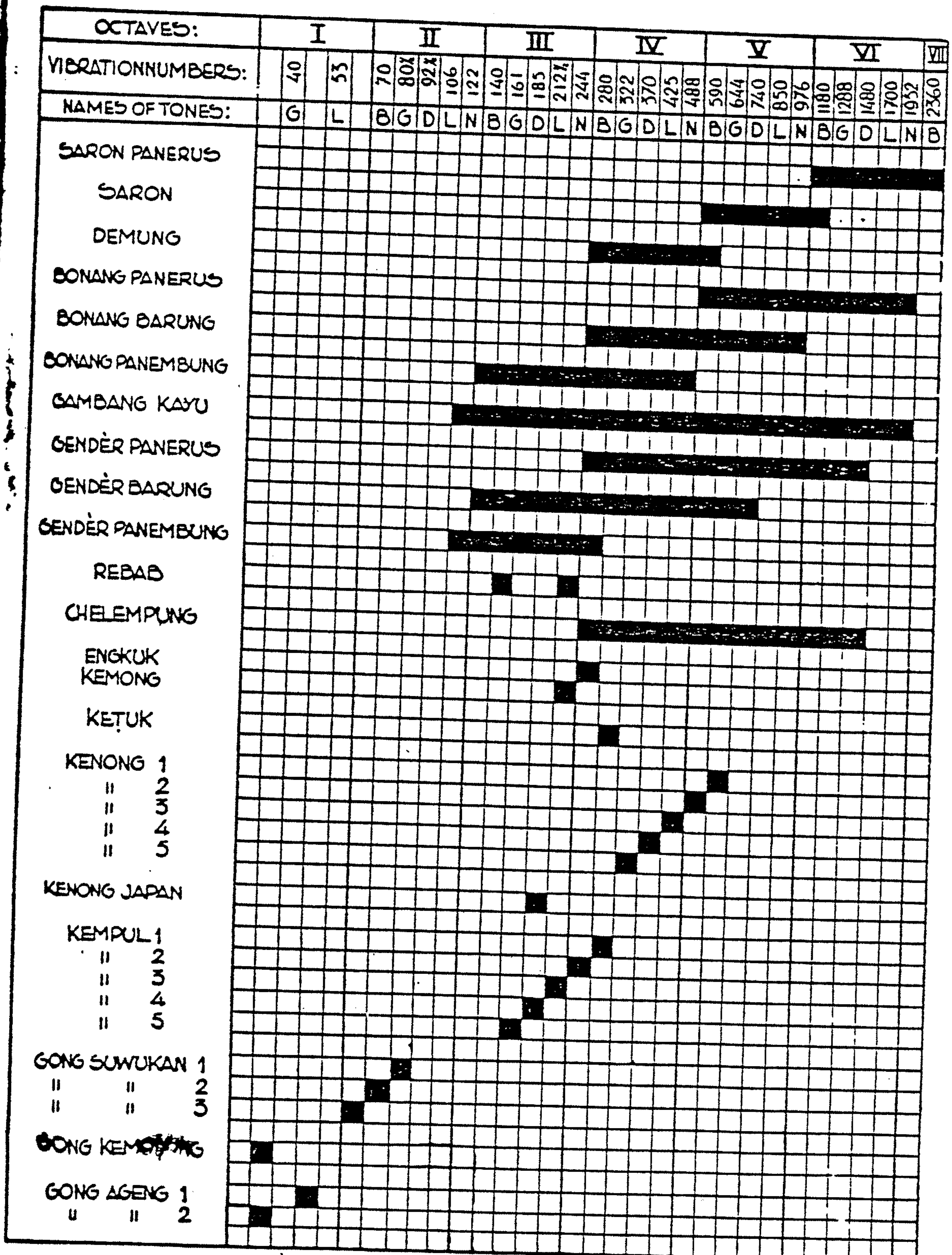
Chart for 1/8 inch brass

| Octave in Hz. | 262-131 | 131-65.4 |
|---|---|---|
| Pitch Area | | |
| C | 8½ | 12 |
| B | 8-3/4 | 12½ |
| A# | 9 | 13 |
| A | 9¼ | 13¼ |
| G# | 9½ | 13½ |
| G | 10 | 13-3/4 |
| F# | 10-3/8 | 14 |
| F | 10-5/8 | 14¼ |
| E | 11 | 14-5/8 |
| D# | 11-5/16 | 15 |
| D | 11½ | |
| C# | 11-3/4 | |
| C | 12 | |

