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A Comparison of the Three Methods Used to Obtain Acoustic Measurements for the NASA Flight Effects Program

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A COMPARISON OF THE THREE METHODS USED TO OBTAIN ACOUSTIC MEASUREMENTS FOR THE NASA FLIGHT EFFECTS PROGRAM

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SUMMARY

The NASA Flight Effects Program has a requirement to compare acoustic data obtained from flyover, static test-stand and wind tunnel tests. Three measurement techniques using different types of microphones, protective coverings and geometrical mounting configurations are used to measure the data. This report presents the results of a laboratory study of the acoustic characteristics of the three techniques used by the NASA Langley, Lewis, and Ames Research Centers. Recommendations are made to allow a more direct comparison of data measured with each technique.

INTRODUCTION

The purpose of this report is to present a comparison study of different measurement techniques used to obtain acoustic data for the NASA Flight Effects program. This program is a joint effort by the Langley, Ames, and Lewis Research Centers. Part of the program will consist of comparing narrowband fan noise data, obtained from JT15D gas turbine engines operating statically and in simulated and actual flight. The engine fan noise data to be compared will be measured by different types of microphones mounted in different configurations. Data will be obtained for the engine under static conditions at an outdoor test facility at the Lewis Research Center, and simulated flight conditions in a 40 x 80 wind tunnel at the Ames Research Center. The Langley Research Center will obtain data during flight with the engine mounted under the wing of an OV-1B aircraft.

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Due to the differing nature of noise test environments and the different types of noise (jet, fan, etc.) studied, different measurement techniques using different types of microphones (pressure, freefield) are employed. Outdoor static tests using microphones placed on the ground must contend with ground reflection difficulties and surface micrometeorology (Ref. 1), whereas wind tunnel testing has high wind velocities and reflecting surfaces which may compromise acoustic data (Ref. 2,3). Measuring aircraft flyover noise presents similar difficulties plus those resulting from propagation through the atmosphere (Ref. 4). Also, in each of these three types of tests, the measurement of noise radiation patterns may introduce the further difficulty of changing acoustic angles-of-incidence on the microphone if either the source or microphone is moving. To try to compensate for some of these noise measurement problems, microphones may be fitted with various protective coverings (i.e., grid caps, nose cones, windscreens, etc). Each combination of microphone size, type, protection cover, and location of microphone with respect to the source, affects the sensitivity and frequency response of the measurement system (Ref. 5,6,7).

Data presented in this report will relate the various noise measurement techniques used in the NASA Flight Effects Program as studied under a constant environment in an anechoic chamber. These techniques include the use of both pressure and freefield microphones with protective coverings and mounted vertically on a pole, flat on a ground board, and in a wind vane device.

DESCRIPTION OF NOISE MEASUREMENT TECHNIQUES

Figure 1 is a photo showing three types of noise measurements configurations used by Langley to measure aircraft flyover noise. These included using microphones placed on ground boards, and at 1.2 m and 10 m above the ground. The configuration which serves as the primary unit, and the one considered in this report, consists of commercially available 1.27 cm diameter pressure type condenser microphones mounted 10 meters above the ground surface. They are oriented for an acoustic grazing incidence angle, and are protected by a grid cap and a 90 mm diameter spherical reticulated polyester foam windscreen. The height of the microphone minimizes the effect of ground reflections above 1 KHz, and eliminates any micrometeorology effects present near the ground. The windscreen reduces the influence of any winds, and fixing the acoustic angle-of-incidence at 90° yields the most uniform frequency response.

Figure 2 is a sketch showing the technique used by the Lewis Research Center to measure fan noise from engine static tests (Ref. 1). The microphone is a 1.27 cm diameter free-field type microphone specially mounted on a 61 x 61 x 0.6 cm plywood board which is placed on the ground 27.4 m from the source. The microphone, covered by a 65 cm diameter reticulated polyester foam spherical windscreen cut in half, is pointed toward the source. When mounted on the static test stand, the JT15D engine has the centerline 2.9m above the ground. The microphone is located such that the acoustic angle of incidence is about 6°, which is close to the zero degree angle of incidence for which the microphone is designed to have the flattest frequency response.

Figure 3 is a photo showing a typical microphone set-up in the Ames 40 x 80 wind tunnel. Two configurations are used, a fixed microphone array and a continuously movable microphone. Both systems employ a 1.27 cm diameter free-field type commercially available condenser microphone which is mounted in a wind vane device. The microphone diaphram is protected by a bullet nose and is always pointed into the airflow.

The movable microphone permits a careful definition of the radiation directivity pattern of the source. The movement, however, introduces a changing acoustic angle-of-incidence since the microphone is continuously pointed into the airflow as it is traversed around the noise source. The occurrence of different acoustic angles of incidence require corrections to be applied to the measured data (Ref. 5,6). The manufacturer's literature presents graphed frequency response corrections for 30° angular increments from 0° to 180°. In order to make acoustic corrections for other angles, or for a continuously changing angle of incidence, a considerable amount of interpolation is required.

An additional problem associated with the interpretation of the wind tunnel acoustic data is due to the wind vane. In order for it to properly function, it cannot be wrapped in sound absorbing material and hence may act as an acoustic reflector.

Although the effects of microphone diffraction, reflection, ground impedance and scattering have been studied in the past (Ref. 1,5,10 thru 14) a wide range of correction values have been proposed. No study has been reported where three such techniques as described above have been systematically examined.

DESCRIPTION OF EXPERIMENT

In the Flight Effects Program there is a requirement to be able to relate the data obtained from these various noise measurement techniques. Since each test environment is different, a study was conducted whereby each of the techniques used in the Flight Effects Program was evaluated in an anechoic chamber under the same constant environment with the same constant acoustic input. The anechoic chamber used in this study is located at Langley and has internal dimensions of 7.6 x 7.6 x 7 m between wedge tips. All wall and floor surfaces of the chamber are covered with acoustically absorbent fiberglass or foam wedges. The fiberglass wedges are impregnated with phenolformaldehyde and enclosed with hardware cloth in order to maintain their geometrical shape.

Figure 4 shows how the primary noise measuring technique used in the aircraft flyover tests was simulated in the anechoic chamber. A B&K 4134 pressure microphone was mounted on a pole which was 4.8 m from the source and oriented for grazing incidence. The microphone was fitted with a protective grid cap and a 90mm diameter B&K UA0237 windscreen. A second pressure type microphone oriented for grazing incidence was located 1.48 m in front of the noise source. This microphone, present during all tests, was used as a control microphone in a feedback loop with the source. It insured that the generated sound field for the differing techniques studied was constant. Neither this control microphone nor the source was moved during these studies. Both microphones were located along the centerline of the source.

Figure 5 shows the set-up used to simulate the outdoor static measuring technique. The technique used at Lewis is to mount a free field microphone on a 61 x 61 x 0.6 cm plywood board and place this on the ground such that there is a 6° acoustic angle-of-incidence at the microphone diaphram. In order to simulate the ground in the anechoic chamber a 1.22 m square, 1.9 cm thick piece of plywood board was placed beneath a smaller plywood board of dimensions used in the Lewis tests. This arrangement was fixed so that the microphone diaphram was oriented for a 6° acoustic angle-of-incidence.

The microphone was a B&K 4133 free field microphone protected by a grid cap and a 65 mm diameter foam windscreen B&K UA0459. It was attached to the ground board using a special attachment clip borrowed from the Lewis Research Center.

Figure 6 shows the test set-up used to simulate the wind tunnel microphone configuration. A wind vane device borrowed from the Ames Center was mounted on a turntable covered by fiberglass. The microphone mounted in the wind vane device was the same free field type B&K 4133 used in the Lewis simulation. It was protected by a B&K type UA0386 sharp nose cone, the configuration used in the wind tunnel tests. The position coordinates of the center of the microphone diaphram were fixed to be the same as those of the pole mounted microphone. The turntable allowed for a continuously changing acoustic angle-of-incidence. Figures 7 and 8 show close-up views of the wind vane mounted microphone and turntable.

TEST PROCEDURE

Each of the microphones used in this study were inspected by eye to insure clean diaphrams. They were then calibrated using the electrostatic actuator procedure recommended by the manufacturer. The pressure calibration curves of the two test microphones are presented in Figure 9.

Figure 10 presents the instrumentation block diaphram used throughout the tests. The instruments were checked during the various phases of the test to insure that they experienced no frequency response changes or malfunctions. All data obtained were accurately measured to within ± 0.5 dB.

The test procedure was divided into three phases. The first phase of the test consisted of determining the sound field at the test position using the pole mounted microphone. This was accomplished by generating a pure tone with a sweep frequency oscillator. This signal was fed into the noise source. The control microphone, placed in a feedback loop with the source, produced a constant sound field as the oscillator was linearly swept from 1 KHz to 15 KHz in a 70 sec time period. The sound pressure measured by the pole microphone, was then recorded on an analog magnetic tape, along with the control microphone signal, the input signal to the source and a time code. The pole microphone was also simultaneously recorded on an X-Y recorder so that data acquisition could be easily monitored. After this data acquisition the 90 mm diameter windscreen was removed from the pole microphone and the test was repeated.

The second phase of the test was to place the Lewis noise measurement system in the anechoic chamber. Care was taken to see that the microphone diaphram was located at the same position coordinates as used for the pole mounted microphone. The sound field was again generated as before and checked at the control microphone. These signals were recorded as before along with the signal measured by the ground board microphone.

The third and final phase of this study consisted of placing the free-field microphone (protected by a sharp nose cone) in the turntable mounted wind-vane device. The assembly was mounted so that when the turntable was rotated the center of the microphone remained at the position coordinates of the pole mounted microphone. A constant pure tone sound level was generated, in 1 KHz increments, from 1 KHz to 15 KHz. At each frequency increment, the sound level measured by the wind-vane mounted microphone was recorded as the acoustic angle of incidence was continuously changed from 0° to 180°.

RESULTS AND DISCUSSIONS

Figure 11 shows the sound level measured by the control microphone, with and without the automatic level control regulator. It is presented to indicate the constant noise field effect the regulator maintained on the noise source.

Figure 12 shows the sound field measured by the pole mounted microphone with a protective grid cap and windscreen. This curve was used throughout this report as the baseline to which all other data were related. It was chosen since it represents the primary technique to be used in measuring flyover noise in the field. Figure 13 shows the influence of the windscreen. The curve was obtained by arithmetically subtracting the measured levels without a windscreen from those with a windscreen and show good agreement with published data (Ref. 12). This curve is given so that the effect of the windscreen may be removed if desired.

The baseline data are again shown in Figure 14 along with data measured by the Lewis technique. If one considers only the pressure doubling effect which may be expected to occur for a microphone on a ground board, there would be 6 dB increase in measured sound pressure level relative to the pole mounted microphone measurement (Ref. 5). The data presented in Figure 14 show that, as expected, the ground board microphone measured a signal which is larger than that sensed by the pole microphone. In order to determine the relationship between these two techniques these signals were subtracted from each other. This difference, ground board microphone minus pole microphone SPL, is presented in the curve of Figure 15. It may be seen that the differences range up to about 5 dB, and are not the uniform 6 dB. Several factors that may be the cause of this discrepancy are the varying specific acoustic impedance of the ground board as a function of frequency and the scattering of acoustic energy from the ground board (Ref. 13 & 14) and from the special clip holding the microphone.

The data obtained during the third phase of the study are presented in Figure 16. The figure shows the measured sound pressure levels at constant frequencies for a continuously changing angle-of-incidence. The level measured by the pole microphone technique at the appropriate frequency was subtracted from the data of Figure 16 and these results are presented in Figure 17. Figure 17 thus provides another correction (along with the inverse square law, Doppler shift, atmospheric propagation, etc.) which may be used to compare wind tunnel to flyover noise data.

With the aid of Figures 15 and 17 it is possible to determine a correction which would permit a direct comparison of data obtained by one measurement technique to that of a different technique. For example, assume that during the course of an angular traverse of the wind vane device (which contains a 1.27 cm free field microphone), a measurement was made at a 60° position angle of the microphone relative to the source centerline. Assume the sound pressure level after the appropriate tunnel corrections was 96 dB at a frequency of 5 KHz. The acoustic angle-of-incidence would be 120°. By considering Figure 17, it may be seen that this microphone would be measuring a level 2 dB below that which would be expected to be measured by a pole mounted 1.27 cm pressure microphone protected by a grid cap and a windscreen and oriented for 90° angle-of-incidence. Thus the level expected to be measured by the pole microphone would be 98 dB. If it were desired to relate this traverse measurement to a free-field type microphone mounted on a ground board for a 6° angle-of-incidence use would be made of Figure 15. Figure 15 indicates that at 5 KHz the measured sound pressure level is about 3.8 dB above the level expected to be measured by the pole microphone technique just discussed. Thus one might expect the ground board microphone to measure 101.8 dB at 5 KHz, or 5.8 dB greater than the traverse microphone measurement.

CONCLUDING REMARKS

This report has presented the results of a laboratory study of three noise measuring techniques. These techniques are representative of those used by the NASA Langley, Ames, and Lewis Research Centers for flyover, wind tunnel and outdoor static tests, respectively. The data are presented in graphic form showing the difference sound pressure levels between the Ames and Lewis techniques relative to the Langley technique. These results are recommended to be used in the correction of data obtained from the various types of microphones, protective coverings and geometrical orientations. The data thus corrected may be directly compared to each other.

