THE EFFECTS OF HARDNESS AND STIFFNESS OF BASSOON CANE UPON PERFORMANCE OF THE REED

By Laurence J. Intravaia (d. 1973)

Lawrence J. Intravaia

Editor's note: The following article describes a most interesting and valuable experiment of testing bassoon cane for hardness and stiffness with a goal in mind of finding a better way to select cane pieces as to their potential for becoming excellent-playing reeds. The test forms the major part of a dissertation written by Lawrence Intravaia at the University of Texas some years ago. The thesis was included among many papers from the work of Mr. Intravaia, a charter member of I.D.R.S. and IDRS Librarian until his untimely death in 1973, which were sent to this editor by Mrs. Tony Intravaia for possible publication for the Society. When I first read over this paper, I was a bit skeptical of the practicality of testing cane in the manner described - even though the procedure is simplicity itself. My reasoning suggested that probably this careful a test of all the cane which comes to my house destined for eventual formation into many bassoon reeds, might occupy as much time or more time than the reed-making itself, which after many years has been going quite well. But on careful second thought, I could clearly visualize the advantage of being able to purchase from one or more cane suppliers *(either in North America or at the source in France)*. . .*cane which has been* pre-tested and graded *according to stiffness and hardness. If this experimental work of Larry Intravaia's enables even a few careful reed makers to improve upon their craft by having available to them a repeatable and reliable way of testing cane for potential excellence, then I believe we have found another example of the great importance to double reed musicians of this dedicated bassoonist's life and work.*

CHAPTER I

INTRODUCTION

Introduction to the Problem

For many years double-reed performers have been confronted with an infinite number of problems concerning reeds and reed making. Most of the attempts to solve these problems have been directly related to the shape and dimension of the reed, but it is the belief of many that some of the answers lie partly in the cane from which the reeds are constructed. This material is so variable, and so little is known about its properties that it is impossible always to be assured of satisfactory results in the finished product.

After exhausting the sources of information concerning reeds, it was discovered that there was only one article directly related to grading cane, and this one relies upon guess work; consequently the results were not reliable.

Before the problem of constructing reeds with consistent results can be solved, the following problems need to be scientifically investigated:

(1) the effect of hardness of cane upon tone quality and response;

(2) the effect of stiffness of cane upon the tone quality and response;

(3) the modes of vibration in the reed;

(4) the dampening effect of the cane;

(5) the composition of the cane which would yield its specific gravity and elasticity coefficient;

(6) controlled experiments with growing and seasoning of cane;

(7) the effect of blade and throat dimensions upon tone quality and response; and

(8) the effect of reed and throat shape on tone quality and response.

It is with these problems that the reed maker needs the assistance of the botanist and xylotomist. The answers might eventually lead to a substitute material for the inconsistent cane.

Statement of the Problem

Of the problems listed above, the first two, effect of hardness and the effect of stiffness of cane upon tone quality of the reed have been chosen for investigation by the writer. One of the difficulties connected with this type of experiment is that the results are to a certain degree the product of personal taste. Assuming, however, that good for one style of playing is good for any style, the writer proceeded with the belief that the results would be of interest to all reed makers.

Definition of Terms

For the purposes of this study, the terms listed below are defined according to the sources indicated in the footnotes in Chapter II.

Abguss. Abguss is the joint which connects the two air chambers of the bottom section of the bassoon.

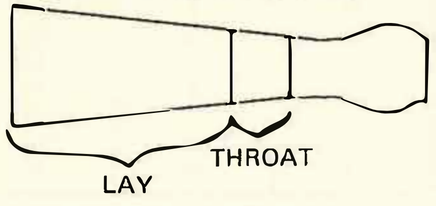
Cane. Cane, as it is used in this research, is of the *arundo donax* species.

Crow. This is the term used for the sound produced when the reed is vibrated alone and not attached to the instrument; the sound should be a heterogeneous mixture of the root plus several of the overtones.

Fixing. This is a term used to indicate the final adjustments made on a finished reed.

Lay. Lay, as it is used in this study, refers to the vibrating portion of the reed, from the first wire to the tip.

Throat. When this word is used in connection with reeds, it refers to the portion of reed between the first two wires.



Organization of the Remainder of the Thesis

In Chapter II a review of literature pertinent to bassoon reeds will be given. Chapter III will be devoted to the results of the investigations chosen for this study; effect of hardness and stiffness upon tone quality. A brief description of the procedure for the experiments is as follows: eight pieces of cane were tested for hardness and stiffness and then made into reeds. The tone quality was then tested by analyzing harmonically tones produced with each reed. Chapter IV contains the summary, conclusions, and recommendations.

(Editor's note. I have deleted CHAPTER II of this paper, which is a review of Literature About Double Reed Making and does not present new material germane to the testing of cane.)

CHAPTER III

PRESENTATION OF DATA

As indicated in Chapter I, the purpose of this study was to investigate two of the problems associated with cane with respect to its quality and treatment in the preparation of bassoon reeds: (1) the effect of hardness, and (2) the effect of stiffness upon tone quality. Only when all of the problems mentioned in Chapter I have been investigated can there be devised a reliable method of grading cane, but after subjection to the two experiments presented in this chapter, most of the inferior cane can be discovered and discarded.

Plan for the Experiment

Five pieces of cane were chosen from varied sources and three from identical sources. The purpose in choosing three from the same source was to ascertain whether or not they contained similar characteristics.

All of the cane was gouged to a thickness of from 46 to 50 thousandths of an inch, and cut to a length of five inches so that the only variable factor was the material. The cane was tested for hardness and stiffness, as will be shown later, and then made into reeds. Four tones of each reed were recorded with a tape recorder and harmonically analyzed in an attempt to show a correlation between hardness and stiffness of cane; and the relative strength of the partials.

The Hardness Test

Equipment

A Rockwell Superficial Hardness Tester was chosen for this test, because of its sensitivity. The principle underlying the readings of the tester is based upon an increment in depth due to an increment in load.

It is pertinent to mention at this time another tester that possibly could be used, that is, a wood hardness tester manufactured by Tinias Olsen Testing Machine Company in Philadelphia, Pennsylvania.

Procedure

The tester was loaded with the minimum load of fifteen kilograms and a diamond cone indenter was used to make the indention. Two sets of readings were taken for each piece of cane, one dry and one wet. For both sets each piece was tested in three places; one in the middle and one an inch on each side of the center. All tests were made at points of 46 to 48 thousandths of an inch thick. Because of the extreme softness of the pitch of the cane, all tests were made on the bark side.

Problems Involved in the Testing

Inconsistent readings within one piece of cane may be produced by the indention being made either on the fiber or on the material holding those fibers together.

The indentions could not be made very close to the end of the piece of cane because of splitting.

Explanation of Table I

Table I showed the following data resulting from the test for hardness performed on eight pieces of cane. The Rockwell Superficial Hardness Tester which was used makes an indention in each cane segment resulting in a reading from the calibrated dial. These readings appear in Table I. In the first column appears the number of each piece of cane, and this number remains with each cane segment throughout all of the investigations. The columns headed Dry and Wet are divided into three, each representing one indention produced by the initial load of three kilograms. It is pertinent to mention here that the Rockwell Superficial Hardness Tester and the Rockwell Hardness Tester have the same characteristics with the exception of the amount of load that can be applied, the Superficial Tester taking a smaller load.

