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The Vocascope - An Experimental Study in the Visual Measurement of Pitch and Quality

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THE VOCASCOPE

AN EXPERIMENTAL STUDY

IN THE

VISUAL MEASUREMENT

OF

PITCH AND QUALITY

By

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CONTENTS

UNIT I

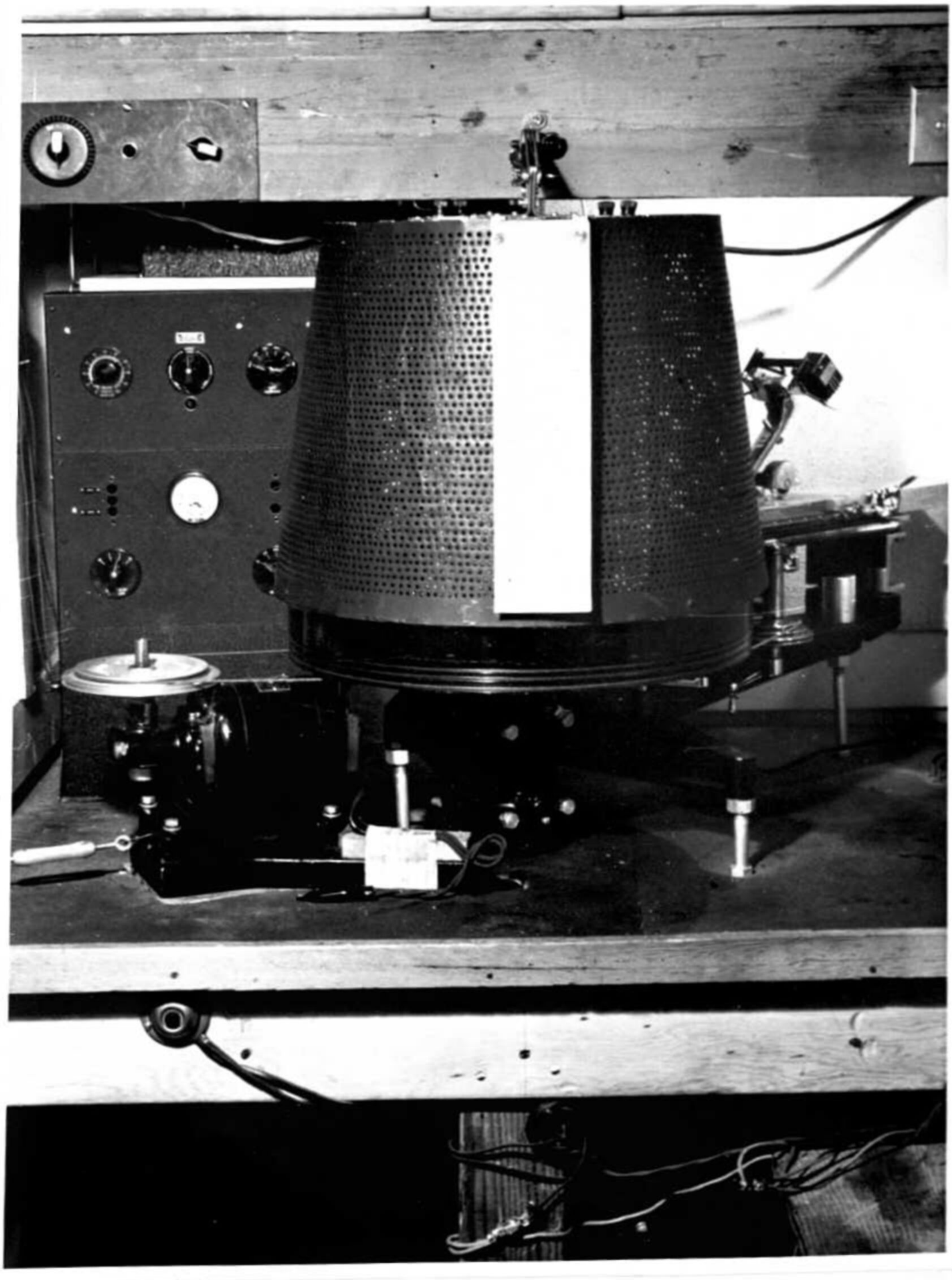
THE VOCASCOPE

The project herein described is an experimental attempt to construct visual aids for the study of voice. Its purposes are: (1) to make possible the visual perception of pitch change on a vertical scale; (2) to isolate certain overtones of the fundamental frequency in the hope of deriving some assistance to the improvement of quality.