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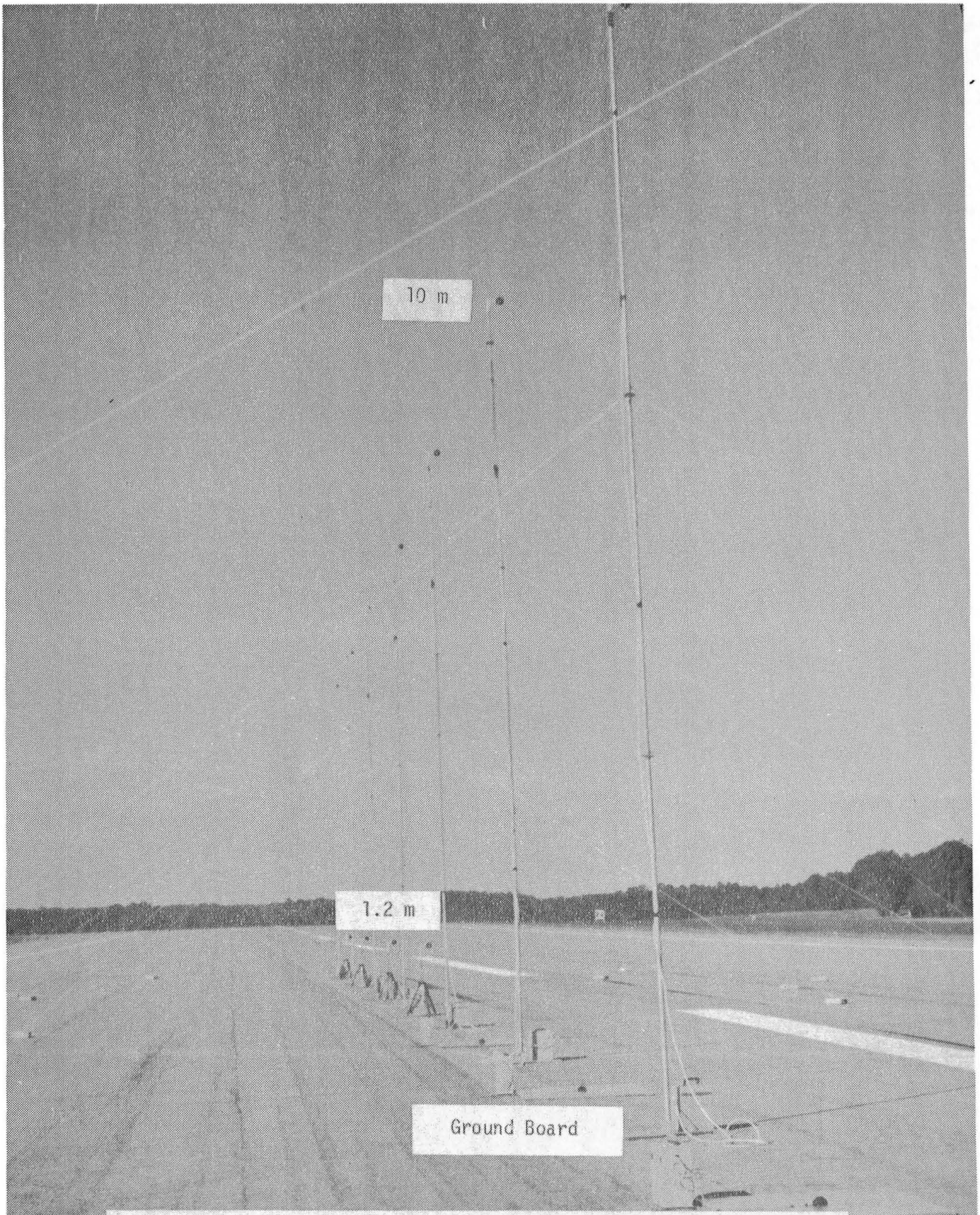

Figure 1. - Three aircraft flyover noise measurement techniques used by Langley Research Center.

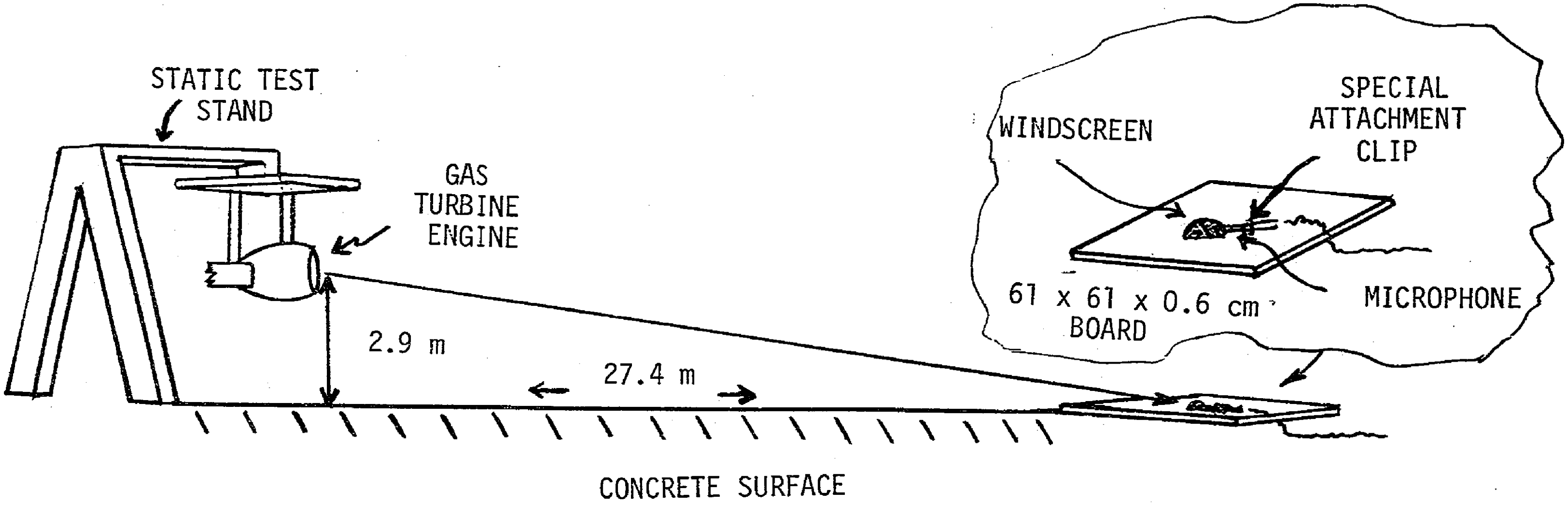

Figure 2. - Schematic diagram of typcial Lewis Research Center noise measurement technique.

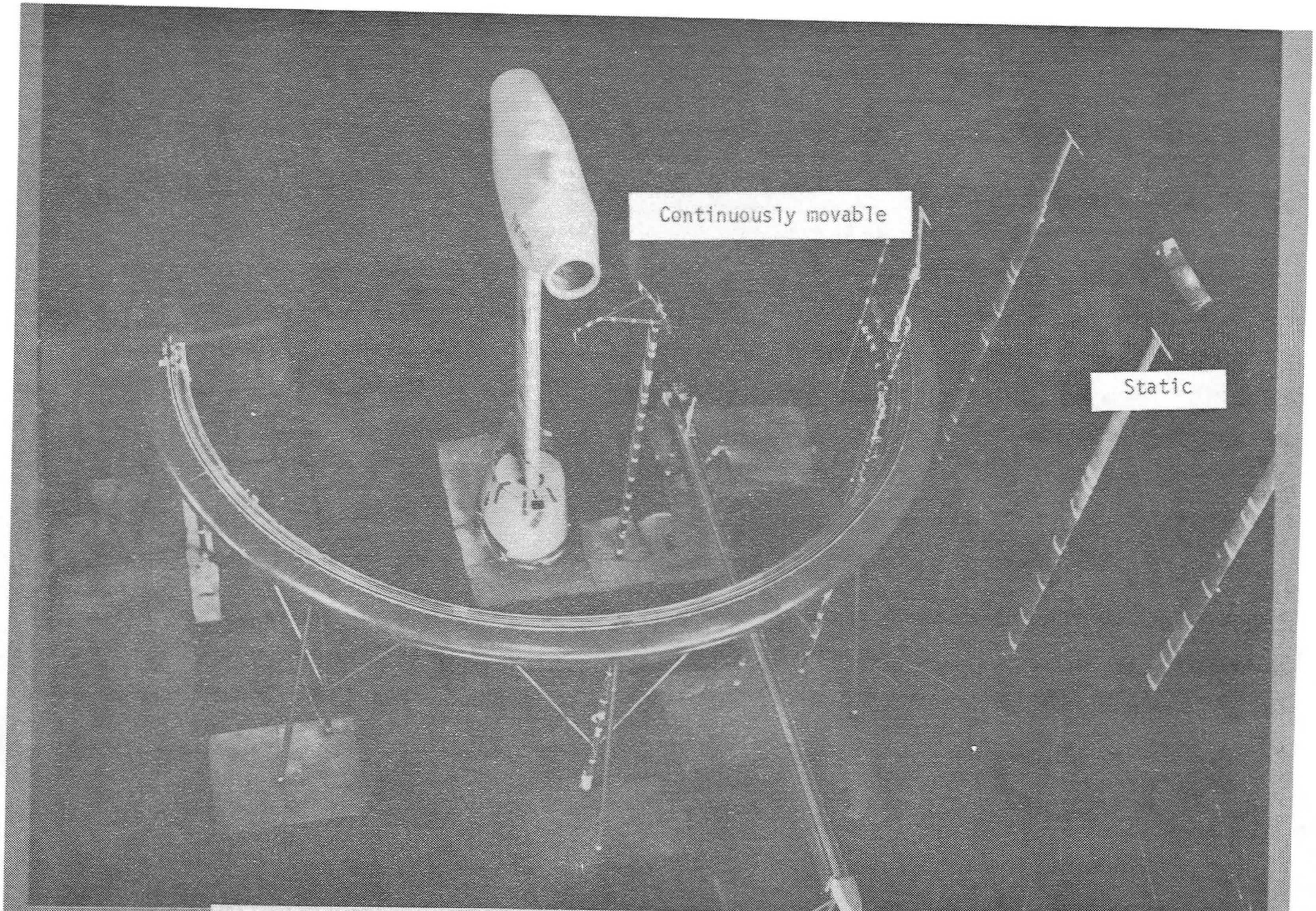

Figure 3. - Noise measurement technique used in the Ames Research Center 40 x 80 tunnel.

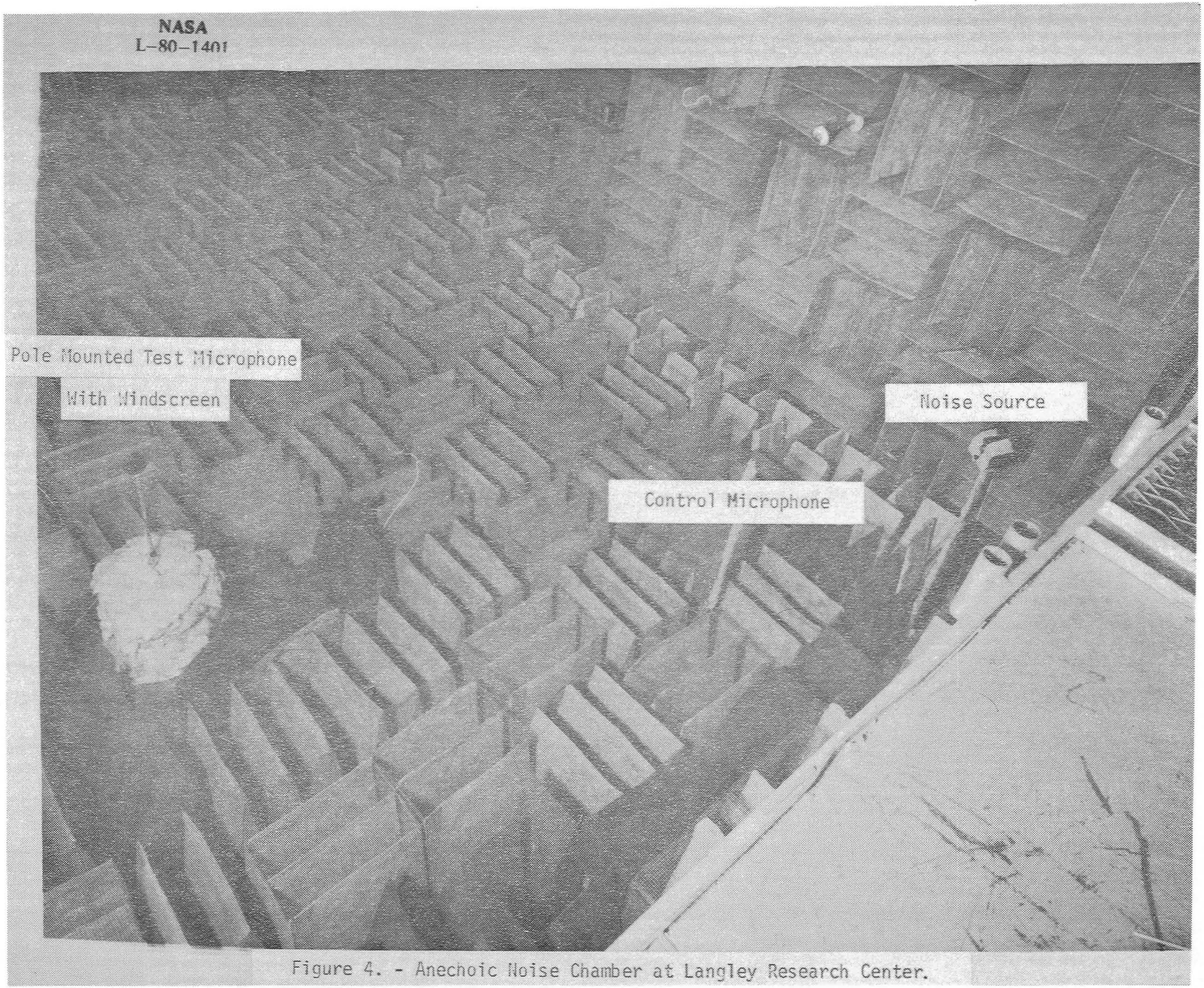

Figure 4. - Anechoic Noise Chamber at Langley Research Center.