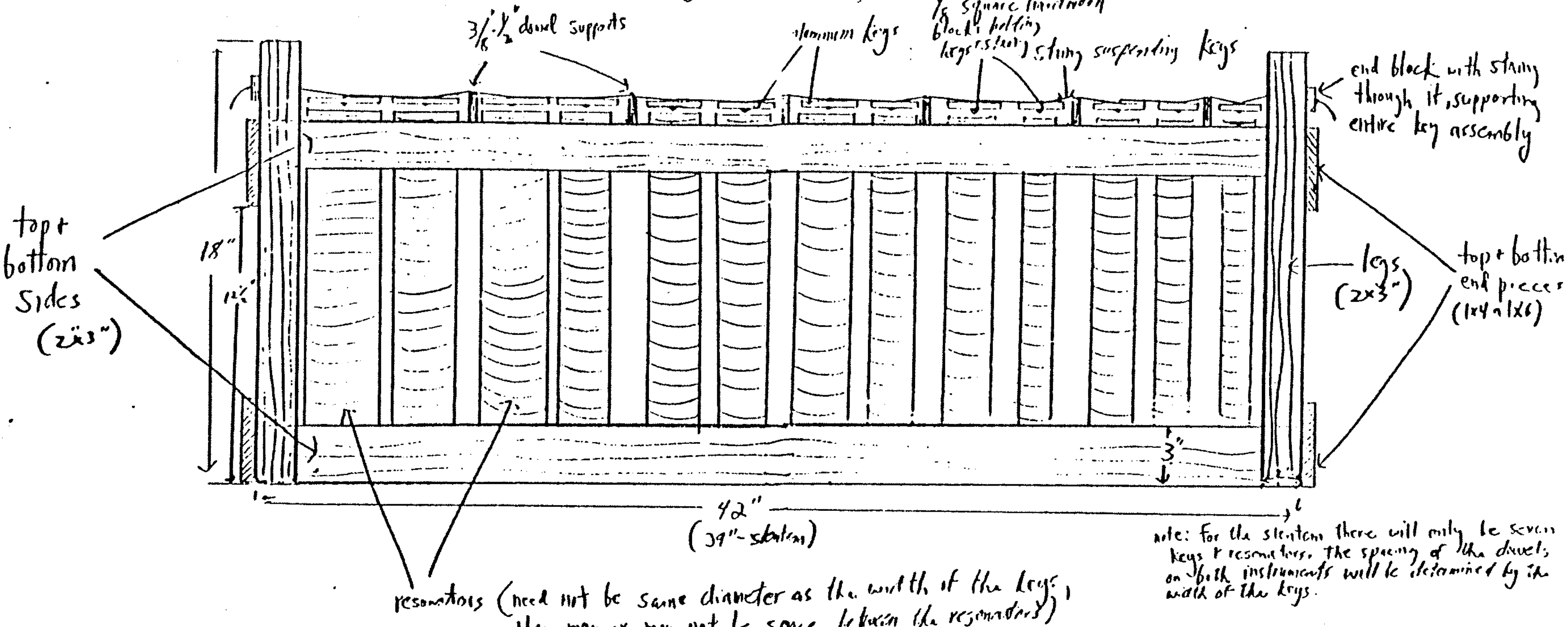
These keys are generally about 3 inches wide. The style two tuning bracket should be about (each of two pieces) 4" long, 9/16" wide, and 1/8 or 3/16" thick. These specifications are for an aluminum tuning bracket, not brass.