The principle of operation is the psychological phenomenon of stroboscopy, the illusion of stationary, constant light, as a result of synchronized interrupted vision.

The Vocascope[1] is composed of four essential parts: (1) the scanning drum, (2) the light source, (3) the amplifier, (4) the filter.

1 Modification of Carl E. Seashore's Tonoscope. See University of Iowa Studies, First Series No. 172, February, 1929.



SCANNING DRUM

PLATE I

THE VOCASCOPE

PLATE II

SCANNING DRUM

UNIT II

THE SCANNING DRUM

The scanning drum is in the form of a frustum of a cone, top diameter -- 13.926 inches, bottom diameter -- 17.5 inches, slant height -- 11.25 inches. (See Plate II). 46 parallel lines, spaced $\frac{1}{4}$ inch apart, are drawn around the drum. On these lines are arranged 8050 holes, each .125 inch in diameter, their horizontal spacing varying from .25 to .332 inches. The greatest number of holes along any one line is 220, and from this the number decreases by two holes along alternate lines. The arrangement is such that (1) there are 46 lines of holes, decreasing in number in steps of two from 220 to 130; (2) no two lines of holes closely related in number are adjacent.

Painted a dull black, inside and out, the drum is mounted on a horizontal flywheel and rotated at 60 revolutions per minute by a one-sixth horsepower synchronous motor.