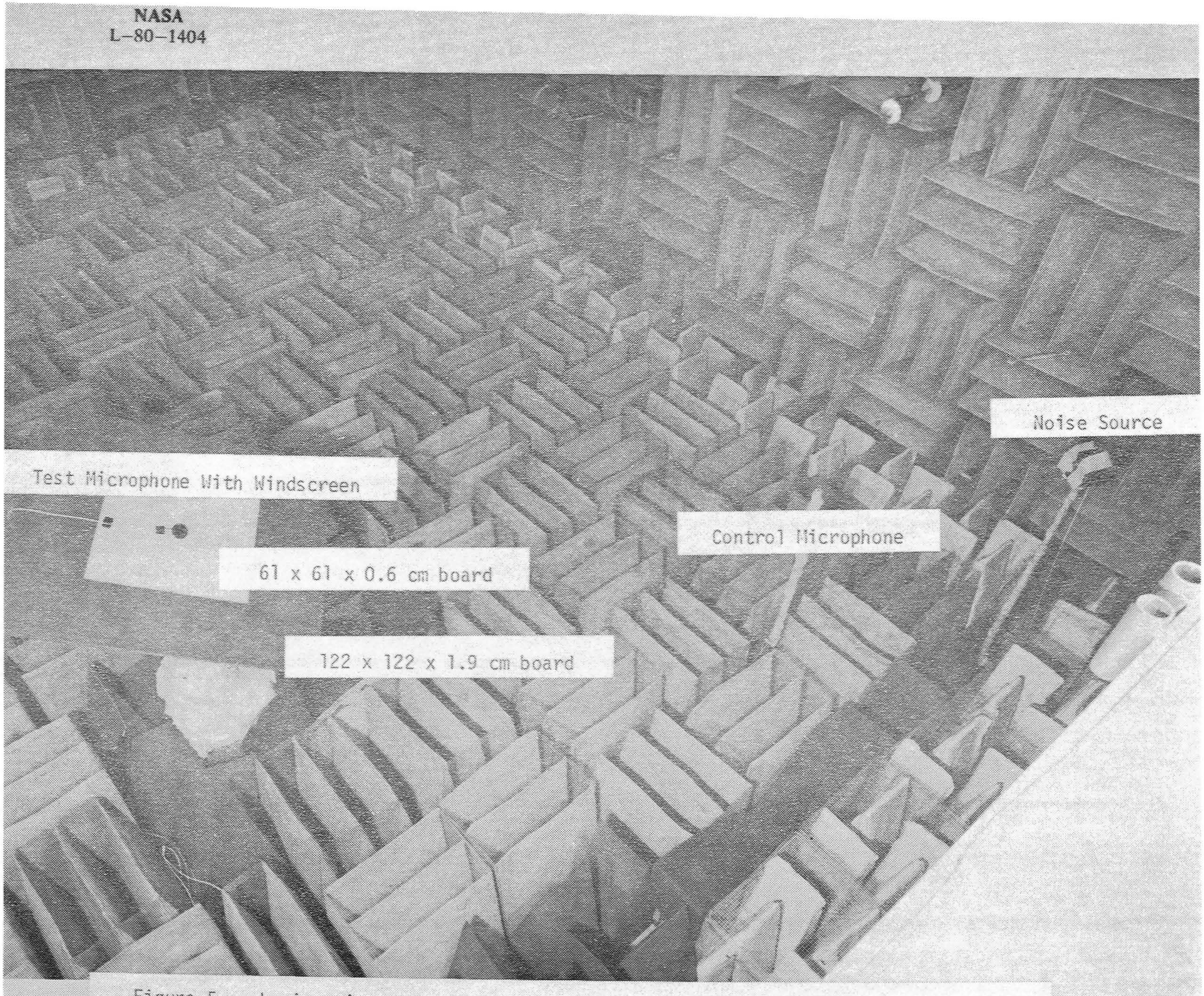

Figure 5. - Lewis noise measurement technique in test position in Anechoic Chamber.

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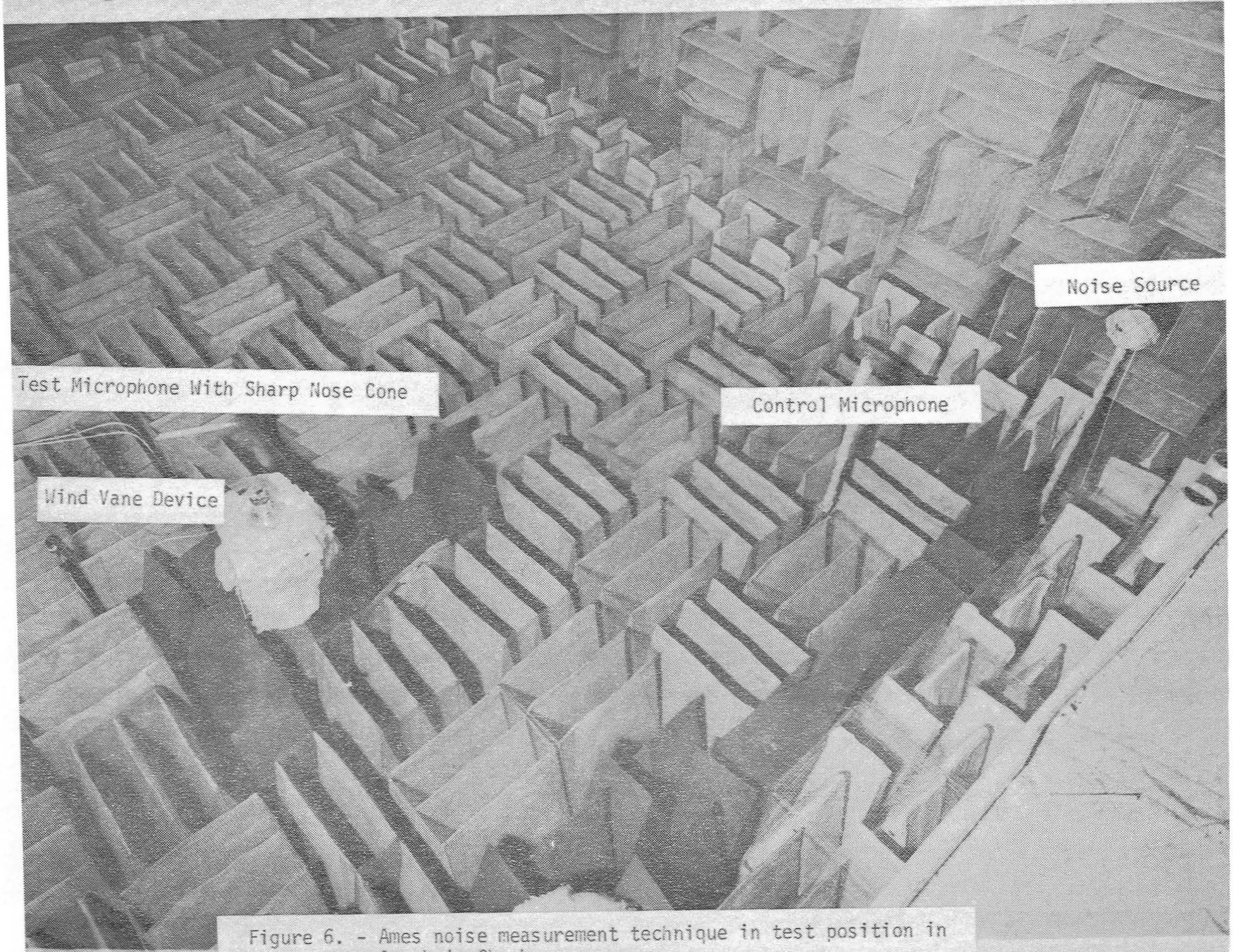

Figure 6. - Ames noise measurement technique in test position in Anechoic Chamber.

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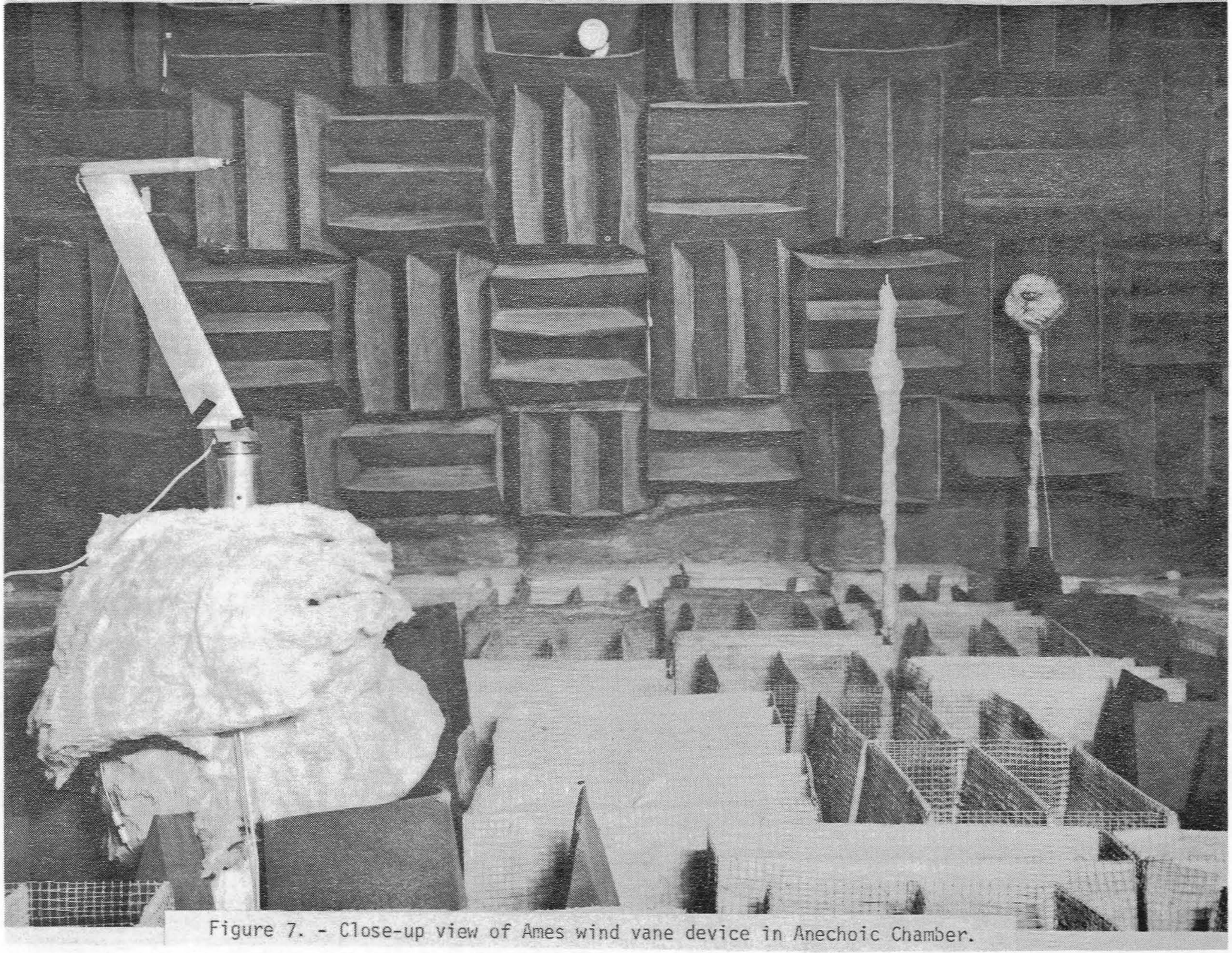


Figure 7. - Close-up view of Ames wind vane device in Anechoic Chamber.

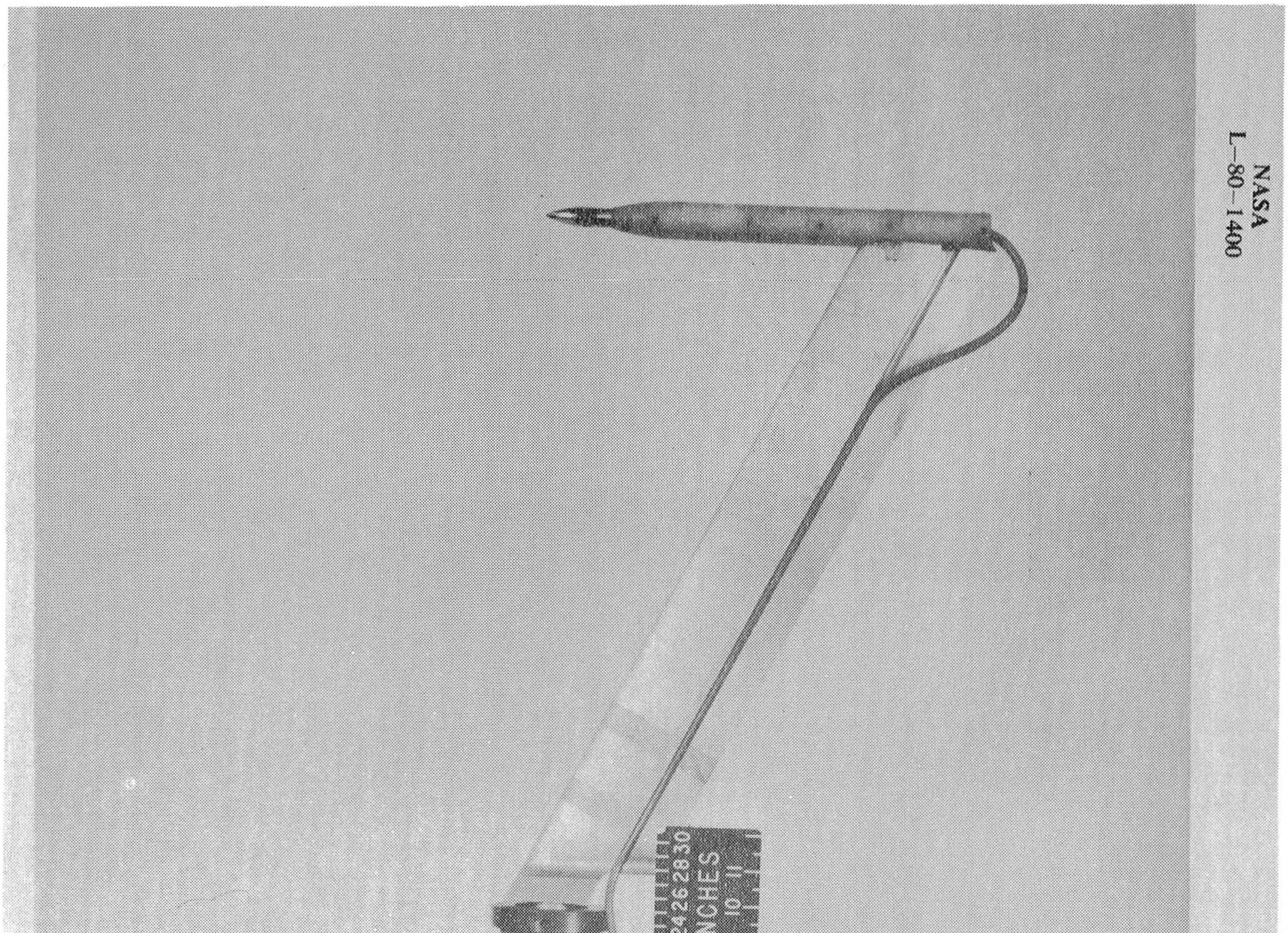


Figure 8. - Close-up view of Ames wind vane device and revolving turntable.