Appendix 1

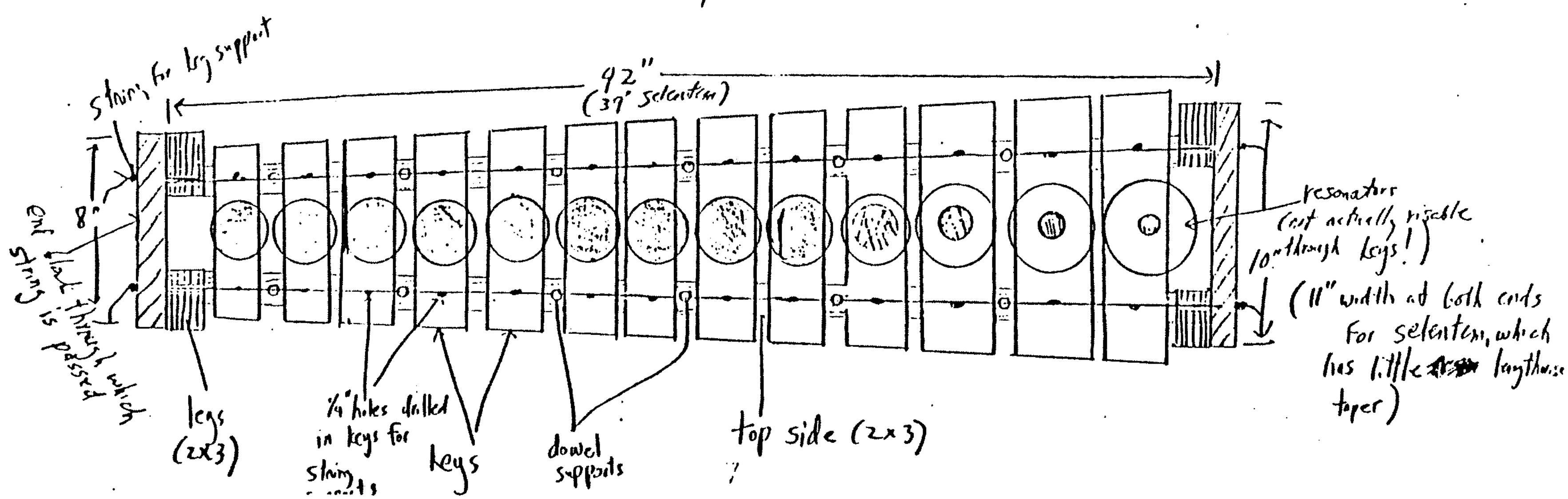
## RANGE AND PITCH OF INSTRUMENTS WITH FIXED PITCHES, FORMING PART OF A GAMELAN SLENDRO FROM JOGYA



Scale approx 1" = 4"
Side View

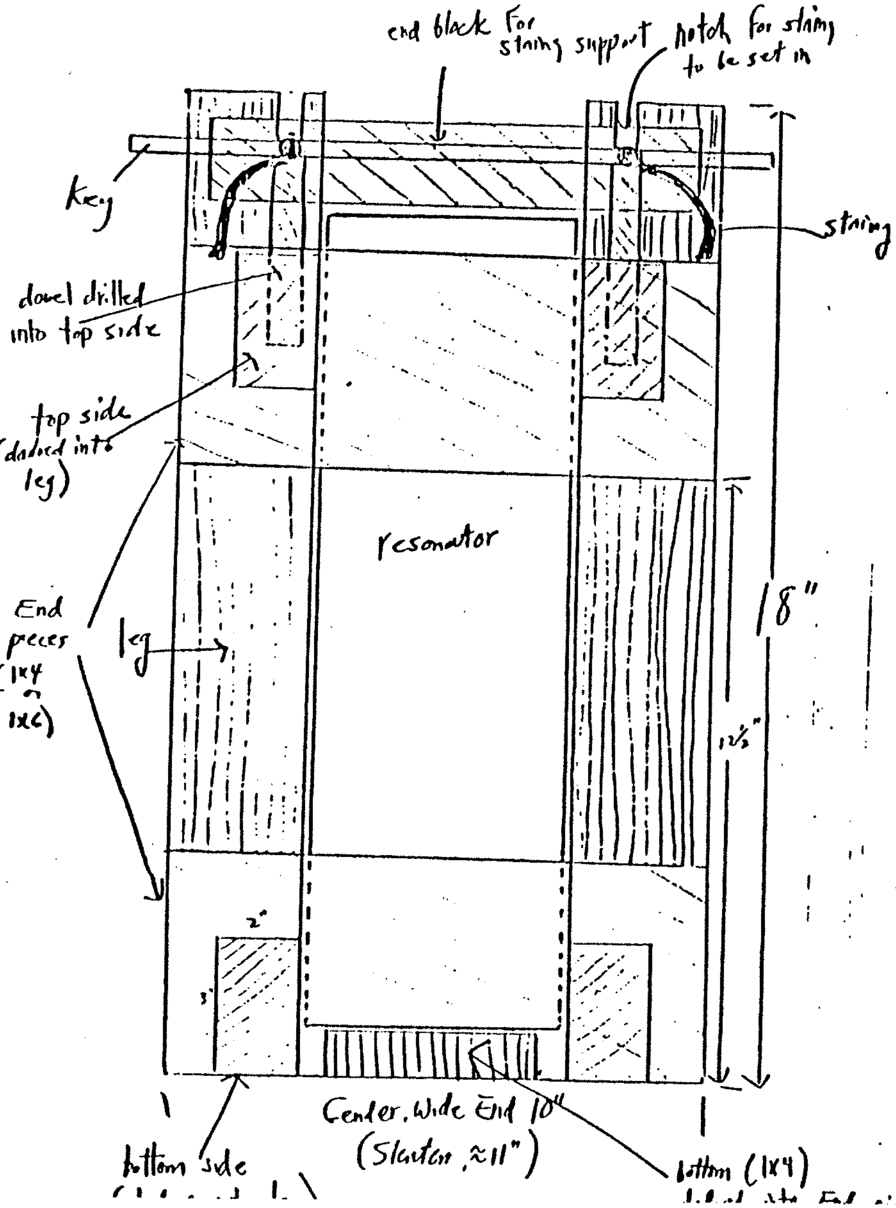



top view (right + left are reversed in above + below pictures)



