A STUDY OF MUTES FOR TUBA

THESIS

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By

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PREFACE

One problem in tuba performance is the use of a mute for the tuba. With no research existing a tubist has two methods with which to gain knowledge about mutes; he can learn by trial and error or he can consult a tubist having more experience with the problem.

A source is needed to aid a tubist in locating information on mutes for tuba. By learning more about the uses of mutes, the availability of mutes, and the effects of mutes on tuba performance, a tubist will be better equipped to select a mute for personal use. This study is designed to provide, objectively, that knowledge to the tubist.

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STATEMENT OF THE PROBLEM

The Purpose

The purpose of this study was to determine what mutes are available for the tuba, how these mutes are constructed, how a tuba mute can be constructed, and how these mutes affect tuba performance.

Sub-Problems

1. What mutes are available for the tuba?

2. What materials and methods are employed in the construction of tuba mutes?

3. What considerations are involved in the design and construction of a tuba mute?

4. What intonation discrepancies occur when a mute is added to the tuba?

5. What is the acoustical structure of tones produced by the muted tuba compared to those of the unmuted tuba?

Definition of Terms

1. The "mute" is a mechanical device for softening or muffling the tone of a musical instrument.

2. The term "tuba" refers to a large, low-pitched brass instrument that is basically conical in bore and utilizes valves to alter its pitch.

3. The phrase "intonation discrepancies" refers to any changes or differences in pitch.

4. The term "acoustical structure" refers to the series and relative strength of the partials present in each tone studied.

5. The term "tonal spectrum" is used interchangeably with the term "acoustical structure."

Delimitations

1. With one exception commercially available mutes were included in this study.

2. Five performers were used in the testing of the mutes. This number was determined by the availability of competent tubists. It was also felt that a representative sampling could be obtained from five performances on each of the mutes.

3. Only one tuba and mouthpiece was used in this study. Any changes in intonation or acoustical structure of tones could then be attributed to the use of a mute.

Basic Hypothesis

The basic hypothesis of this study was that the use of different mutes in conjunction with a tuba would cause certain changes in both the pitch and acoustical structure of tones.

Basic Assumption

1. It was assumed that the six mutes discussed in this study were representative of mutes available in the United States and England.

2. It was assumed that five performers would be sufficient to determine intonation discrepancies and acoustical structures of tones of a muted tuba as compared to an unmuted tuba.

3. It was assumed that a reasonable mute could be constructed without access to sophisticated tools and machinery.

Methodology

To determine the availability of mutes, known mute manufacturers were contacted and asked for details concerning their tuba mutes. The methods used to contact the manufacturers were correspondence, personal interview, and telephone conversations. Information obtained from the manufacturers can be found in Chapter III, Appendix C, and Appendix D.

To supplement information supplied by mute manufacturers, six mutes, representative of those available, were obtained. Personal observation and measurement of each mute aided in determining materials and methods employed in construction.

In order to better understand the problems of designing and constructing a tuba mute, a mute was built as part of the study. Careful examination of other similar mutes and certain mathematical computations helped determine the design from which an experimental mute was constructed.

Two tests were devised to enable comparison of the various mutes. A tape recording was made of each of the five tubists playing a pre-selected musical example unmuted and with each mute. After being edited the tape was used to test any changes of intonation or acoustical structure of tones that might be caused by the mutes.

Plan for the Report

Chapter II, "Background for the Study," is divided into three sections: (1) development of the mute, (2) uses of the tuba mute, and (3) related literature. A general explanation of the development and evolution of the mute for brass instruments is given. Several examples of the use of the tuba mute in various mediums are listed. Related literature is concerned with a previous study in this general area.

Chapter III, "Availability and Specifications of Tuba Mutes," presents as complete information as possible about mutes known to be presently available.

Chapter IV, "Constructing a Tuba Mute," deals with the problems facing a mute maker and how some of these problems are solved.

Chapter V, "Testing the Tuba Mutes," explains how the mutes were tested, the equipment used in these tests, and the results of the tests.

Chapter VI, "Summary, Conclusions, and Recommendations," is a statement of the results of the study with conclusions and recommendations drawn from these results.

CHAPTER II

BACKGROUND FOR THE STUDY

Development of the Mute

One of the earliest known mutes for brass instruments was a trumpet mute mentioned by Praetorius in 1619 (3, p. 1044) and illustrated in Mersenne's Harmonie Universelle in 1636 (2, p. 330). This prototype was made of wood and was hollow throughout (Figure 1). In addition to being used in funeral music, this mute was also used by armies for sounding signals when the enemy stood close by.

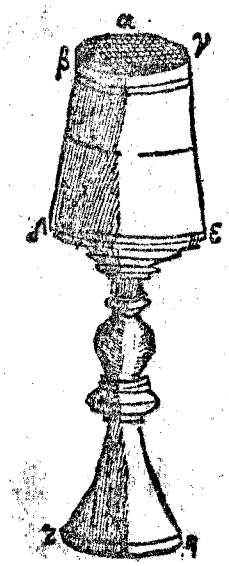

Fig. 1--Early Trumpet Mute

It was generally agreed that the use of this early mute raised the pitch of the trumpet one whole tone. To compensate for this difference orchestral players exchanged crooks in their trumpets to lower the pitch one whole step.

Use of the mute can be dated back as far as 1607 when Monteverdi scored for the mute in his Orfeo (3, p. 1045). In Haydn's Symphony No. 102 (1795) the entire second movement is muted in both the trumpets and French horns. The second finale of Mozart's Magic Flute (1791) requires muted trumpet.

From its early forms the mute has progressed to such a degree that it is found in several shapes and is made of various materials. Probably the most widely-used shape is the one incorporated in the straight mute (Figure 2). The straight

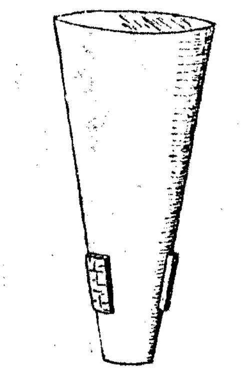

Fig. 2--Straight Mute

mute is basically conical in shape, with the wide end closed. It is commonly made of fiber or compressed cardboard but recent developments have brought into use other materials such as aluminum and plastic.

The brass instruments using mutes most frequently are the trumpet, trombone, and French horn, with the horn also requiring hand-stopping. The muted tuba is used less frequently; however, several twentieth-century composers are currently scoring for muted tuba.

Uses of the Tuba Mute

One of the earliest compositions requiring muted tuba is Don Quixote, written by Richard Strauss in 1897. At least two other orchestral works by Strauss, Ein Heldenleben (1898) and Salome (1906), included muted parts for tuba. Other orchestral compositions making use of the muted tuba are Petrouska by Igor Stravinsky, Wozzeck by Alban Berg, Pictures at an Exhibition by Modest Mussorgsky (orchestrated by Ravel), and Schoenberg's Theme and Variations.

Donald Swann's Two Moods (for tuba and piano) is an example of the use of the muted tuba. The solo begins with a slow section of muted tuba, creating a tonal contrast with the fast, lively section that is played without mute. Leonard Bernstein's Waltz for Mippy III (solo tuba and piano) ends with a short muted phrase, giving the piece an added dimension. Possibly even more interesting is Durations III (for violin, tuba, and piano) by Morton Feldman which is scored with muted tuba throughout.

Two compositions for brass quintet requiring muted tuba are Quintet for Brass by Gunther Schuller and Quintet for Brass by Alvin Etler. Music for Brass and Percussion, a composition by Schuller for brass choir, indicates the use of the mute for the second tuba part only.

Related Literature

A Study of the Acoustical Effects of Mutes on Wind Instruments by Martin J. Kurka (1) is currently the only study available dealing with the acoustical aspects of muted brass instruments. In this study Kurka tested the effects of mutes on the sound intensity of the instrument, on the pitch of the instrument, on the sound field of the instrument, and on the formant of the instrument. He included only those trumpet, trombone, and French horn mutes that were commercially available at the time of his study; no tuba mutes were included.

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CHAPTER III

AVAILABILITY AND SPECIFICATIONS OF TUBA MUTES

Currently available to the tubist are approximately one dozen tuba mutes. Most of these mutes are commercially made, but a few are custom made and limited in quantity. The materials used in the manufacture of these mutes varies, with everything from vulcanized fiber to aluminum being utilized. The basic shape in nearly all the mutes is straight, with the sizes varying somewhat. A listing of available mutes with their current prices is included in Appendix C. The addresses of known mute manufacturers can be found in Appendix D.

One mute, not currently available but deserving special mention, is the Gossick mute (1). Ben Gossick, who is Chairman of the Department of Physics and Astronomy at the University of Kentucky, has developed a new type of mute for brass instruments including the tuba. The Gossick mute is made of brass and is cup-shaped in such a manner that it attaches to, rather than fits inside, a tuba. An interesting feature is a center orifice which allows a variety of threaded attachments (such as a trumpet bell) to be screwed into the mute.

Another mute deserving special mention is the Kincaid mute. Designed and built by Michael Kincaid, it is available from the Tennessee Technological University Chapter of Tubists Universal Brotherhood Association in Cooksville, Tennessee, at a price of $25.00. The Kincaid mute became known to the author too late to be included in this study.

The Accura mute (Figure 3) is one of the more widely available mutes. It is made of embossed alloy aluminum with a Philippine mahogany plywood top. Rivets are used to hold the aluminum together and a leather scuff ring is attached to the bottom edge to prevent scratches to the tuba bell. A

Fig. 3--Accura mute and Aulos mute

handle is attached on the side of the mute near the top to facilitate easy insertion into and removal from the tuba. The height of the Accura mute is 27 5/8 inches, the top diameter is 11 1/2 inches, and the diameter of the bottom is 2 1/8 inches.

The Aulos mute (Figure 3) was designed by Ted Griffith and is essentially hand-made by William Cook, instrument repairman at Aulos, Incorporated. The main body of the mute is constructed from Spaulding vulcanized fiber with the top being cut from one-half-inch birch plywood. The construction techniques employed are gluing and clamping. Two handles are placed on the mute, one on the top and one on the side near the top. The height of the mute is 24 inches, diameter of the top is 10 1/8 inches, and the bottom diameter is 5 1/8 inches.