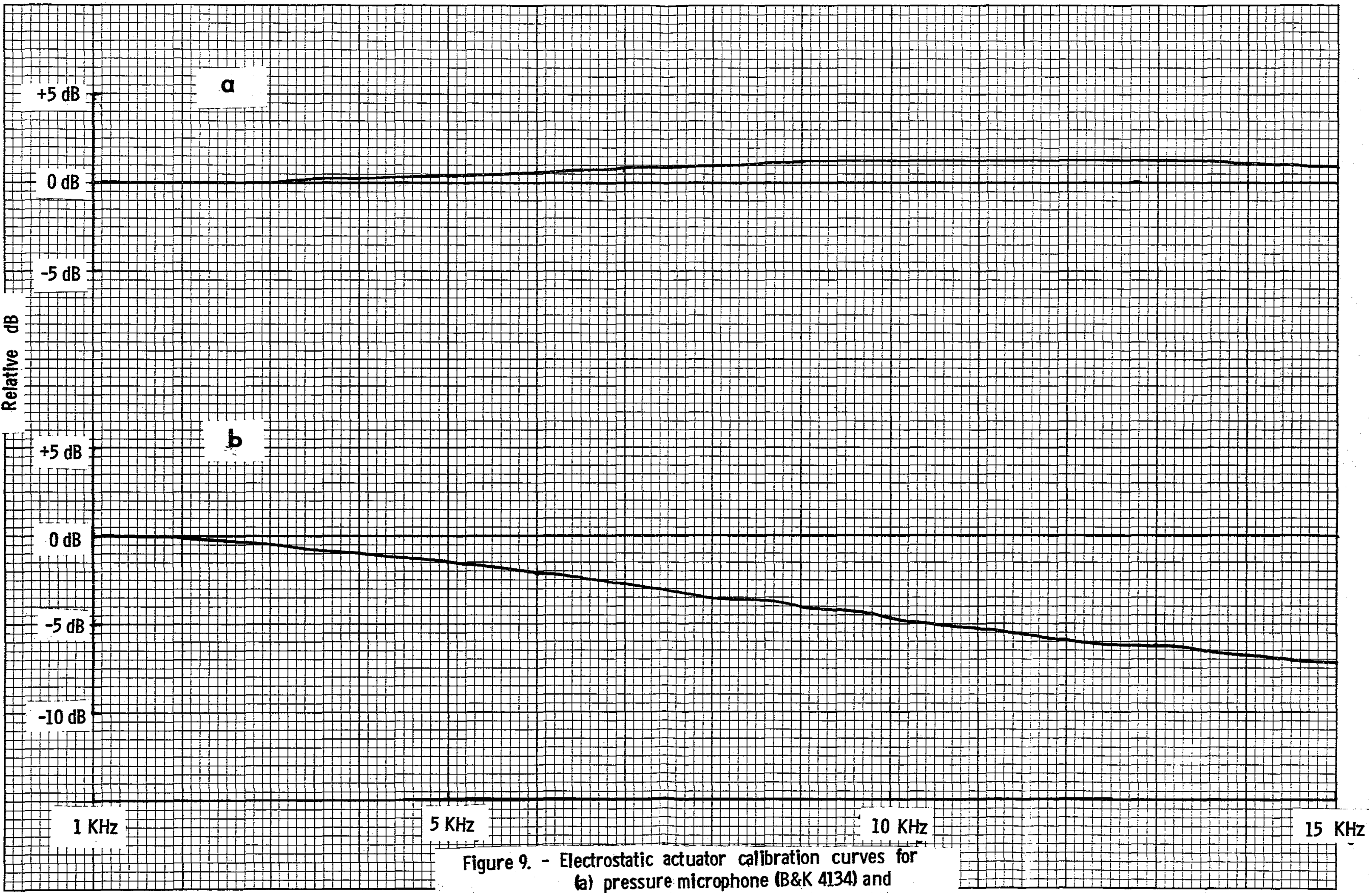


Figure 9. - Electrostatic actuator calibration curves for
(a) pressure microphone (B&K 4134) and
(b) a free-field microphone (B&K 4133).

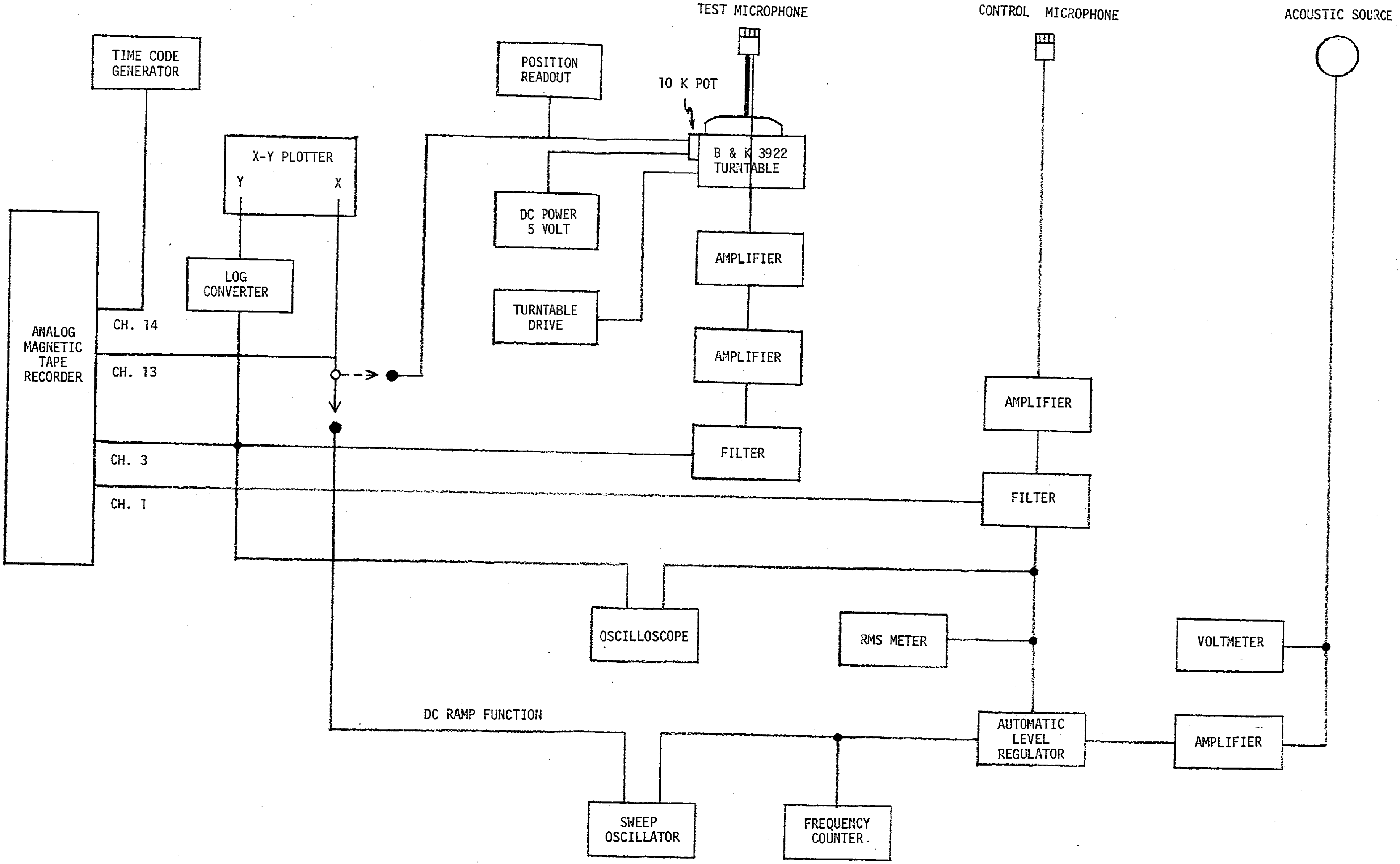


Figure 10. - Instrumentation Block Diagram.

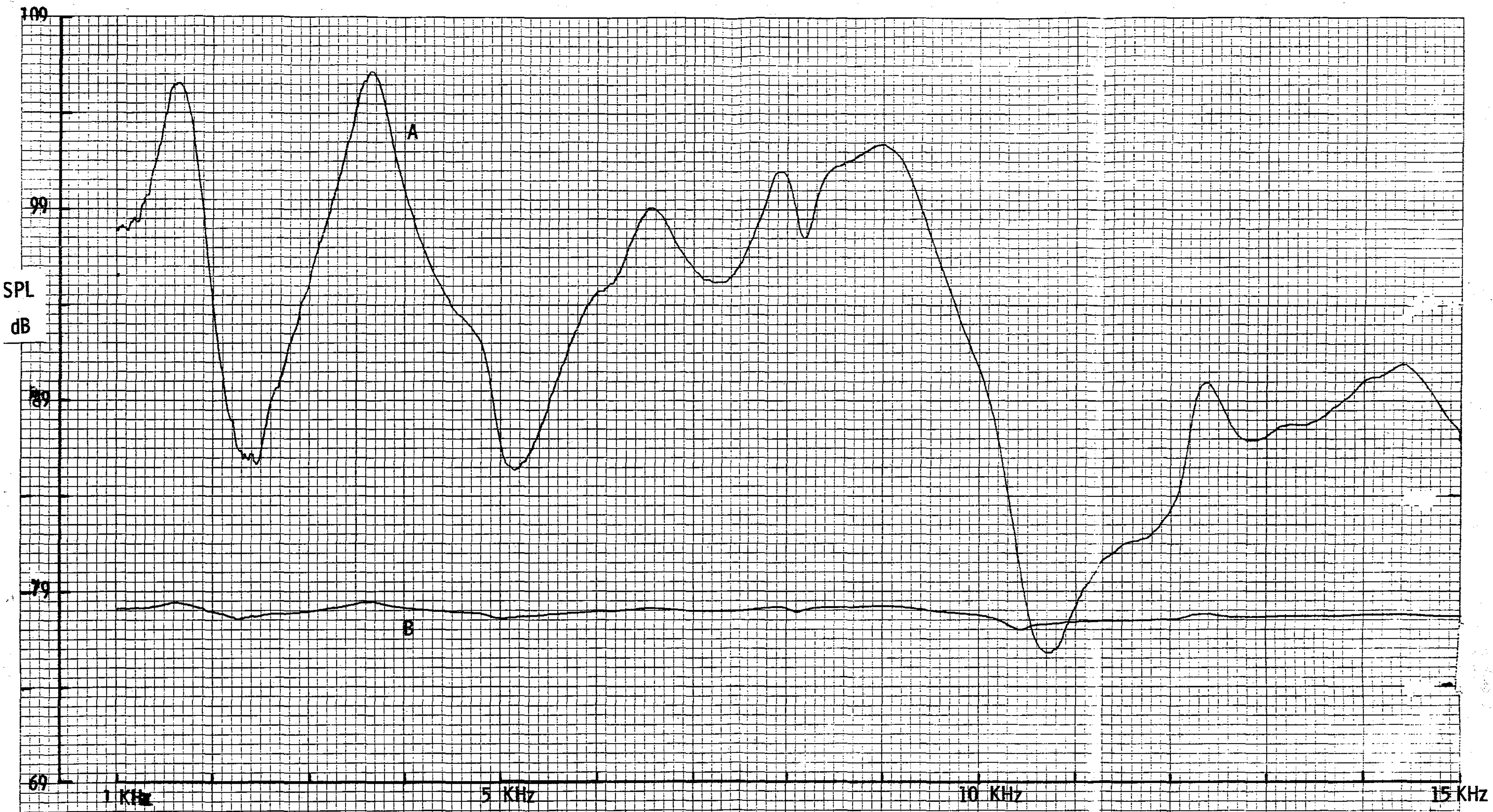


Figure 11. - Sound field measured by control microphone
(a) with and
(b) without automatic level regulator in the control circuit.