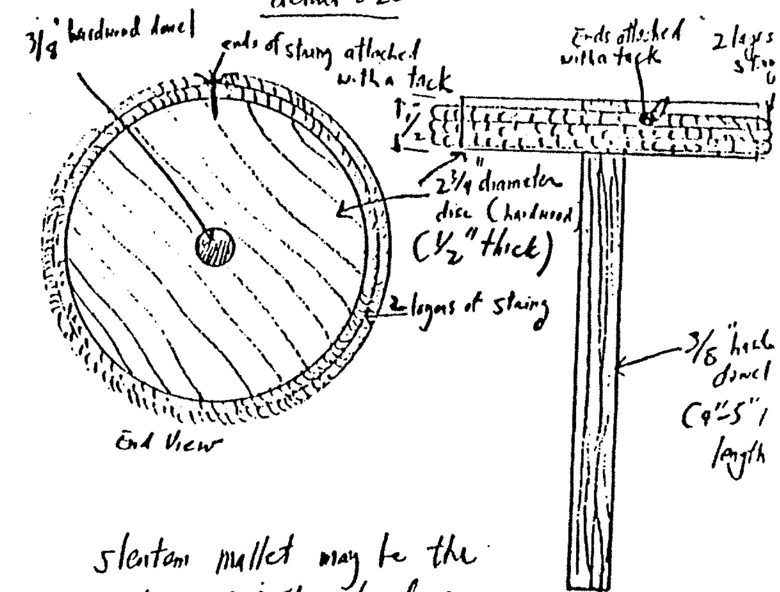
## Gender - End View

Scale approx 1" = 2"
(transparent)




## Mallets for Gender

actual size

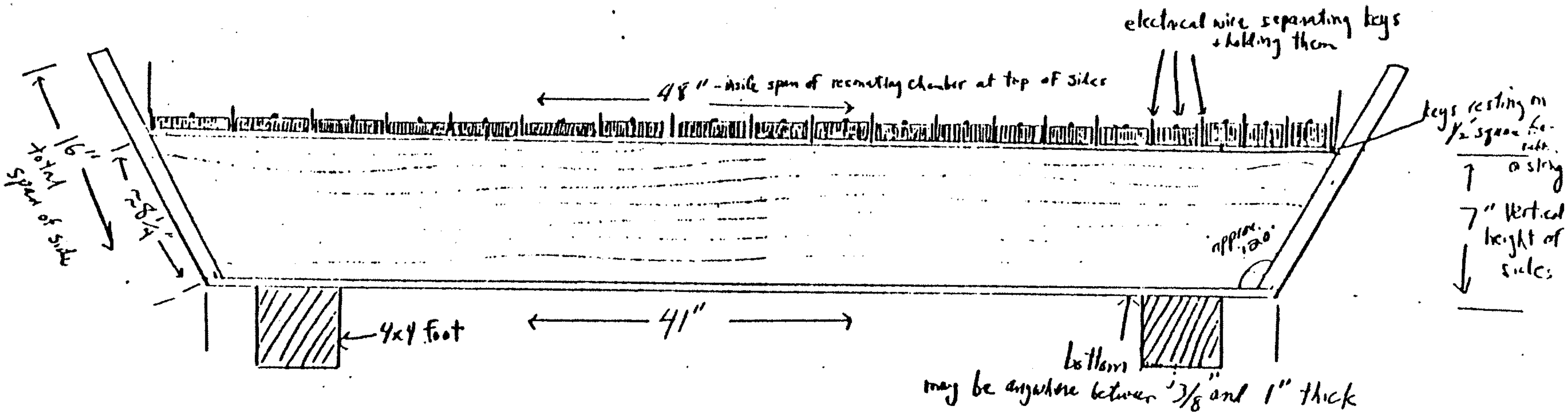



Slentem mallet may be the same design but the head is 4"-5" in diameter. Handle may be 7"-9" long. It may require 3 layers of staring. Head may be 3/4" thick. The circumference of the head (area covered by the staring) may be covered with a thin fabric as on the Gong & kempul mallets.

