MEASUREMENT OF THE DIFFRACTION CORRECTION OF THE GULTON MODEL P420M-6 MICROPHONE

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FOREWORD

The research and measurements described in this report were performed by Western Electro-Acoustic Laboratory, Inc., Los Angeles, California, for the Flight Dynamics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, under Contract No. AF 33(615)-3746. The Air Force program, Project 1472, Dynamic Measurement and Analysis Technology; Task 147203, Development of Dynamic Measurement and Analysis Systems, was monitored by Mr. R. P. Boyd, FDDS, and later in the program, Mr. G. Plzak, FDDS. The research was conducted from May 1966 to September 1966, and the report submitted in October 1966.

The author of this report is Jose C. Ortega of Western Electro-Acoustic Laboratory, Inc. The author wishes to acknowledge the very capable assistance of Mr. John Huh who performed the majority of the measurements reported on here, and to express appreciation to the staff of Western Electro-Acoustic Laboratory for overall support.

This technical report has been reviewed and is approved.

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ABSTRACT

The methods and instrumentation used to obtain the diffraction correction for the Gulton P420M-6 microphone are described. The diffraction correction has been measured for two microphone mounting configurations at several angles of sound incidence over the frequency range 400 CPS to 25 KCPS. In addition, the random incidence response for the Gulton P420M-6 microphone has been obtained over the same frequency range.

Analysis of the measured data shows that the precision of the measurements is very good below 15 KCPS (standard deviation being within ±.6 db) and gradually decreases at higher frequencies (standard deviation being ±1.2 db at 20 KCPS and +3.9 db, -7.4 db at 25 KCPS).

The pressure calibration for the Gulton P420M-6 microphone was obtained using the well-known coupler method and also using an electrostatic actuator. The results of these measurements show that the electrostatic actuator method of calibration produces reliable results when used with the Gulton microphone.

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SECTION I

INTRODUCTION

Reliable acoustical measurements to a very large degree depend on knowledge of the characteristics of the instrumentation used for the measurements. In general, the characteristics of the electronic instrumentation used are well known or can be easily obtained. This cannot always be said for the electro-acoustic transducer, however, simply because the important acoustical characteristics of an electro-acoustic transducer are not easily obtained. It is very common for manufacturers of microphones used in the measurement of sound pressure level to supply the nominal sensitivity along with a frequency response at some angle of sound incidence.

The Gulton Industries, Inc., Model P420M-6 microphone has gained widespread use in recent years with little published knowledge of some of its more important acoustical characteristics. This report describes an extensive series of measurements performed on the Gulton P420M-6 microphone. The purpose of the work described herein was to obtain the diffraction correction at several angles of sound incidence for this microphone for two different mounting configurations.

The diffraction correction of a microphone at some specified angle of sound incidence is defined as the difference between the free field response at some specified angle of sound incidence and the pressure response of the microphone. The pressure response is defined as the ratio of microphone output voltage to pressure acting at the microphone sensing element, and the free field response is defined as the ratio of microphone output voltage to the pressure acting at the location of the microphone in a free field prior to introduction of the microphone. From the definitions above, it is clear that the disturbance of the sound field by the microphone will in general result in the two types of response being different; and, in particular, since the disturbance is a wavelength phenomenon, this difference or diffraction correction will depend on both frequency and the angle of sound incidence. (Ref. 1) The diffraction correction is also a function of the geometry of the disturbing microphone and will be greater at high frequencies and zero at those frequencies when the sound wavelength is large relative to the dimensions of the microphone and its mounting apparatus. The last statement merely says that the free field and pressure responses of a microphone are equal at low frequencies where the disturbance of the sound field due to introduction of the microphone is negligible.

It is clear from the definition given above for the diffraction correction that both the pressure response and the free field response must be known over the entire frequency range of interest. In this work, the diffraction correction is obtained up to a frequency of 25 KCPS for angles of incidence of 0°, 30°, 60°, 90°, 120°, 150° and 180° for the microphone mounted on a cylinder (see figure 1) and for angles of incidence of 0°, 30°, 60°, 90°, 120°, 150°, 180°, 210°, 240°, 270°, 300° and 300° with the microphone mounted on the Gulton microphone clamp (see figure 1). The symmetry about the longitudinal axis of Gulton microphone mounted on the cylinder as shown in figure 1 makes it possible to delete the measurements from 180° to 360°.

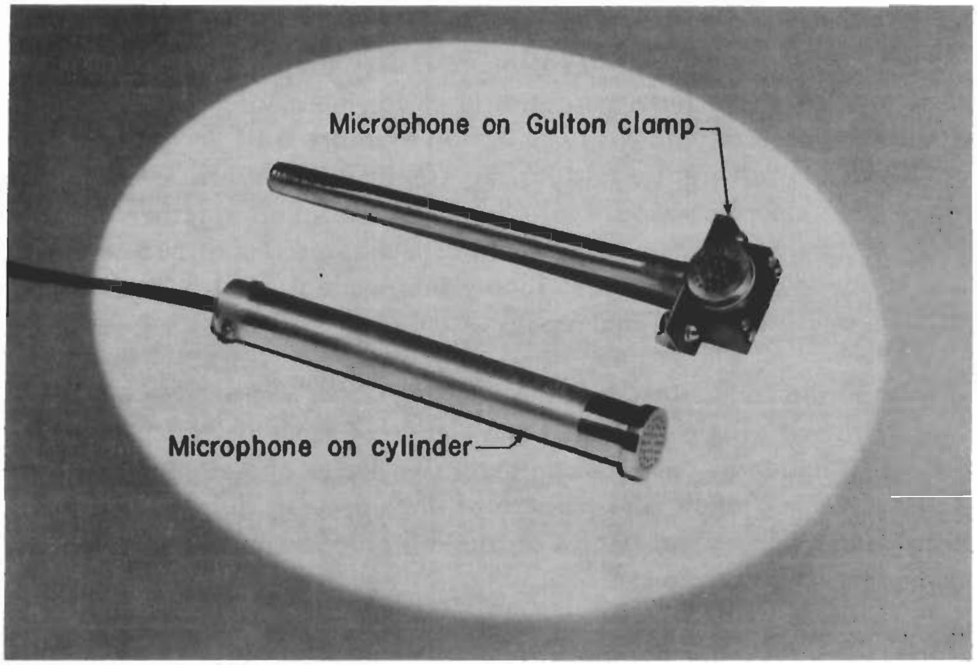

Figure 1. Gulton P420M-6 microphone shown in the two mounting configurations used in the measurements.

In addition to the diffraction correction noted above, the following microphone characteristics were obtained in the course of the program work:

(a) Microphone free field response at several angles of incidence to 25 KCPS.
(b) Microphone pressure response to 25 KCPS.
(c) Microphone equivalent volume.
(d) Microphone polar response.
(e) Microphone random incidence response to 25 KCPS.

The random incidence response of the microphone is a particularly useful one for the measurement of sound in enclosed reverberant spaces. The random incidence response in this work is calculated using an energy integrating technique which utilizes all the free field angle of incidence data. (Refs. 2, 3)

It was suspected prior to actual measurements that the most difficult part of the program would be the obtaining of the pressure calibration of the Gulton microphone to 25 KCPS, particularly if a coupler calibration method was to be used. This difficulty stems from the problem arising at the higher frequencies where wave motion in the coupler becomes important. At these frequencies the coupler ceases to be a true pressure coupler, (Ref. 4) where a true pressure coupler is one in which the sound pressure is uniform over the entire coupler volume. As is shown later in this report, a valid coupler pressure calibration can be obtained with the proper care. However, it was also felt that another method of obtaining a pressure calibration for the Gulton P420M-6 should be explored. This method employs an electrostatic actuator which was first introduced by Ballentine in 1932. (Ref. 5) This method offers distinct advantages over others and, therefore, it was decided to obtain the pressure calibration of the Gulton P420M-6 microphone using the two methods described and the results are presented in this report. As shown in Section III of this report, the pressure calibrations on these microphones using the electrostatic actuator, are equivalent to those obtained on the same microphones using a pressure coupler. This fact is of more than academic interest since the electrostatic actuator method of calibration can be obtained rather simply and quickly when compared to the pressure coupler calibration technique.

It was expected that the data for the measurements would exhibit some scatter, particularly the free field measurements at the higher frequencies. Accordingly, it was decided to perform the required measurements on three different microphones. In addition, the measurements were repeated so that several data points at each frequency and angle of incidence were obtained. These data were then averaged and standard deviations calculated. In this way, some indication of the precision of the measurements was obtained. As expected, the scatter at low frequencies is very small with a gradual increase at the higher frequencies. For example, for the case when the microphone is mounted on the cylinder (figure 1), the calculated standard deviations for the diffraction correction at 1, 5, 10, 15, 20 and 25 KCPS are ±.1, ±.1, ±.2, ±.6, ±1.2 and +3.9, -7.4 db, respectively. Similar values were noted for the case when the microphone is mounted on the Gulton microphone clamp. (figure 1)

The remainder of this report presents a detailed description of the methods and apparatus used in the measurements (Section II). Section III presents the results of the calibrations and Section IV conclusions based on the results.

SECTION II

MEASUREMENT METHODS AND APPARATUS

This section presents details of the methods and measurement apparatus used to obtain the pressure and free field calibrations of the Gulton P420M-6 microphone and the standard Western Electric 640AA condenser microphone.

A. Pressure Calibrations

The pressure calibration of the standard microphone (W.E. 640AA serial number 1196) was obtained using the well known reciprocity technique. (Refs. 6, 7) In order to obtain the pressure calibration of this microphone in the frequency range to 25 KCPS, it was necessary to design and build a small "plain wave" coupler similar to that described in Ref. 8. In addition, a helium retention system patterned after the one described in Ref. 9 was built and used. The coupler and helium retention system are shown in figure 2.

Figure 3 shows a block diagram of the reciprocity system used in the pressure calibration of the W.E. 640AA standard microphone. Use of this system allows all data to be recorded in decibels directly and the data reduction is reduced to the addition and subtraction of decibels. The results of the pressure calibration of the standard microphone are discussed in Section III.

The pressure calibration of the Gulton microphone was obtained by a comparison technique. Using the system shown in figure 4, the standard and test microphones are in turn placed in the plain wave coupler filled with helium. Comparison of these data (with proper corrections which are discussed below) and knowledge of the absolute calibration of the standard microphones yields the absolute calibration of the Gulton microphone. Note that in all measurements using the Gulton microphone, use is made of an Endevco model 2607 amplifier with a nominal 40 db gain. Hence, all the calibration data reflects this gain. However, the frequency response of this amplifier is flat within ±.1 db over the frequency range of interest in this work. Hence, the gain is canceled out in the data reduction which yields the diffraction correction.

Because the acoustical impedance of the W.E. 640AA and the Gulton P420M-6 microphone are not equal, substitution of these microphones into the small (3 cc) coupler would be expected to produce a different sound pressure in the coupler for a constant electrical input to the W.E. 640AA used as a sound source. The change in sound pressure can be accounted for if one has knowledge of the magnitude of the ratio of acoustical impedance for the two microphones.