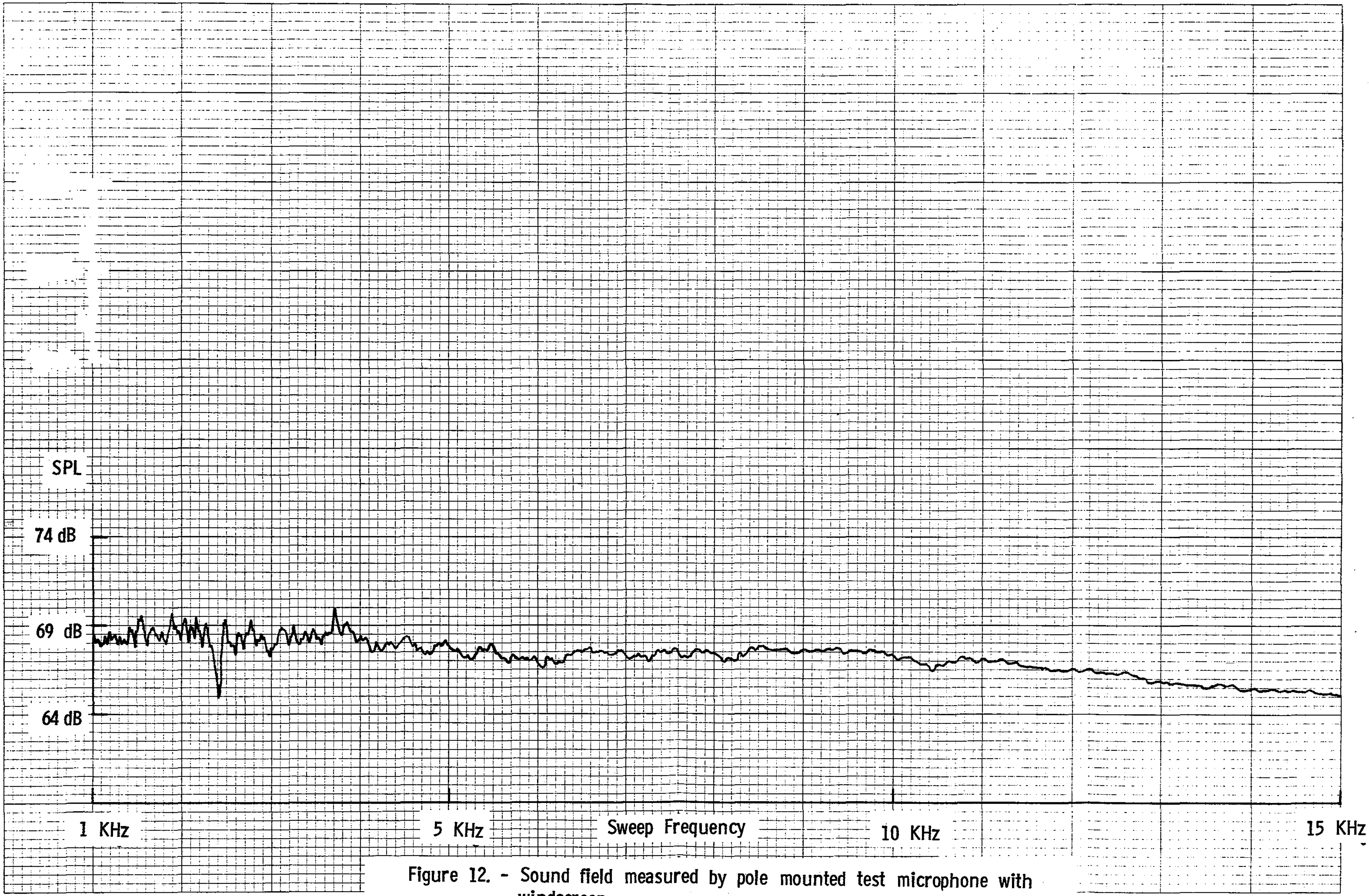


Figure 12. - Sound field measured by pole mounted test microphone with windscreen.

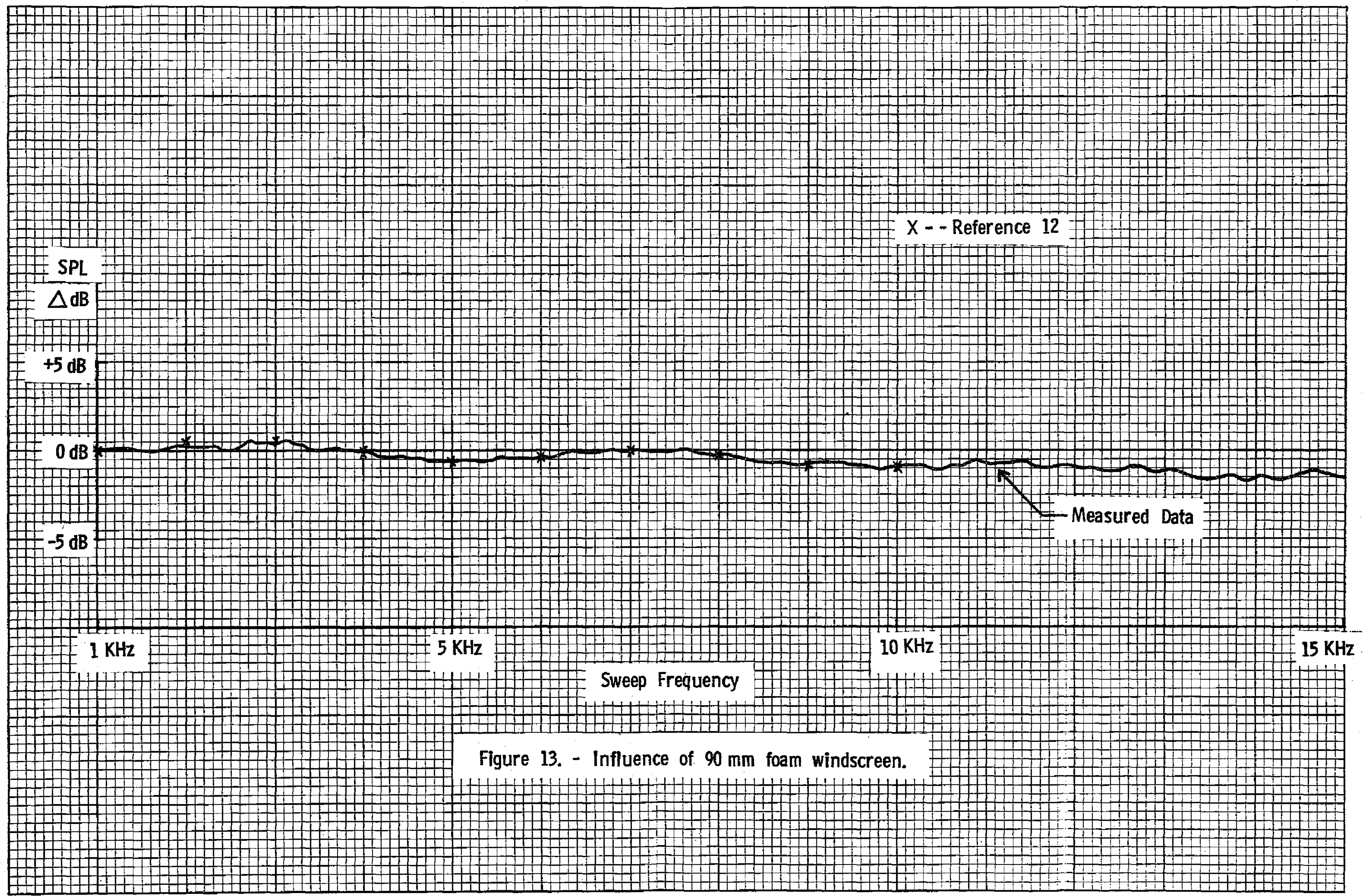


Figure 13. - Influence of 90 mm foam windscreen.

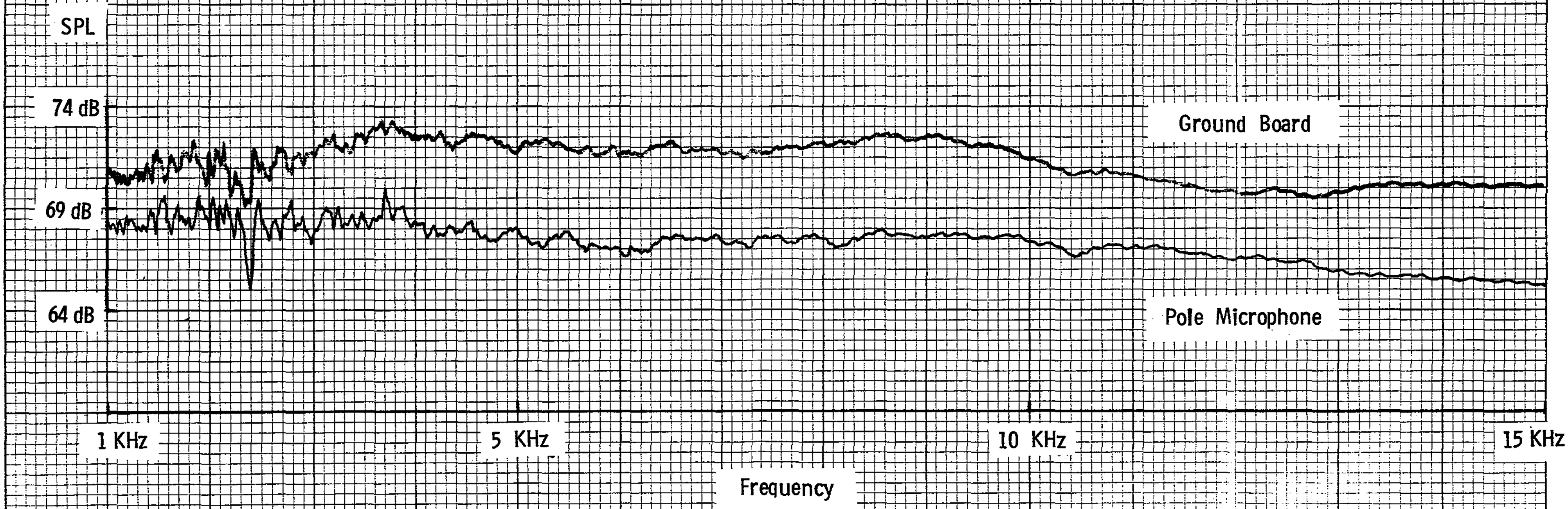


Figure 14. - Sound field measured by the Lewis ground board compared to that measured by Langley pole microphone.

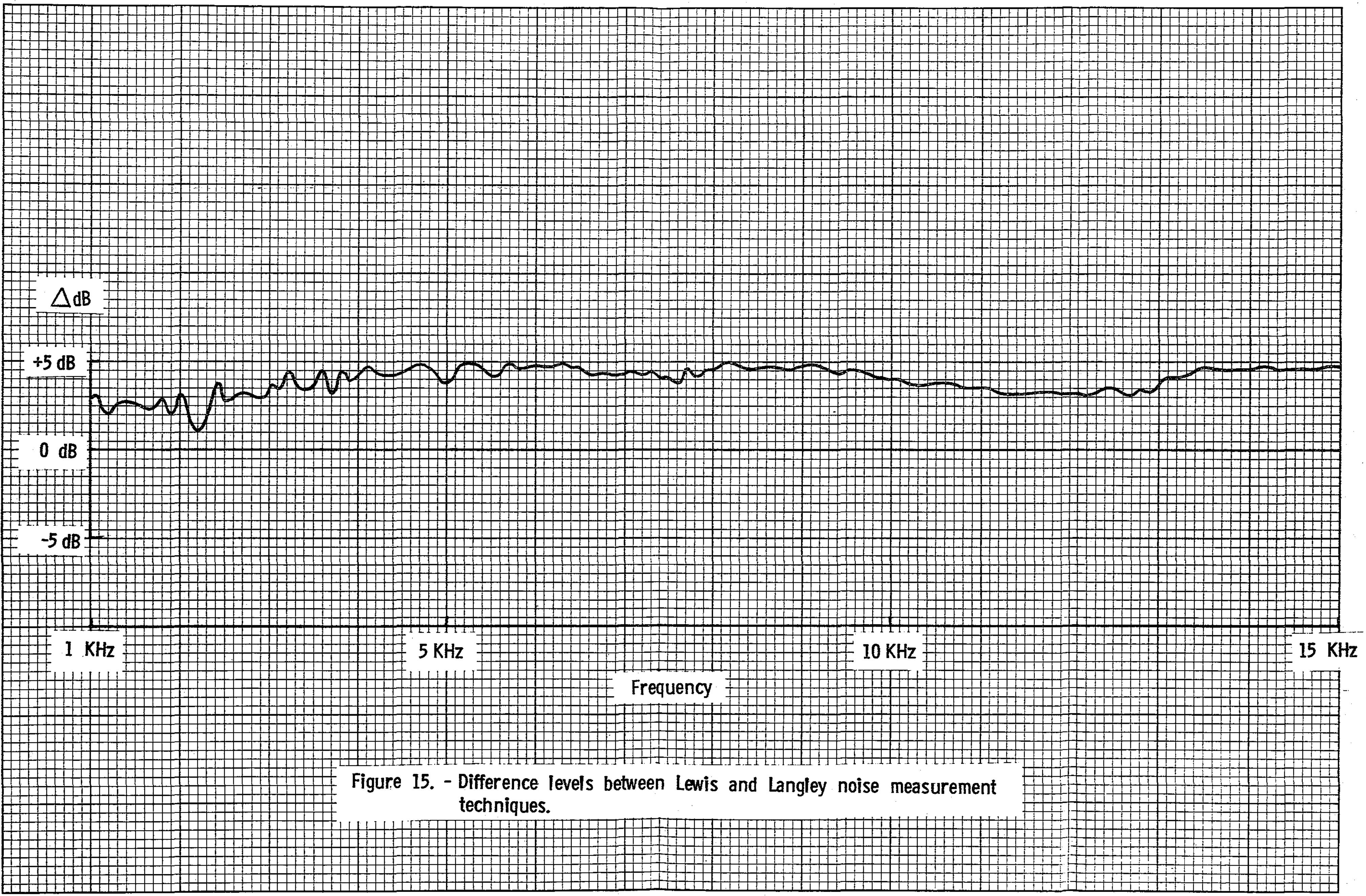


Figure 15. - Difference levels between Lewis and Langley noise measurement techniques.