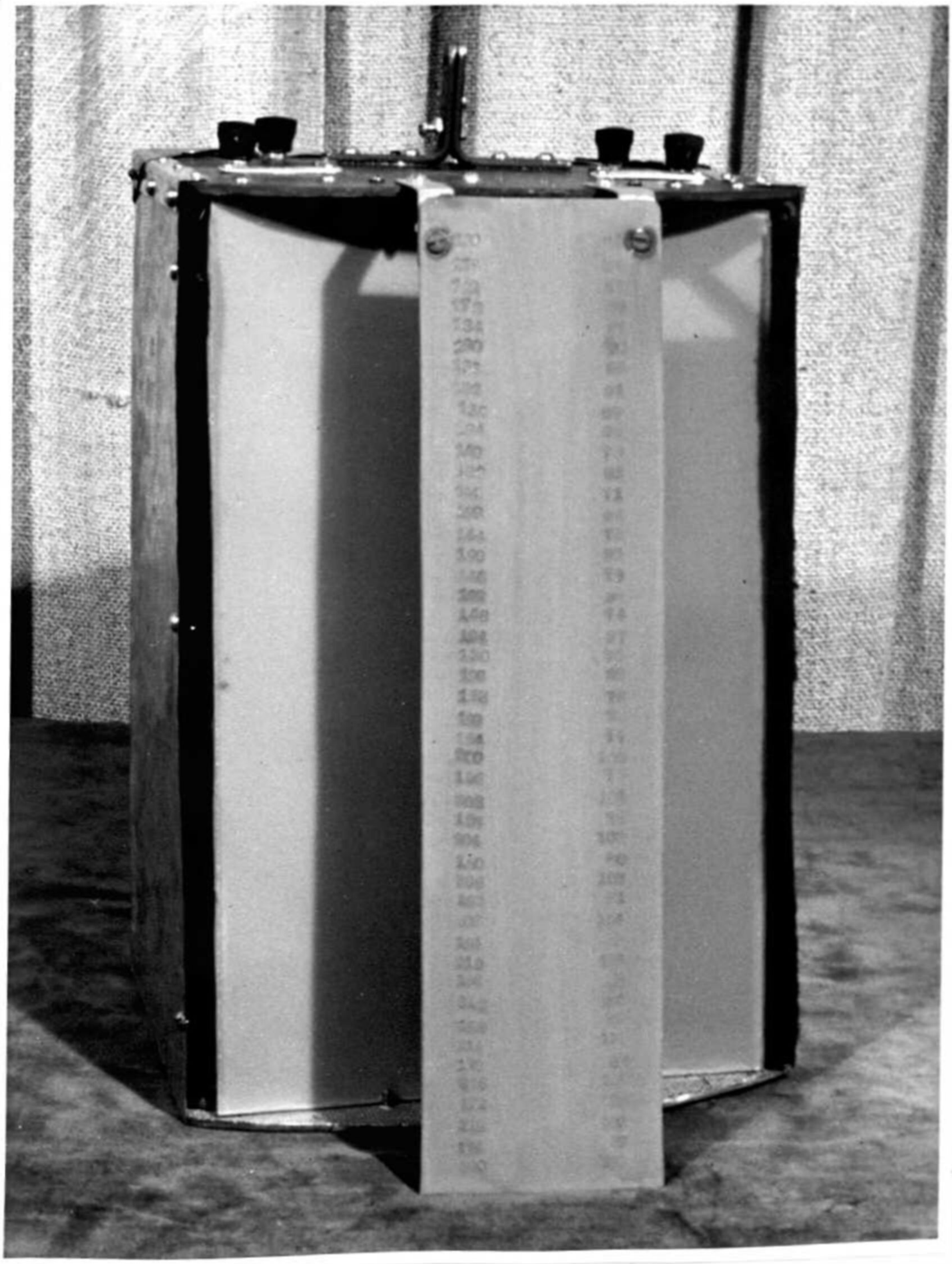


PLATE III

LIGHT SOURCE

UNIT III

THE LIGHT SOURCE

The light source is a box 6 inches deep, 8 inches wide, 12 inches high, longitudinally divided. The open front is shaped to articulate with the inner curve of the drum and closed with flashed opal. (See Plate III). In each section are arranged six 2 watt neon lamps wired in parallel.

Attached to the light source is the scale plate, indicating on one edge the actual number of holes in the line opposite, and on the other, half the actual number. The wall of the drum will pass between the scale and the light source.

UNIT IV

THE AMPLIFIER

In this particular instance two separate amplifiers were used. However, a single two-channel amplifier would suffice. These are rated at 20 watts, each using three "56" tubes and two "2-A-3" tubes in class "A". Both are transformer coupled, and each has a 500 ohm input and output terminated on the secondary winding of a 500 ohm line to voice coil transformer. Final coupling to the light unit is from the primary winding of these transformers.