The change in sound pressure in the coupler can be thought of as due to an effective change in coupler acoustical impedance which is brought about by the introduction of the microphone sensing element. Since in the frequency range of interest, the coupler acoustical impedance is due to a volume, the change in coupler acoustical impedance can be thought of as due to a change in this volume, and this change in volume is due to the so-called "equivalent volume" of the microphone (Ref. 4) In order to account for the microphone equivalent volumes, it was necessary to measure these parameters. The measurements were made utilizing a Helmholtz resonator technique. The method measures

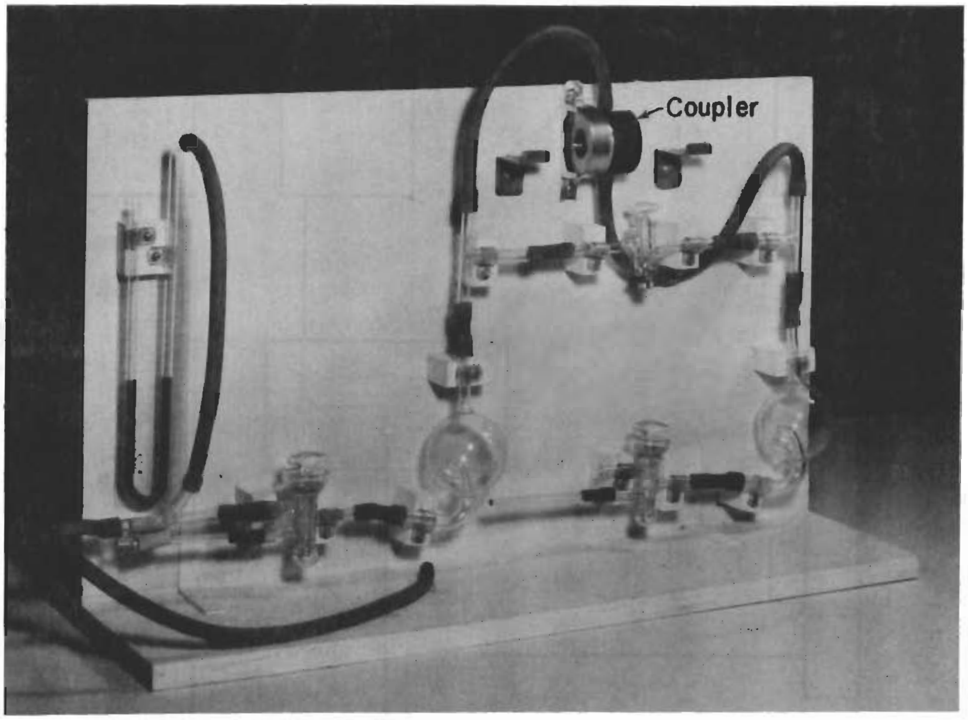

Figure 2. Plane wave coupler and helium retention system used in obtaining the pressure calibrations of the W.E. 640AA condenser microphone and the Gulton P420M-6 microphone.

the change in resonant frequency of a small Helmholtz resonator when the hard surface of one of the walls of the resonator is replaced by the sensing element of the microphone of interest. The change in the resonant frequency is related directly to the equivalent volume of the introduced microphone. The method has been described in the literature. (Ref. 10) The results of the measurements for the 640AA microphone and for the three Gulton microphones used in this program are shown in Table I below.

Table I

Measured Microphone Equivalent Volumes

Microphone Type	Serial No.	Equivalent Volumes (cm^3)
W.E. 640AA	1196	.15
Gulton P420M-6	2342	.072
"	2345	.062
"	2349	.072

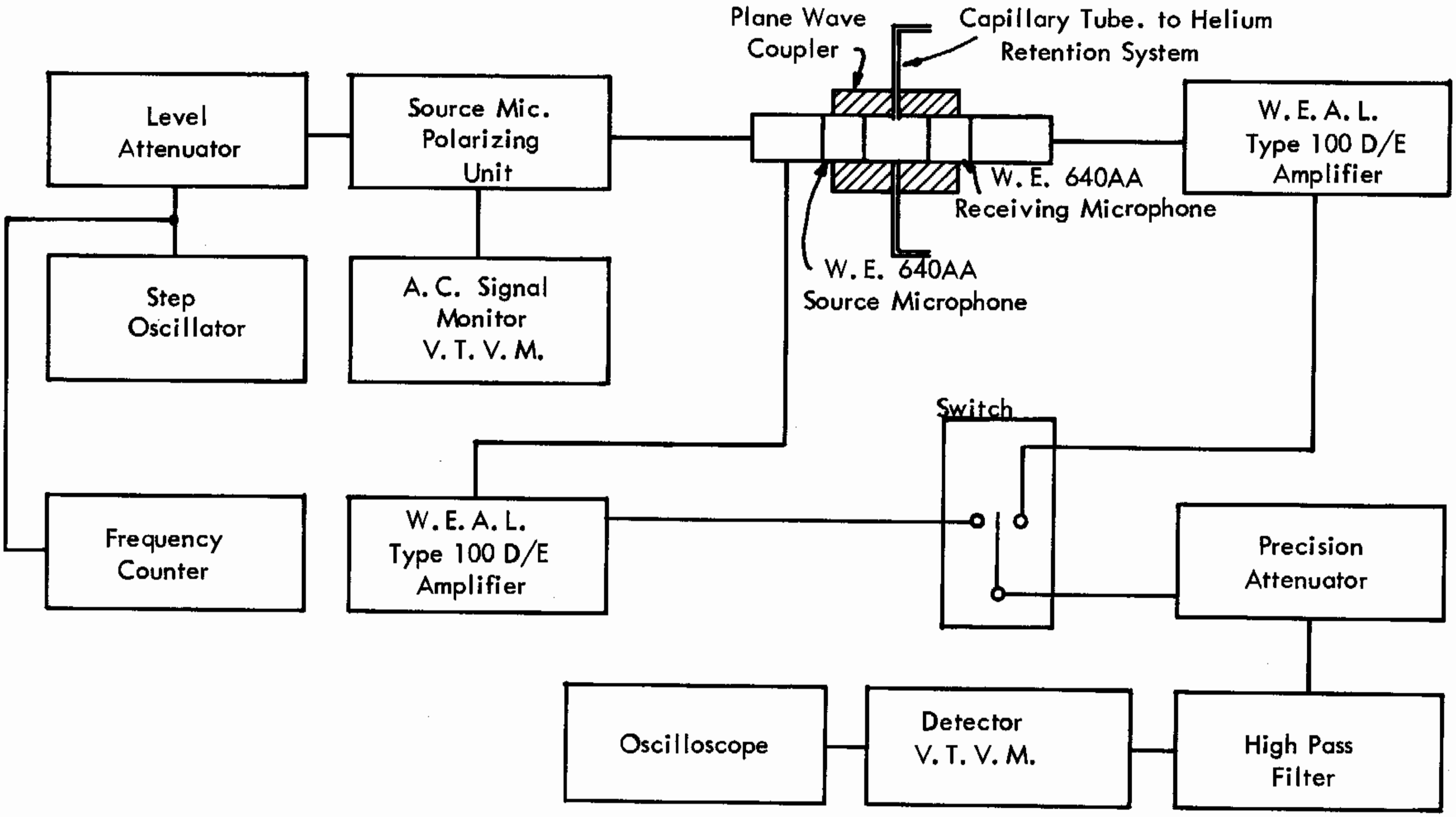

Figure 3. Plane wave coupler reciprocity calibration circuit.

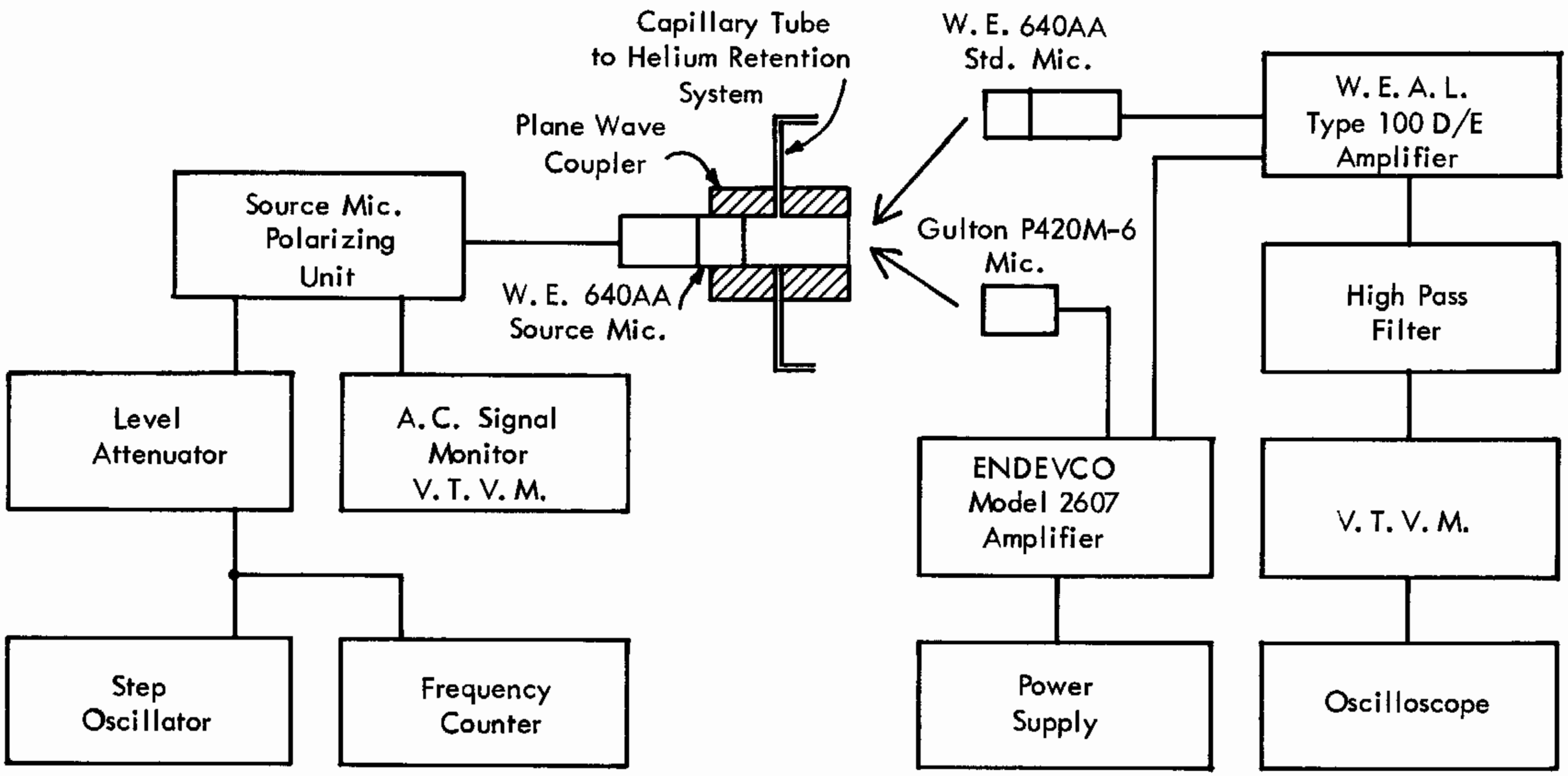

Figure 4. Plane wave coupler comparison calibration circuit.

The value of the equivalent volume measured for the W.E. 640AA agrees well with reported values for this microphone (Ref. 10). It is not possible to correlate the values measured for the Gulton microphone since no published data exists; however, the data do appear reasonable. The data of Table I were used to correct the measured data in the comparison pressure valibration of the Gulton microphones.

Figure 5 shows the block diagram of the system used to obtain the electrostatic actuator response of the three Gulton microphones. The electrostatic actuator is a device which is designed to drive the sensing element of a pressure transducer by means of the electrostatic forces which are set up between the actuator and the sensing element of the transducer (Ref. 5). The device has the property of applying a uniform force on the sensing element which is independent of frequency. Theoretically, the absolute amplitude of this force can be determined if the spacing between the actuator and transducer sensing element is known. In addition, the alternating and polarizing voltages must be known. Unfortunately, the spacing is not easily determined with high accuracy and since the applied force varies inversely as the square of the spacing, absolute force amplitudes are subject to error. However, if absolute force or pressure amplitudes are not desired, for example, if only the shape of the frequency response curve is desired, then this device can be used to obtain the pressure response in the following manner: first, the actuator is used to obtain the shape of the pressure response curve of the test microphone; then the absolute calibration of the test microphone is obtained at a low frequency where the diffraction correction is zero. This can be performed in free field or in a coupler, as outlined earlier. This single frequency calibration allows one to fix the absolute level of the frequency response curve obtained with the electrostatic actuator. The method has proved valid in calibration of condenser microphones at frequencies up to 10 KC. (Ref. 11) We point out here that objections to the method have been raised by various workers in the electro-acoustic field (Ref. 12). It has been pointed out that the resultant force acting on the diaphragm of a pressure transducer whose mechanical impedance is not infinite at all frequencies will not remain constant with frequency, as indicated by the electrostatic actuator theory. For example, work performed at NBS with a W.E. 640AA condenser microphone shows good agreement between a coupler calibration and an electrostatic calibration up to about 3 KCPS, and deviations between the two methods of up to 1.0 db at 10 KCPS. We note, however, that the mechanical impedance of the P420M-6 microphone should be very much larger than for a condenser microphone of similar size and therefore this objection may not be valid. As pointed out in Ref. 12, the errors arise because of the movement of the test microphone diaphragm. We note that a piezoelectric sensing element for all practical purposes does not vibrate in response to the electrostatic forces produced by the actuator, hence the errors for this type of microphone will be very small.