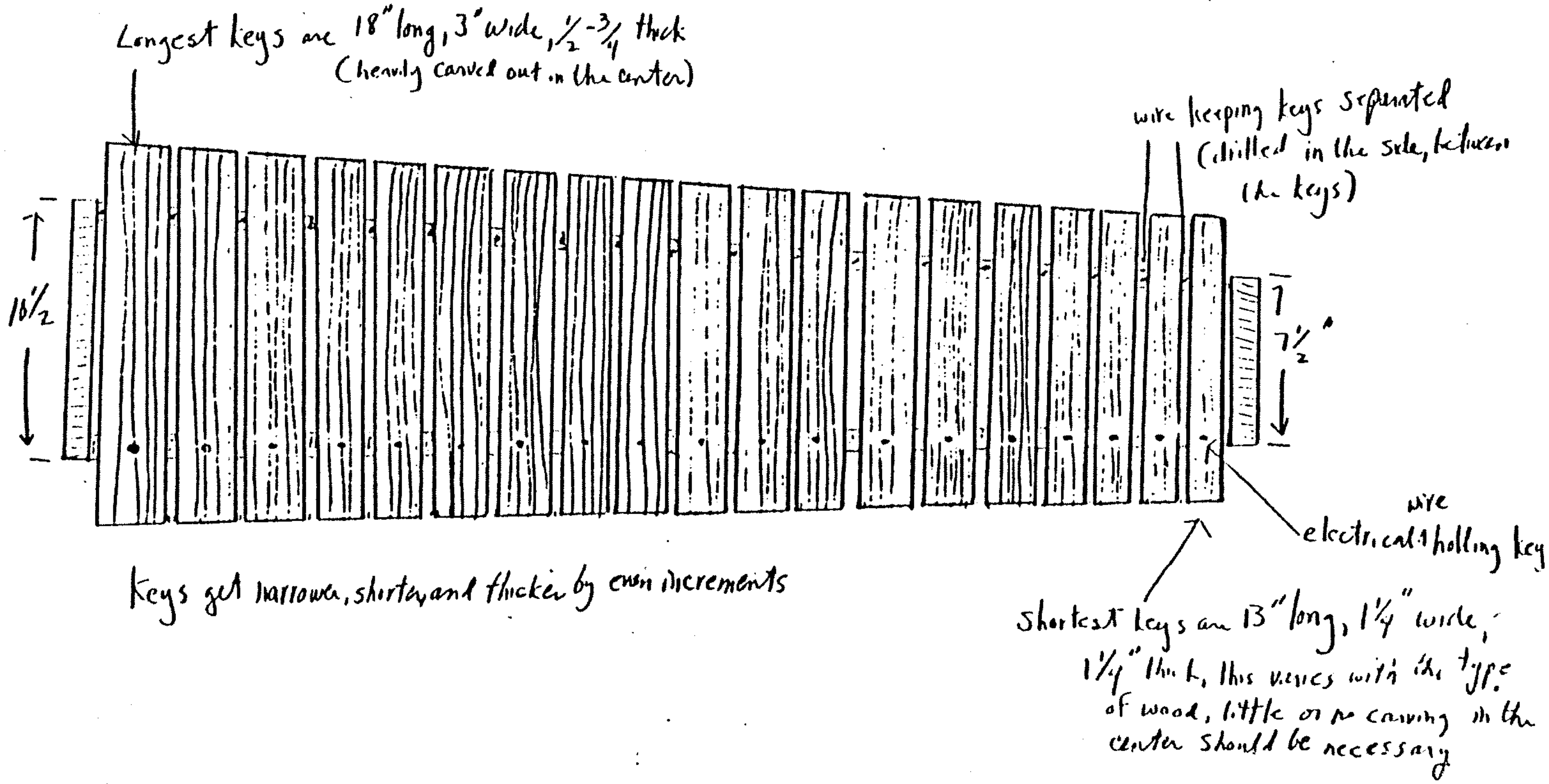
A thin layer of white glue may be spread around the circumference of the head to hold the staring. Glue (very sparingly applied) may also be put in the groove between two starings on the first layer of staring (to hold the second layer)