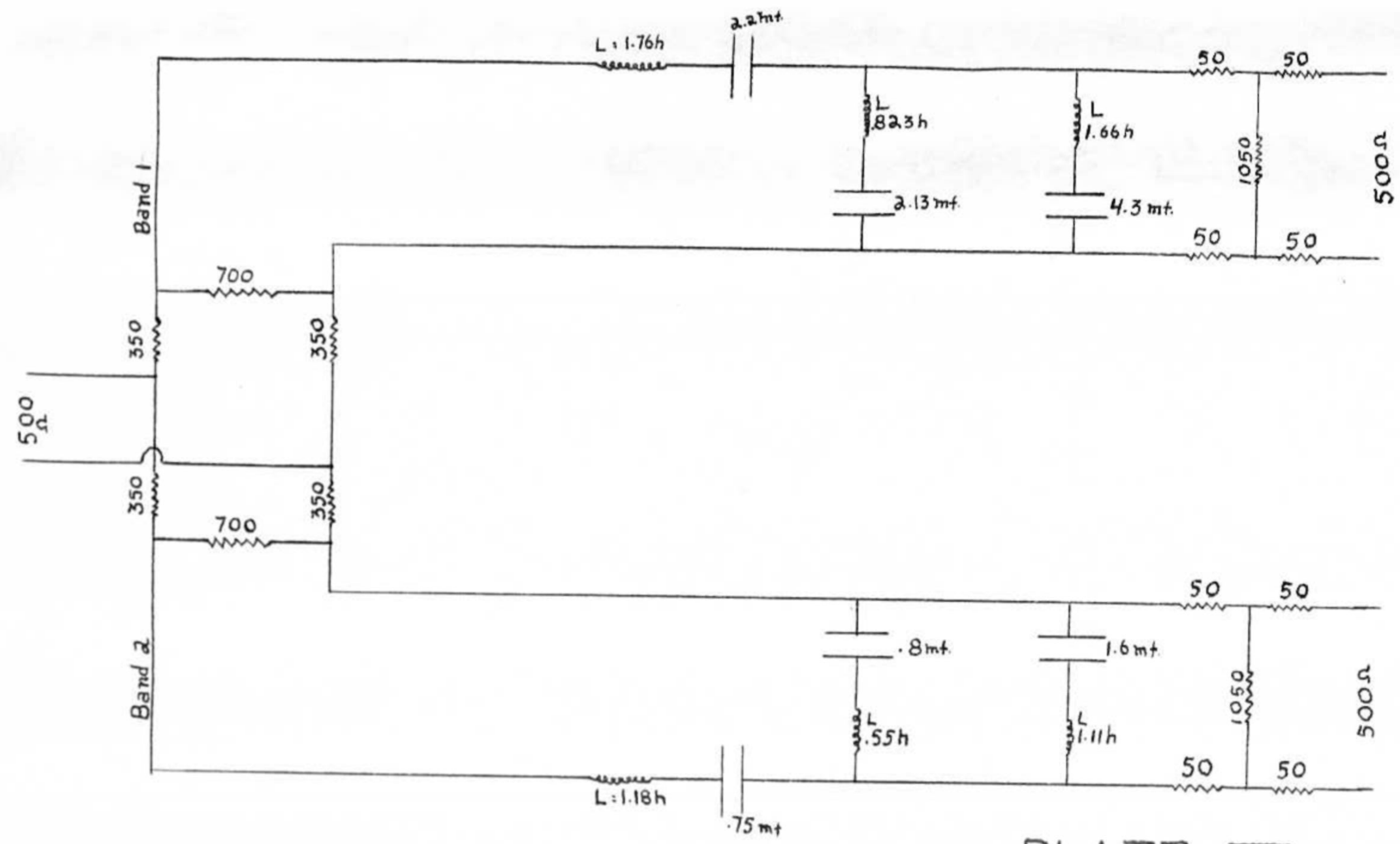


PLATE IV

Proposed Filter I

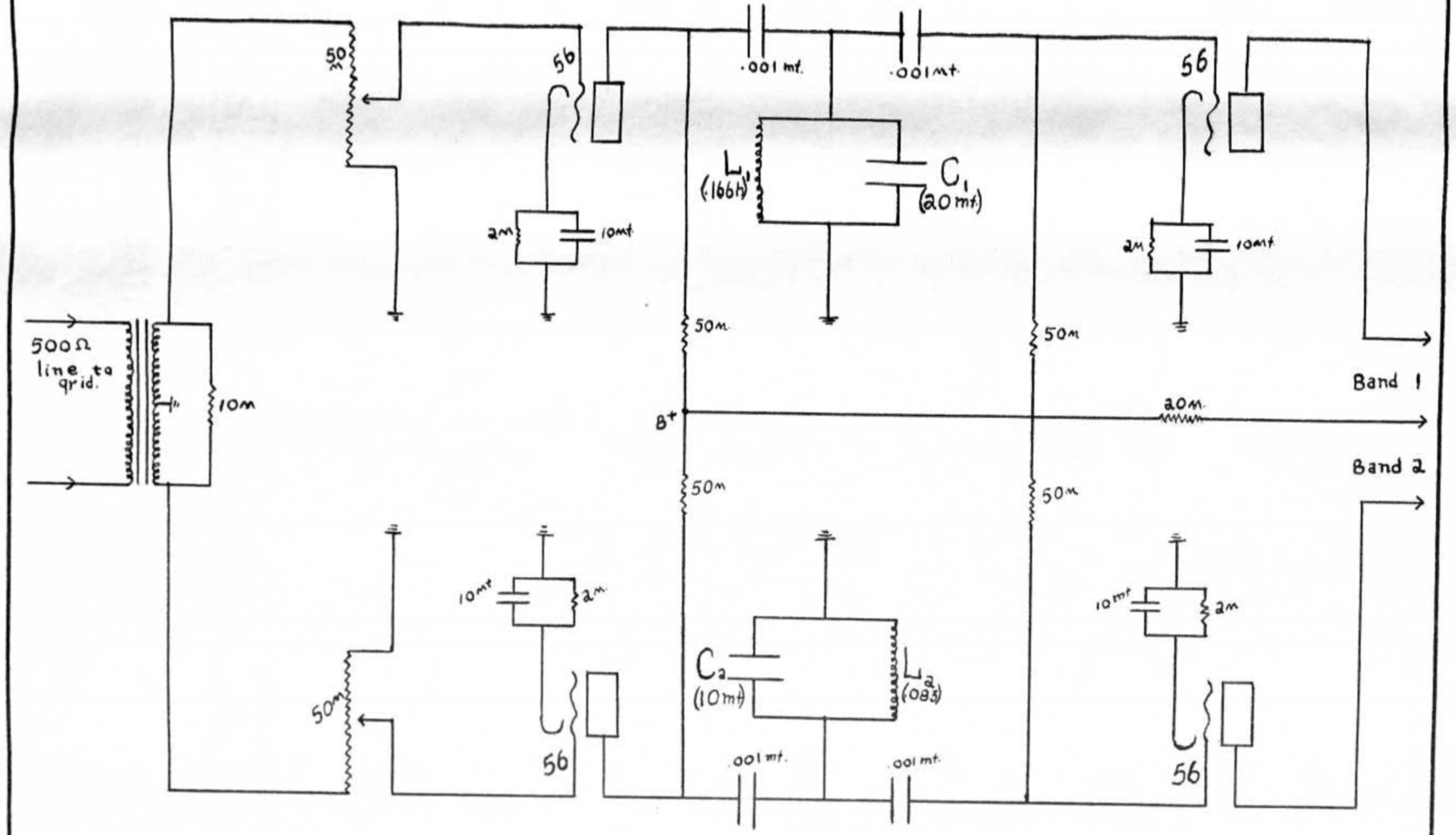


PLATE V Proposed Filter II

UNIT V

THE FILTER

The attempt to isolate certain overtones through the adaptation of known filter circuits to rigid standards imposed by the character of the particular instrument constituted the more truly experimental aspect of this thesis project. Necessity for the use of some type of band-pass filter arises from the fact that, because harmonic partials of a fundamental frequency are direct multiples of that fundamental, they must be isolated from it in order to actually ascertain their presence. It was not possible to anticipate, at the time the study was undertaken, what success might be achieved in this respect. It was hoped that actual overtone isolation might be effected and presented as a successful operation of the instrument. On the other hand, full realization was in mind that limitations of laboratory facilities, financial resources, and time might render possible only the accomplishment of a plausible basis for further experiment toward the desired end. It is with regret, but without apology, that admission of the latter result is recorded. The discoveries and gains toward the desired end, however, were sufficiently substantial to warrant the assumption that when the necessary laboratory facilities and financial resources are available the unit may be completed as originally conceived. The purpose of this section, then, is to describe briefly the process of experimentation and to explain the conclusions derived therefrom.

The particular problem at hand was to arrange a band-pass filter that would absorb all frequencies in the spectrum with the exception of two narrow bands, those bands being; (1) 65-110 cycles per second, (2) 130-220 cycles per second. It will be noted that an extremely narrow band of 20 cycles, lying between these two bands, must be absorbed to avoid