As will be shown in Section III, these statements are confirmed.

B. Free Field Calibrations

The free field normal incidence calibration for the three Gulton microphones was obtained by comparison to a Western Electric 640AA condenser microphone (serial no. 1196). Prior to these measurements, the W.E. 640AA microphone was calibrated in a free

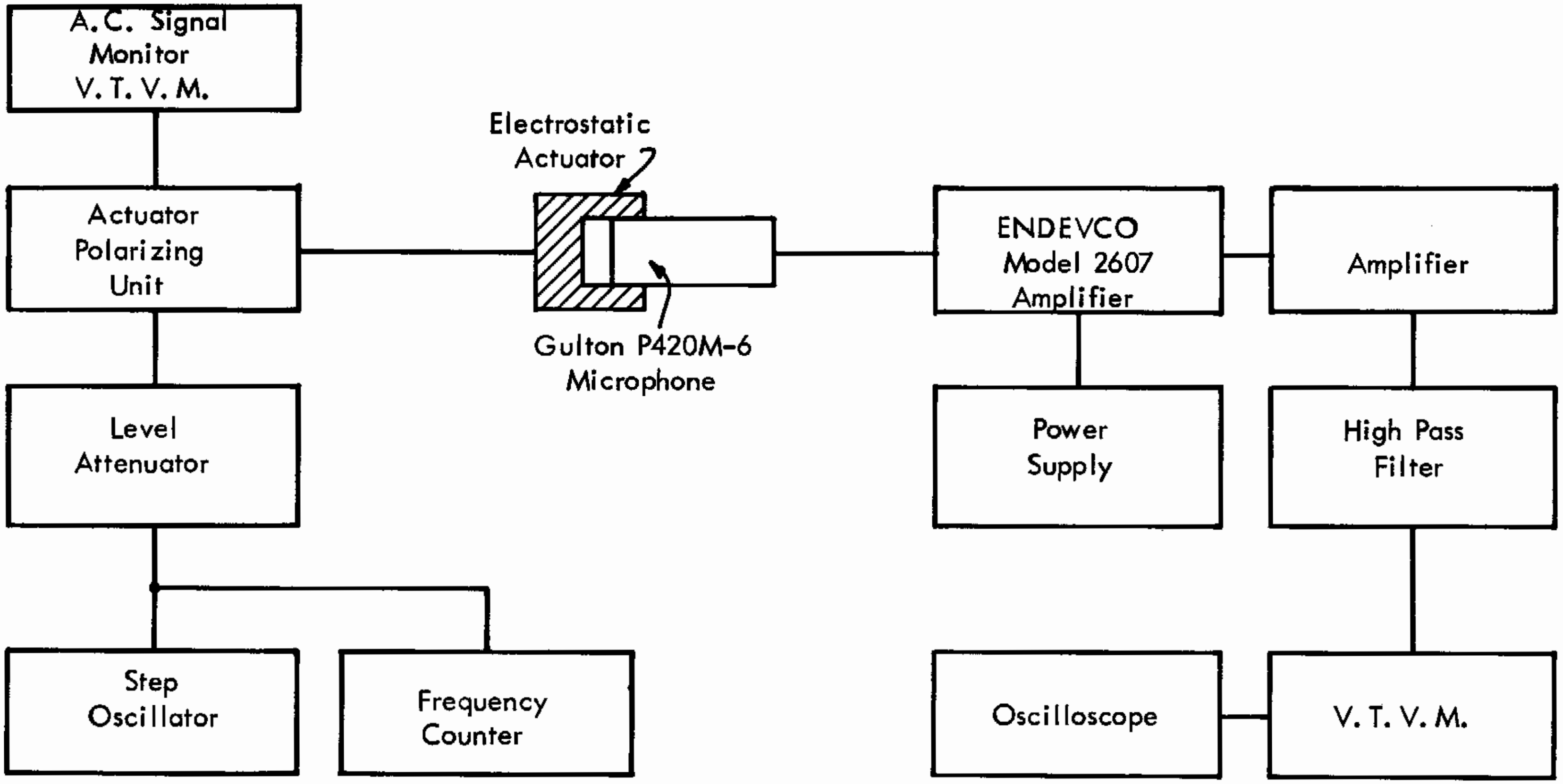

Figure 5. Electrostatic actuator calibration circuit.

field using the reciprocity technique (Ref. 13) in the frequency range 1 KCPS to 25 KCPS. The system used in this measurement is shown in figure 6, which except for the coupling between source and receiving transducer is similar to the pressure reciprocity system discussed earlier.

The block diagram of the system used to obtain the free field normal incidence calibration is shown in figure 7. The procedure for this calibration consists of subjecting the standard and test microphones in turn to the same sound field and comparing their output signals. Knowledge of the standard microphone absolute sensitivity allows calculation of the test microphone absolute sensitivity. The calibration on the three Gulton microphones was performed over the frequency range 400 CPS to 25 KCPS using fixed frequencies. The number of fixed frequencies in this range was 32, which assured that adequate response detail could be measured. As in the pressure calibration of these microphones, the Endevco Model 2607 amplifier was included in the free field calibration; hence the ordinate of the calibration curves for the Gulton microphones are 40 db greater than if the calibration of the microphones without amplifier were shown.

The normal incidence free field calibrations of the Gulton microphones were obtained for two different mounting configurations. These are shown in figure 1.

In order to measure the free field response of the Gulton microphones at various angles of sound incidence, the apparatus shown in figure 8 was utilized. This equipment when mounted in the anechoic chamber was used to measure the difference in microphone response between normal incidence (zero degree) and any other angle of incidence. The protractor and pointer allowed setting of the angle of incidence in one degree increments from zero to 360°. These differences could then be added to the measured response at zero degrees to obtain the response at any desired angle of incidence.

The apparatus shown in figure 8 was designed so that the microphone was rotated about an axis which was parallel to and passed through the face of the sensing element. The distance between microphone and sound source was constant within ± 1/16 inch for all free field measurements.

The response versus angle of incidence was obtained at 15° increments from 0° to 180° for the microphone mounted on the cylinder. For the microphone mounted on the Gulton clamp, the response was obtained in 30° increments from 0° to 360°. The latter configuration because of its asymmetry dictated that the angle of incidence data be measured in more than one plane. Figure 9 is a sketch which shows the three planes in which the angle of incidence was measured. The added measurements were required in order to insure that the calculated value for the random incidence response have greater validity.

It was expected that the free field data would exhibit scatter at the higher frequencies, particularly above 15 KCPS. Hence, in order to obtain data with some degree of confidence, it was decided to repeat the measurements using three different microphones.

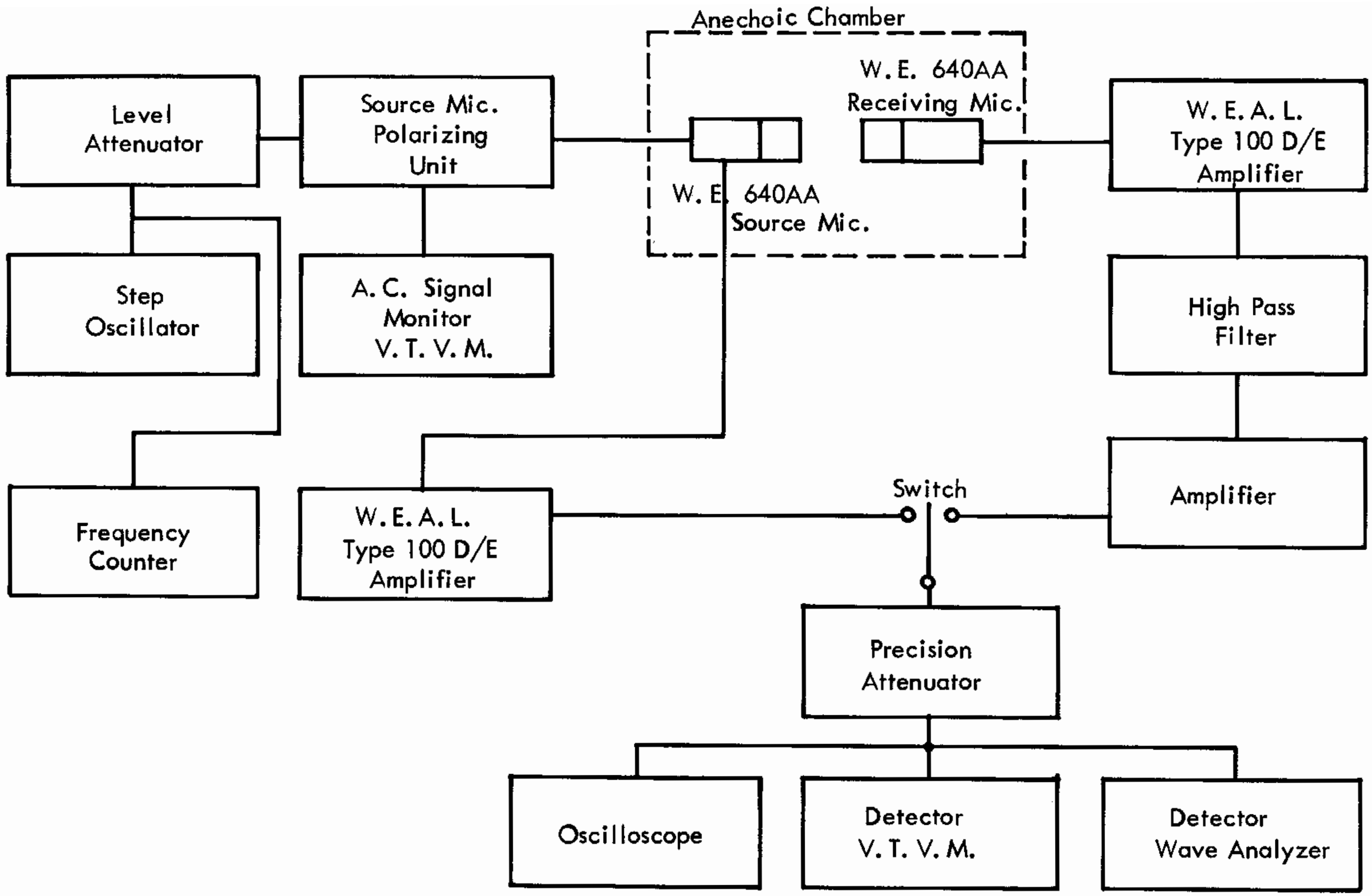

Figure 6. Free field reciprocity calibration circuit.