The most unique feature of the Aulos mute is its tuning chimney (Figure 4). According to the manufacturer, rotating

Fig. 4--Tuning chimney of the Aulos mute

this chimney changes the resonance of the mute, thus changing its pitch. The chimney is actually two tubes, one of which fits snugly inside the other. Rotating the inside tube causes certain holes in the two tubes to align. The mute has four settings ranging from 0 (no holes open) to 3 (three holes aligned and open). Turning the chimney from 0 to 3 raises the pitch of the mute.

Humes and Berg Manufacturing Company has available seven different models of tuba mutes. Model 190 is designed to be used on tubas having bells up to 25 inches in diameter. Its dimensions are: height--20 1/4 inches; top diameter--14 7/8 inches; and bottom diameter--4 1/8 inches. The model 190 illustrated (Figure 5) is made primarily with a heavy metal, using rivets as fasteners.

The Humes and Berg Model 193 (Figure 5) is designed to accommodate bell sizes from 14 inches to 18 inches in diameter. The body of the mute is constructed from fiberboard and the

Fig. 5--Humes and Berg mutes--Model 193 and Model 190

top is made of wood. The height of Model 193 is 19 1/2 inches, the top diameter is 8 3/4 inches, and the diameter of the bottom is 4 1/2 inches. This mute also has an adjustable tuning slide which, unlike the Aulos mute, moves in and out of the mute.

Model 194 by Humes and Berg is a straight mute designed for E-flat tubas. It is similar to Model 193, but does not have the adjustable tuning slide. The Model 197 is another straight mute and has been designed specifically for the William Bell Model of Meinl-Weston tubas.

According to Humes and Berg, two other straight mutes are available. Model 195 is a curved model of a straight mute designed to fit a recording bass (i.e. a tuba with the bell facing forward). Model 196 is also a curved model, but is for a sousaphone.

The Velvet-tone mute, Humes and Berg Model 191, is a bucket mute designed to clip onto rather than being inserted into the bell. It is the only mute of this type available for the tuba. The purpose in its design is to mellow the sound.

The Lea mute, hand crafted to personal customer specifications, is made by James Lea of London. Each customer is required to furnish a paper pattern showing the dimensions and taper of the bell of his tuba. From this pattern Mr. Lea designs and constructs the mute. The body of the mute is made from vulcanized fiber and the top is formed from traffolite engraving formica one-eighth-inch thick. The fiber is molded under steam into the mute shape and, after being assembled, is covered with a hard coating of polyurethane varnish. A leather strap attached to the top is used for a handle. The dimensions of a Lea mute (Figure 6) designed specifically for a Meinl-Weston CC tuba (standard model) are: height--26 1/4 inches; top diameter--11 3/4 inches; and bottom diameter--4 1/4 inches. This mute is probably the most difficult to obtain, as Mr. Lea accepts only a limited number of orders.

The Mirafone mute (Figure 6) exhibits excellent craftsmanship. It is made entirely of birch plywood, a feature not found in any other mute. A handle is attached to the top of the mute to facilitate handling. The mute is 25 1/2 inches high, and its top and bottom diameters are 9 1/8 inches and 2 3/8 inches respectively.

Fig. 6--Lea mute and Mirafone mute

In the United States and England there are about twelve mutes currently available to the tubist. Most of these mutes can be classified as being straight mutes, although curved models of straight mutes and bucket mutes are also available. Materials used for construction vary, with vulcanized fiber being used frequently. Almost all the mutes had tops made of some type of plywood. The sizes and shapes of the different mutes, while similar in some respects, did vary to some degree. A good example is the Humes and Berg Model 193, compared to the Model 190 (see Figure 5).

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CHAPTER IV

CONSTRUCTING A TUBA MUTE

The project of constructing a tuba mute was undertaken for four reasons:

(1) to better understand the problems involved in mute making;

(2) to determine if a mute can be made without access to sophisticated tools and machinery;

(3) to decide the feasibility of an average tubist making his own mute;

(4) to determine the expense of constructing a mute.

The materials of construction were selected primarily on the basis of availability. Birch plywood one-fourth inch thick was used for the top of the mute and for the bracing in the bottom of the mute. For the body of the mute a flexible, durable material was needed. Vulcanized fiber was considered to be a suitable material for this purpose but was not available locally. (Vulcanized fiber is available from Spaulding Fibre Company in Tonawanda, New York. Minimum order is $100.) Brown press board, although not as durable, was substituted. The cork spacers were cut from a cork sheet three-sixteenths inch thick.

The mute was designed to have the same taper as the Mirafone Model 186-4U CC tuba. The taper of the bell section of the Mirafone tuba was found to be approximately 7 degrees. Measurements, to be valid, were taken below the flare of the bell.

To simplify computation a diagram representing a section of the bell was drawn showing the various dimensions. By using the formula, sine A = $\frac{a}{h}$ with <u>a</u> equaling .398 and <u>h</u> equaling 6.75, then sine A is .05896 and angle A is approximately 3 1/2 degrees. Since triangle ABC is a right triangle (see Figure 7) then angle B is 86 1/2 degrees. And since angle B and angle B' are equal then angle E is 7 degrees.

Using essentially the same method, dimensions for an experimental mute were obtained. These dimensions were: top diameter--8 7/8 inches; bottom diameter--6 inches; and height--22 5/8 inches. In order that the assembled mute might have these dimensions, the top must have a circumference of 27 3/4 inches and the bottom must have a circumference of 18 7/8 inches. It was found that an extra 1/2 inch must be added to these dimensions to allow overlapping of the edges during assembly.

Using an ordinary saber saw, the top was cut from one-quarter-inch birch plywood such that it would fit inside the top of the mute. To allow an exact fit inside the top edge of the mute, the diameter of the top was found to be 8 3/4 inches. To brace the bottom of the mute a plywood ring was

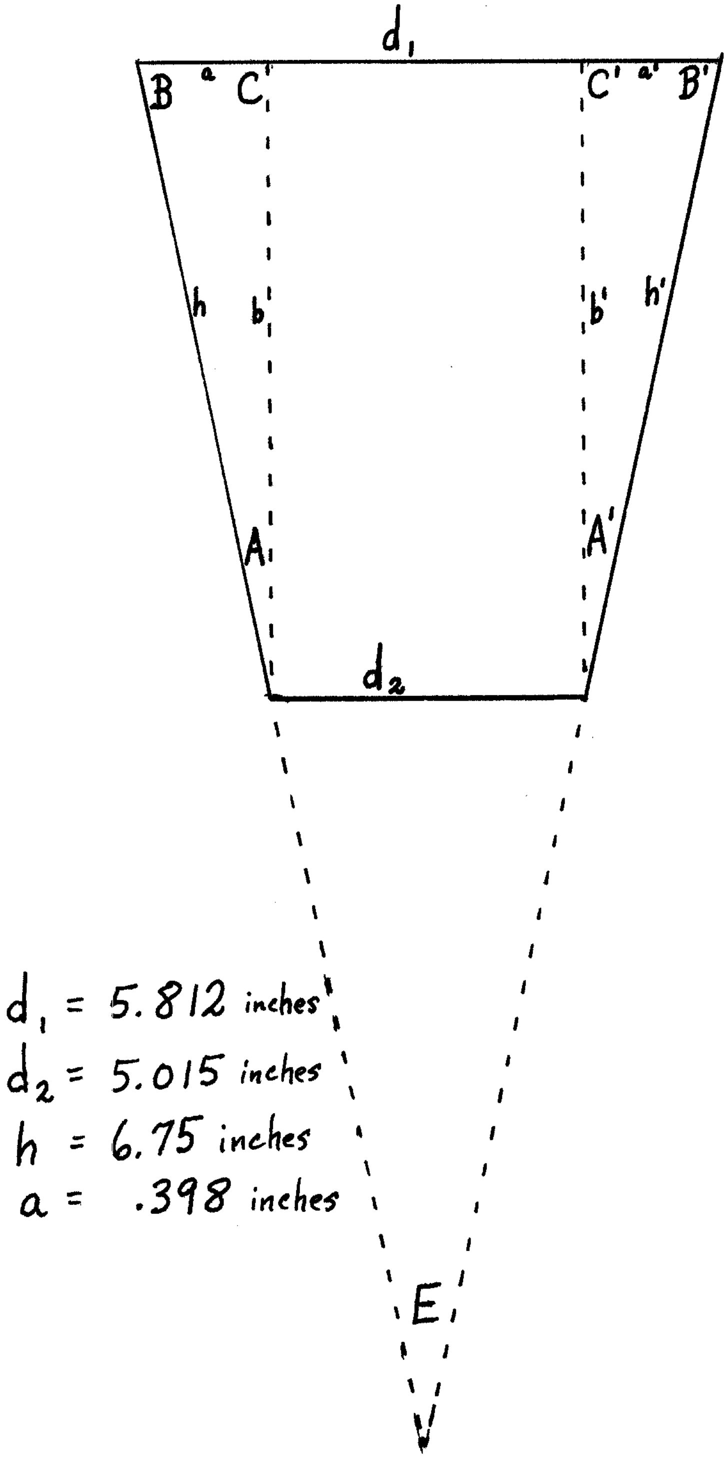

Fig. 7--Diagram showing taper of Mirafone tuba

cut with an inside diameter of 4 1/8 inches and an outside diameter of 6 inches.