overlapping. On the basis of accepted engineering standards a multi-section composite filter of the "M" derived type seemed to be the one best suited to obtain this sharp cut-off. Such a filter was arranged to accomplish the desired results (See Plate IV) and experiments started from this point.

Because the inductances required were so large, it was decided to use closed iron core coils instead of the conventional air core type, thus keeping their resistances at a minimum. It was hoped that the problem of flux density change of the iron core would not alter the characteristics of the inductances, because the position of the filter in the completed network would mean that the signal passing through would be at intensities of less than one milliwatt. This was soon proved to be a fallacious assumption when it was determined that minute changes of current flow caused too great changed of inductance in the coil.

This, however, was not the first difficulty encountered. It was soon discovered that, due to lack of adequate laboratory facilities, an accurate measurement of the inductances was going to present a major problem. Several methods were tried, two of those being:

1. inserting the inductance in one arm of a balanced Wheatstone bridge, charging it, then measuring its discharge on a ballistic galvanometer and comparing the discharge with that of a known condenser by means of the formula

$$L \quad U^2C \frac{\theta_1}{\theta_2}$$

where θ_1 is the throw of the galvanometer for the inductance, θ_2 is the throw for the condenser.

2. inserting the inductance and a known condenser, paralleled to ground, between the stages of a voltage amplifier and determining the frequency at which they resonate. (Observation of one circuit of Plate V will illustrate)

A measurement was possible with the second method described above, but it also served to demonstrate the flux density change as caused by a slight signal intensity change.