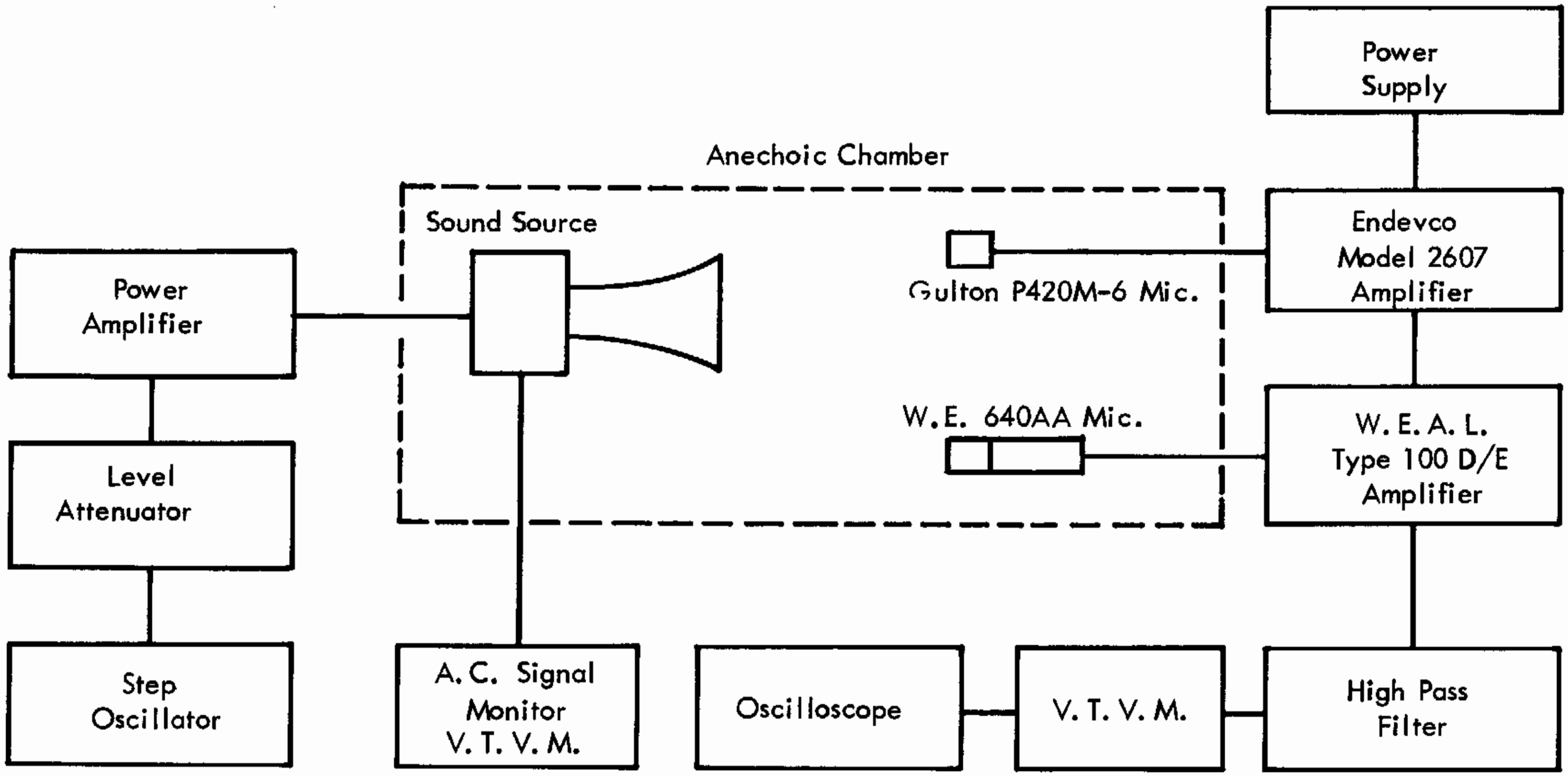

Figure 7. Free Field comparison calibration circuit.

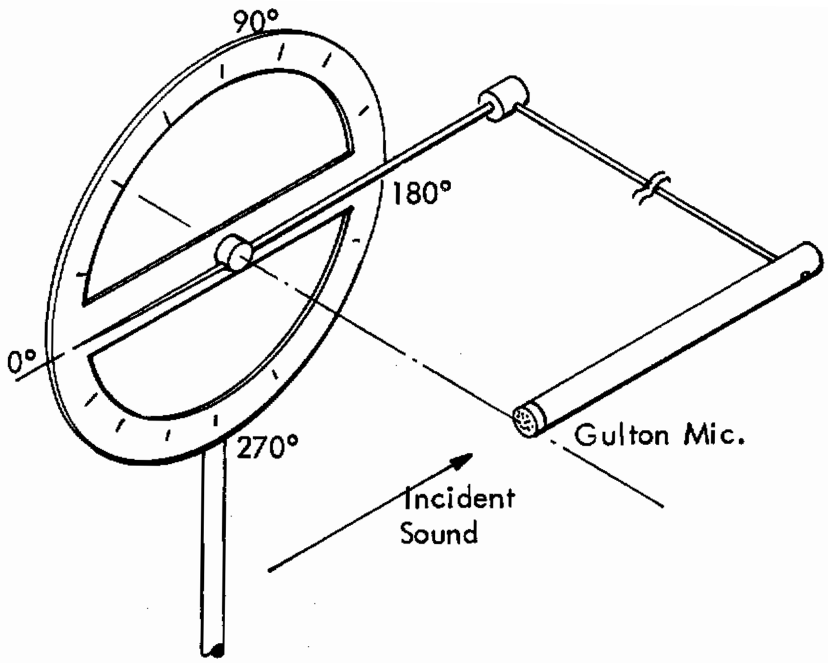

Figure 8. Protractor apparatus used to obtain the free field angle of incidence data for the Gulton P420M-6 microphone.

With the microphones mounted on the cylinder, this method resulted in six data points at each angle of incidence and each frequency point in the frequency range up to 14 KCPS. In the frequency range 15 KCPS to 25 KCPS, nine data points were measured (three microphones and three different measurements). The several data points at each frequency and angle of incidence were then averaged and standard deviations calculated. These average values were then used in the final calculations of the diffraction correction.

For the case with the microphone mounted in the Gulton clamp, the procedure was slightly different. Based on the experience with the microphone mounted on the cylinder and on the fact that the clamp configuration needed to be measured in three planes, the number of data points in each plane was reduced (six data points from 400 CPS to 25 KCPS), but the total number including three planes was increased. The random incidence calibration for this configuration was based on all of the measured data.

The random incidence data for both configurations was obtained using the methods described in Refs. 2 and 3. The method is an energy integrating one in which all of the free field data versus angle of incidence is utilized. A sample calculation and plot is shown in figure 10 for the microphones on the cylinder at a frequency of 15 KCPS.

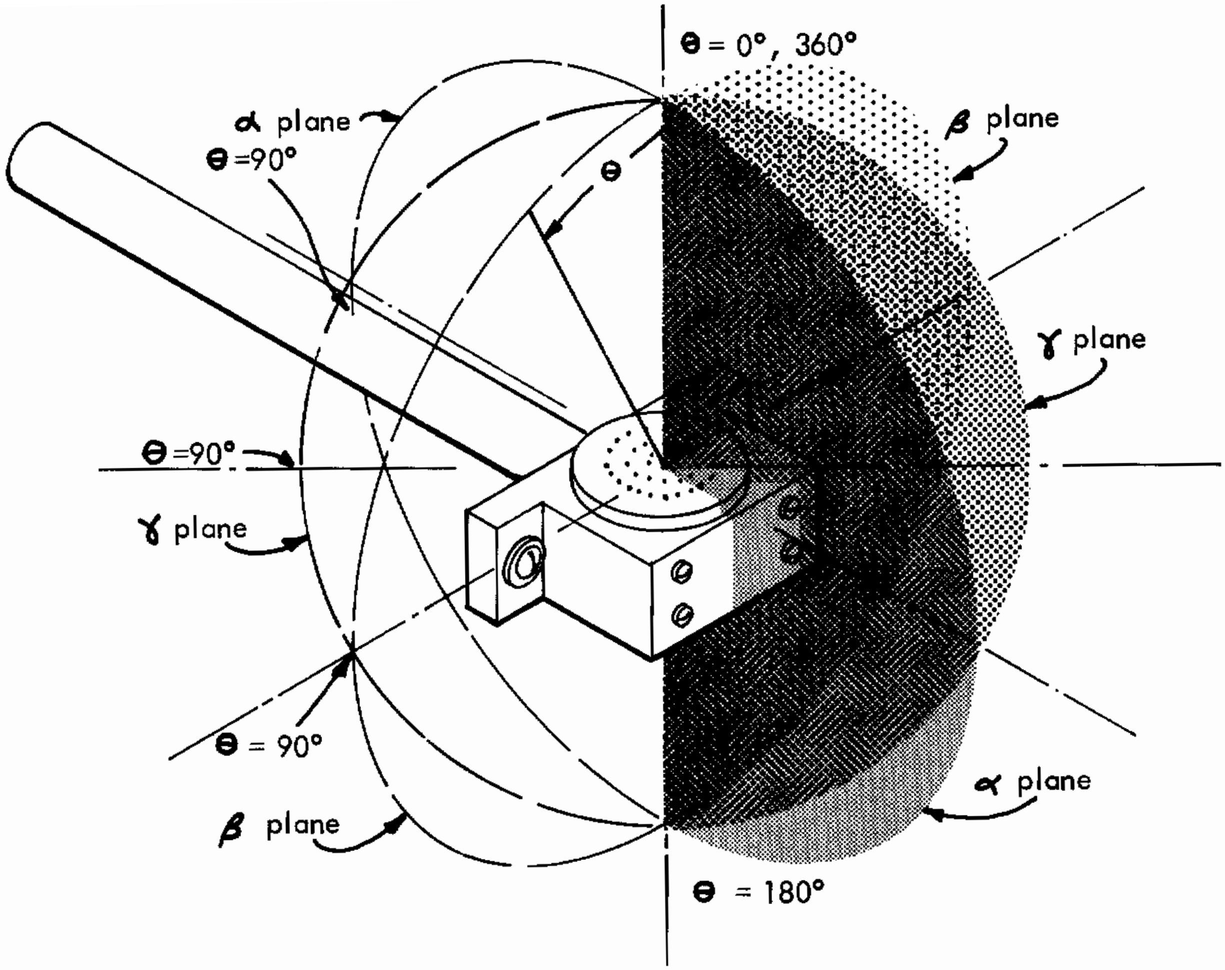

Figure 9. Sketch of Gulton microphone mounted on Gulton clamp showing three planes in which angle of incidence measurements were performed. The angle of incidence θ is measured relative to a normal on the microphone grid as shown.

The ratio of the total area of the graph to the area under the curve is a measure of the difference between the random incidence response and the response at zero angle of incidence. The areas are measured directly using a polar planimeter.

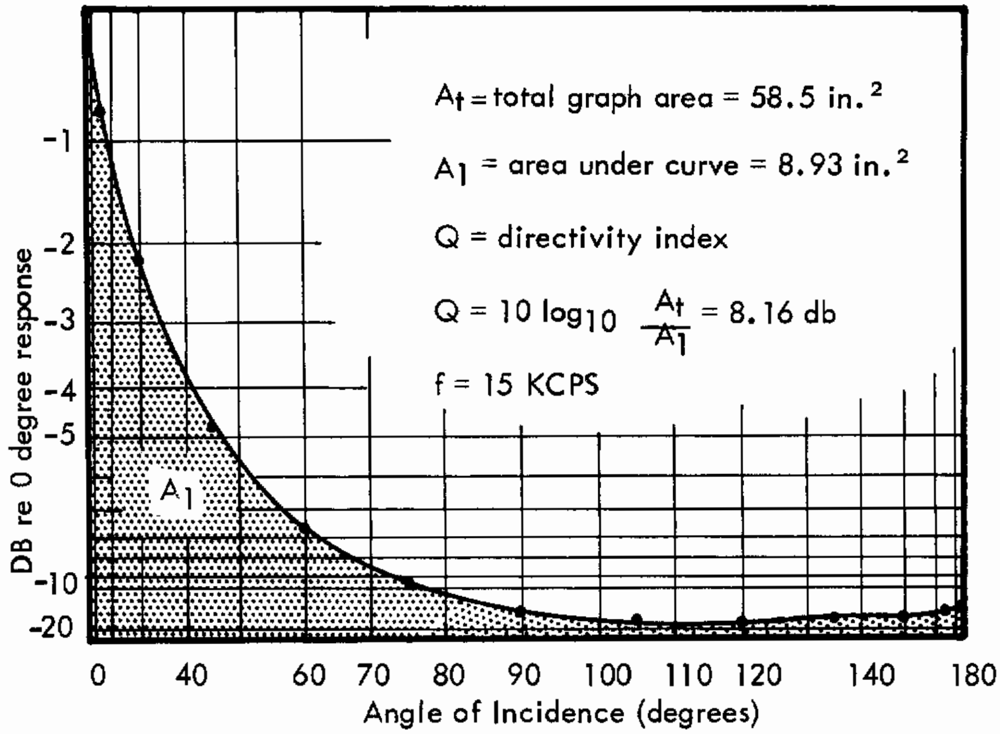

Figure 10. Illustration of the method of calculation used to obtain the random incidence response. The random incidence response is defined as the difference between the normal incidence response (zero degrees) and the directivity index Q. In the example shown, the random incidence response at 15 KCPS for the Gulton mic. mounted on the cylinder, is 8.16 db down from the response at zero degrees.