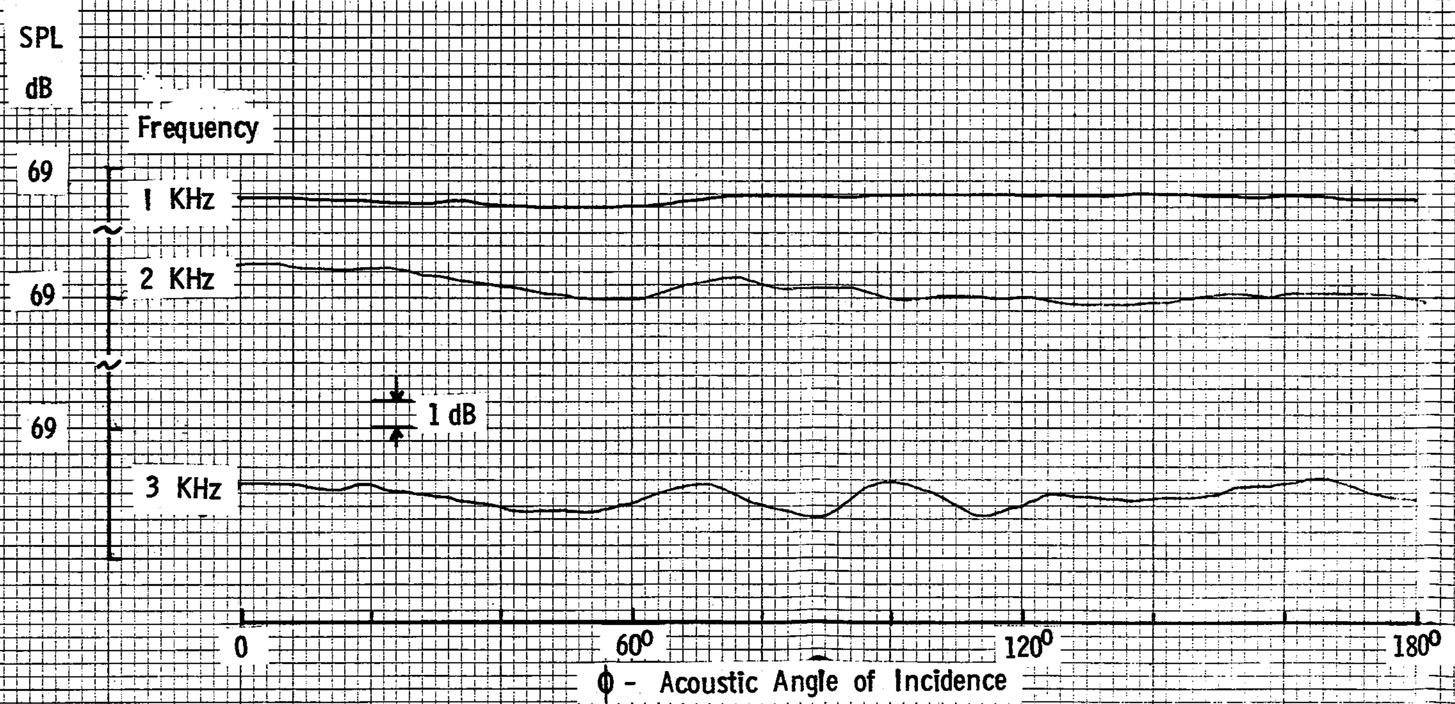


Figure 16a. - Noise levels measured by the Ames wind vane technique for constant frequency and continuously changing acoustic angles of incidence.

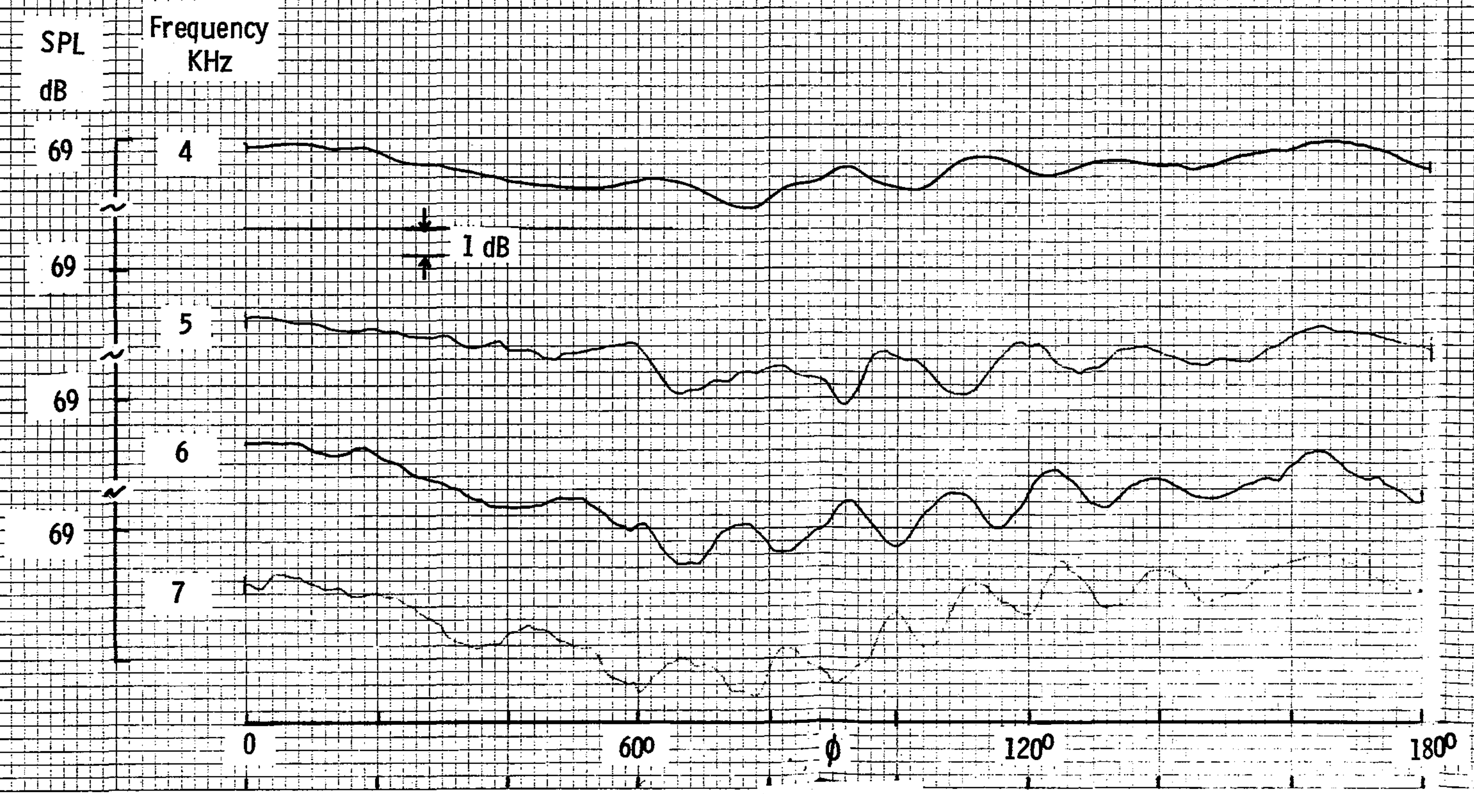


Figure 16b.

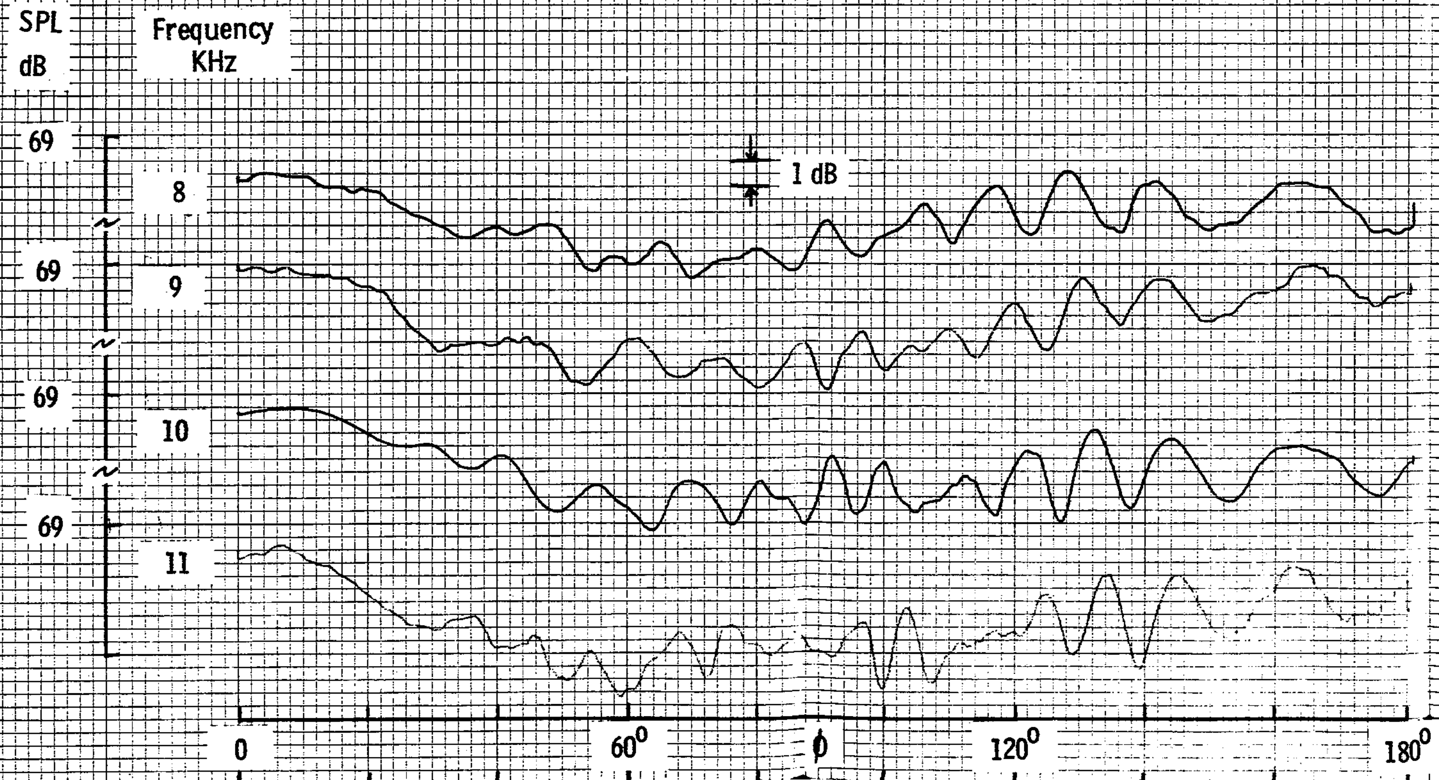
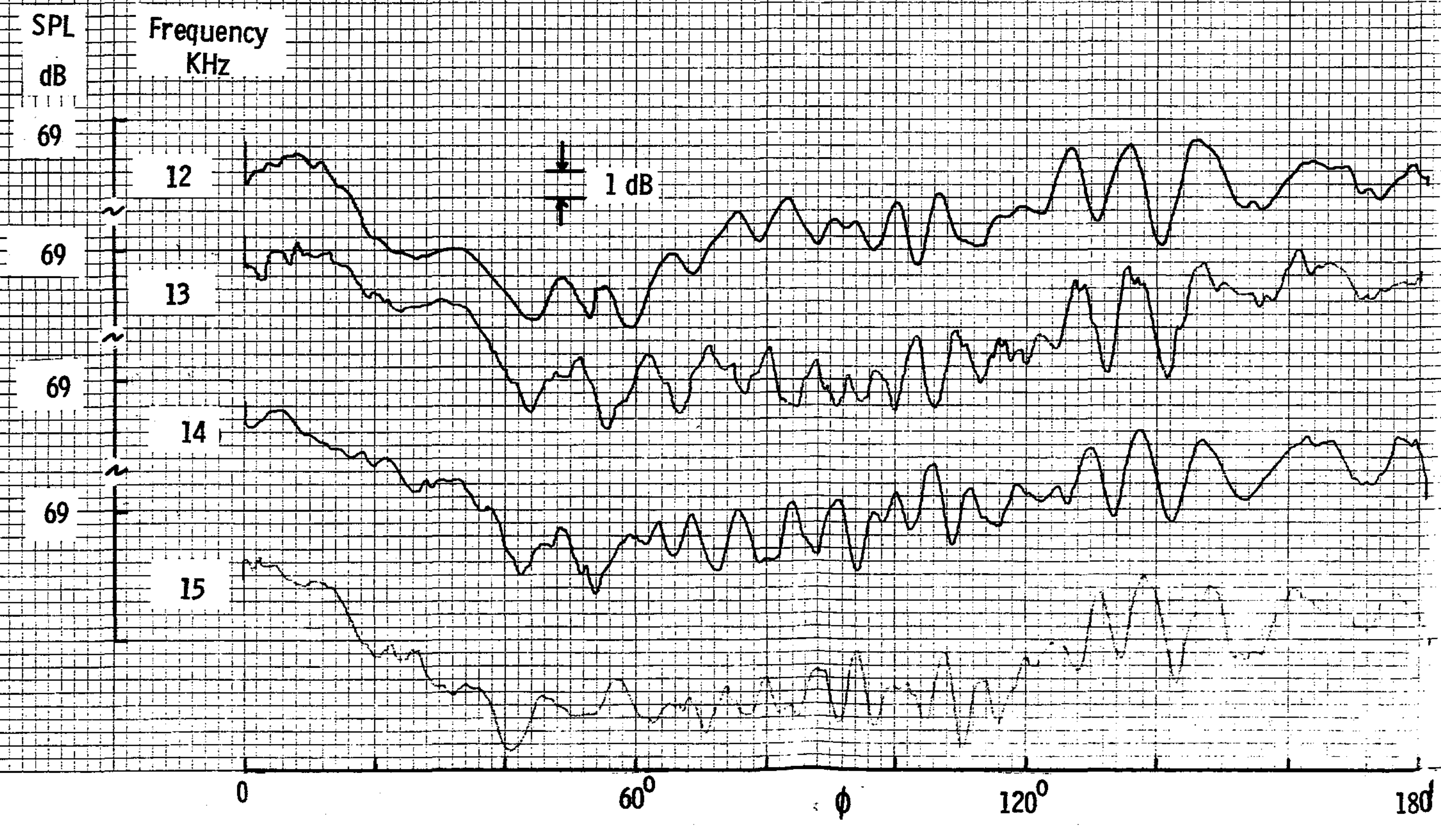


Figure 16c.