TABLE I

DATA FROM HARDNESS TEST USING ROCKWELL SUPERFICIAL HARDNESS TESTER

Cane Number	Dry			Wet		
	First Indention with Initial Load	Second Indention with Initial Load	Third Indention with Initial Load	First Indention with Initial Load	Second Indention with Initial Load	Third Indention with Initial Load
1	77	67	77	71	75	75
2	90	83	83	88	75	81
3	86	100	81	90	91	88
4	78	80	88	77	85	86
5	92	90	73	77	81	80
6	80	83	70	73	81	84
7	85	86	75	87	100	97
8	83	89	80	86	88	91

Results

This experiment resulted in a comparison of eight pieces of cane according to hardness under conditions both dry and wet.

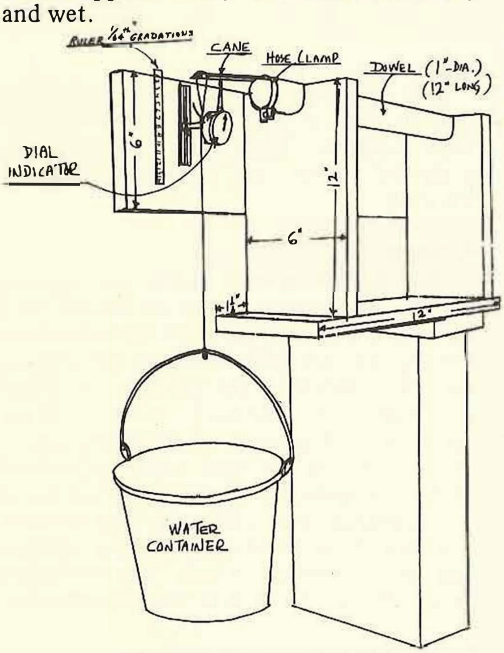
Following is a list of the numbers of the pieces of cane in rank order of softness to hardness when tested dry and the average hardness readings of each reed as indicated on the Rockwell Superficial Hardness Tester.

Cane Number	Average
1	73.6
6	77.6
4,7	82
8	84
5	85
2	85.3
3	89.3

The rank order and averages when tested wet were as follows:

Cane Number	Average
1	73.6
5,6	79.3
2	81.3
4	82.6
8	88.3
3	89.6
7	94.6

One interesting observation was made; the pieces of cane that tested harder when wet than when dry were obtained from the same source. Cane numbers 1, 3, and 4 tested approximately the same when dry and wet.



APPARATUS FOR CANE STIFFNESS TEST

PLATE 5 (V)

The Stiffness Test

Equipment

The apparatus used in this experiment was designed and constructed by the experimenter (See Plate V).

Procedure

A small *notch* was cut across the cane *one eighth of an inch from the end.* With a hose clamp, the cane was attached to the dowel so that its *actual deflecting length was three inches.* A *container* weighing *five ounces* was then suspended at the notch by means of a piece of cord (See Plate V). The amount of deflection at the end of the cane was measured from the scale in sixty fourths of an inch. Three fluid ounces of water, weighing 29.6 grams each, were placed in the container one at a time, and readings were taken after each fluid ounce was added. The total load was left suspended from the cane for a period of five minutes, and a reading recorded. The load was then removed and another reading taken. A period of five minutes was allowed to lapse with the load removed and then a final reading recorded. The readings were taken by placing a square under the cane and against the scale.

It is pertinent at this time to mention one other means of performing this stiffness test using the same apparatus. Arbitrary amounts of deflection would be chosen, and the amount of weight necessary to produce these deflections would be measured.

Problems Involved in the Testing

Consistent results can be achieved only if the *cane is gouged to the same thickness, cut from stalks of the same diameter and cut to the same length and width.*

Explanation of Table II

Table II is made up of eight columns. The first column contains the cane numbers as they were numbered in the preceding experiment, and the numbers in the remaining columns are recorded from a scale calibrated in sixty-fourths of an inch. The stiffness is measured by the amount of deflection under a given load, and the greater the deflection, the greater will be the flexibility of the cane. The numbers in columns two, three, four, five, and six are the amounts of deflection in terms of sixty fourths of an inch, produced by addition of a given load which is specified in the Table. Columns seven and eight determine the magnitude of recovery by indicating, in sixty fourths of an inch, the amount of deflection when unloaded. If the figures in these columns are subtracted from those in the preceding column, the distance each piece of cane has returned to its normal position can be determined, if so desired.

TABLE II

AMOUNT OF DEFLECTION AND RECOVERY OF EACH CANE SEGMENT AS MEASURED IN SIXTY FOURTHS OF AN INCH

Cane No.	Initial Load of Five Oz.	Addition of 29.6 Grams	Addition of 29.6 Grams	Addition of 29.6 Grams	Five Minute Period w/Load	Unloaded	Five Minute Period After Unloading
1	17	20	23	30	35	15	11
2	10	12	14	15	19	4	2
3	9	11	12	13	15	5	3
4	4	4	4	5	6	2	0
5	11	13	14	16	20	4	4
6	6	8	8	10	12	2	1
7	6	6	10	10	11	2	1
8	6	7	8	9	10	1	1

Results

This experiment resulted in a comparison of eight pieces of cane based on stiffness and amount of recovery.

Following is a list of the pieces of cane in rank order of stiffness:

1
5
2
3
6
7
8
4

Based on magnitude of recovery five minutes after unloading, the rank order was:

1
2,3,4
6,7
5,8

The Harmonic Analysis

After the cane had been tested for hardness and stiffness, reeds were constructed from each piece. These reeds were made as identical as possible in every respect so that the quality of the cane would be the only variable factor. Each blade was cut the identical thickness within two thousandths of an inch, as measured by a dial test indicator.

The reeds were played upon for approximately two hours before a tonal spectrum was made of each reed.

Equipment

The equipment used for the harmonic analysis was as follows: a General Radio Wave Analyser. Type 736-A, a Strobconn, a decibel meter, and a Concertone Tape Recorder.

Procedure

One tone from each of the four registers of the bassoon was chosen to record: 65.5 vibrations per second, C_2;[4] 110 vibrations per second, A_2; 220 vibrations per second, A_3; 440 vibrations per second, A_4. These four tones were recorded with each of the eight reeds. A portion of the tape containing each of the recorded tones was cut and each piece spliced together so as to produce a continuous tone with one loop of tape. This was done to simplify and aid the process of harmonic analysis. The performer producing the tones was the experimenter.

Precautions Taken in Recording

The Stroboconn was used to keep each tone on a constant frequency and a decibel meter was used to keep the volume constant: The microphone was kept at the same distance from the performer and in the same place in the room, throughout the recording. The recording volume was set at the number six. The decibel meter was set at 1.0 ODB or RMS volts. The performer played the tones with the following intensities as measured by this decibel meter:

[1] "American Standard Acoustical Terminology," *The Journal of the Acoustical Society of America*, XIV (July, October, 1942-Jan., April, 1943), 98.