For the assembled mute to have the correct shape, a pattern was designed from which the body of the mute was cut. (See Figure 8.) To obtain the correct curve in the pattern, a compass with a radius of approximately fifty inches was needed. Since a compass of this size was not available, a suitable substitute was devised using a pencil attached to

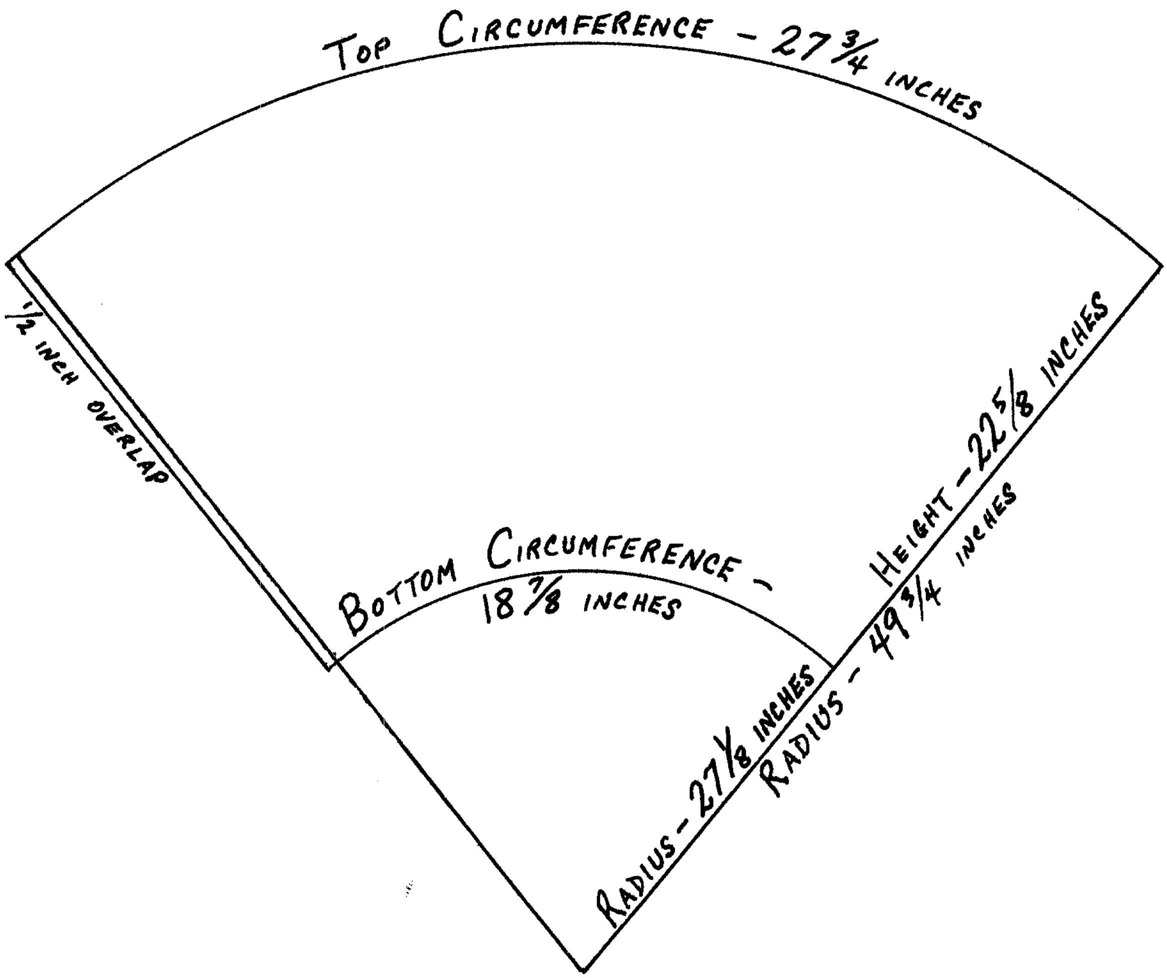

Fig. 8--Pattern for experimental mute

one end of the proper length of wire. Although crude, this compass worked satisfactorily, enabling a fairly accurate pattern to be made.

The mute (Figure 9) was assembled by first gluing the overlapping edges together using contact cement. Then the bottom brace and the top were glued in place with white glue. For appearance the mute was painted black. Four equally spaced strips of cork were glued to the edge of the mute.

Fig. 9--The experimental mute

Because the mute was found to play quite sharp, one modification was included in the final design. By experimentation it was discovered that a tube (or cylinder) inserted lengthwise into the bottom end of the mute acted as a tuning device enabling the pitch to be lowered. Pulling the tube out from the mute had the effect of extending the mute further into the tuba. The Humes and Berg Model 193 mute has the same feature incorporated in its design. (See Chapter III, page 13.) The tube, which is hollow, is 19 1/4 inches long and 4 1/8 inches in diameter. (See Figure 10.) It was also constructed from the brown press board.

The actual cost of the raw materials used in building the experimental mute was negligible. The brown press board, from which the body and tube were cut, cost $1.00. The top of the mute was cut from a sheet of plywood costing $10.00. Approximately fifty tops could be cut from this sheet of plywood resulting in a cost of $.20 per top. The cork strips were cut from a sheet of cork costing $2.00 and the paint and glue cost another $2.00. The total cost of the experimental mute was approximately $2.00.

The amount of time spent in designing the mute, locating the materials, and actually constructing the mute was considerable. Designing the mute was by far the most time-consuming part of the project. Total time spent was approximately thirty hours.

As a result of this project it has been found that one of the biggest problems facing a mute manufacturer is that of design. The most careful planning of design does not necessarily guarantee a good mute. Sometimes modifications must be included.

It has been determined that a tuba mute can be constructed using common hand tools. Having access to more sophisticated

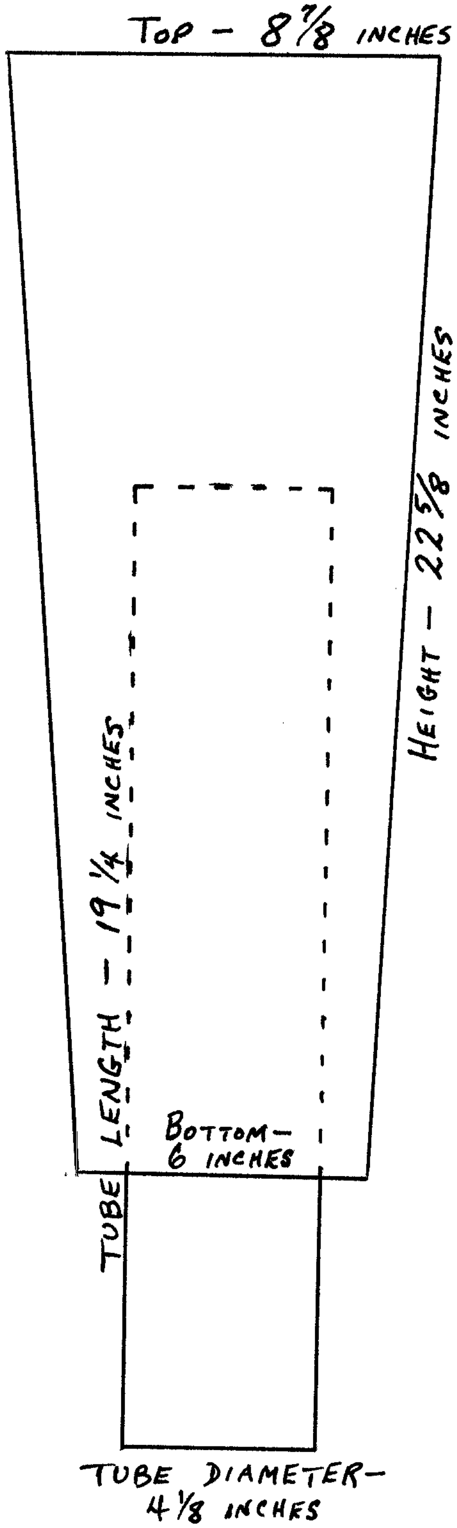

Fig. 10--Diagram of modification to the experimental mute.

equipment such as a band saw and specially devised gluing clamps would certainly ease the task of construction.

Because of the great amount of time involved in the design and construction of a tuba mute, it is not considered feasible for the average tubist to build his own mute. If he should have the time and inclination to design, construct, and experiment on a mute, then the average tubist could probably build an acceptable mute. Purchasing a mute of known design and quality is probably the best choice for most tubists.

CHAPTER V

TESTING THE TUBA MUTES

Two tests were devised to demonstrate any changes in pitch of the acoustical structure of tones resulting from the addition of a mute to a tuba. These tests were designed to be both objective and accurate.

The seven mutes selected for testing were the Accura, the Aulos, the Humes and Berg Model 193, the Humes and Berg Model 190, the Lea, the Mirafone, and the experimental mute discussed in Chapter IV. Five tubists were selected to play the tuba with each of the seven mutes. The same tuba, a Mirafone Model 186-4U CC, and the same mouthpiece, a Bach 18, were used for all tests. A short musical example (Figure 11) encompassing a two octave range was selected.

Fig. 11--Musical example used in the testing

Each tubist played the example eight times, once unmuted and once with each of the seven mutes. A tape recording was made using a condenser microphone (RCA), a tape deck (Ampex Model 354), and professional quality recording tape (Ampex 406). The resulting tape recording was edited into two tapes; tape A contained only the first six measures of the example and tape B contained the last nine measures.

Tape B was used in testing intonation discrepancies of each mute. Although the musical example was played in the sequence A-B, tape B was treated first to allow a better explanation of the results of the tests. A Sony Model TC-252 tape recorder was used to play back the tape. The signal from the recorder was sent through a low pass filter (Model 1952 General Radio Universal). The signal was then sent to an EMR subcarrier pitch discriminator which extracted the fundamental of each pitch and changed it into a square wave. The resulting square wave was recorded on an Easterline Angus chart recorder.

The information recorded on the chart indicated the pitch's frequency in Hz* and its duration. Using pitches produced by the unmuted tuba as constants, the pitches played with each of the mutes in the tuba were determined as being the same, higher, or lower. This information was recorded and averaged and can be found in Table I, Pitch Deviations in

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*Hz, abbreviation for Hertz, is synonomous with the term "cycles per second."

Hertz Resulting from the Use of Different Mutes, and in Appendix A.

Table I shows the average pitch deviations measured in Hz caused by the use of different mutes. The plus (+) symbol indicates a pitch higher than that of the unmuted tuba; a minus (-) symbol indicates a lower pitch. Therefore the note A played on the Accura mute was .70 Hz higher than the same note played unmuted.