SECTION III

MEASUREMENT RESULTS

A. Pressure Calibrations

The result of the coupler pressure calibration of the W. E. 640AA standard microphone is shown in figure 11. Also included in the figure are the measured data on the same microphone obtained by the National Bureau of Standards. The agreement is excellent, with the maximum variation of .5 db occurring at 18 and 19 KCPS. Considering that the calibrations were performed by two different laboratories using slightly different measuring techniques, the small variations noted are surprising. The pressure calibration in the figure was used in the comparison calibration of the three Gulton microphones.

The results of the coupler comparison calibrations for the three Gulton microphones and Endevco amplifier are shown in figure 12. The similarity between the three microphones is evident. We note that the calibrations of figure 12 are valid for the Gulton microphones with or without protection grid.

As discussed in an earlier section of this report, the pressure calibration for the three Gulton microphones was also obtained using an electrostatic actuator. Figure 13 presents the pressure coupler and electrostatic actuator calibration for one of the microphones. The data is typical of all three microphones and as seen in the figure, very little difference exists between the sets of data. The maximum variation between the two types of calibration is .7 db at 12 and 16 KCPS. Considering the completely different methods of calibration, this agreement is quite good. It is noted also that in the area of maximum variation, the electrostatic calibration presents a smoother response versus frequency. The results of figure 13 serve to confirm earlier statements that the electrostatic actuator method of calibration is a valid method for the Gulton P420M-6 microphone and is probably valid for any other microphone of similar construction. Since this method of calibration is much more readily obtained, this fact is of practical importance.

B. Free Field Calibrations

The result of the free field reciprocity calibration of the W.E. 640AA condenser microphone is presented in figure 14. The response is typical for these microphones. Note that the sensitivity at the lower frequencies where the diffraction correction is zero is equal to that shown in figure 11 for the same microphone. In fact, the difference in the response of figures 11 and 14 gives the diffraction correction for the standard microphone used in these measurements.

The free field normal incidence response for one of the Gulton microphones is given in figure 15 for the two mounting configurations. The data shown is typical of the three microphones, and it is seen that the two responses are different at frequencies above 1000 CPS. This difference is , of course, reflected in the diffraction correction as will be shown below.

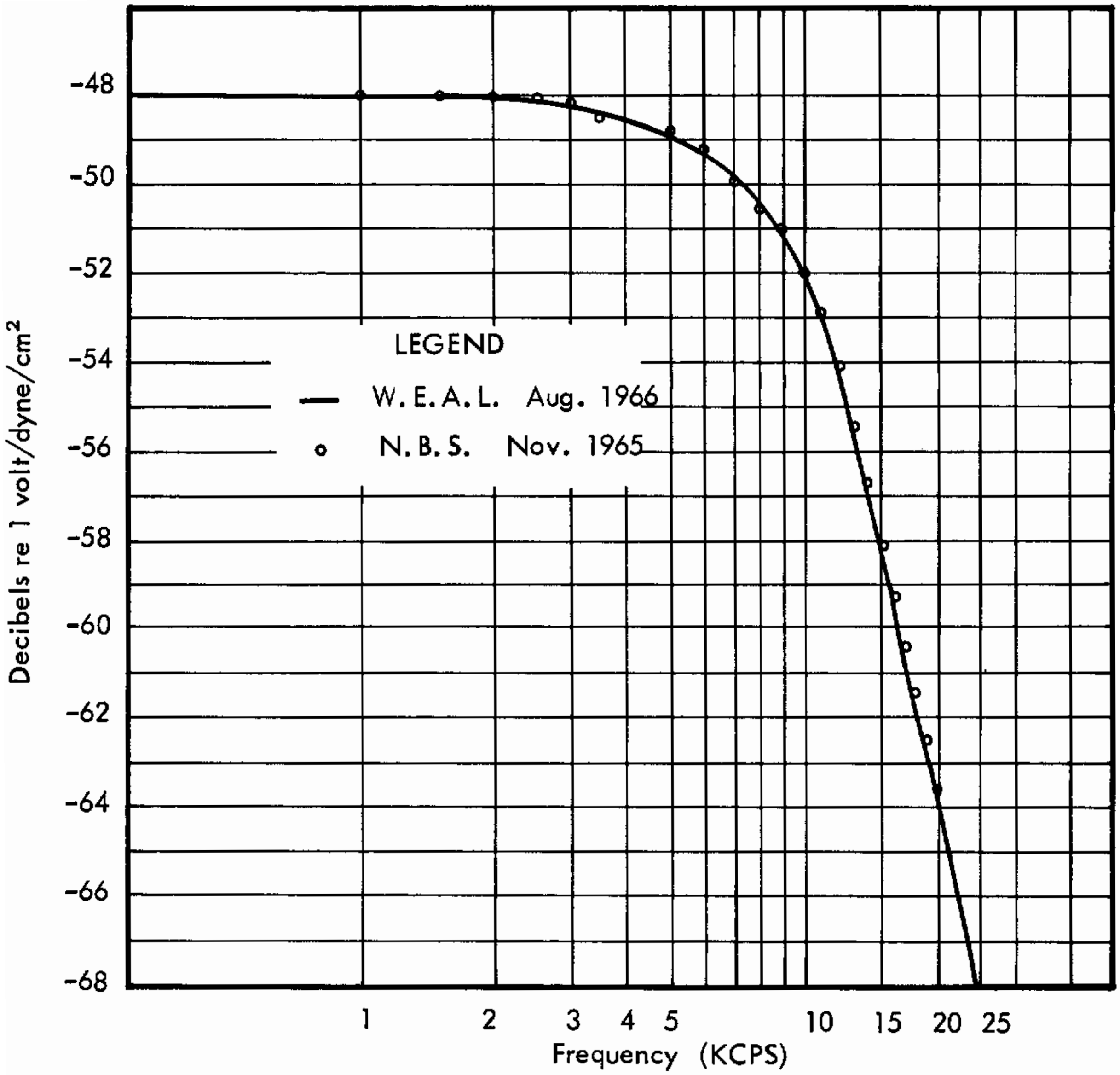

Figure 11. Open circuit pressure calibration for the standard W. E. 640AA condenser microphone, serial no. 1196. The data from a previous calibration performed by the National Bureau of Standards is included for comparison.

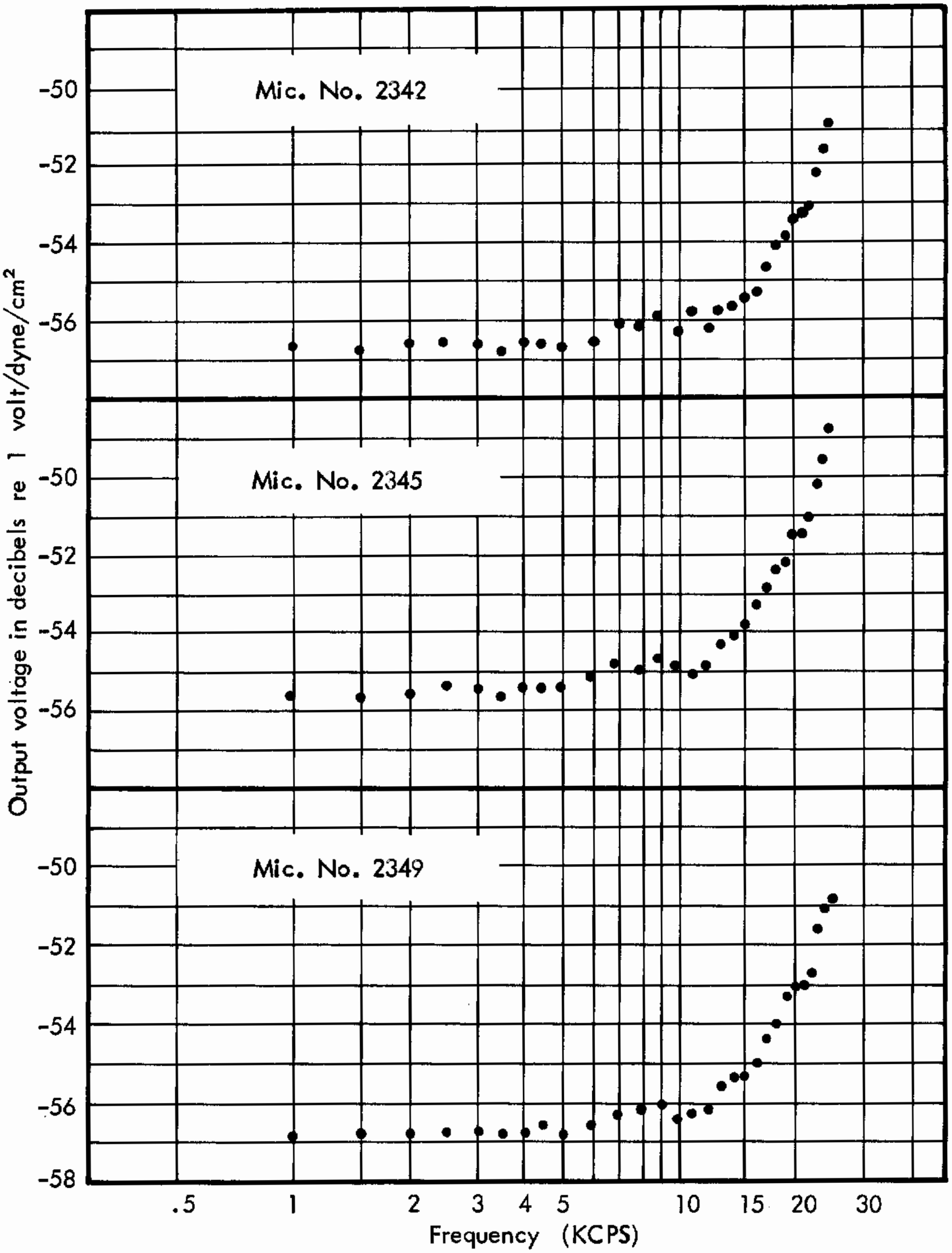

Figure 12. Pressure calibration of the three Gulton P420M-6 microphones. The calibration includes the 40 db gain of the Endevco Model 2607 amplifier.

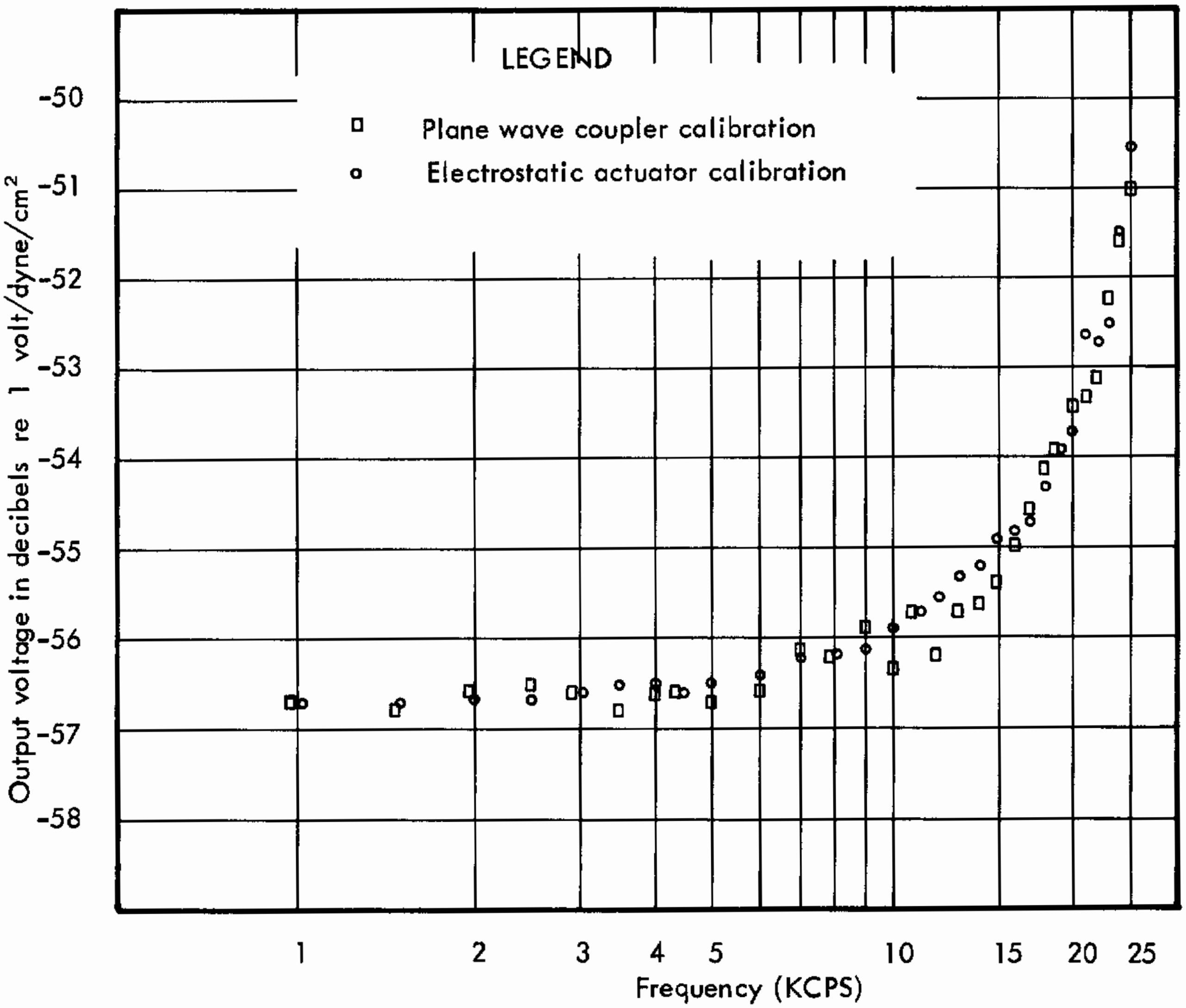

Figure 13. Comparison between two methods of obtaining the pressure calibration of a Gulton P420M-6 microphone, serial no. 2342. The calibration includes the 40 db gain of the Endevco Model 2607 amplifier.