C_2 - 1.6
A_2 - 1.5
A_3 - 1.3
A_4 - 1.3

Explanation of Graphs

For the harmonic analysis, four tones of each reed were recorded; consequently there was one graph of each tone or four graphs for each of the eight reeds being tested. The graphs indicate the relative strength in decibels of each partial. There was indicated by the wave analyser an average of twenty partials for the pitch C_2, twelve for the pitch A_2, ten for the pitch A_3, and eight for the pitch A_4. The frequencies of the partials are indicated on the horizontal axis at every octave.

Results of the Harmonic Analysis

The complete results of the harmonic analysis are shown in Figs. 1 through 8. In addition, a brief summary of these results are set forth below. This summary includes a description of the analysis of the four tones recorded for each reed.

Reed No. 1

Pitch C_2: Of the twenty partials shown by the analyser, the eighth was the strongest and the twelfth the weakest. Throughout the series within the intervals of every four or five partials, the strength tended to increase and then decrease.

Pitch A_2: From the pitch A_2, the fifth partial was the strongest and the tenth the weakest. The first two partials were of the same strength, then was shown a gradual increase in strength to the fifth, and then a gradual decrease to the tenth which was the weakest partial. From the tenth through the fourteenth partials, there was shown an increase in strength.

Pitch A_3: With this pitch, the second partial was the strongest and the eighth the weakest. At the fifth partial there was a sharp decrease in strength.

Pitch A_4: With the pitch A_4, the first partial was the strongest and the sixth the weakest. With the seventh partial, there was a sudden increase in strength.

Reed No. 2

Pitch C_2: Of the twenty partials shown by the analyser, the seventh was the strongest and the seventeenth the weakest. Throughout the series, at every fourth or fifth partial, the strength tended to increase and then decrease.

Pitch A_2: From the pitch A_2, the fifth partial was the strongest and the first the weakest. With this pitch, only ten partials were obtainable with the analyser, as compared to an average of twelve with the other reeds. There was shown a gradual increase in strength to the fifth partial, then an irregular decrease to the tenth.

Pitch A_3: With this pitch, the second partial was the strongest, and the ninth and tenth were the weakest, and of the same strength.

Pitch A_4: With the pitch A_4, the second partial was the strongest and the eighth the weakest. From the second to the eighth partials, there was a gradual decrease in strength.

Reed No. 3

Pitch C_2: Of the twenty partials shown by the analyser, the seventh was the strongest and the twentieth the weakest. There was a gradual increase in strength from the first to the seventh partial, and from the seventh to the twentieth partial there was an irregular decrease in strength.

Pitch A_2: The pitch A_2 produced a gradual increase in the strength of the first five partials. The fifth partial was the strongest and the twelfth the weakest. Partials six, seven, and eight were of the same strength.

Pitch A_3: With this pitch the second partial was the strongest and the tenth the weakest. There was a gradual decrease in the strength of the partials from the second through the tenth with the exception of the ninth, which was much stronger than its adjacent partials.

Pitch A_4: With the pitch A_4, the second partial was the strongest and the seventh the weakest. The fifth partial was much stronger than its adjacent ones.

Reed No. 4

Pitch C_2: With this pitch, the eighth partial was the strongest and the sixteenth the weakest. In this series the partials increased irregularly in strength from the first to the eighth, then within the interval of every four partials there was an increase and decrease in strength.

Pitch A_2: This pitch produced thirteen partials; whereas the average for the eight reeds was twelve. The fifth partial was the strongest and the thirteenth the weakest. There was a gradual increase in the strength of the partials from the first to the fifth, then an irregular decrease to the thirteenth partial.

Pitch A3: With the pitch A3, the second partial was the strongest and the tenth was the weakest. There was a gradual decrease in the strength of the partials from number two to ten, with the exception of the ninth, which was stronger than its adjacent partials.

Pitch A4: With this pitch, the second partial was the strongest and the sixth and seventh the weakest. There was a sudden decrease in strength with the sixth partial. The eighth partial was too weak to be picked up by the analyser.

Reed No. 5

Pitch C2: With this pitch, the seventh and eighth partials were the strongest and the twentieth the weakest. There was an irregular increase in the strength of the partials up to number seven, then an irregular decrease to number twenty. The eleventh partial was much weaker than its adjacent partials and the nineteenth much stronger than its adjacent ones.

Pitch A2: This pitch produced a very weak fundamental and a strong fourth partial.

Pitch A3: With the pitch A3, the second partial was the strongest and the tenth the weakest. There was a gradual decrease in the strength of the partials from the second to the tenth, with the exception of the seventh, which was much stronger than its adjacent partials.

Pitch A4: With this pitch, the first two partials were almost the same strength; the second being slightly the stronger. From the second to the eighth, there was a gradual decrease in strength of the partials, with the exception of the fifth, which was weaker than its adjacent partials.

Reed No. 6

Pitch C2: This pitch produced partials which gradually increased in strength from the first to the eighth, then a sudden drop; then the partials slowly decreased in strength from the ninth to the eighteenth. Partials nineteen and twenty were not picked up by the analyser.

Pitch A2: With this pitch, the fifth partial was the strongest and the twelfth the weakest. There was a sudden increase in strength with the ninth partial.

Pitch A3: With the pitch A3, the second partial was the strongest and the tenth the weakest. There was an irregular decrease in the strength of the partials from the second to the tenth, with a sudden drop at number five.

Pitch A4: With this pitch, the first two partials were the strongest and the eighth the weakest. With the fourth partial, there was a sudden decrease in strength.

Reed No. 7

Pitch C2: With this pitch, the strongest partial was the seventh and the weakest the twentieth. There was an increase in the strength of the partials from the first to the seventh, then a very irregular decrease to the twentieth. Partial number nineteen was much stronger than its adjacent partials.

Pitch A2: The partials of this pitch increased in strength to partial number five, then began to decrease until partial number thirteen, which decreased by a considerable amount. Thirteen partials were obtained from this pitch by the analyser.

Pitch A3: The strongest partial of this pitch was the second and the weakest the tenth. From the seventh through the ninth partials, there was a gradual decrease in strength, but the tenth partial showed a sudden increase.

Pitch A4: With this pitch, the first partial was the strongest and the sixth the weakest. Partials number seven and eight were stronger than number six.

Reed No. 8

Pitch C2: With this pitch, the eighth partial was the strongest and the eighteenth the weakest. The nineteenth partial was very strong in comparison to the other upper partials.

Pitch C2: This pitch produced a very weak fundamental and a strong fifth partial. The eighth partial was weaker than its adjacent partials.

Pitch A3: With this pitch, A3, the second and third partials were the strongest and the seventh and eighth the weakest. This pitch contained several sudden drops in the strength of its partials.

Pitch A4: The first three partials of this pitch were the strongest and the fourth, sixth and eighth the weakest.