-17-

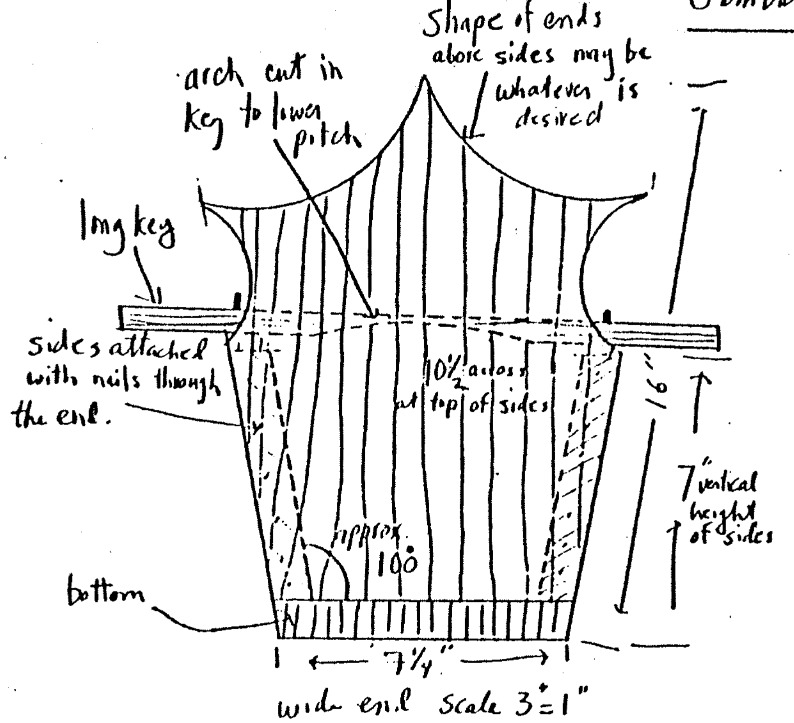
Side View - Scale approx 5" = 1"