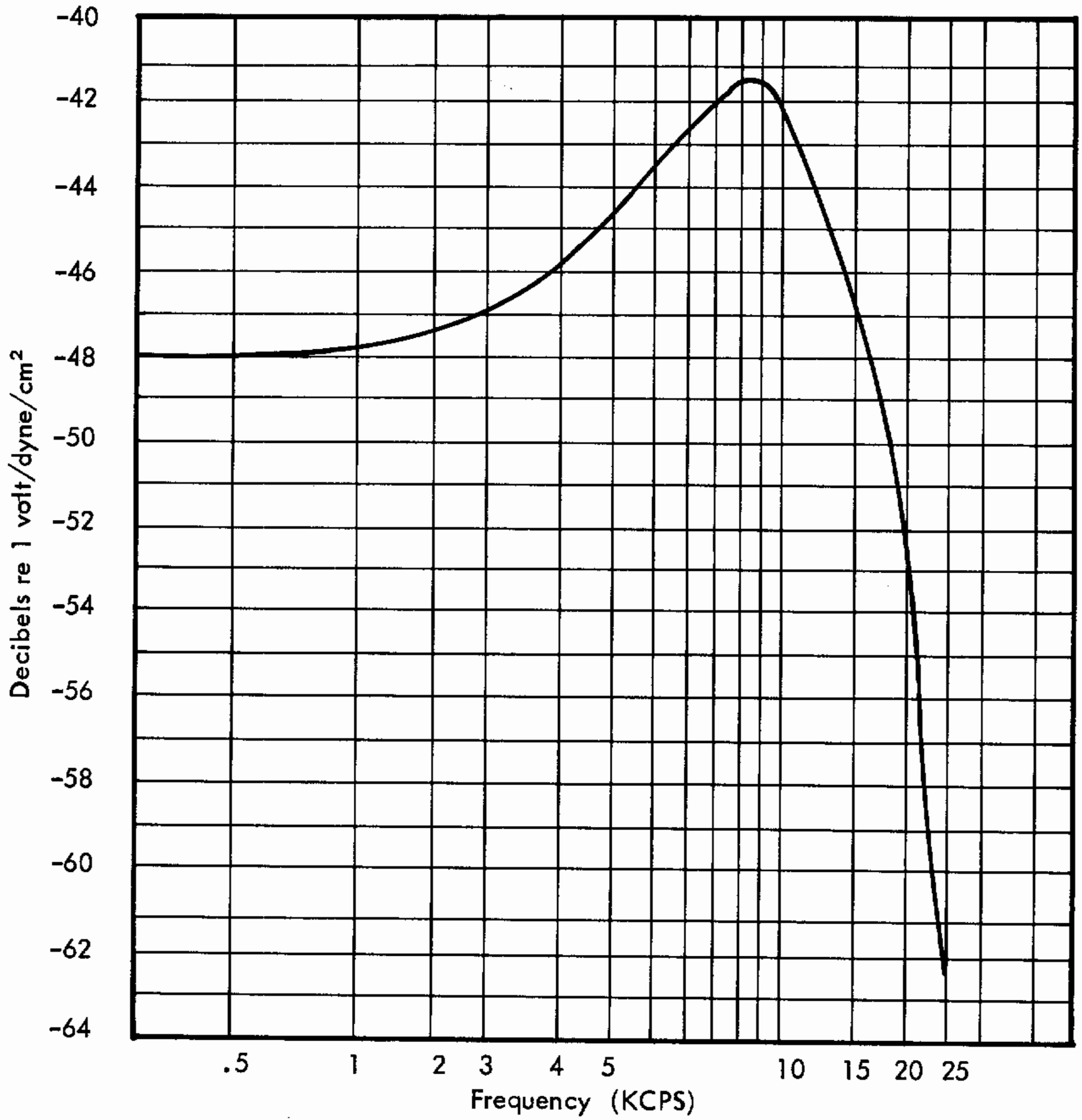

Figure 14. Open circuit free field calibration for the standard W. E. 640AA condenser microphone, serial no. 1196.

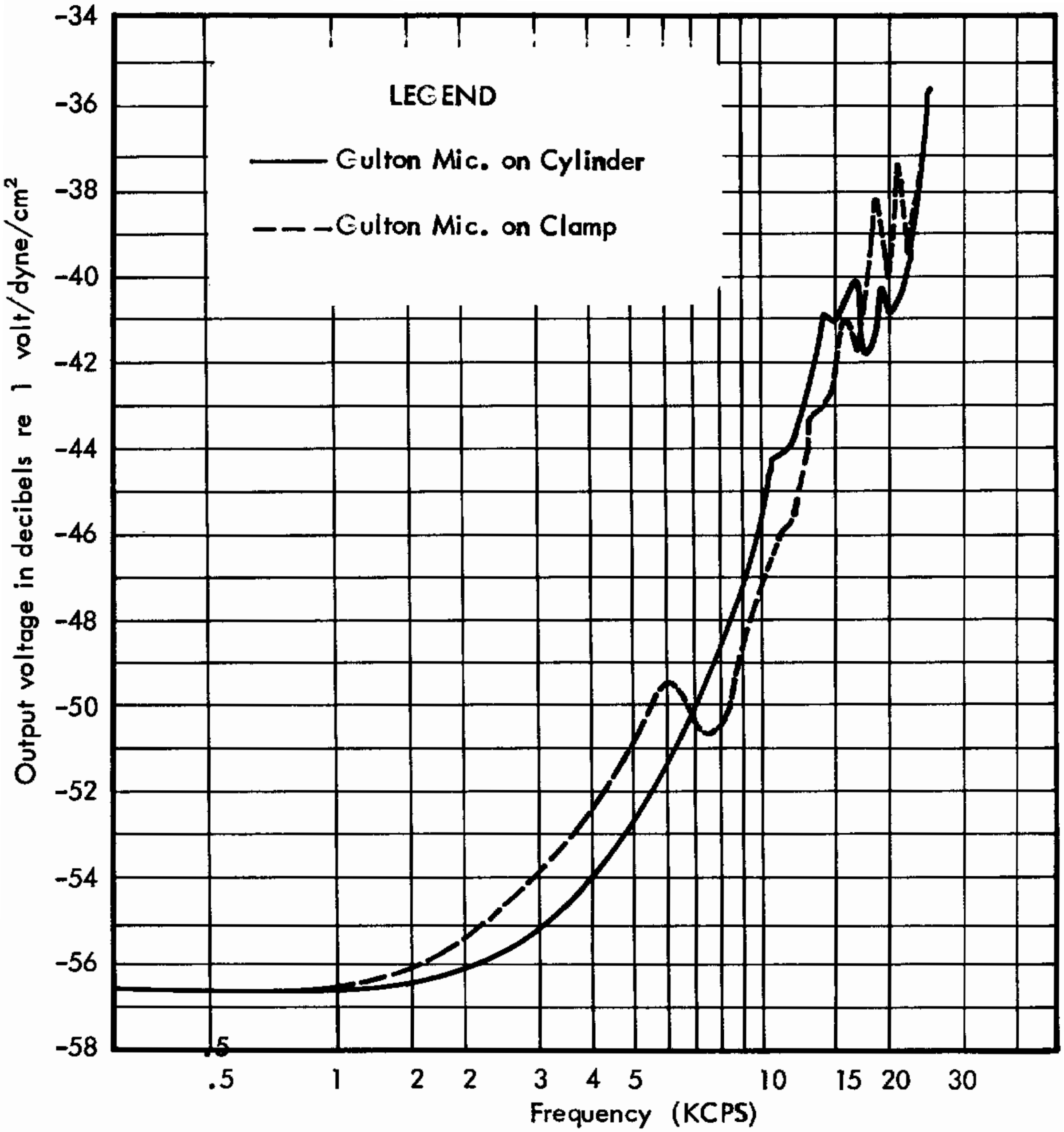

Figure 15. Free field normal incidence calibration of a Gulton P420M-6 microphone for two different mounting configurations. The calibration includes the 40 db gain of the Endevco model 2607 amplifier.

C. Diffraction Correction

Figure 16 presents the calculated diffraction correction for the Gulton microphone when mounted on the cylinder as shown in figure 1. As noted earlier, the diffraction correction is defined as the difference in decibels between the free field response at some specified angle of incidence and the pressure response. The data of figure 16 is an average of several measurements, and Table II below presents the calculated standard deviation of the diffraction correction at the 90° angle of incidence. The standard deviations for this angle of incidence are similar to all other angles and can therefore be considered typical

Table II

Calculated Standard Deviations for the Diffraction Correction
of the Gulton P420M-6 Microphone when mounted on cylinder
Angle of incidence = 90°

f(KCPS)	Standard Deviation (db)	f(KCPS)	Standard Deviation (db)
.7	±.1	15	±.6
1	±.1	18	±.9
2	±.1	20	±1.2
5	±.1	22	+1.5, -1.9
10	±.2	24	+3.3, -5.7
12	±.5	25	+3.9, -7.4

It is clear from Table II that the level of confidence up to about 20 KCPS is good but that above this frequency, the confidence level decreases rapidly.

We note here that all data were measured in decibels and that the decibel averages were calculated by first converting the decibel values to voltage ratios. These voltage ratios were averaged and this average converted back to a decibel value. This procedure was followed in order to obtain valid averages when the data exhibited large scatter. Similarly, the standard deviations in Table II were obtained by working with voltage ratios, then converting to decibel values. The asymmetrical values of the standard deviations in Table II at frequencies above 20 KCPS, where the scatter is relatively large, result from the logarithmic character of the decibel. That is, the error in the data as exemplified by the standard deviation when converted to a decibel value is not symmetrical about the average decibel value.

The data of figure 16 have been plotted on an expanded vertical scale to simplify their use. Note also that no smoothing of the data has been performed. It is felt that this is best performed by the user, who is in a much better position to judge when smoothing of the curves is justified.