The stiffer the cane, the more prominent were the tenth and eleventh partials and the weaker was the fundamental for the pitch A2. For the pitch A3, the most prominent was the ninth partial. The cane that tested softest also tested least stiff and had the largest amount of recovery. The harmonic analysis of the reed made from this cane is shown in Figure 1.

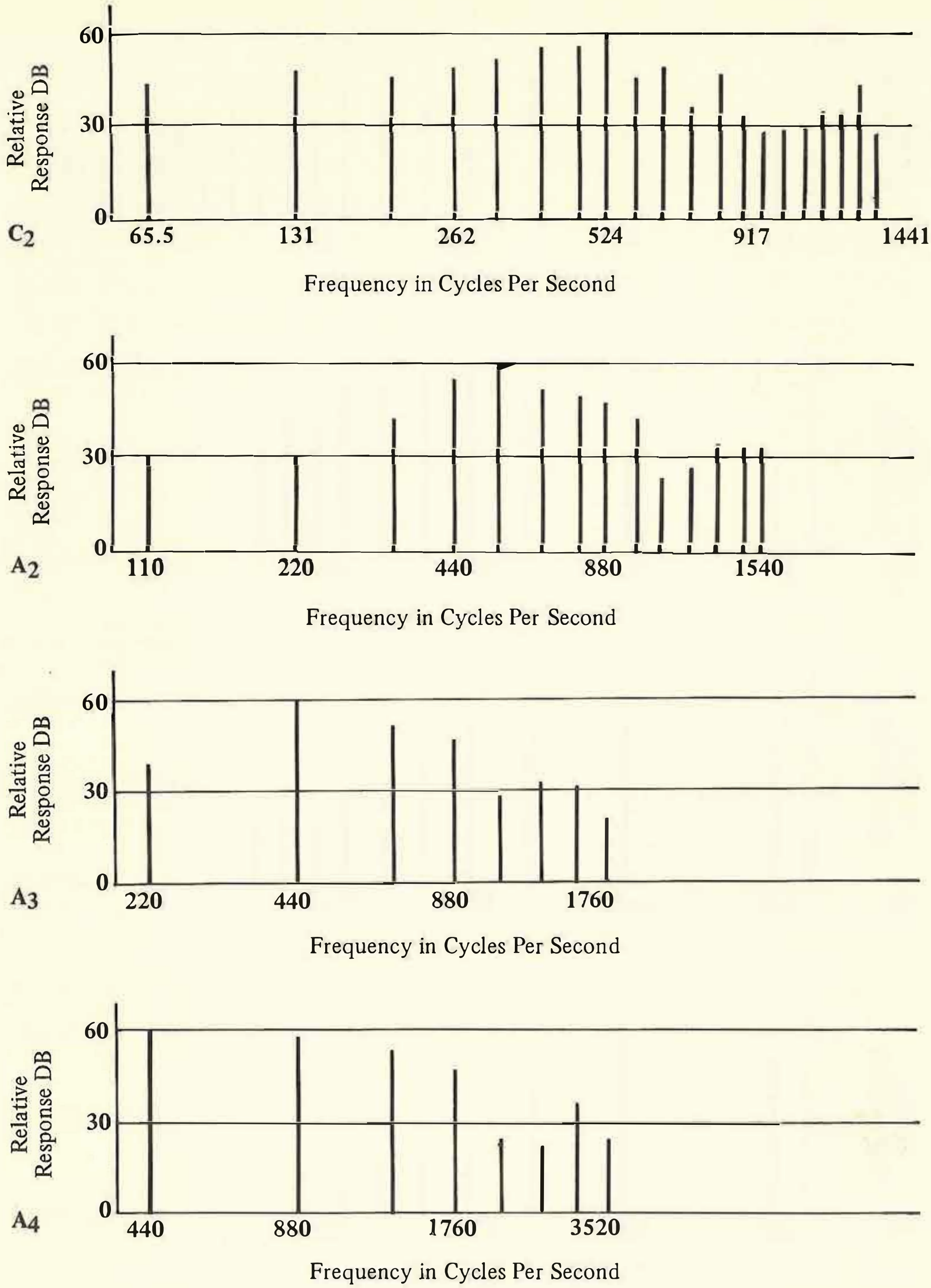


FIGURE 1

HARMONIC ANALYSIS OF REED NO. 1

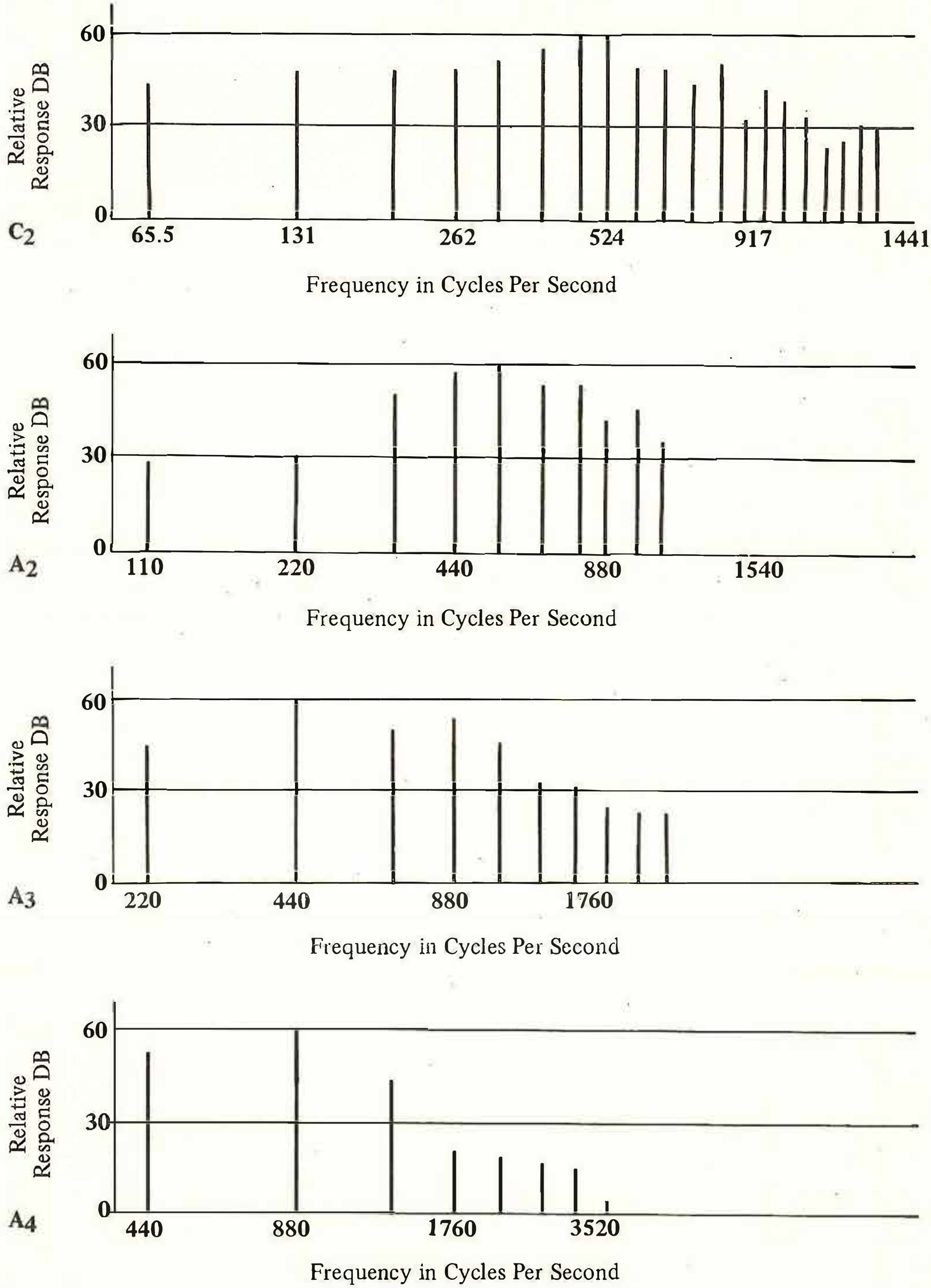


FIGURE 2

HARMONIC ANALYSIS OF REED No. 2

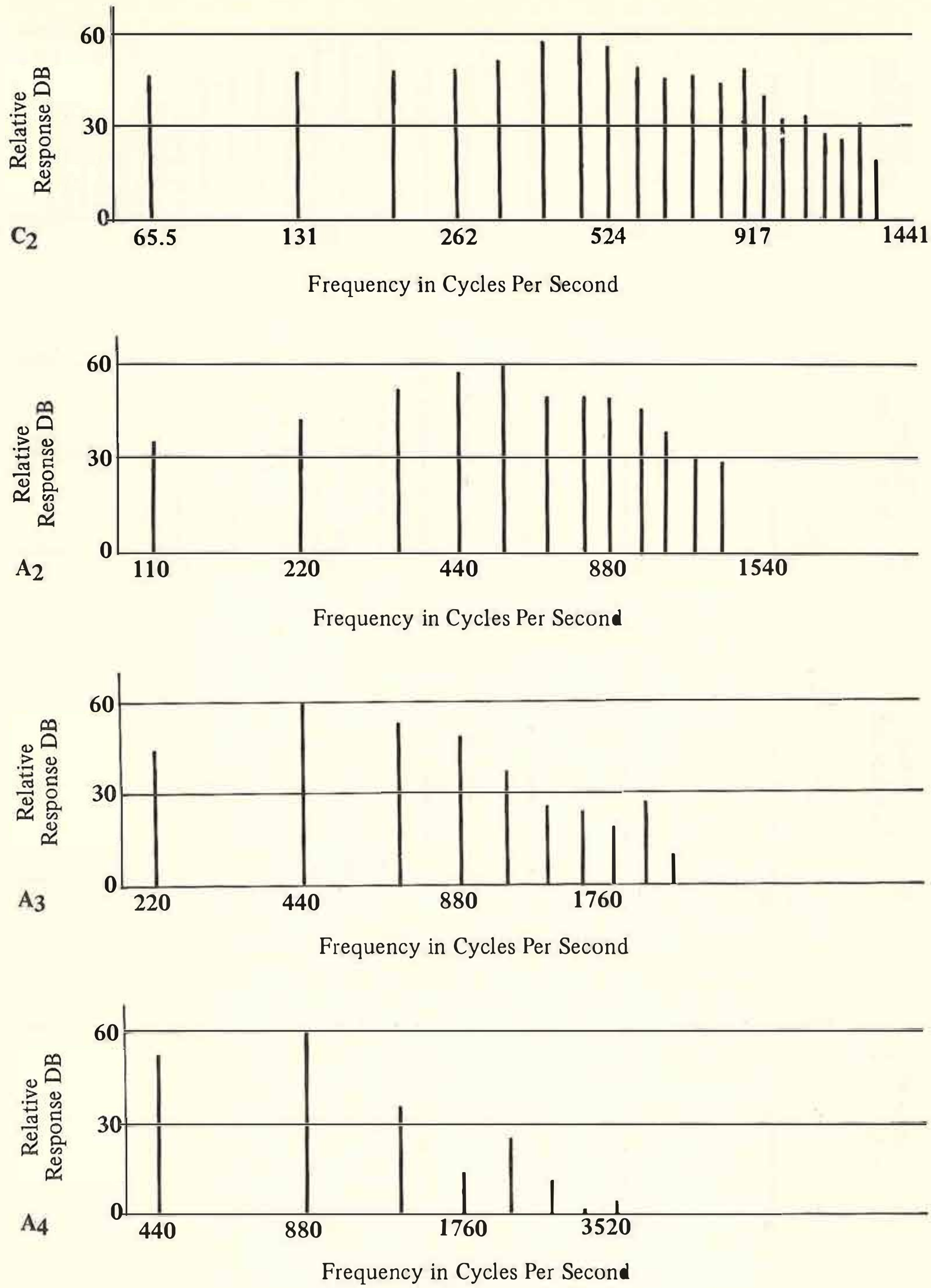


FIGURE 3

HARMONIC ANALYSIS OF REED No. 3

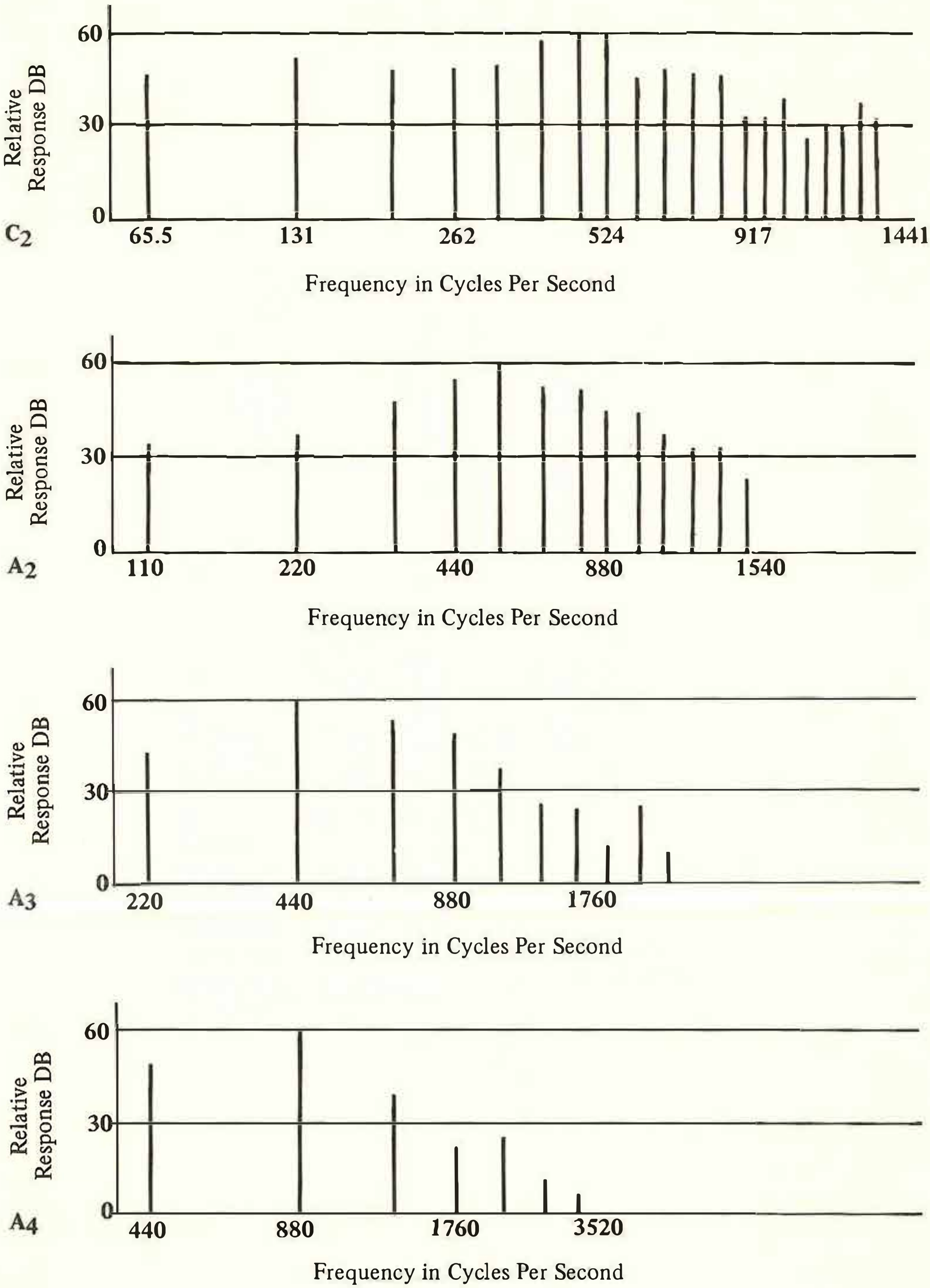


FIGURE 4

HARMONIC ANALYSIS OF REED No. 4

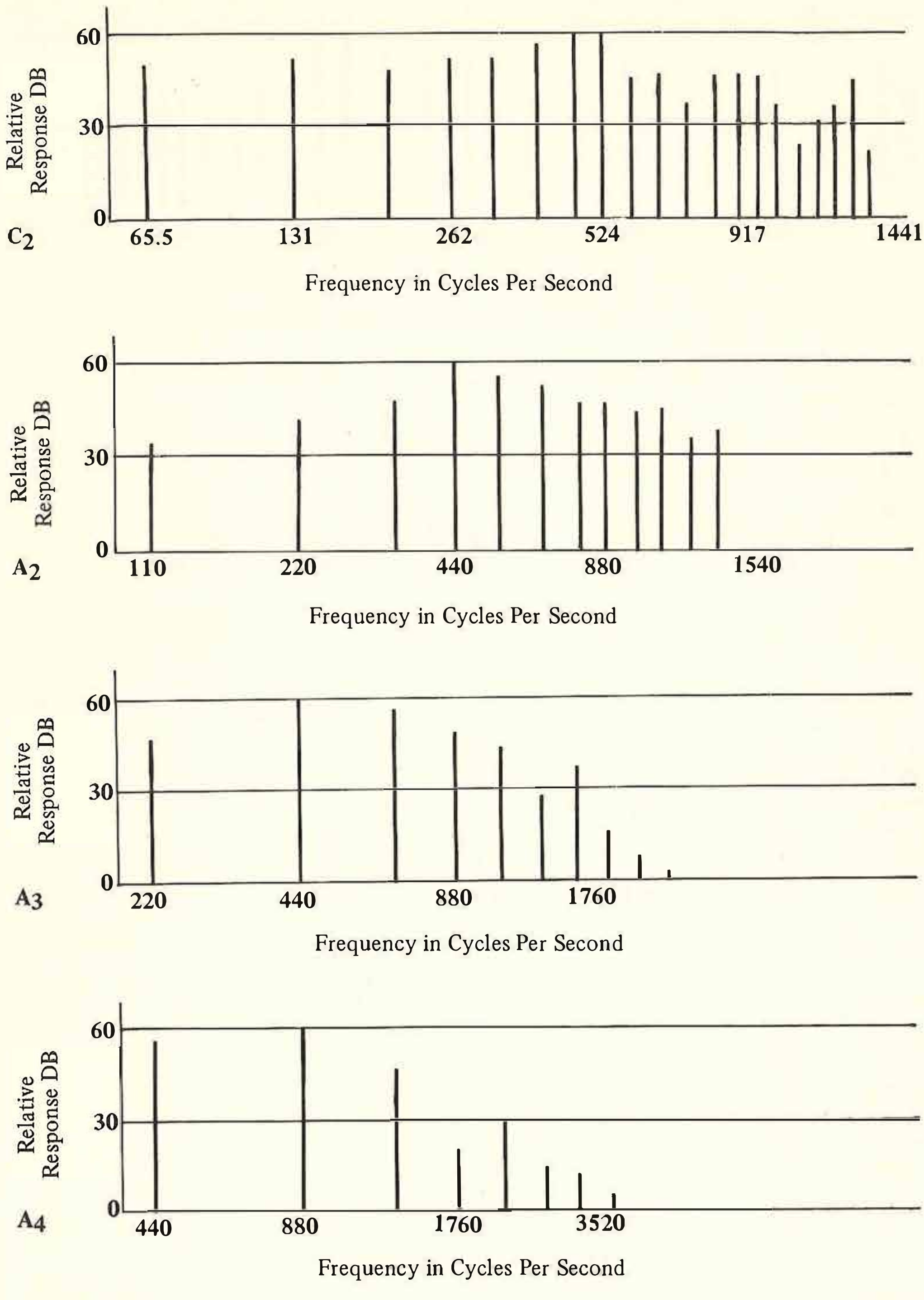


FIGURE 5

HARMONIC ANALYSIS OF REED No. 5

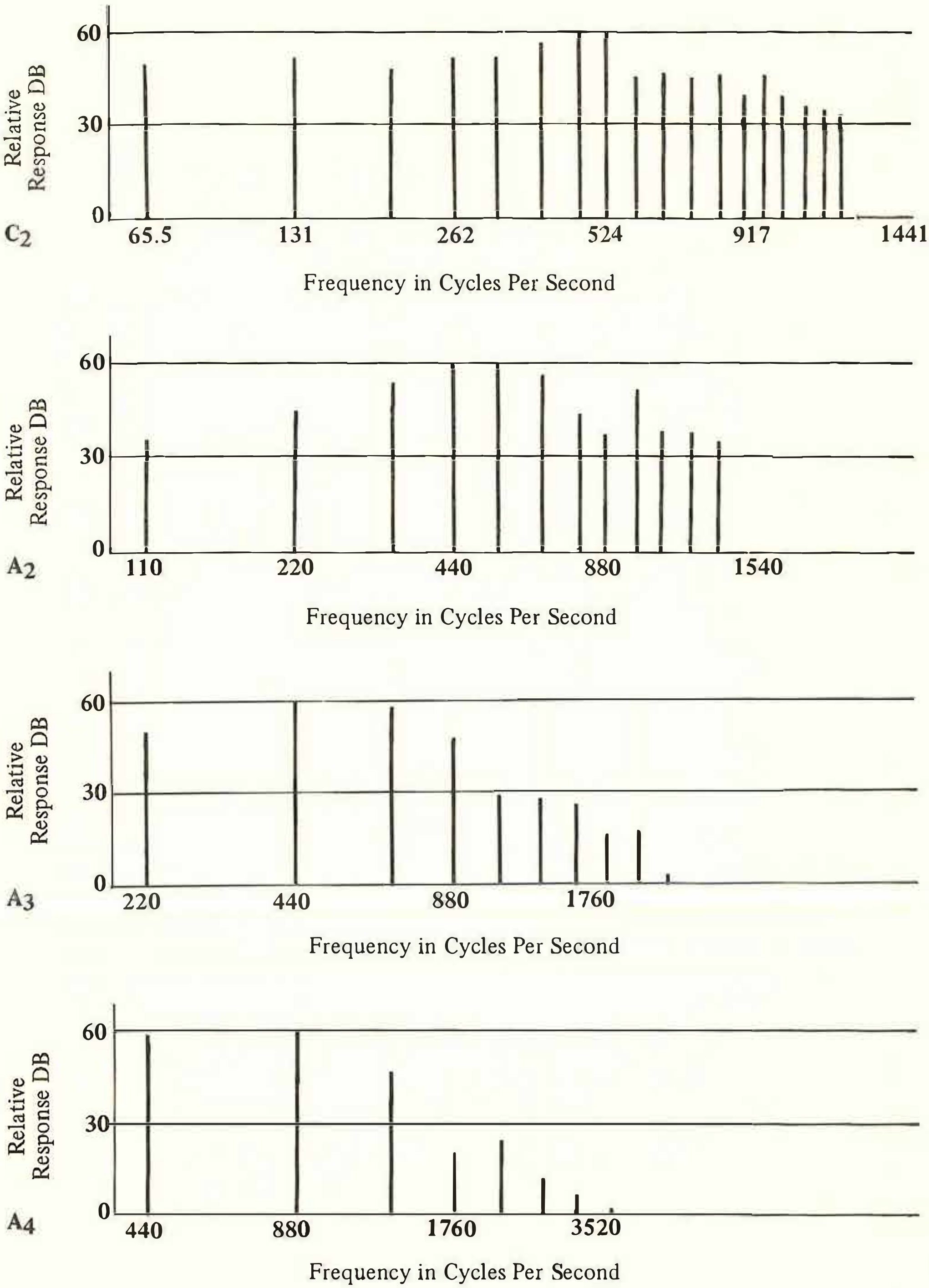


FIGURE 6

HARMONIC ANALYSIS OF REED No. 6

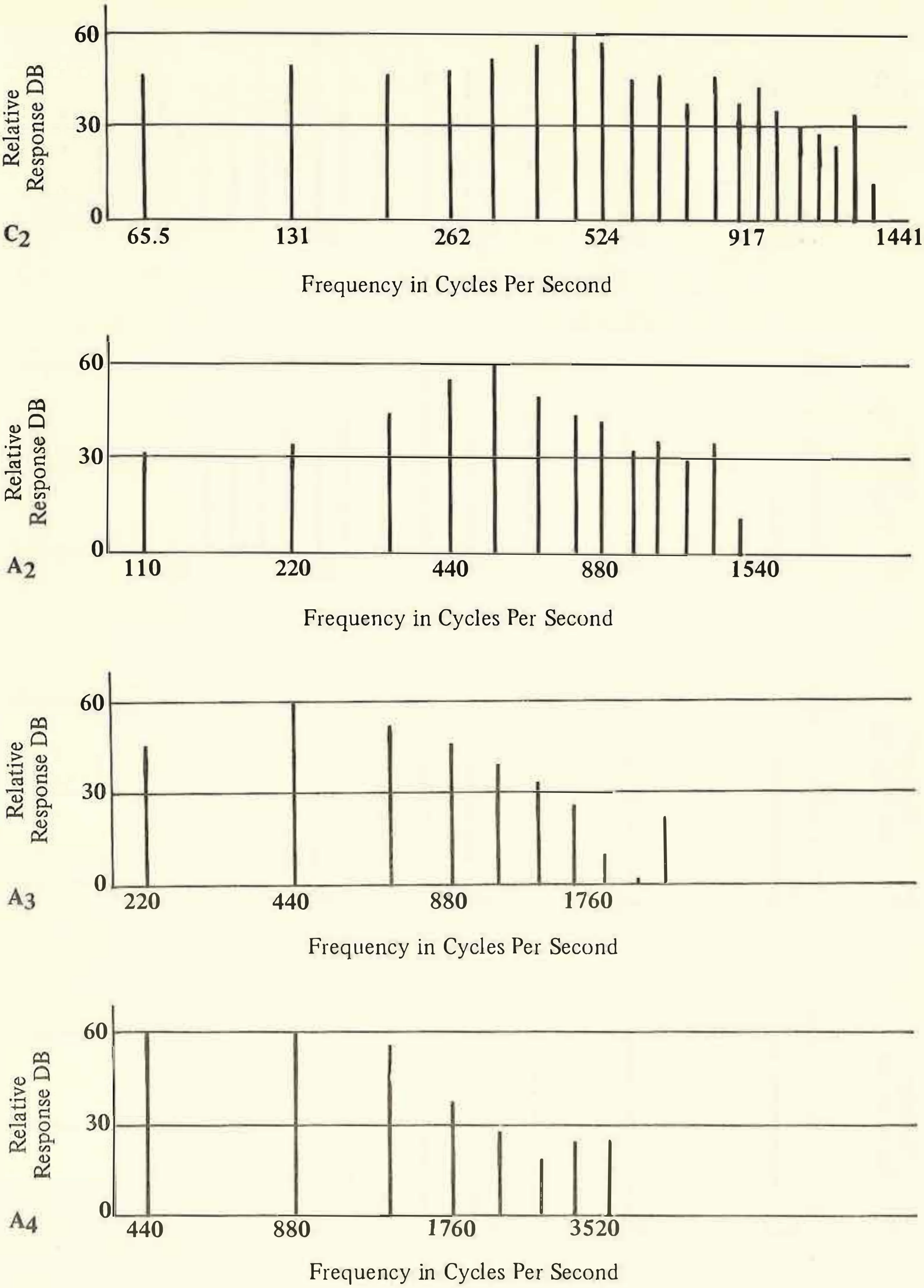


FIGURE 7

HARMONIC ANALYSIS OF REED No. 7

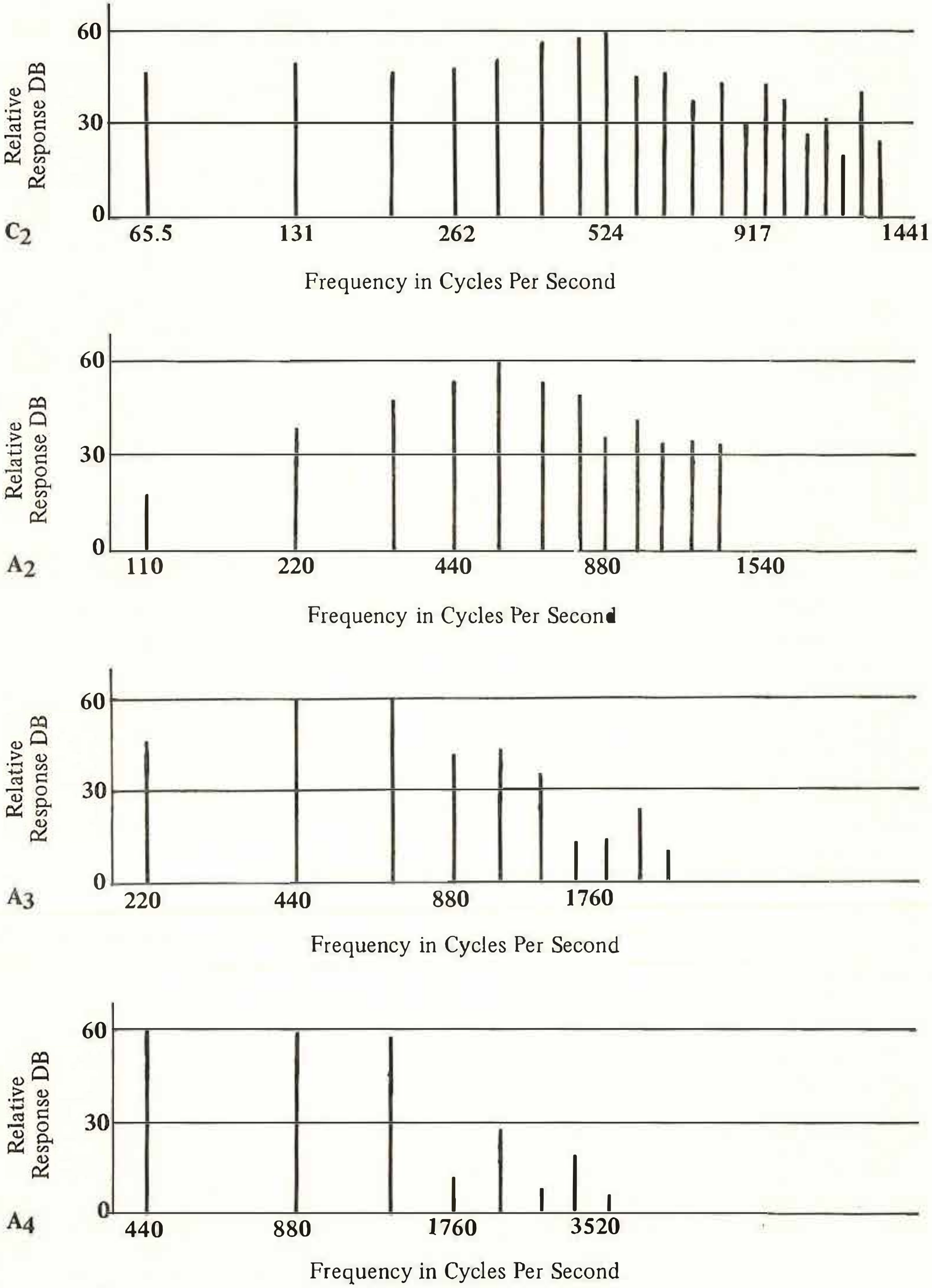


FIGURE 8

HARMONIC ANALYSIS OF REED No. 8

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