On the other hand, from the second method described above came a possible circuit for the final filter. Repeated experiment showed that when the resonant frequency was reached the intensity curve of the signal at the amplifier output showed a sharp peak. Thus, if the capacitance and inductance were known and selected to resonate at a given frequency, the circuit would, in essence, pass only that frequency. The curve could be broadened by inserting resistance in series with the resonant circuit. Inductance could be decreased to a measurable amount and capacitance increased accordingly. Air core coils could be used, avoiding the difficulties encountered with iron cores, and at the same time resistance could be kept at a minimum.

A great deal of time was spent in varying the procedure of the two basic experiments set forth above in the way of substituting various types of equipment in order that all readings could be considered as absolute. From these variations and the subsequent results, it is possible to make the following recommendations.

PROPOSED FILTER I

A multi-section composite filter of the "M" derived type as shown in Plate IV, in which the only unknown is the part the high resistance of such large air core inductances may play in the completed circuit.

PROPOSED FILTER II

A two stage amplifier in which, inserted between the stages, is a resonant circuit made up of an inductance and a condenser paralleled to ground and tuned to the mid-frequency of the desired band, the only remaining unknown being the sharpness of the cut-off that will result in the finished circuit (See Plate V).

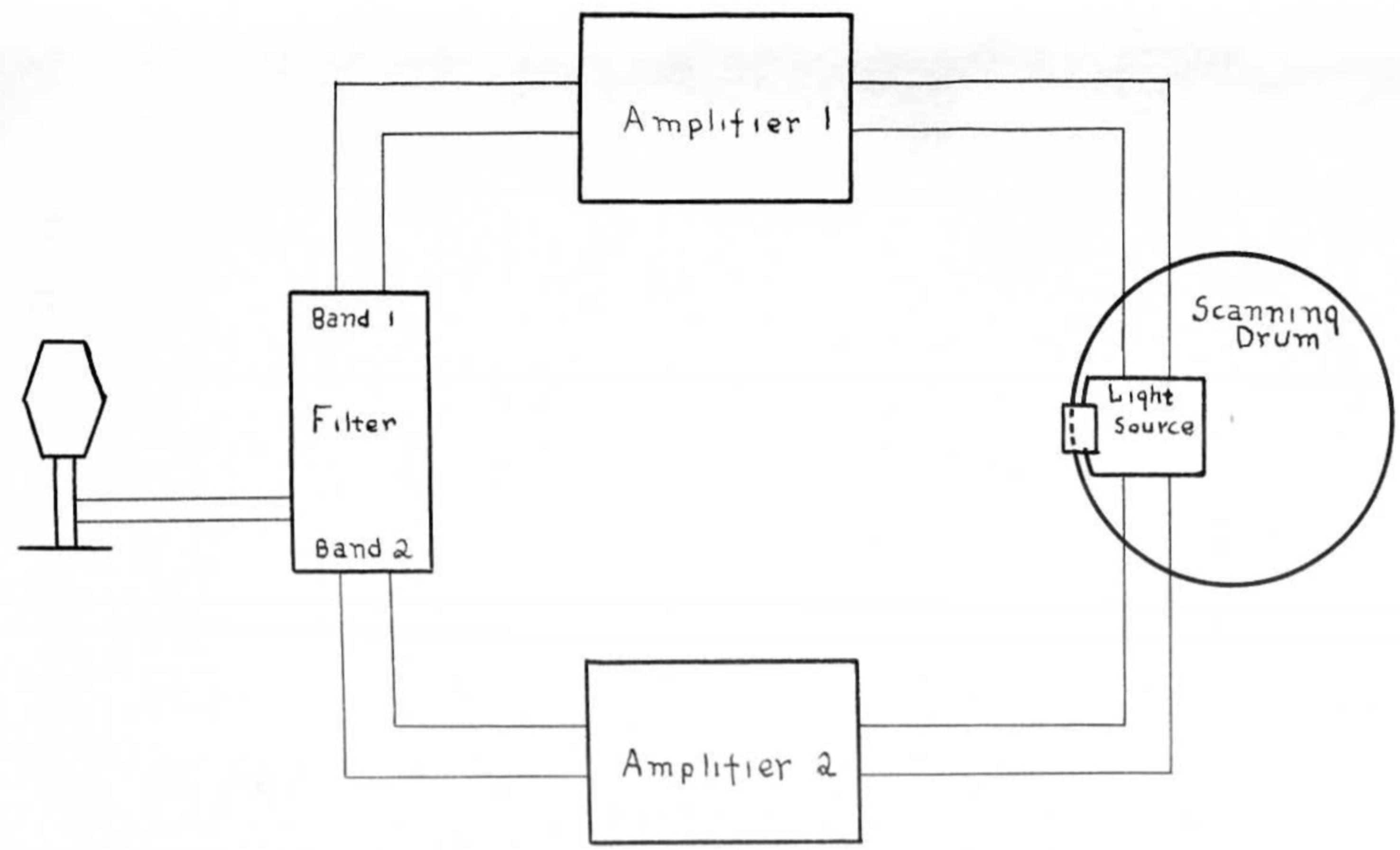


PLATE VI Assembly

UNIT VI

ASSEMBLY AND OPERATION

The Vocascope is assembled as illustrated in Plate VI. Connected to the filter input is a microphone with a 500 ohm output from the pre-amplifier. With the scanning drum rotating, the amplifiers are turned on and volume increased until the lights glow, then decreased until they go out, then left in that position. Any signal picked up by the microphone will cause the lights to glow.

When a sustained tone is directed into the microphone, pitch may be read directly from the scale by observing which line of holes is apparently stationary. If both bands light up, the overtone can be read in like manner on Band #2. If only Band #2 lights up, any overtone that is not a harmonic of the fundamental can be read by observing the apparently stationary lines in which the holes are half the actual distance apart.

UNIT VII

SUGGESTED APPLICATIONS