Figure 16d. Concluded



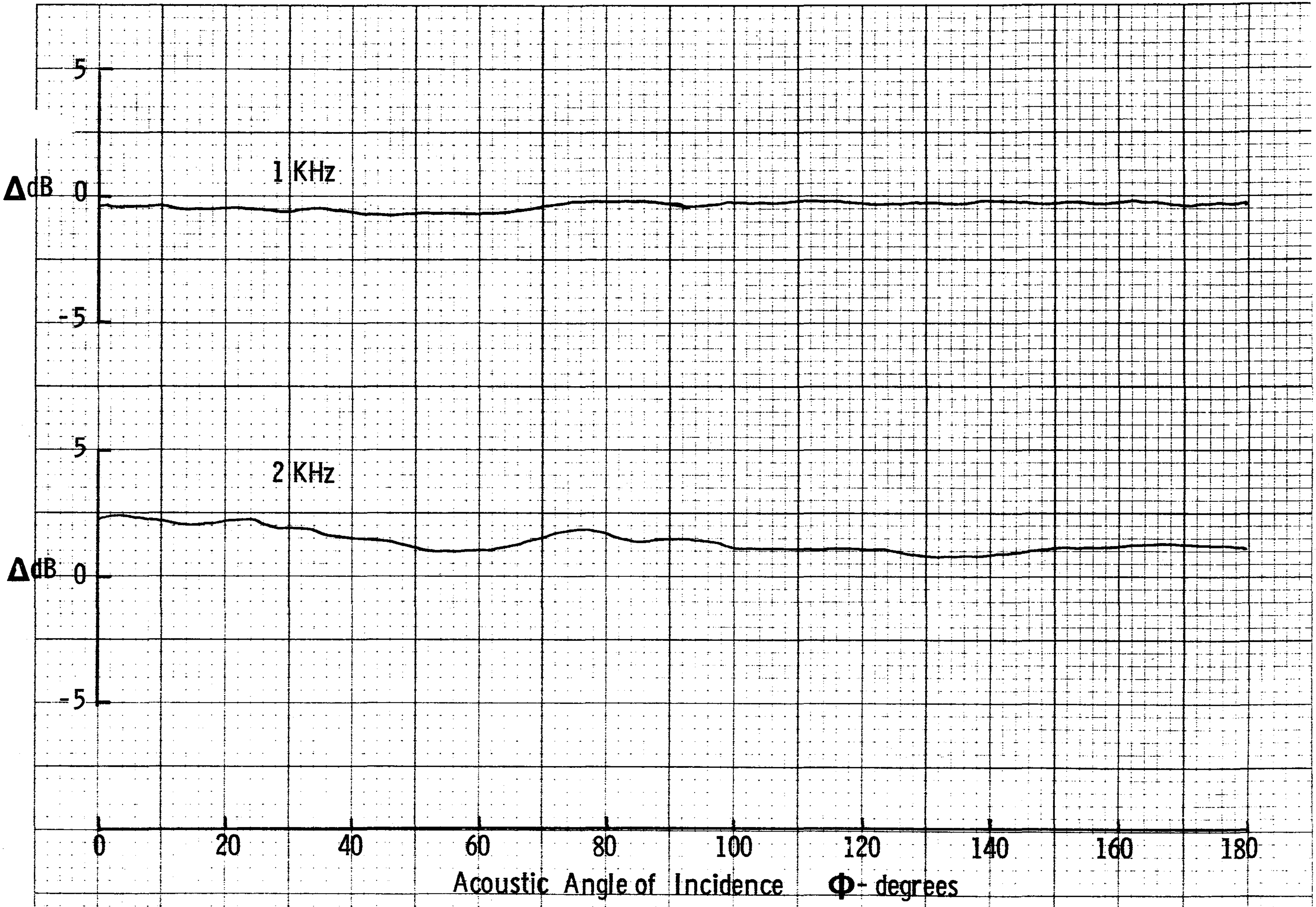


Figure 17a. Frequency difference levels between the Ames wind vane technique and the Langley technique for continuously changing acoustic angles of incidence.