An interesting phenomenon occurred with four of the mutes: the Accura, the Aulos, the Mirafone, and the experimental mute. In the lower register these mutes caused the fundamental to disappear or be so weak as to be unmeasurable. In the pictures of the acoustical structure of these tones (see Appendix B), the absence of the fundamental can be seen.

All of the mutes tested had certain intonation discrepancies. The Accura mute and the Aulos mute, although sharp in pitch, were the most consistent, having the least variation throughout the two-octave scale. On this basis alone it could be assumed that these two mutes could be played better in tune with fewer adjustments made to the tuba.

The Humes and Berg Model 193 and the experimental mute appeared to be rather inconsistent in pitch and probably would require more frequent adjustments by the tubist. The Lea mute and the Mirafone mute were consistent throughout most of the range, but the two highest notes were extremely sharp.

TABLE I

PITCH DEVIATIONS IN HERTZ RESULTING FROM THE USE OF DIFFERENT MUTES

Note*	Mute #1**	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
c'	+2.20	+1.64	+0.92	+3.32	+4.48	+4.44	+1.08
b	+2.28	+2.08	+1.64	+3.06	+4.92	+5.12	+0.88
a	+1.04	+1.40	+1.44	+0.88	+3.36	+2.92	+0.16
g	+0.44	+1.00	+0.42	+0.64	+3.00	+2.20	-0.92
f	+0.38	+0.48	+0.52	+0.20	+2.32	+1.80	-0.80
e	+0.88	+0.48	+0.76	+0.56	+2.48	+1.92	-0.56
d	+0.64	0	+1.72	+0.68	+2.56	+1.76	-1.00
c	+0.32	+0.76	+1.12	-0.28	+2.40	+0.96	-1.40
B	+0.58	+0.70	+1.18	+0.06	+2.18	+1.22	-0.50
A	+0.70	+1.14	+2.10	+0.34	+1.34	+1.54	+0.18
G	+0.82	+1.50	+0.18	+0.06	+1.78	+1.88	+0.04
F	+1.58	+1.74	+0.86	+0.96	+2.26	+2.24	+0.64
E	+0.56	+1.56	+1.08	+0.56	+1.86	+2.20	+0.52
D			+0.52	+0.32	+1.36	+1.80	+0.28
C			+1.52	+0.78	+2.45		

*C denotes two octaves below middle c; c is one octave below middle c; and c' is middle c.

**Each mute was assigned a number. The names of the mutes and their corresponding numbers are as follows:

Accura (1)
Aulos (2)
Humes and Berg Model 193 (3)
Humes and Berg Model 190 (4)
Lea (5)
Mirafone (6)
Experimental mute (7)

Tape A was used in determining the acoustical structure of tones played unmuted and with each of the seven mutes. The equipment used for these tests was a Sony Model 350 tape deck, a Panoramic Sonic Analyzer Model LP-laZ, and a Hewlett-Packard Model 197A oscilloscope camera.

Tape A was played back on the Sony tape deck into the sonic analyzer, a device for determining visually the frequency-energy distribution of a signal or group of signals in the 20 Hz to 22,500 Hz range. The oscilloscope camera, with its Polaroid back, was attached to the sonic analyzer, enabling pictures to be taken and developed in a short amount of time.

Figure 12 shows a fundamental tone with six overtones present. The frequencies are read on the horizontal scales at the top and bottom of the screen. For this study the linear scale at the top was used with each marker representing 100 Hz. The amplitude of the partials is read vertically on the left scale. For purposes of this study the equipment was set for decibel readings (logarithmic amplitude), allowing the partials to be read in relation to each other. Figure 12 can therefore be read as follows:

(1) first partial is about 100 Hz and seventeen decibels above the second partial;

(2) second partial is about 200 Hz and seventeen decibels below the fundamental,

(3) third partial is about 300 Hz and five decibels below the second partial,

(4) fourth partial is about 390 Hz and two decibels below the third partial,

(5) fifth partial is about 480 Hz and six decibels below the fourth partial,

(6) sixth partial is about 580 Hz and ten decibels below the fifth partial,

(7) seventh partial is about 680 Hz and ten decibels below the fifth partial.

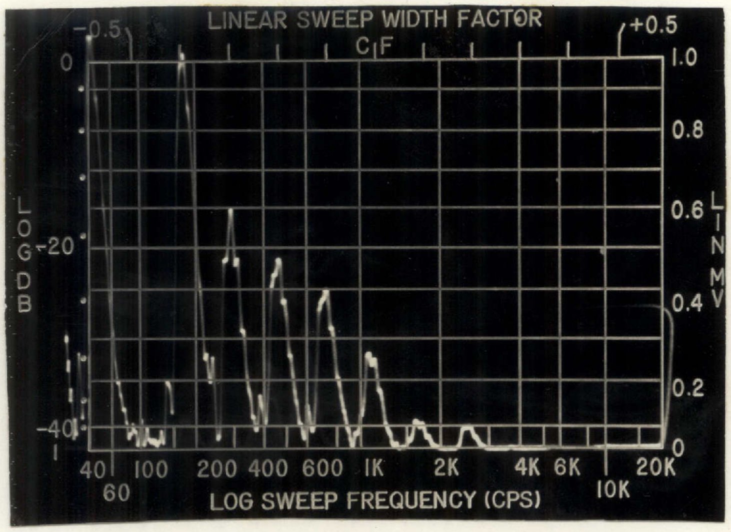

Fig. 12--Tonal spectrum of the note G

Each partial is progressively weaker in strength, or amplitude. Referring to a frequency chart (1, p. 95) Figure 12 can be computed as being a tonal spectrum of the note G.

Preliminary investigation showed the tonal spectrums produced by the different mutes to be similar regardless of the person playing the tuba. For this reason only selected notes played by one performer were used for this test (Appendix B contains the photographs of all the tonal spectrums of the notes tested).

As mentioned earlier, several of the mutes caused the fundamental to be weakened considerably. This is readily noticeable in the Aulos and the Mirafone mutes when the note C is played. (See Appendix B.) When the note c is played, however, the fundamental is present. Possibly these two mutes do not have the capacity to adequately produce the lower notes.

Most of the mutes tended to strengthen the upper partials. This is especially noticeable in the tonal spectrums for the note c. Kurka found essentially the same trend for trumpet straight mutes (2, p. 28).

The tonal spectrum of one mute, the Humes and Berg Model 193, was similar to that of the unmuted tuba. The pictures of the notes C and c' show this similarity. One possible explanation is that the muted tone sounds the same as the unmuted tone except that the volume is reduced. This cannot be verified because of the subjectivity of comparing sounds.

Other than weakening the fundamental (in certain situations) and strengthening the upper partials, the mutes apparently did not have any other pattern. With a variety of tonal spectrums produced by the different mutes, it may be concluded that the design and/or the materials of construction (i.e. aluminum, fiberboard, or wood) have a definite effect on tuba performance.

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CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to determine what mutes are available for the tuba, how these mutes are constructed, how a tuba mute can be constructed, and how these mutes affect tuba performance. The sub-problems were the following:

1. What mutes are available for the tuba?

2. What materials and methods are employed in the construction of tuba mutes?

3. What considerations are involved in the design and construction of a tuba mute?

4. What intonation discrepancies occur when a mute is added to the tuba?

5. What is the acoustical structure of tones produced by the muted tuba compared to those of the unmuted tuba?

Information regarding mutes available for purchase was obtained by contacting known mute makers. Individual specifications of mutes was provided, in part, by information supplied by mute makers and also by inspection of the mutes. The materials used to construct mutes have varied, with vulcanized fiber, aluminum, and thin plywood being used most frequently. For the tops of mutes plywood was used almost exclusively. Handles were provided on all the mutes although the location of the handle differed in some instances.

Further insight into the various problems of mute making was gained by the construction of an experimental mute. Designing a better mute was found to be the most perplexing problem and the most difficult to solve.

The mutes selected for testing were representative of those used by tubists. Each manufacturer was represented with at least one model. Two tests were conducted on each mute; one to show any intonation discrepancies and the other to show the acoustical structure of certain tones.

It was found that all mutes tested had intonation discrepancies. Analysis of the test results led to the conclusion that, on the basis of intonation, certain mutes would be easier to play in tune than others. Although causing the pitch to be sharp, these mutes, the Accura and the Aulos, were more consistent, having the least variation in pitch throughout a two-octave range.

Most of the mutes were found to intensify the strength of the upper partials and several were found to decrease the strength of the fundamental. Studying the photographs of the tonal spectrums revealed the absence of any pattern being formed. The conclusion is that the design or materials used for construction (or both) may be the major factors determining the acoustical structure of tones produced by the muted tuba.

Based on the information gained in this study, several recommendations can be made. The tubist needing to purchase a mute should attempt to personally inspect and play as many different mutes as possible, looking for quality in construction and consistency of intonation. Mute manufacturers, in designing and building new mutes, should attempt to construct mutes with fewer intonation problems without sacrificing tone production. Mutes should be light in weight and have handles conveniently placed for quick mute changes. Composers should be encouraged to write more for muted tuba, thereby aiding the development of an important aspect of tuba performance.

APPENDIX A

PITCH DEVIATIONS IN HERTZ RESULTING FROM THE USE OF DIFFERENT MUTES

NOTE: C

Name	Mute* #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+1.6**	NF***	+2.8	+1.9	+2.8	NF	+1.5
Bird	NF	NF	+1.2	+1.2	+3.2	NF	NF
Ross	NF	NF	+1.6	+0.6	+2.0	NF	NF
Kleeman	+0.8	NF	+1.0	+0.2	+2.0	NF	NF
Kaplan	NF	NF	+1.0	0	+2.2	NF	+0.6
Average			+1.52	+0.78	+2.45		

*Each mute was assigned a number. The names of the mutes and their corresponding numbers are as follows:

Accura (1)
Aulos (2)
Humes and Berg Model 193 (3)
Humes and Berg Model 190 (4)
Lea (5)
Mirafone (6)
Experimental Mute (7)

**A positive (+) sign indicates the pitch being higher compared to the unmuted tuba. A negative (-) sign indicates a lower pitch.