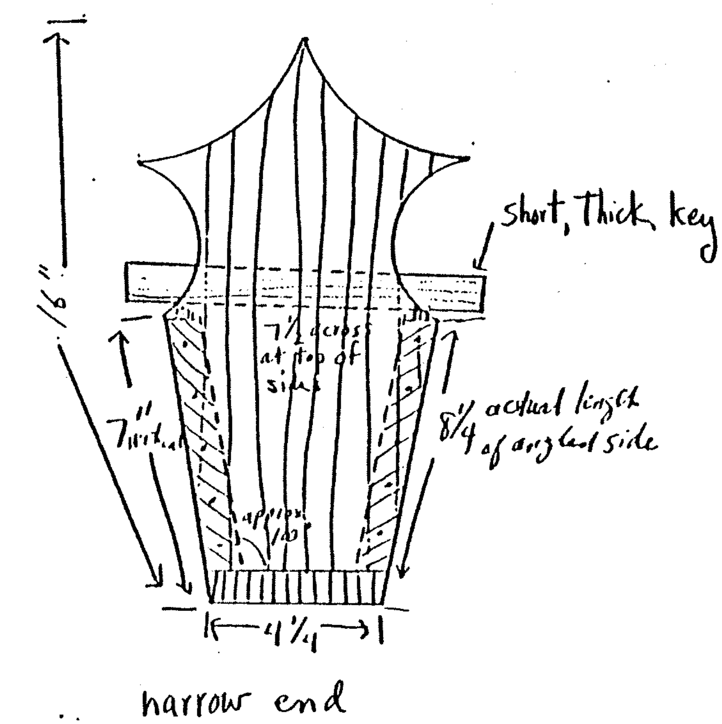



Top View

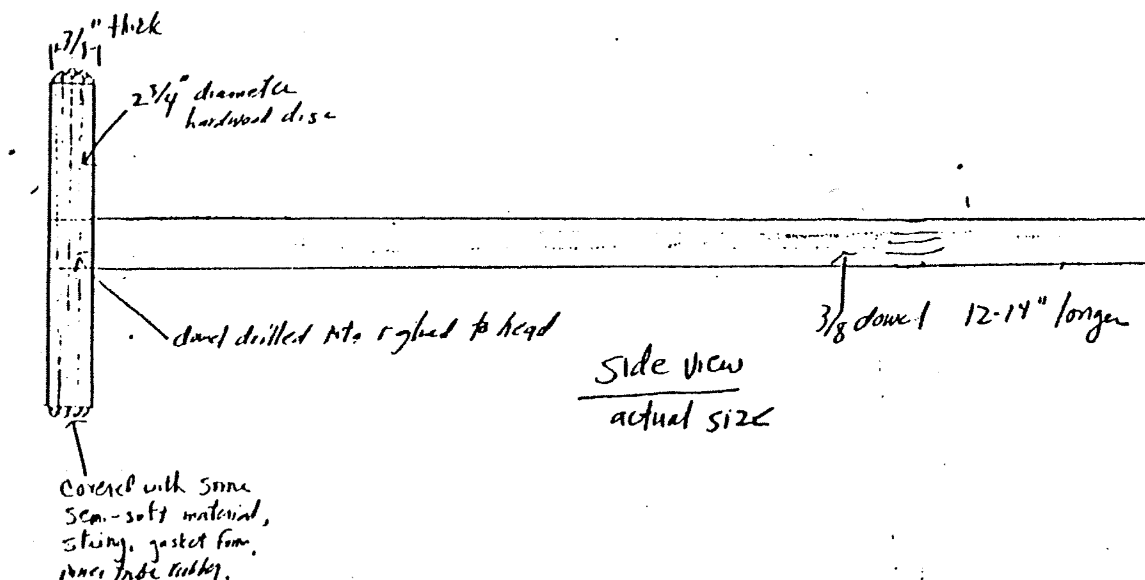


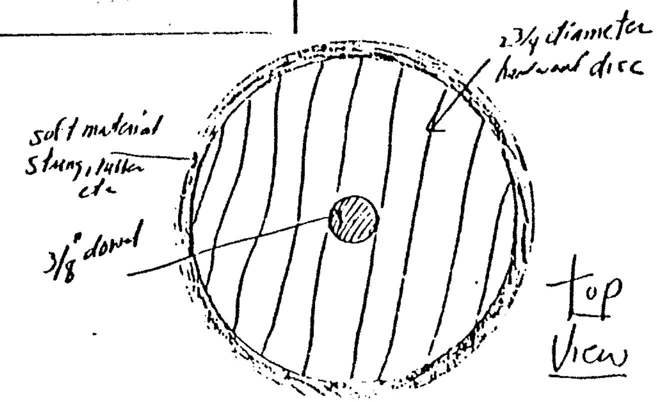
## Gambang – Views Scale 3 = 1




## Gambang Mallets (make two)



# MALLETS (TABUH)

## Gong A Gong and Suwakan

Materials:

1)4 inch length of 4X4, fir or redwood
2)10" length of 3/4" dowel, soft or hardwood.
3)A large ball of fairly light, soft string.
4)Piece of soft fabric, such as flannel, of size 12"X24".

## Instructions

1)Take the 4" length of 4X4 and trace a circle of 3½" diameter on the top of it. Cut this out on a band saw.

2)In the center of the bottom, bore a 3/4" hole, 2" deep. Using glue, insert the 10" length of dowel into the hole. Round off the exposed end of the dowel with sandpaper or a file.

3)Take the ball of string and wrap it around the circumference of the 3½" circle, placing substantially more in the center and little at the edges . Wrap it rather tightly. Enough string should be put on such that the diameter of the circle is increased to about 5½" at the center.

4)Tie the two ends of string together.

5)Take the fabric and wrap it around the circle. Tack or staple it to the top and the bottom of the circle, not on the face of the circle. Pull it tight and try to avoid creases and folds wherever possible.

6)The end of the material should be pasted with white glue to keep it from fraying away.

Kempul Mallets-The mallet for the kempul follows the same design as for the gong a gong, with the following changes.

1)The head should be only 2" high and have a diameter of about 2½".