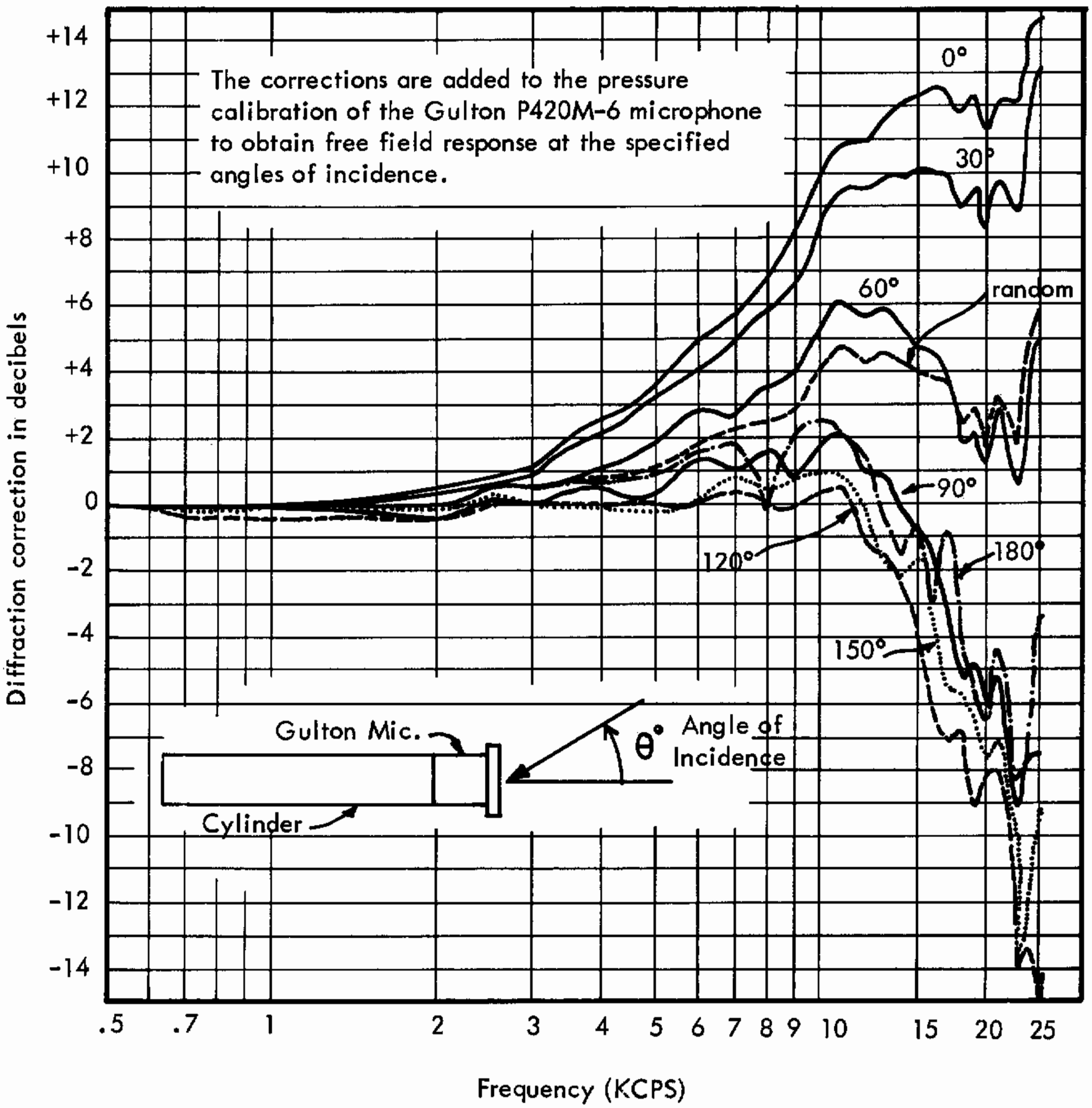

Figure 16. Measured diffraction correction for the Gulton P420M-6 microphone with grid and mounted on cylinder.

A by-product of the measurements to determine the diffraction correction is the polar resonse of the microphones. Figure 17 presents the polar response of the Gulton microphone mounted on the cylinder for several frequencies. The data plotted is the average of all the free field measurements discussed above.

The diffraction correction for the Gulton microphone when mounted in the Gulton clamp is presented in figures 18 and 19. The major difference between these data and that shown in figure 16 is in the frequency range from 5 to 10 KCPS. This difference stems from diffraction phenomena associated with the Gulton clamp and cylinder and is clearly evident in figure 15, which compares the free field responses of the two mounting configurations.

As discussed earlier, the asymmetry of the microphones mounted in the Gulton clamp necessitated angle of incidence measurements around a full 360° arc. Figure 19 presents the data in the range 210° to 330°. It is noted that the differences between these curves and the corresponding angle of incidence curves of figure 18 are small except for some of the data at the high frequencies.

The asymmetry discussed above also necessitated that angle of incidence data be measured in more than one plane. The reader is referred to the sketch in figure 9 which depicts the three planes in which angle of incidence measurements were made. The primary reason for the added measurements was to obtain enough data which would enable a more accurate calculation of the random incidence response.

The data shown in figures 18 and 19 is an average of all data measured in the three planes. Analysis of this data showed that the data measured in the three planes did not significantly differ from the average value shown in figures 18 and 19, at frequencies below 15 KCPS. Hence, the data of figures 18 and 19 are valid for any plane used in practice up to 15 KCPS. In order not to introduce added charts which would be identical below 15 KCPS, the diffraction corrections in the three measured planes above 15 KCPS are tabulated and located in the Appendix. It will be noted that the differences involved are not large except, again, for the very high frequencies.

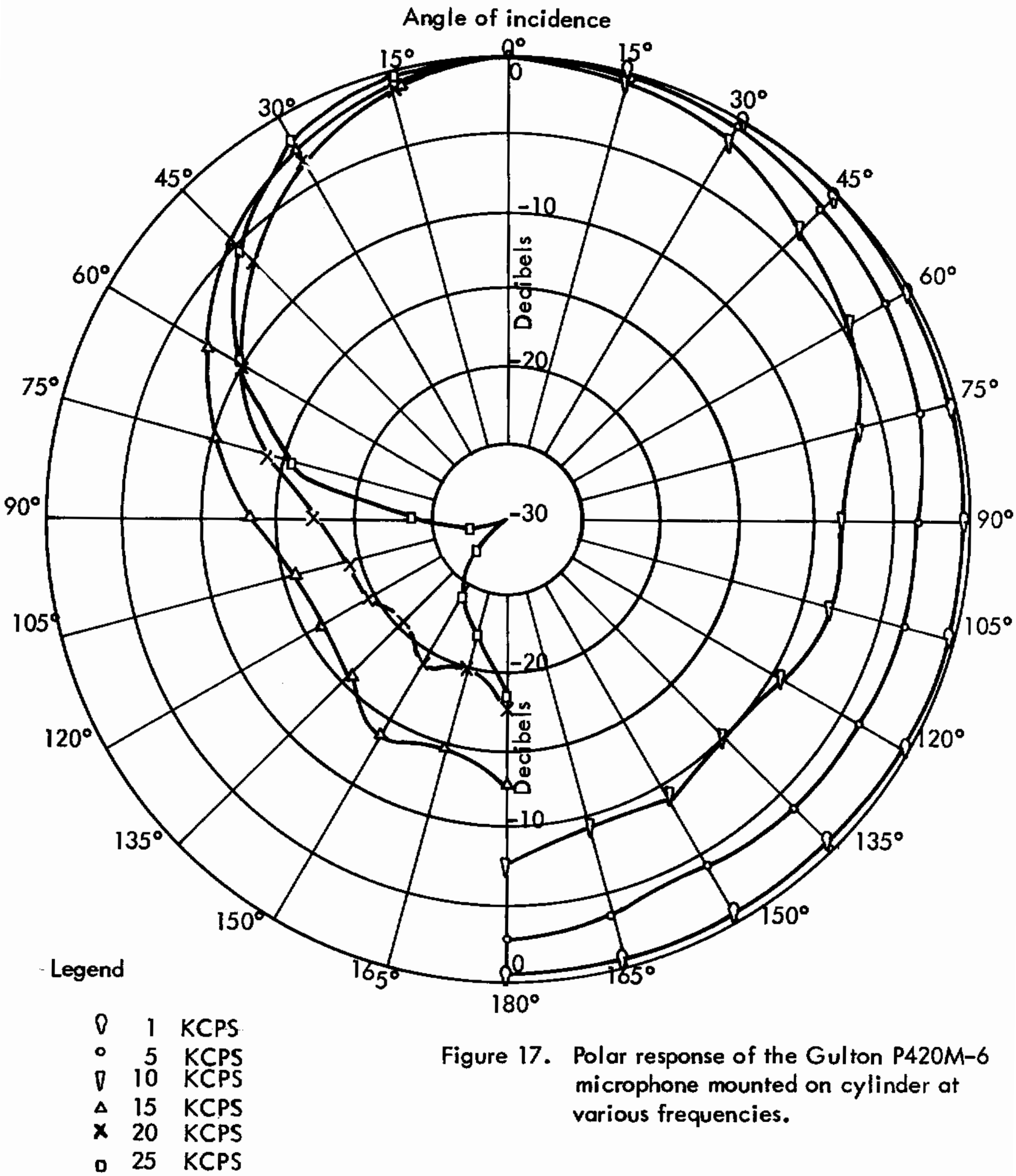

Figure 17. Polar response of the Gulton P420M-6 microphone mounted on cylinder at various frequencies.

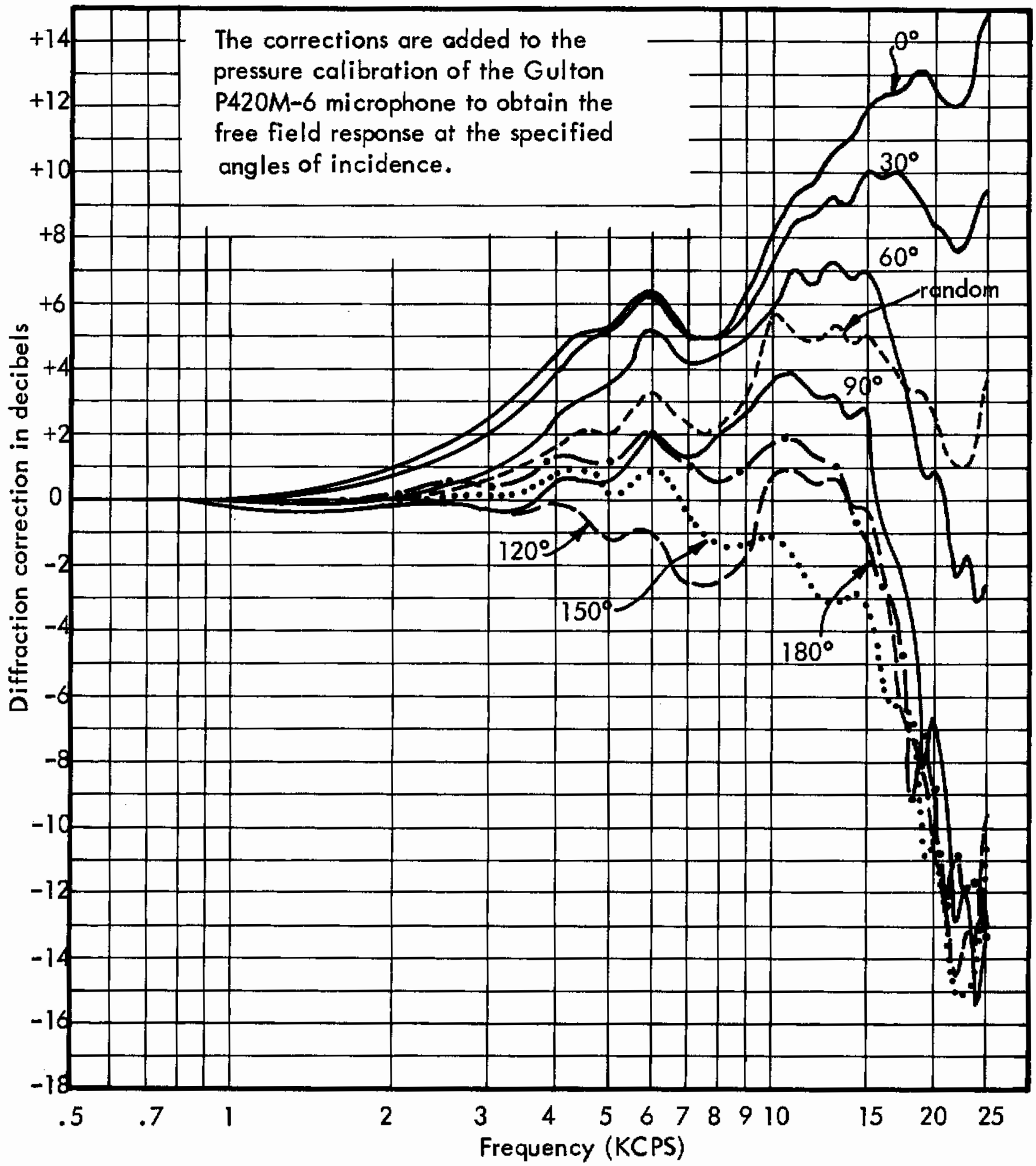

Figure 18. Measured diffraction correction for the Gulton P420M-6 microphone with grid and mounted on Gulton clamp.