***The abbreviation "NF" means either no fundamental was present or the fundamental was too weak to be measured.

NOTE: D

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.4	NF	+0.9	+0.8	+1.6	+2.2	+0.6
Bird	NF	NF	+0.4	+1.2	+1.4	+2.0	0
Ross	+0.4	NF	+0.8	+0.2	+2.0	+1.6	+1.2
Kleeman	+0.8	NF	+0.1	-0.2	+1.2	+1.4	-0.4
Kaplan	NF	NF	+0.4	-0.4	+0.6	NF	0
Average			+0.52	+0.32	+1.36	+1.80	+0.28

NOTE: E

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.8	+2.0	+1.2	+0.4	+2.3	+2.6	+1.2
Bird	+0.4	+2.0	+0.4	0	+1.6	+1.6	0
Ross	+0.2	+1.4	+0.6	+1.0	+1.8	+2.2	+0.6
Kleeman	+0.8	+0.4	+2.0	+1.0	+1.6	+2.4	+0.4
Kaplan	+0.6	+2.0	+1.2	+0.4	+2.0	+2.2	+0.4
Average	+0.56	+1.56	+1.08	+0.56	+1.86	+2.20	+0.52

NOTE: F

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+1.6	+2.0	+1.2	+0.8	+2.1	+2.4	+1.2
Bird	+1.6	+1.9	+0.7	+0.4	+2.4	+2.0	0
Ross	+1.1	+1.2	+0.4	+1.2	+2.2	+2.0	+1.6
Kleeman	+2.0	+2.0	+1.2	+2.0	+2.8	+2.8	0
Kaplan	+1.6	+1.6	+0.8	+0.4	+1.8	+2.0	+0.4
Average	+1.58	+1.74	+0.86	+0.96	+2.26	+2.24	+0.64

NOTE: G

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+1.0	+1.8	+0.2	0	+2.0	+2.4	+0.1
Bird	+0.4	+1.2	-0.8	0	+1.6	+2.8	-0.2
Ross	+1.3	+1.5	+0.7	-0.1	+1.5	+1.1	+0.3
Kleeman	+0.6	+1.4	+0.6	0	+1.4	+1.4	-0.2
Kaplan	+0.8	+1.6	+0.2	+0.4	+2.4	+1.7	+0.2
Average	+0.82	+1.50	+0.18	+0.06	+1.78	+1.88	+0.04

NOTE: A

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.7	+1.1	+2.3	+0.1	+1.7	+1.5	+1.5
Bird	+0.8	+1.2	+2.4	+0.4	+2.0	+2.4	-0.4
Ross	0	+2.6	+2.4	+0.8	+1.6	+2.4	+1.0
Kleeman	+0.8	+0.2	+1.0	-0.8	+0.2	+0.2	-0.8
Kaplan	+1.2	+0.6	+2.4	+1.2	+1.2	+1.2	-0.4
Average	+0.70	+1.14	+2.10	+0.34	+1.34	+1.54	+0.18

NOTE: B

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	0	-0.4	+0.6	-1.2	+2.4	0	-1.6
Bird	+0.3	+1.1	+1.9	-0.1	+3.3	+1.9	-1.7
Ross	+0.4	+1.2	+1.0	+0.4	+2.0	+1.6	+1.4
Kleeman	+1.6	+0.8	+0.8	+0.4	+1.6	+1.4	0
Kaplan	+0.6	+0.8	+1.6	+0.8	+1.6	+1.2	-0.6
Average	+0.58	+0.70	+1.18	+0.06	+2.18	+1.22	-0.50

NOTE: c

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.6	+0.2	+0.6	-1.0	+2.6	+1.0	-2.2
Bird	-0.8	0	+0.8	-0.8	+2.0	+0.4	-4.0
Ross	+0.4	+1.2	+2.0	+0.4	+2.0	+1.6	+0.4
Kleeman	+1.6	+1.8	+1.6	+0.2	+2.4	+1.2	+0.2
Kaplan	-0.2	+0.6	+0.6	-0.2	+3.0	+0.6	-1.4
Average	+0.32	+0.76	+1.12	-0.28	+2.40	+0.96	-1.40

NOTE: d

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.8	0	+2.2	+3.0	+3.2	+2.4	0
Bird	+0.8	-0.8	+1.6	-0.4	+2.8	+1.6	-2.4
Ross	-0.8	+0.8	+0.8	+0.8	+2.0	+2.0	-0.6
Kleeman	+0.8	-0.8	+1.6	0	+2.4	+2.0	-1.2
Kaplan	+1.6	+0.8	+2.4	0	+2.4	+0.8	-0.8
Average	+0.64	0	+1.72	+0.68	+2.56	+1.76	-1.00

NOTE: e

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.8	0	+0.2	+0.8	+2.4	+1.6	0
Bird	0	0	0	0	+3.2	+1.2	-2.4
Ross	+1.6	+1.6	+1.6	+1.2	+3.2	+3.2	+0.8
Kleeman	+1.6	-0.4	+0.8	-0.4	+0.8	+1.6	-0.8
Kaplan	+0.4	+1.2	+1.2	+1.2	+2.8	+2.0	-0.4
Average	+0.88	+0.48	+0.76	+0.56	+2.48	+1.92	-0.56

NOTE: f

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.1	-0.4	0	0	+1.6	+0.8	0
Bird	+0.4	+1.2	-0.4	+0.4	+2.8	+2.0	-2.0
Ross	0	+0.8	+1.6	+1.6	+3.2	+3.4	0
Kleeman	+0.8	0	+0.4	-1.0	+1.6	+0.4	-2.8
Kaplan	+0.6	+0.8	+1.0	0	+2.4	+2.4	+0.8
Average	+0.38	+0.48	+0.52	+0.20	+2.32	+1.80	-0.80

NOTE: g

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+0.8	+0.8	-2.5	+0.8	+3.6	+2.4	-1.2
Bird	-0.8	+0.8	+0.2	0	+3.2	+3.2	-2.4
Ross	+0.6	+1.8	+1.2	+2.4	+3.0	+2.2	+0.6
Kleeman	+1.6	+0.8	+1.6	0	+2.8	+1.6	-0.8
Kaplan	0	+0.8	+1.6	0	+2.4	+1.6	-0.8
Average	+0.44	+1.00	+0.42	+0.64	+3.00	+2.20	-0.92

NOTE: a

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+1.2	+1.2	+1.2	+1.2	+4.4	+2.8	+0.4
Bird	+0.6	+1.8	+1.0	+0.6	+5.0	+6.0	+0.2
Ross	+0.4	+1.8	+1.2	+0.4	+1.2	0	-0.4
Kleeman	+1.6	+1.6	+3.2	+1.6	+3.2	+4.4	0
Kaplan	+1.4	+0.6	+0.6	+0.6	+3.0	+1.4	+0.6
Average	+1.04	+1.40	+1.44	+0.88	+3.36	+2.92	+0.16

NOTE: b

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+2.4	+0.4	0	+2.4	+3.6	+4.0	0
Bird	+2.4	+3.2	+2.4	+4.2	+6.4	+7.2	+1.6
Ross	+3.2	+2.8	+2.4	+3.2	+4.2	+4.0	+0.8
Kleeman	+2.4	+1.6	+1.6	+2.8	+5.6	+5.6	+1.6
Kaplan	+1.0	+2.4	+1.8	+3.2	+4.8	+4.8	+0.4
Average	+2.28	+2.08	+1.64	+3.06	+4.92	+5.12	+0.88

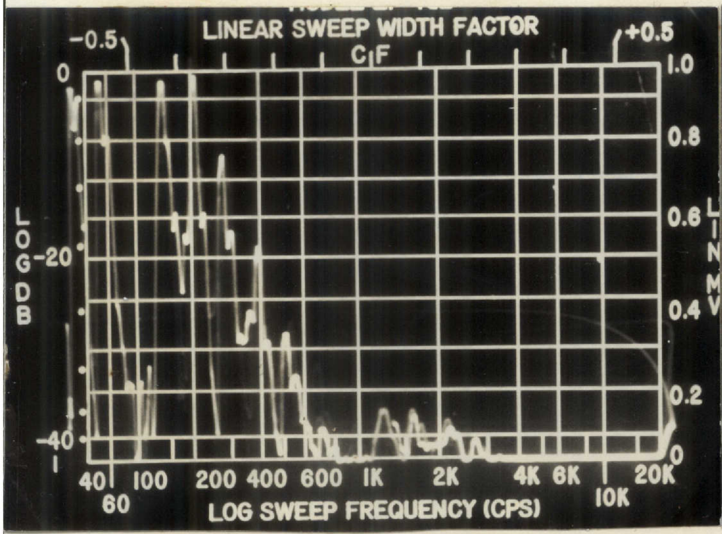
NOTE: c'

Name	Mute #1	Mute #2	Mute #3	Mute #4	Mute #5	Mute #6	Mute #7
Jones	+2.4	+0.8	-0.8	+2.4	+4.0	+4.0	+0.8
Bird	+3.0	+3.4	+3.0	+5.4	+6.2	+7.8	+2.6
Ross	+0.8	+2.4	+0.8	+3.2	+4.2	+2.4	+1.6
Kleeman	+3.2	+0.8	+0.8	+3.2	+5.6	+4.0	0
Kaplan	+1.6	+0.8	+0.8	+2.4	+2.4	+4.0	+0.4
Average	+2.20	+1.64	+0.92	+3.32	+4.48	+4.44	+1.08

APPENDIX B

PHOTOGRAPHS OF TONAL SPECTRUMS

NOTE: C



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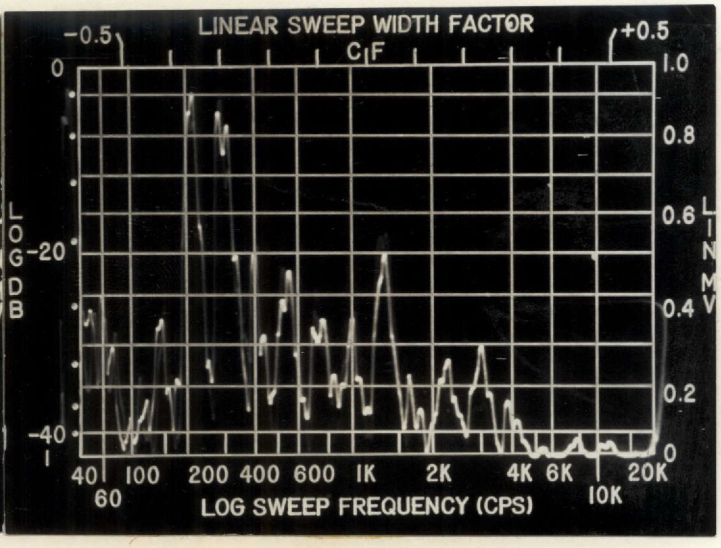