It will be remembered that it was the purpose of this study to investigate two of the eight problems listed in conjunction with the selection of cane for the making of bassoon reeds, the effect of hardness, and the effect of stiffness on tone quality.

In general the eight problems mentioned above can be categorized into three groups: (1) the mechanics of the reeds; (2) the size and shape of the reed; and (3) the material from which the reeds are constructed. This study has confined its objectives to the third group.

An attempt was made:

(1) To investigate two of the problems concerned with cane selection;

(2) To show, by means of harmonic analysis, the effect of hardness and stiffness of cane upon tone quality. The writer wishes to point out the fact that any harmonic analysis made by a mechanical device cannot at the present time give a complete analysis of what the human ear hears;

(3) To make recommendations as to how this study can be of use to other reed makers.

In summarizing the study, the author wishes to point out the major findings:

(1) Following is a list of the pieces of cane in rank order of hardness when tested dry:

1
6
4,7
8
5
2
3

The rank order of hardness when tested wet was as follows:

1
5,6
2
4
8
3
7

It will be noted that in general, the rank orders follow a similar pattern when tested wet and dry. This fact suggests that perhaps one testing might be sufficient.

(2) The cane segments which tested harder when wet than when dry were obtained from the same source;

(3) Cane numbers 1, 3, and 4 tested approximately the same when dry and wet;

(4) Following is a list of the pieces of cane in rank order of stiffness:

1
5
2
3
6
7
8
4

Based upon magnitude of recovery five minutes after unloading, the rank order of the cane numbers was:

1
2,3,4
6,7
5,8

(5) The stiffer the cane, the more prominent were the tenth and eleventh partials and the weaker was the fundamental for the pitch A_2. For the pitch A_3, the most prominent partial was the ninth;

(6) The piece of cane that tested softest also tested least stiff and had the largest amount of recovery. The harmonic analysis of the reed made from this cane is shown in Figure 1;