In its present form, the Vocascope will successfully measure the fundamental pitch of any tone within its range, that is, in the band of 130 to 220 cycles per second. When completed in accordance with the plans herein set forth, it will reveal the presence of and locate partials and inharmonic partials. Of prime importance psychologically, these measurements are accomplished through visual perception, thus bringing to the aid of limited auditory perception the assistance of another sensory function in a field where impressions are more vivid. That is, the value of the Vocascope lies in its principle of transformation of sound into light, thus bringing into play the sensory activity of vision. C.J. Knock, C.E. Seashore, E.A. Jenner, and others have shown through extensive experiments that the introduction of visual perception in both ear and speech organ training results in rapid improvement, and that transferance of such training to actual performance is readily accomplished.[1]

The Vocascope's most ready uses in its present form then are, (1) to assist the monotone to greater flexibility, and (2) to assist the singer to finer pitch discrimination. Thus, the basic application for the Vocascope is its use as a drill device, based on the combining of visual

1 "The Measurement of Pitch Intonation with the Tonoscope in Singing and Playing", University of Iowa Studies, February 1, 1929.

and auditory stimuli. Whether the completed product will be of value in the improvement of voice quality is problematical.

Beyond this direct application in drill work, the Vocascope should be valuable in rendering instruction in the nature of sound. Always difficult, such instruction should become somewhat more tangible, graphic, and consequently easy. These applications are basic. A period of experimentation with the instrument will undoubtedly bring forth many specific uses, but it is felt that they will fall within the classifications herein suggested.

BIBLIOGRAPHY

ARTICLES

Anderson, David Allen, "The Duration of Tones, The Time Interval, The Direction of Sound, Darkness and Quiet, and the Order of Stimuli in Pitch Discrimination", Psychological Monograph, XVI, #3, 150-156, (June, 1914).

Ansberry, Merle, "The Effect Upon Ability to Discriminate Between Sounds by the Elimination of Frequencies Above 4000 Cycles", Quarterly Journal of Speech, 25:381-389, (Oct., 1938).

Bishop, H.G., "A Simple Demonstration of Movement by Disks", Journal of General Psychology, 1:177-178, (Jan., 1928).

Farnsworth, P.R., "Two Independent Developments of the Strobilion", Journal of General Psychology, 2:556-558, (Oct., 1929).

Gough, E., and Robinson, G., "Tonoscope as a Means for Measuring Combination Tones", American Journal of Psychology, 31:91-93, (Jan., 1920).

Kelly, E. Lowell, "The Neon Lamp as an Aid in Starting Synchronous Motors and as a Speed Indicator", Journal of General Psychology, 2:552-553, (Oct., 1929).

Miles, W., "Accuracy of the Voice in Simple Pitch Singing", Psychological Monograph, XVI, #3, 13-66, (June, 1914).