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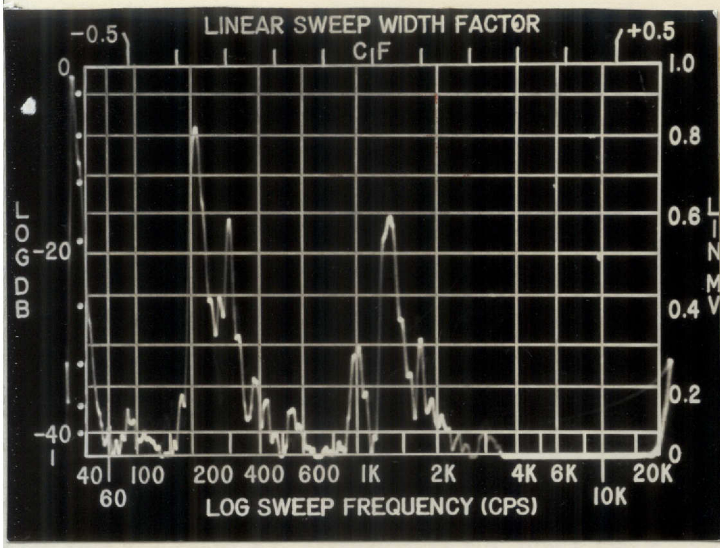
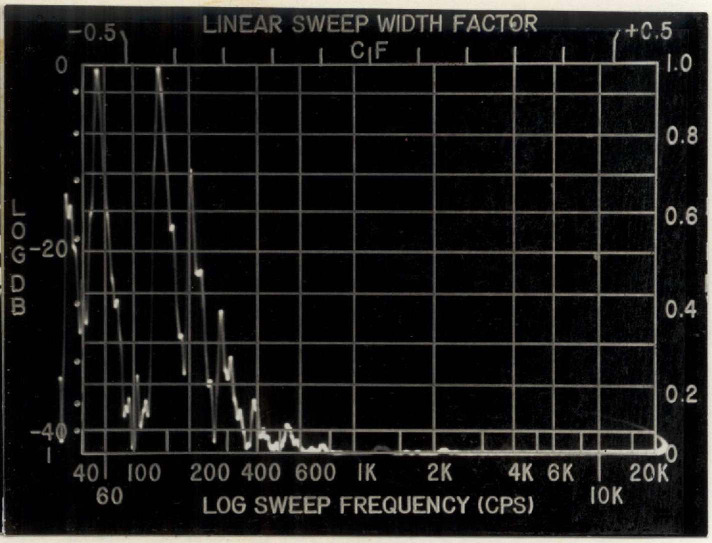
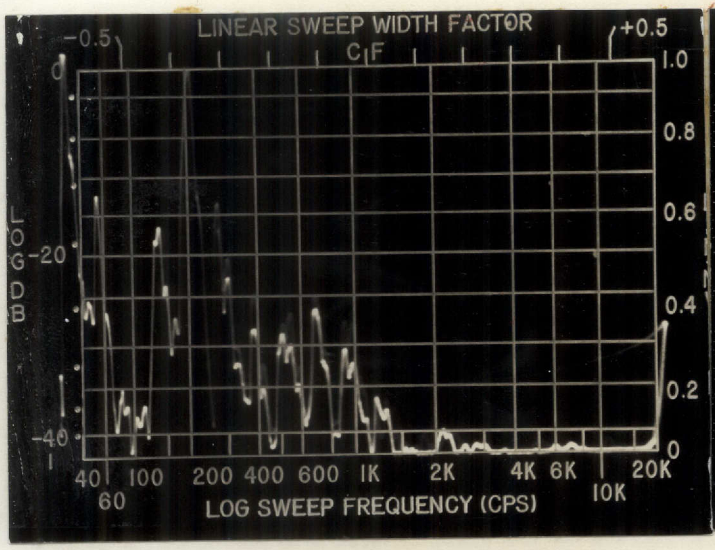


Aulos



Humes and Berg Model 193

NOTE: C



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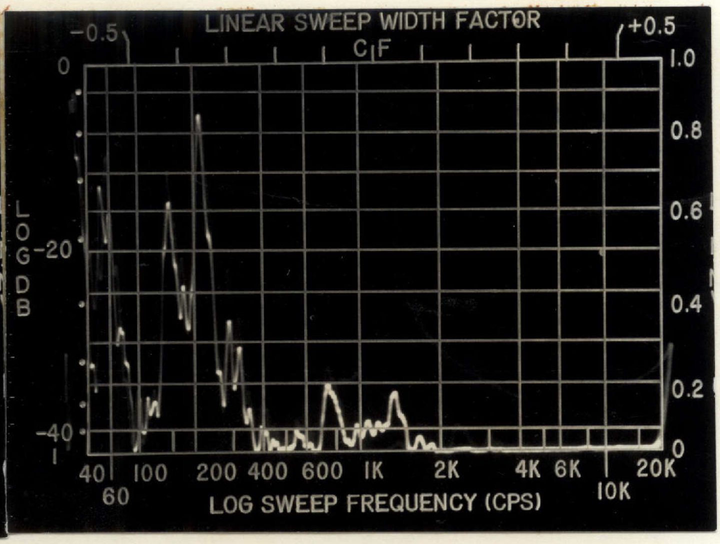

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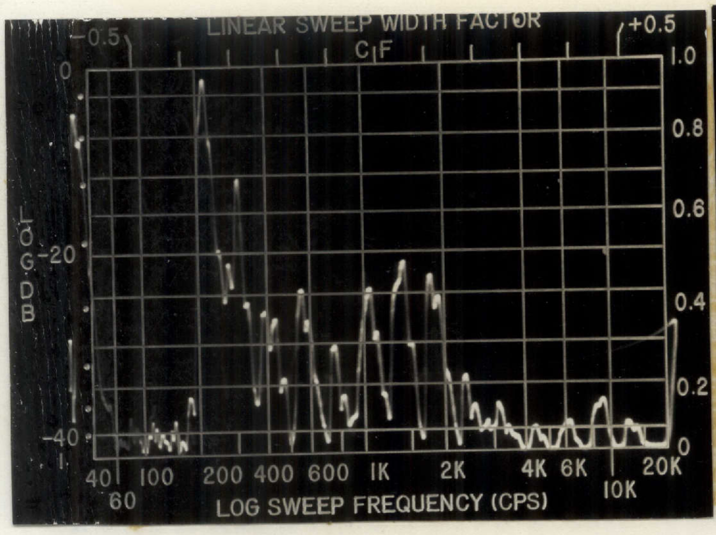
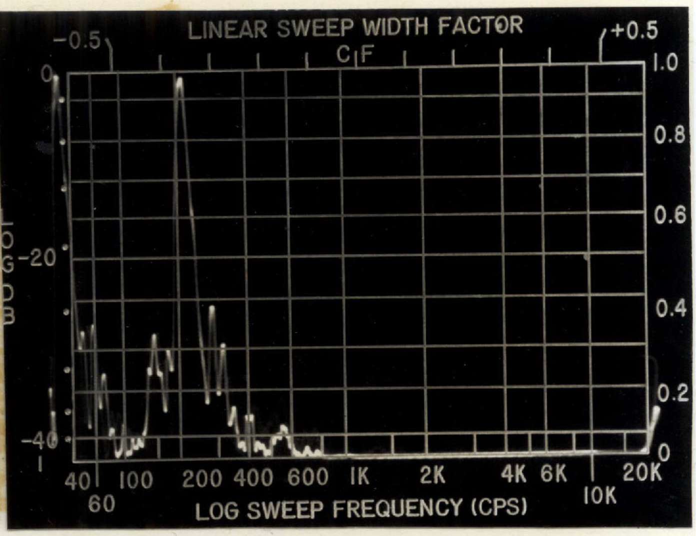
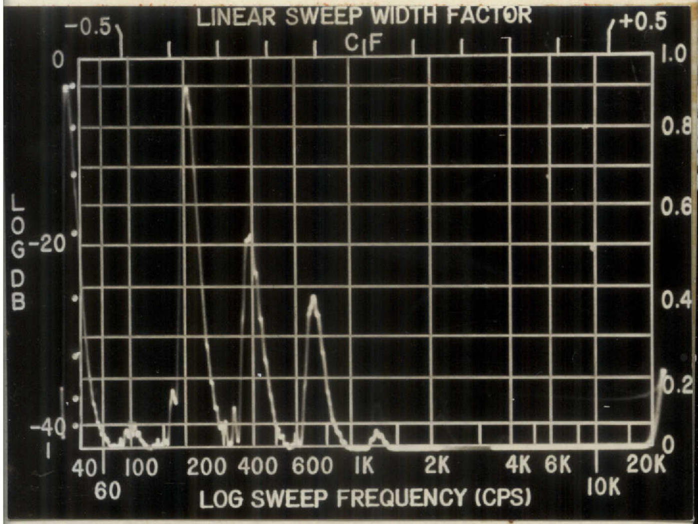