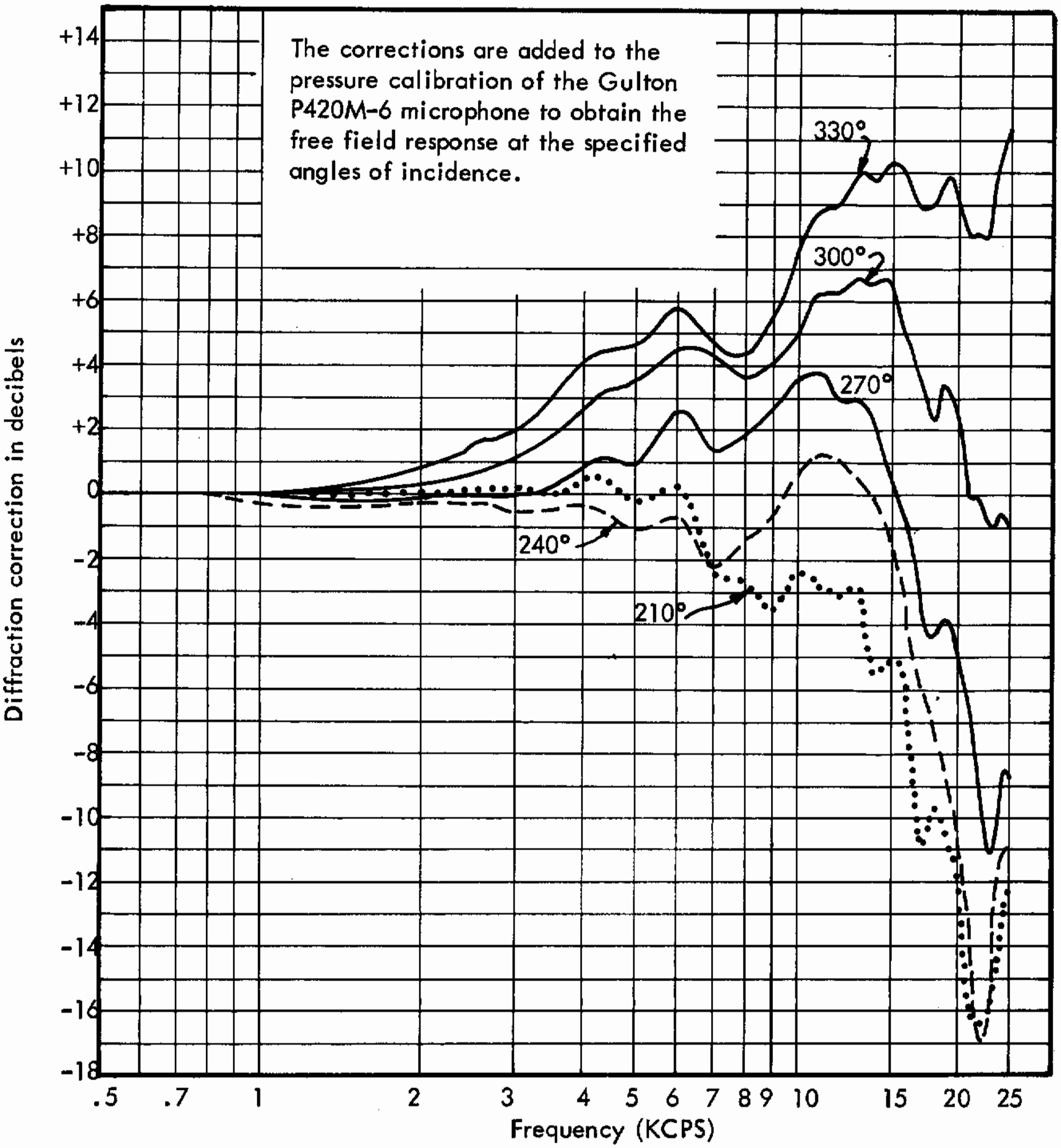

Figure 19. Measured diffraction correction for the Gulton P420M-6 microphone with grid and mounted on Gulton clamp.

SECTION IV

CONCLUSIONS

This report has described in detail the methods and equipment used to obtain the diffraction correction for the Gulton P420M-6 microphone. The diffraction correction has been obtained for two different microphone configurations which are shown in figure 1.

Analysis of the measured data shows that the precision of the measurements is very good at frequencies below 15 KCPS and gradually decreases at higher frequencies. The data of Table II, which shows typical calculated standard deviations, indicates that up to 20 KCPS the diffraction corrections for either mounting configuration can be used with confidence. Above 20 KCPS, the data should be used with care.

One objective of the program work was to investigate the use of an electrostatic actuator to obtain the pressure calibration of the Gulton microphone. The measurements show that the electrostatic actuator can be used with accuracy to obtain the pressure calibration of the Gulton Microphone. Figure 13 presents the comparison of the two methods used in this work and the agreement is seen to be quite good. The relative facility of using the electrostatic actuator to obtain a pressure calibration as compared to the coupler method makes the results obtained of practical importance.

APPENDIX

The data tabulated in this Appendix is the diffraction correction in three different planes for the Gulton P420M-6 microphone mounted on the Gulton clamp in the frequency range 15 to 25 KCPS. The reader is referred to figure 9 for orientation of the α, β and γ planes in which the measurements were performed.

TABLE III

DIFFRACTION CORRECTION FOR GULTON MICROPHONE MOUNTED IN GULTON CLAMP MEASURED IN THE α PLANE

Frequency (KCPS)	Angle of Incidence (degrees)											
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
15	12.1	9.3	6.6	3.0	-1.2	-7.4	-1.5	-4.9	-1.2	1.2	6.0	10.6
16	12.3	8.7	4.2	1.3	-2.9	-8.3	-3.0	-6.0	-4.7	-1.7	5.3	9.7
17	12.4	9.5	4.1	-2.0	-6.4	-9.7	-3.4	-14.7	-5.3	-3.0	3.4	9.6
18	12.8	9.3	1.4	-4.1	-9.3	-11.2*	-7.2	-7.9	-6.9	-2.4	3.7	10.5
19	13.2	9.0	1.5	-5.0	-5.3	-13.3	-5.7	-8.5	-8.3	-3.7	4.0	10.9
20	12.5	8.0	0.6	-7.3	-9.3	-12.3	-9.8	-7.2	-8.8	-4.3	3.6	10.0
21	12.1	7.8	-0.7	-9.3	-10.1	-15.9	-9.0	-12.2	-9.2	-5.5	1.8	9.3
22	12.0	7.3	-3.2	-8.9	-10.7	-18.4	-11.7	-12.3	-18.7	-9.8	-0.2	8.7
23	12.2	8.6	-2.1	-13.1	-11.0	-15.2	-11.0	-17.2	-16.6	-12.9	-0.8	8.5
24	14.3	9.1	-4.1	-16.5	-16.7	-10.6	-10.3	-11.9	-8.8	-8.9	0.5	10.4
25	15.0	8.8	-5.4	-15.7	-12.2	-12.7	-14.1	-14.3	-11.8	-9.6	-0.5	11.8

*This data is a best estimate based on the more reliable measured data. Original data was considered questionable.

TABLE IV

DIFFRACTION CORRECTION FOR GULTON MICROPHONE MOUNTED IN GULTON CLAMP MEASURED IN THE β PLANE

Frequency (KCPS)	Angle of Incidence (degrees)											
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
15	12.1	10.6	7.4	3.0	-0.7	-3.4	-1.0	-5.1	-1.2	1.2	6.3	10.6
16	12.3	10.5	6.9	0.9	-2.9	-6.3	-2.1	-4.0	-2.9	0.3	4.7	10.0
17	12.4	10.1	4.9	0.5	-3.5	-3.9	-3.1	-4.7	-4.7	-4.3	3.5	8.6
18	12.8	9.4	2.5	-2.0	-6.2	-8.0	-11.5	-10.8	-7.7	-5.0	2.6	8.5
19	13.2	9.7	3.5	-2.9	-6.8	-8.9	-7.6	-11.6	-9.2	-5.0	2.5	8.5
20	12.5	8.4	1.0	-5.3	-10.3	-11.6	-7.6	-11.1	-11.2	-5.2	2.1	8.5
21	12.1	8.2	0.3	-7.6	-11.6	-11.9	-13.7	-16.7	-14.7	-7.8	-0.8	7.2
22	12.0	7.4	-2.1	-14.6	-16.3	-14.7	-10.2	-16.8	-14.8	-8.0	-0.1	7.6
23	12.2	7.6	-2.6	-12.6	-14.6	-14.5	-11.8	-15.4	-14.4	-9.8	-1.3	7.6
24	14.3	9.5	-2.8	-15.1	-14.5	-13.8	-12.1	-14.6	-11.9	-8.3	0.4	10.5
25	15.0	9.9	-2.7	-16.0	-10.8	-8.8	-13.6	-12.2	-8.4	-6.4	-1.3	11.2

TABLE V

DIFFRACTION CORRECTION FOR GULTON MICROPHONE MOUNTED IN GULTON CLAMP MEASURED IN THE γ PLANE

Frequency (KCPS)	Angle of Incidence (degrees)											
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
15	12.1	9.9	6.5	2.5	1.8	-1.2	-0.5	-5.0	-4.6	-0.6	3.9	10.2
16	12.3	9.9	5.9	1.0	-1.6	-3.4	-3.0	-6.4	-2.6	-1.4	4.6	9.7
17	12.4	10.2	3.1	-3.1	-7.2	-6.4	-3.1	-12.8	-6.9	-3.7	3.8	8.7
18	12.8	9.8	3.0	-3.8	-6.4	-6.4	-7.1	-8.2	-5.9	-4.4	1.8	8.7
19	13.2	8.3	-1.6	-6.3	-10.0	-11.8	-6.9	-10.1	-6.5	-2.6	4.1	10.9
20	12.5	8.4	0.6	-7.7	-8.0	-8.7	-11.0	-12.2	-9.9	-5.2	2.3	9.3
21	12.1	8.5	0.2	-8.6	-11.8	-11.9	-11.4	-16.4	-11.8	-6.2	0.8	8.2
22	12.0	7.9	-2.1	-10.2	-11.5	-13.4	-10.8	-17.9	-17.9	-8.8	0.1	8.4
23	12.2	8.4	-0.4	-9.8	-11.4	-15.2	-12.4	-15.6	-16.0	-11.6	-0.6	8.2
24	14.3	9.6*	-0.4*	-8.6*	-7.8*	-12.5*	-12.5*	-12.5*	-14.1*	-11.3*	-0.5*	9.1*
25	15.0	10.4	-0.6	-8.5	-7.0	-11.7	-12.2	-11.8	-12.4	-11.0	-0.4	11.5

*This data is a best estimate based on the more reliable measured data. Original data was considered questionable.

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13. ABSTRACT The methods and instrumentation used to obtain the diffraction correction for the Gulton P420M-6 microphone are described. The diffraction correction has been measured for two microphone mounting configurations at several angles of sound incidence over the frequency range 400 cps to 25K cps. In addition, the random incidence response for the Gulton P420M-6 microphone has been obtained over the same frequency range.

Analysis of the measured data shows that the precision of the measurements is very good below 15K cps (standard deviation being within ± .6 db) and gradually decreases at higher frequencies (standard deviation being ±1.2 db at 20K cps and +3.9 db, -7.4 db at 25K cps).

The pressure calibration for the Gulton P420M-6 microphone was obtained using the well known coupler method and also using an electrostatic actuator. The results of these measurements show that the electrostatic actuator method of calibration produces reliable results when used with the Gulton microphone.

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