(7) The partials in the vicinity of 440 and 880 vibrations per second tended to be the strongest for all tones. This observation confirms to a degree the formant theory that the characteristic tone quality of an instrument is due to the relative strengthening of whatever partials lie within a relatively fixed region of the musical scale.

Conclusions and Recommendations

The results of the foregoing study give evidence to the fact that the following conclusions and recommendations are justified:

(1) Cane in which there is a positive correlation between hardness, stiffness and amount of recovery makes the best reeds regardless of the strength desired by the performer;

(2) Cane may be discarded if it tests either stiff and soft, or hard and flexible;

(3) Because of the simplicity of the apparatus used in the stiffness test, it is suggested that reed makers use this test;

(4) The validity of the hardness test is questionable, because the structure of cane makes it impossible to produce consistent readings using the Rockwell Superficial Hardness Tester;

(5) Cane from the same growth tended to test approximately the same hardness;

(6) Cane that tested the softest was also the least stiff and had the greatest amount of recovery. This cane, in the opinion of the writer, made the best reed;

(7) Amount of recovery of a piece of cane is one of the most important problems associated with the tone quality and response of a finished reed; therefore it is suggested that extensive investigating be done on this problem.

The reader should take into consideration that the foregoing conclusions are based on limited data and are to a certain degree the results of personal opinions; consequently the following recommendation is made: that the reed maker construct an apparatus similar to the one in Plate V and subject his cane to the stiffness test described in Chapter III. After a number of pieces of cane have been tested one will discover the stiffness of cane that suits his particular taste. He will also discover that these pieces of cane will not always make good reeds because of the many other variable factors, but he will be able to discard most of the inferior cane.

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