Mirafone



Experimental Mute

NOTE: c



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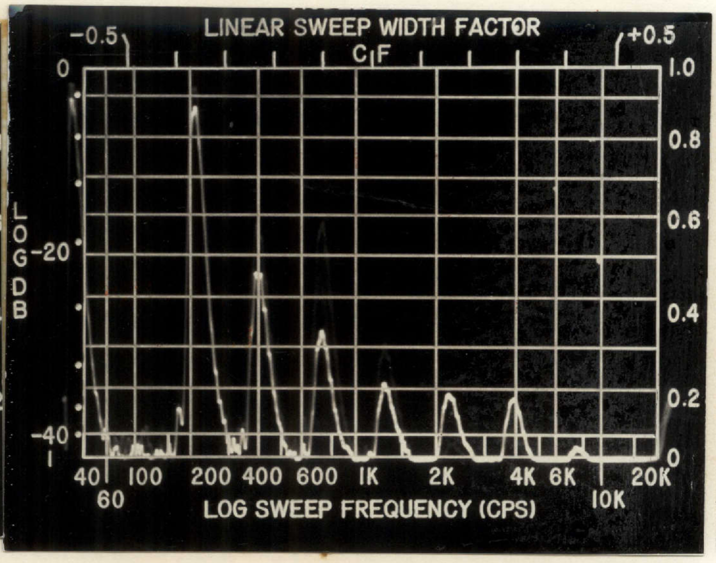

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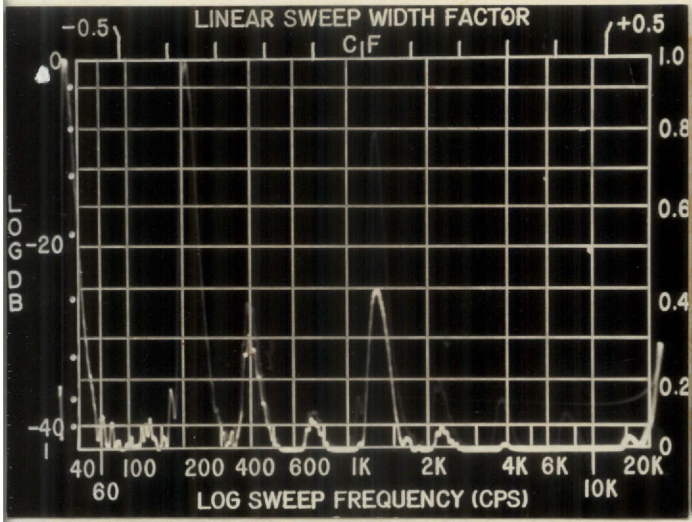

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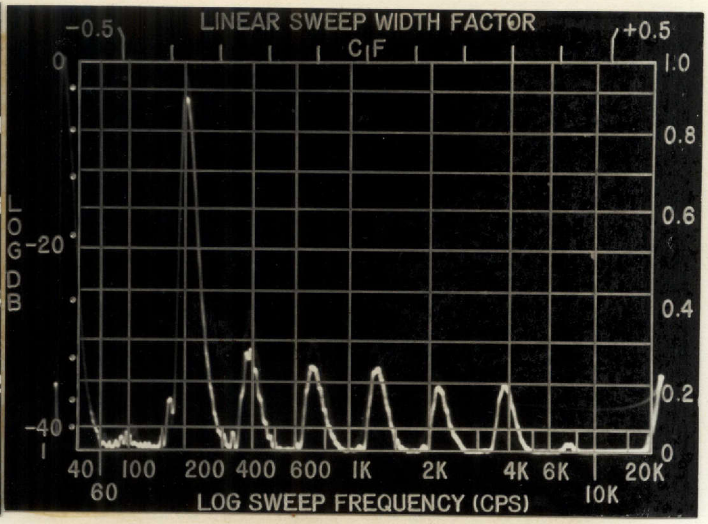

Humes and Berg Model 193

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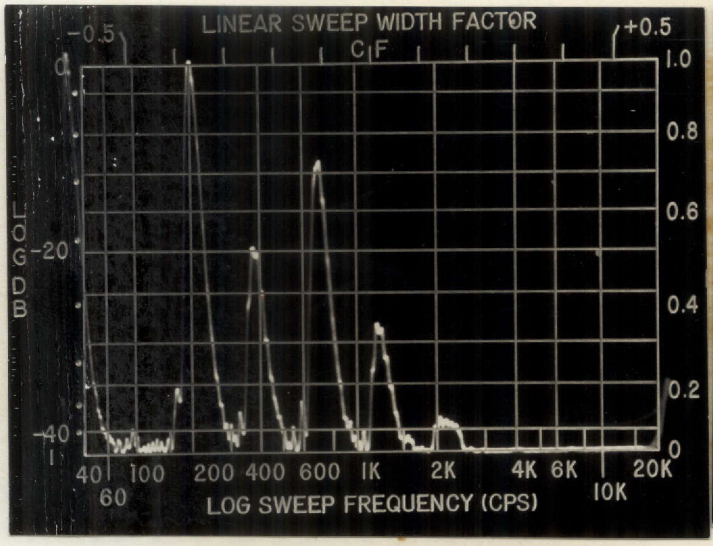
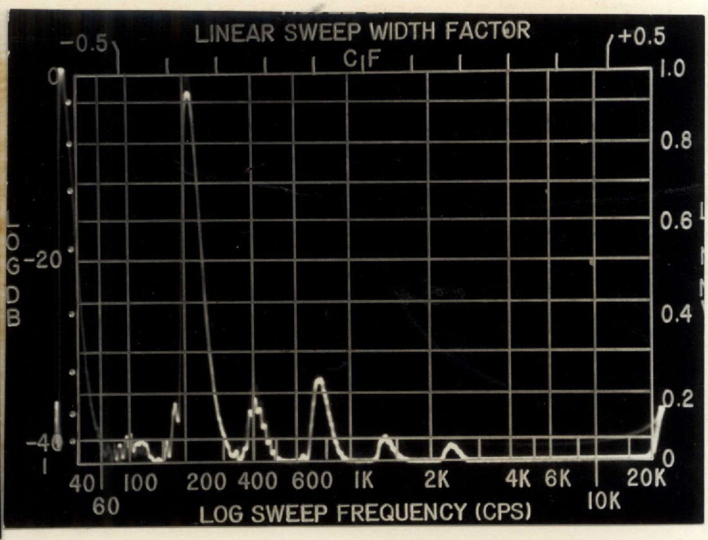


Humes and Berg Model 190



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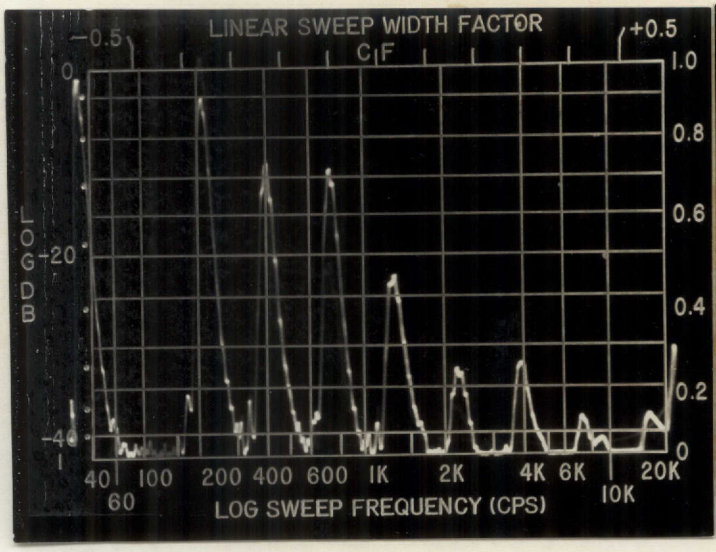

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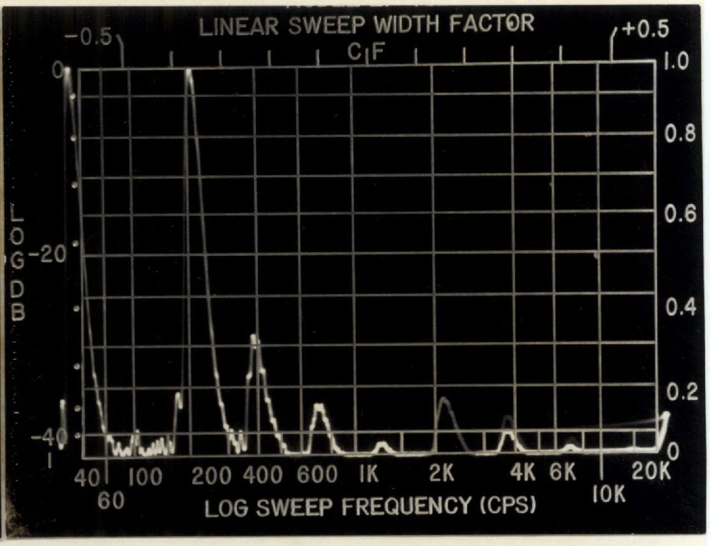
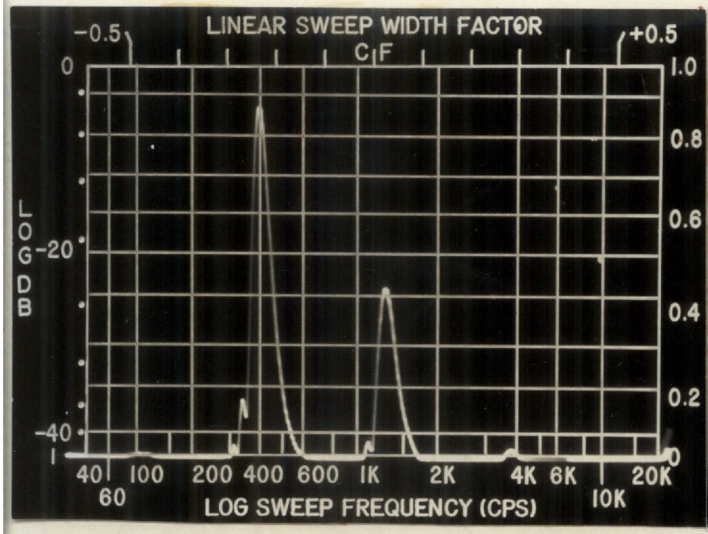


Experimental Mute

NOTE: c'