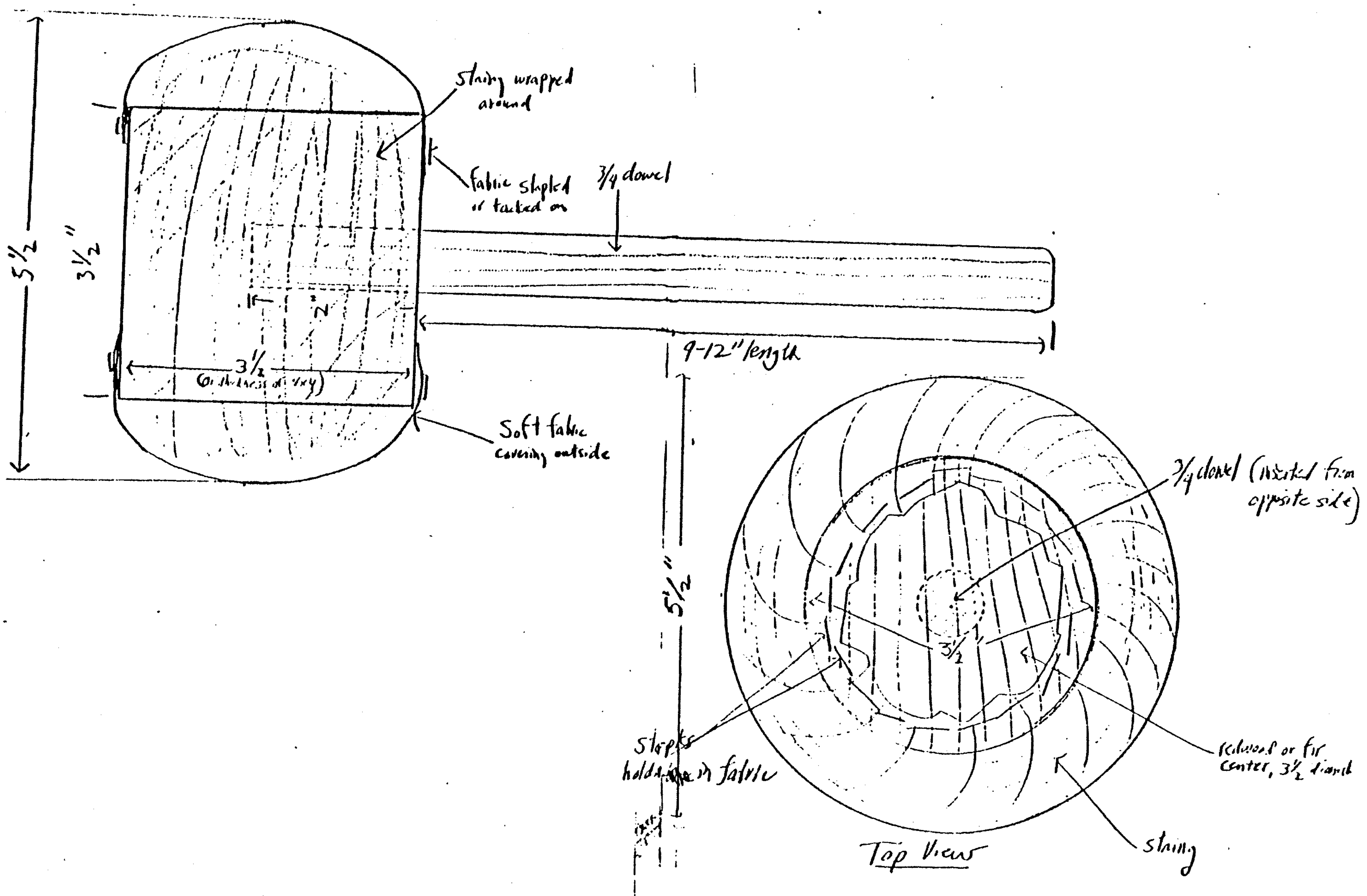
2)Drill the hole only about 1½" into the head.

3)Substantially less string will be needed for wrapping the outside. It will also require less fabric.

4)The finished diameter whould be 4".

Mallets - 6 Gong & Suwukan (see instructions for different dimensions f[illegible]

Actual size



55. PANGKUR
Slendro patet Manyura

Buka : 3232 3732 375(6)

Dados : 3 2 3 7 3 2 7 6
7 6 3 2 5 3 2 7
3 5 3 2 7 6 3 2
5 3 2 7 3 2 7(6)
T P T N

56. UDAN MAS

Buka :

Dados : 6 5 3 2 6 5 3 2
3 3 2 3 6 5 3(2)
6 5 3 2 6 5 3 2
3 3 2 3 66 5 3(2)
7 5 6 7 5 6 7 2
2 1 6 5 6 7 6(5)
7 5 6 7 5 6 7 2
2 1 6 5 6 7 6(5)
T P T N

57. ELING ELING
slendro patet

Buka : 6676 5.75 6.72 (X)

Dados : 3 2 1 6 5 6 7 2
3 2 1 6 5 6 7 2
5 2 3 5 7 6 7 2
7 6 7 5 3 1 3 2 (X)
T P T N

58. SIGRO MANGSAH

Buka : 3565 3266 5523 5(6)

Dados : 2 3 2 1 3 5 3 2
5 3 2 1 3 5 3 2
6 3 5 6 5 7 6 5
3 6 3 2 5 3 5(6)
T P T N

59. KUDA LUMPING

Buka :

Dados : 322 1 . 3 2 1 .
3 2 1 . 2 3 5 .
2 3 5 . 2 3 5 .
5 5 5 6 322 1 (X)
T P T N

60. PANGKUK

Buka : 2121 2621 263(5)

Dados : 2 1 2 6 2 1 6 5
6 5 2 1 3 2 1 6
2 3 2 1 6 5 2 1
3 2 1 6 2 1 6(5)
T P T N

61. RICIK RICIK (LANCARAN)
Pelog Barang

Buka :

Dados : 3 5 6 5 6 5 7(6)
3 5 6 5 6 5 7(6)
3 2 3 2 3 2 7(6)
3 2 3 2 3 2 7(6)
T TNTPTNT PTNTP

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