Miles, W., "Neon Glow Lamps and the Demonstration of Visual Phenomena", Journal of General Psychology, 2:445-551, (Oct., 1929).

Miles, W., "The Victor Stroboscopic Disc for Visual Experiments", American Journal of Psychology, 40:312-313, (1928).

Metfessel, Milton, "Stroboscopy by Means of Impressed Eye Movements of Mirror Vibration", Science, 78:416, (Nov. 3, 1933).

Metfessel, Milton, "The Strobophotograph: A Device for Measuring Pitch", Journal of General Psychology, 2:135-139, (Jan., 1929).

Root, A.R. "Pitch Factor in Speech - A Survey", Quarterly Journal of Speech, 17:320, (June, 1930).

Ross, Felix Breune, "The Measurement of Time Sense as an Element in the Sense of Rhythm", Psychological Monograph, XVI, #3, 166-172, (June, 1914).

Scripture, E.W., "An Elementary Course in Psychological Measurements", Yale Studies in Psychology, IV, 135 ff, (1896).

Seashore, C.E., "A Voice Tonoscope", University of Iowa Studies in Psychology, II, 18-29, (1902).

Seashore, C.E., "Mental Measurement", Ch. VII in his Psychology in Daily Life, (1913).

Seashore, C.E., "New Vantage Grounds in the Psychology of Music", Science, 84:517, (Dec. 11, 1936).

Seashore, C.E., "Seeing Yourself Sing", Science, 43:592-596, (April 28, 1916).

Seashore, C.E., "The Measurement of Pitch Discrimination; a Preliminary Report", Psychological Monograph, XIII, #53, 21-60.

Seashore, C.E., "The Measure of a Singer", Science, 35:201-212, (1912).

Seashore, C.E., "The Tonoscope", Psychological Monograph, XVI, #3, 1-12, (June, 1914).

Seashore, C.E., "The Tonoscope and its Uses in the Training of the Voice", The Musician, 51:331-332, (1906).

Seashore, C.E., and Jenner, "Training the Voice by the Aid of the Eye in Singing", Journal of Educational Psychology, 1:311-322.

Smith, Franklin Orion, "The Effect of Training in Pitch Discrimination", Psychological Monograph, XVI, #3, 67-103, (June, 1914).

Stewart, Rolland M., "The Effect of Intensity and Order on the Apparent Pitch of Tones in the Middle Range", Psychological Monograph, XVI, #3, 157-165, (June, 1914).

Sylvester, Paul E., "Some Standardizing Tests on Stern's Tone Variator", Psychological Monograph, XVI, #3, (June, 1914).

Tiffin, Joseph, "An Approach to the Analysis of the Vibration of the Vocal Cords", Quarterly Journal of Speech, 25:156, (Feb., 1933).

Vance, Thomas Franklin, "The Lower Limit of Tonality", Psychological Monograph, XVI, #3, 104-114, (June, 1914).

Vance, Thomas Franklin, "Variation in Pitch Discrimination Within the Tonal Range", Psychological Monograph, XVI, #3, 115-149, (June, 1914).

West, Robert, "A View of the Larynx Through a New Stroboscope", Quarterly Journal of Speech, 22:455, (Nov., 1935).

West, Robert, "Gentlemen, I Stand - Corrected?", Quarterly Journal of Speech, 24:402, (Oct., 1937).

West, Robert, "Speech and Hearing", Quarterly Journal of Speech, 22:178, (April, 1935).

Wever, E.G., "High Speed Lamps for Tachistoscopic Work", Journal of General Psychology, 2:553-556, (Oct., 1929).

BOOKS

Fletcher, Harvey, Speech and Hearing, N.Y., D.Van Nostrand Co., 1929.

Helmholtz, H.von, Sensations of Tone. N.Y., Longmans, Green & Co., 1885.

Henney, Keith, Radio Engineering Handbook. N.Y., McGraw-Hill Book Co., Inc., 1935.

Millikan, Robert Andrews, and Mills, John, Electricity, Sound, and Light. N.Y., Ginn and Company, 1908.

Miller, D.C., Science of Musical Sounds. N.Y., The Macmillan Co., 1916.

Seashore, C.E., Psychology of Music. N.Y., McGraw-Hill Book Co., Inc., 1938.

Stewart, G.W., Introductory Acoustics. N.Y., D.Van Nostrand Co., 1938.