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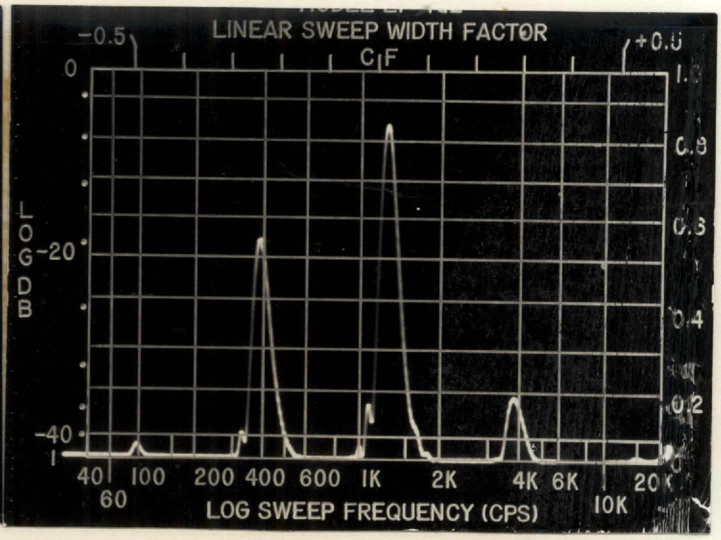
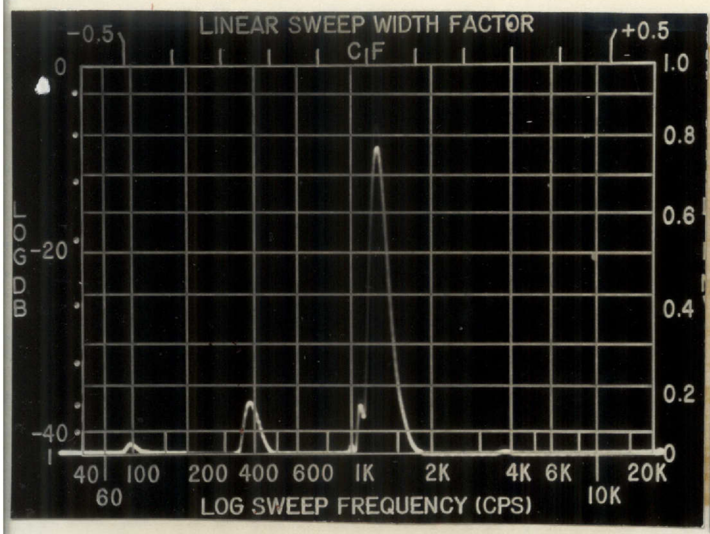


Accura



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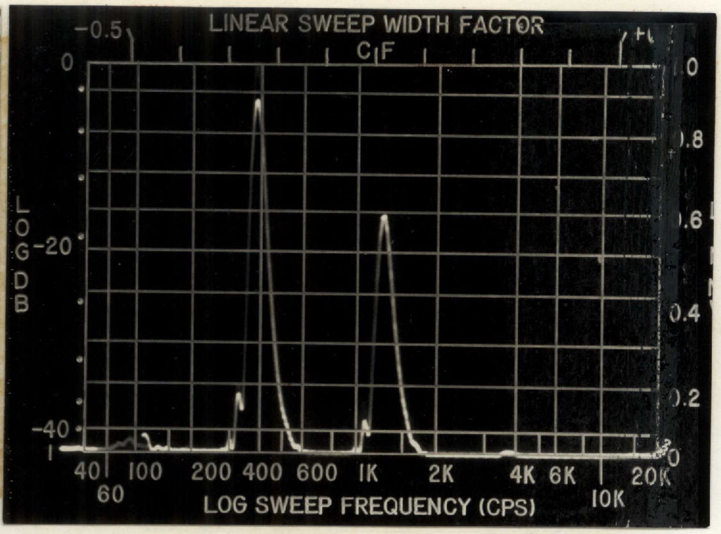
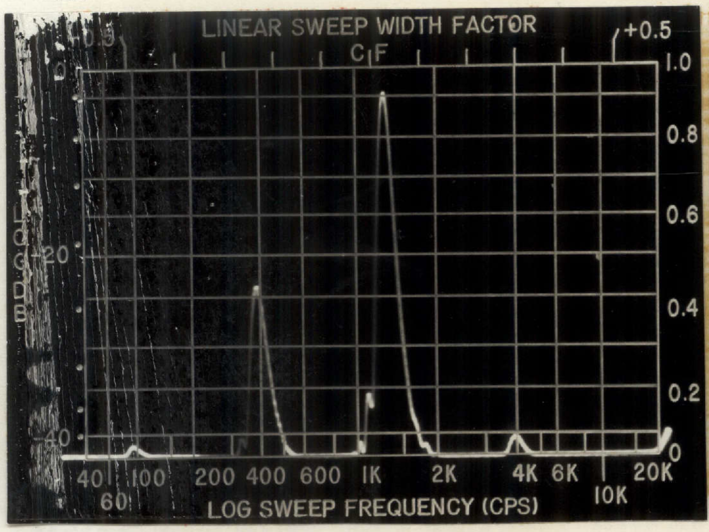
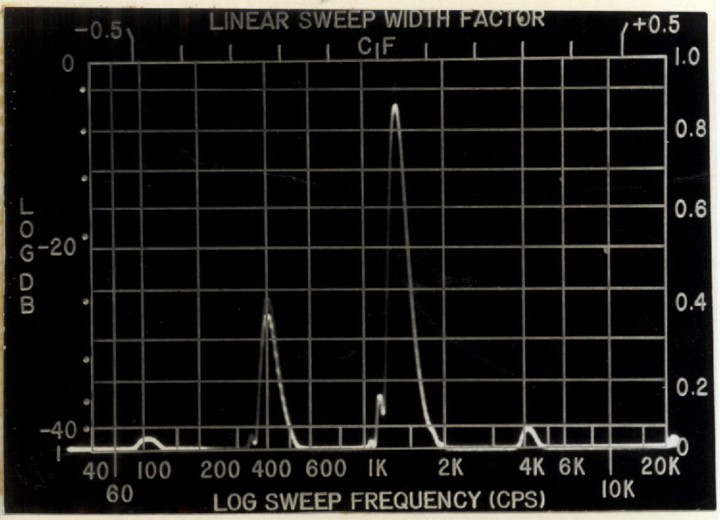


Humes and Berg Model 193

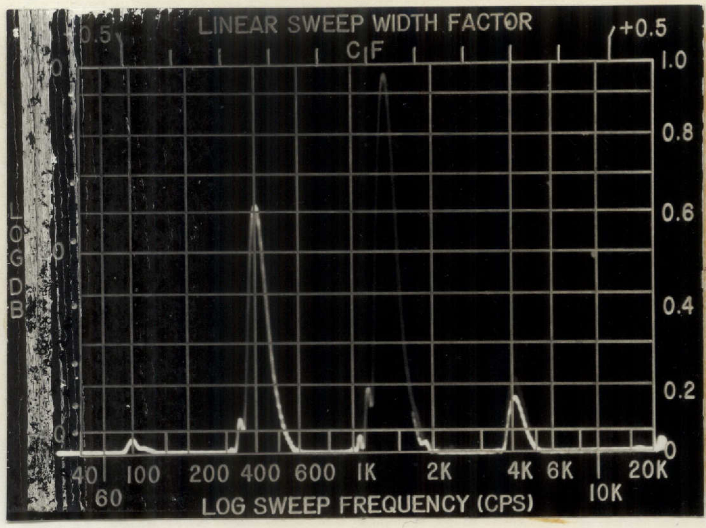
NOTE: c'



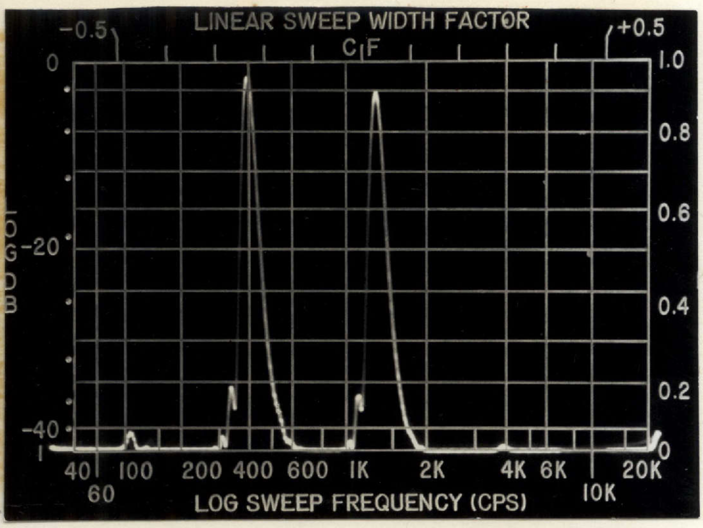
Humes and Berg Model 190



Lea



Mirafone



Experimental Mute

APPENDIX C

AVAILABLE TUBA MUTES

Mute	Type	Special Features	Price*
Accura	Straight	Aluminum construction	$45.00
Aulos #13	Straight	Has tuning chimney	$40.00
Humes and Berg #190	Straight	For bells up to 25 inch diameter	$29.70
Humes and Berg 191	Velvet-tone	Bucket mute that fits over bell	$29.70
Humes and Berg #193	Straight	Adjustable tuning slide; for bells 14-18 inches in diameter	$29.70
Humes and Berg #194	Straight	For E-flat tuba	$28.15
Humes and Berg #195	Straight	Curved model designed for recording bass	$37.50
Humes and Berg #196	Straight	Curved model designed for sousaphone	$36.50
Humes and Berg #197	Straight	For Meinl-Weston tuba (Bill Bell model)	$29.90
Lea	Straight	Custom designed for each instrument	Not available
Mirafone	Straight	Birch plywood construction	$60.00

*Prices are current as of September, 1973.

APPENDIX D

ADDRESSES OF MUTE MANUFACTURERS

Accura Music
Box 887
Athens, Ohio 45701

Aulos, Incorporated
409 Winters Lane
Baltimore, Maryland 21223

Humes and Berg Manufacturing Co., Inc.
4801 Railroad Avenue
East Chicago, Indiana 46312

James Lea
9 Cedar Lawn Avenue
Barnet Herts., England

Mirafone Corporation
P. O. Box 909
Sun Valley, California 91352

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