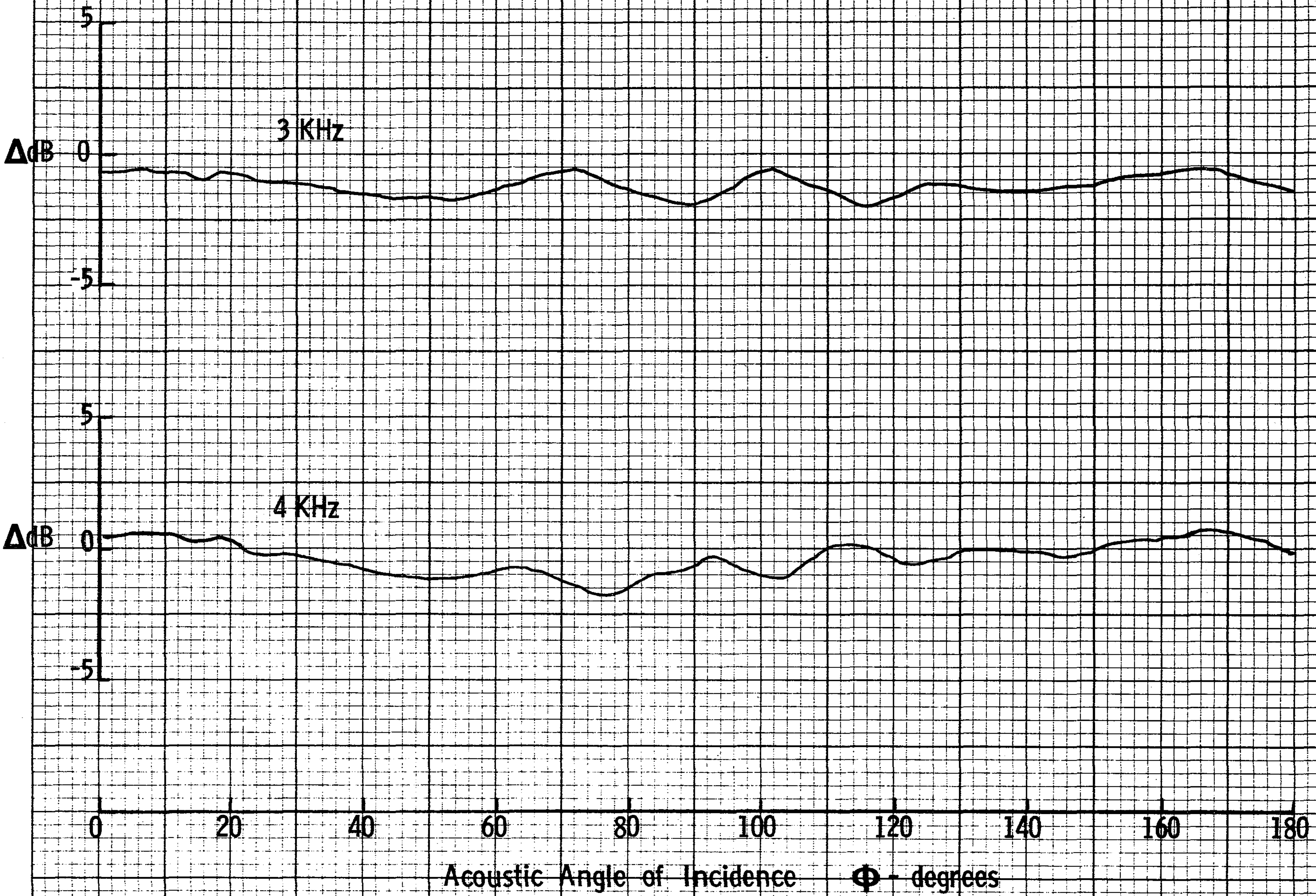


Figure 17b. Continued

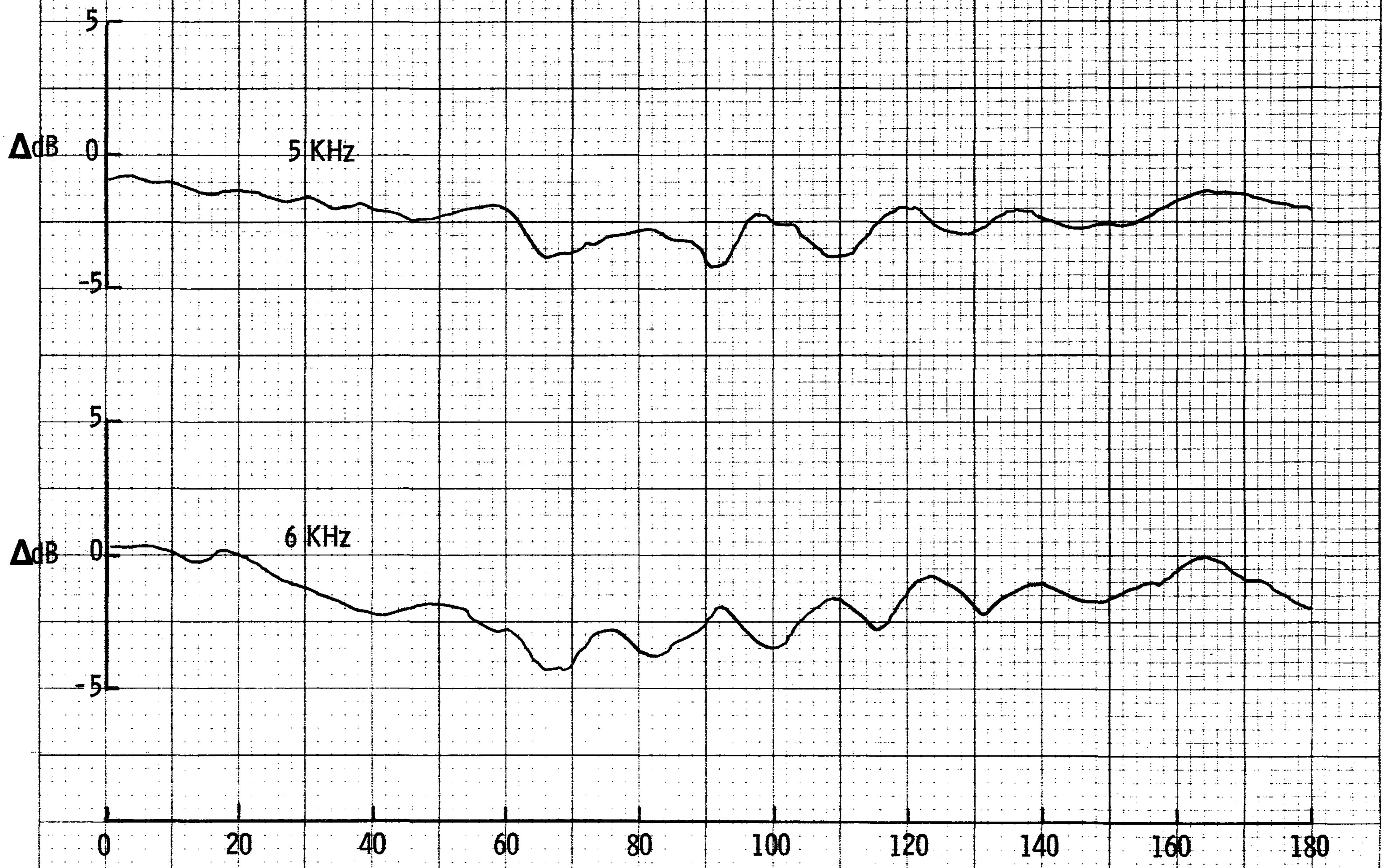


Figure 17c. Continued

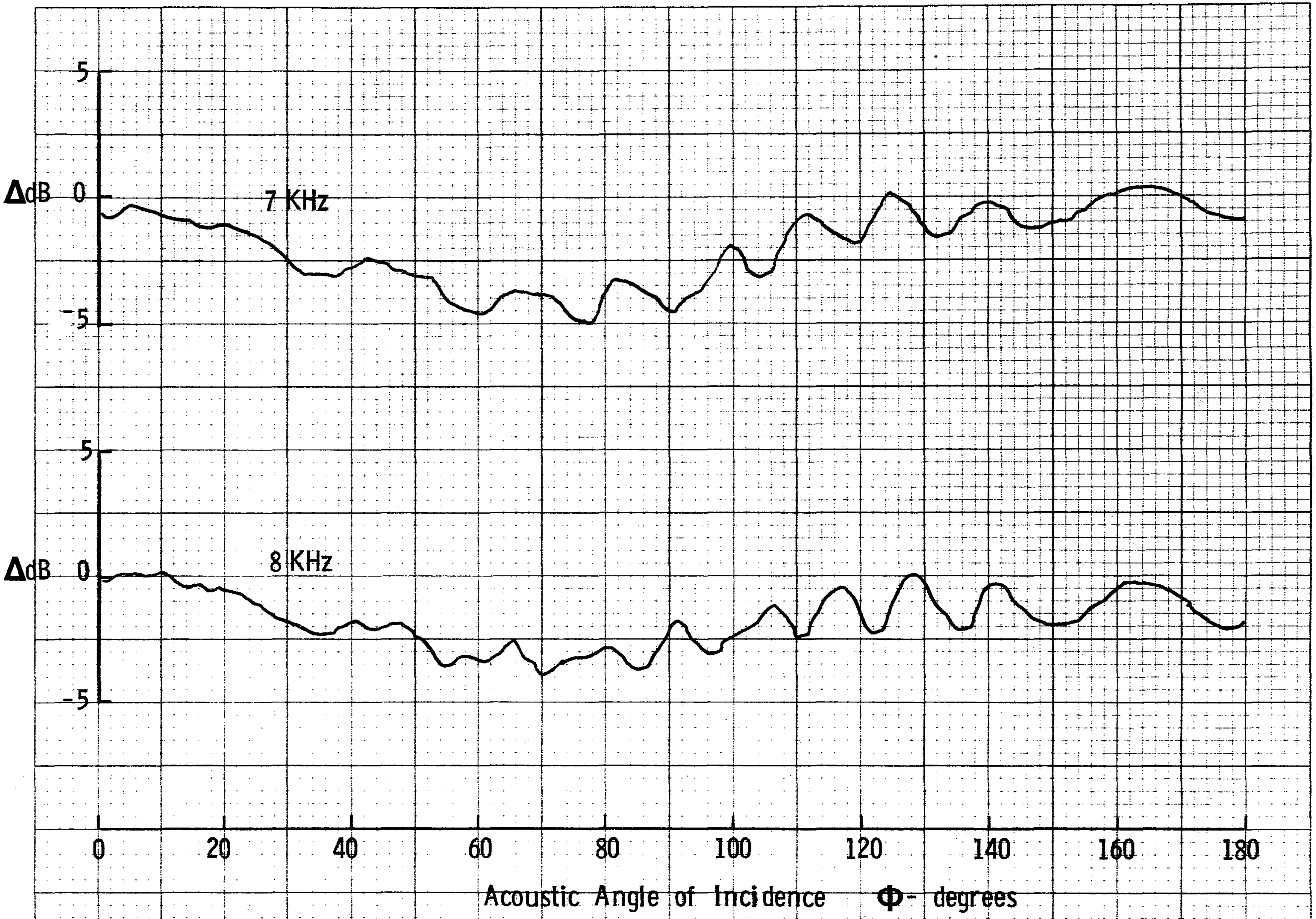


Figure 17d. Continued

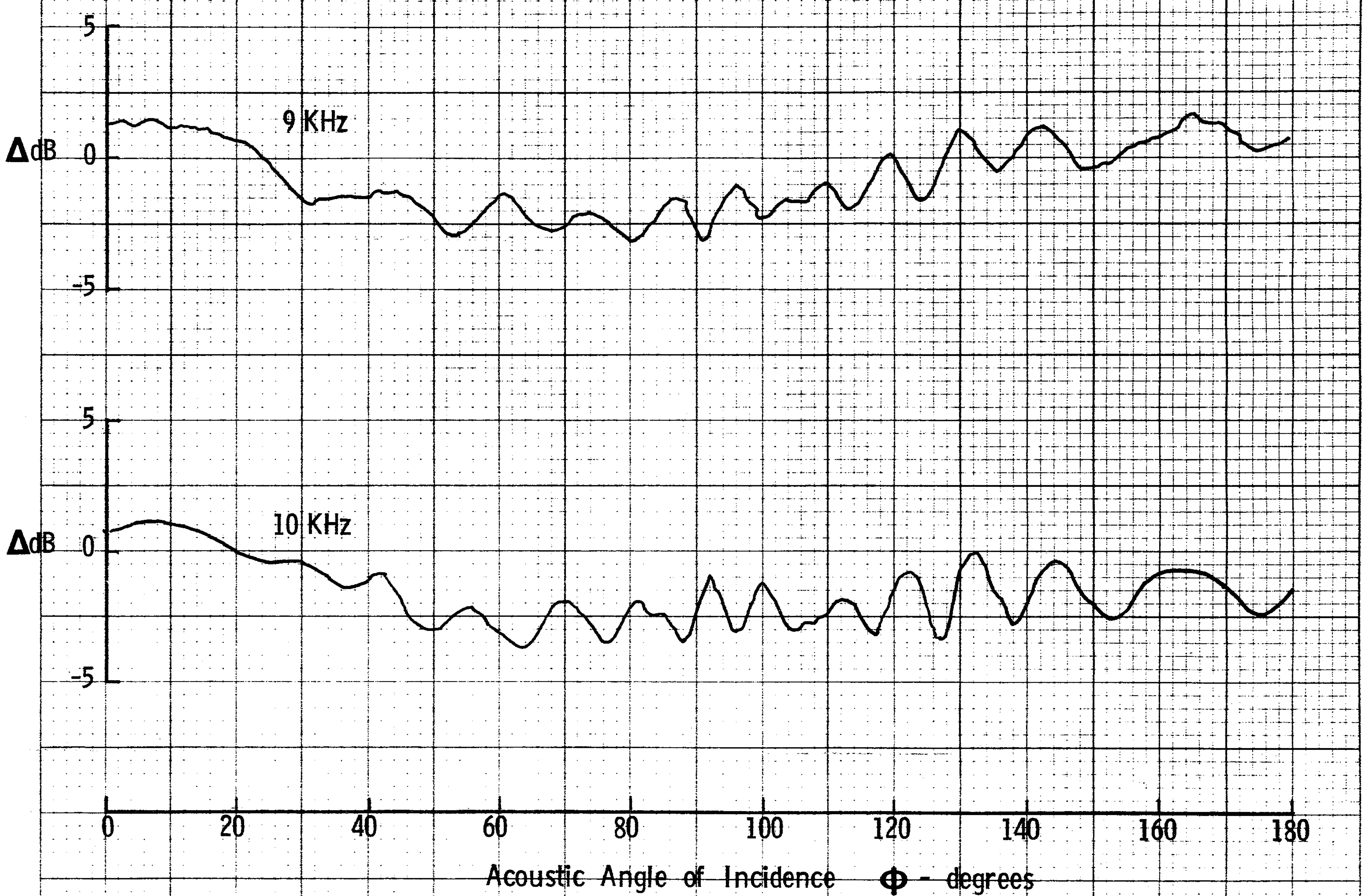
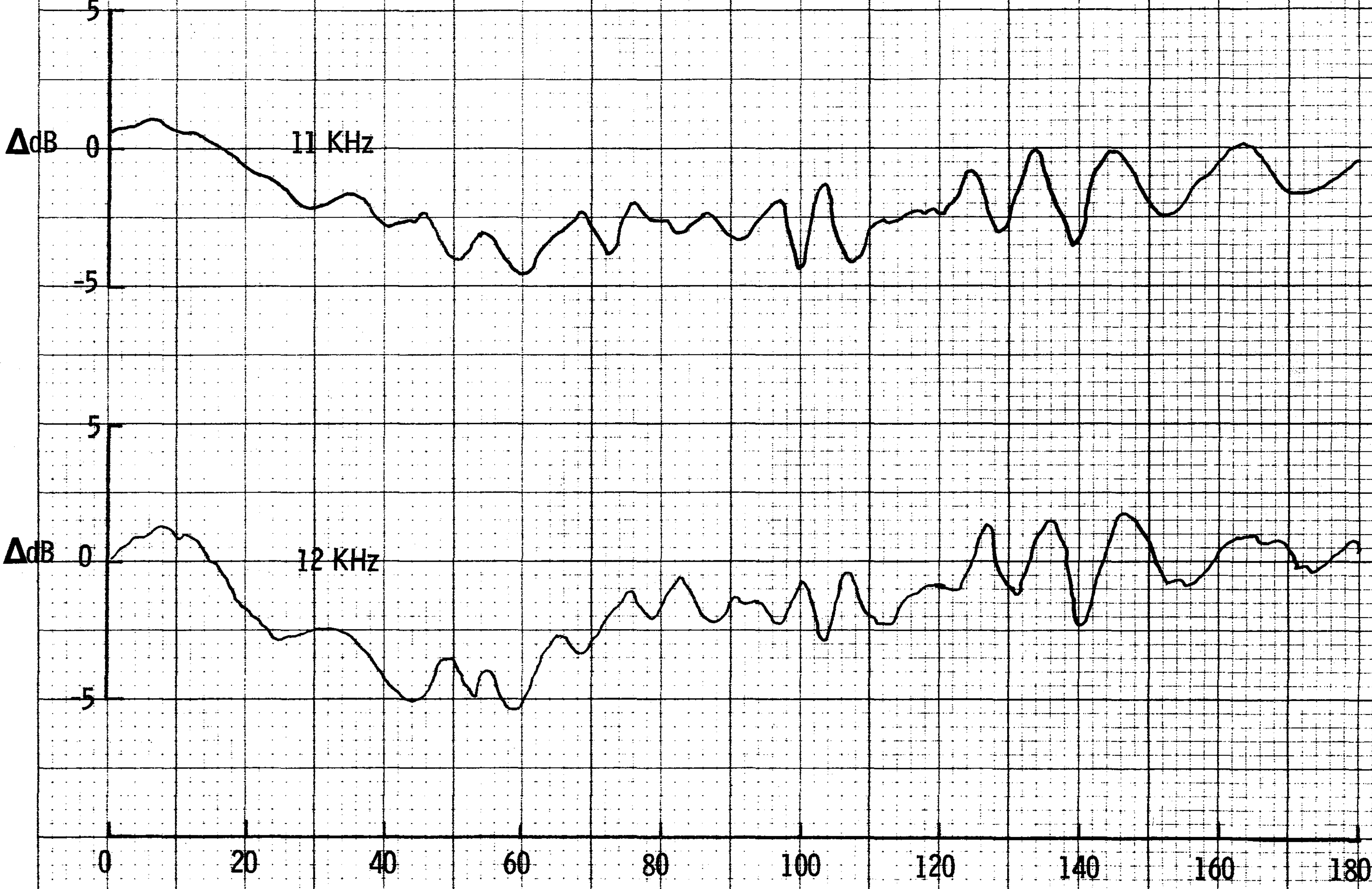


Figure 17e. Continued



Acoustic Angle of Incidence Φ - degrees

Figure 17f. Continued

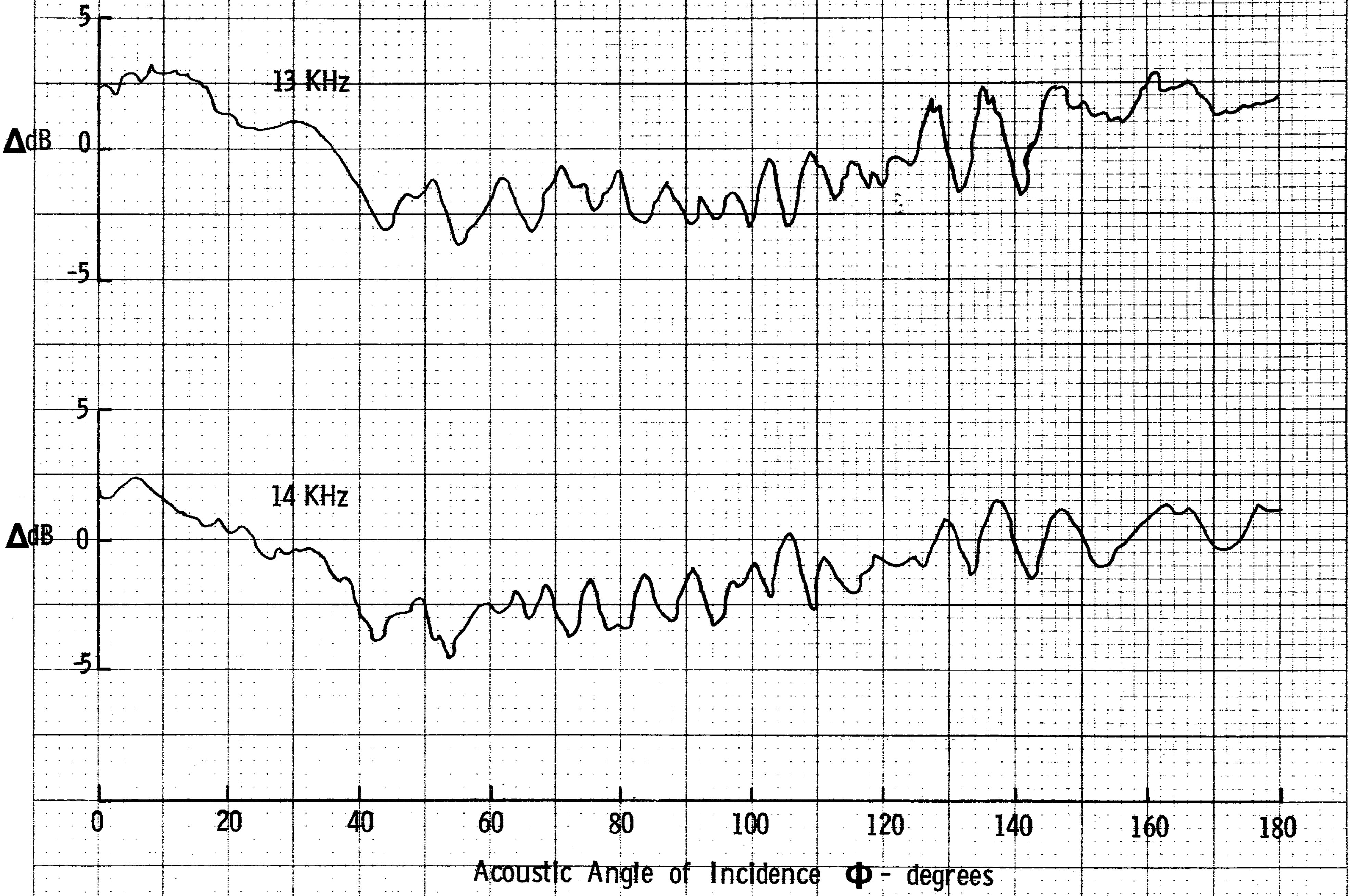


Figure 17g. Continued

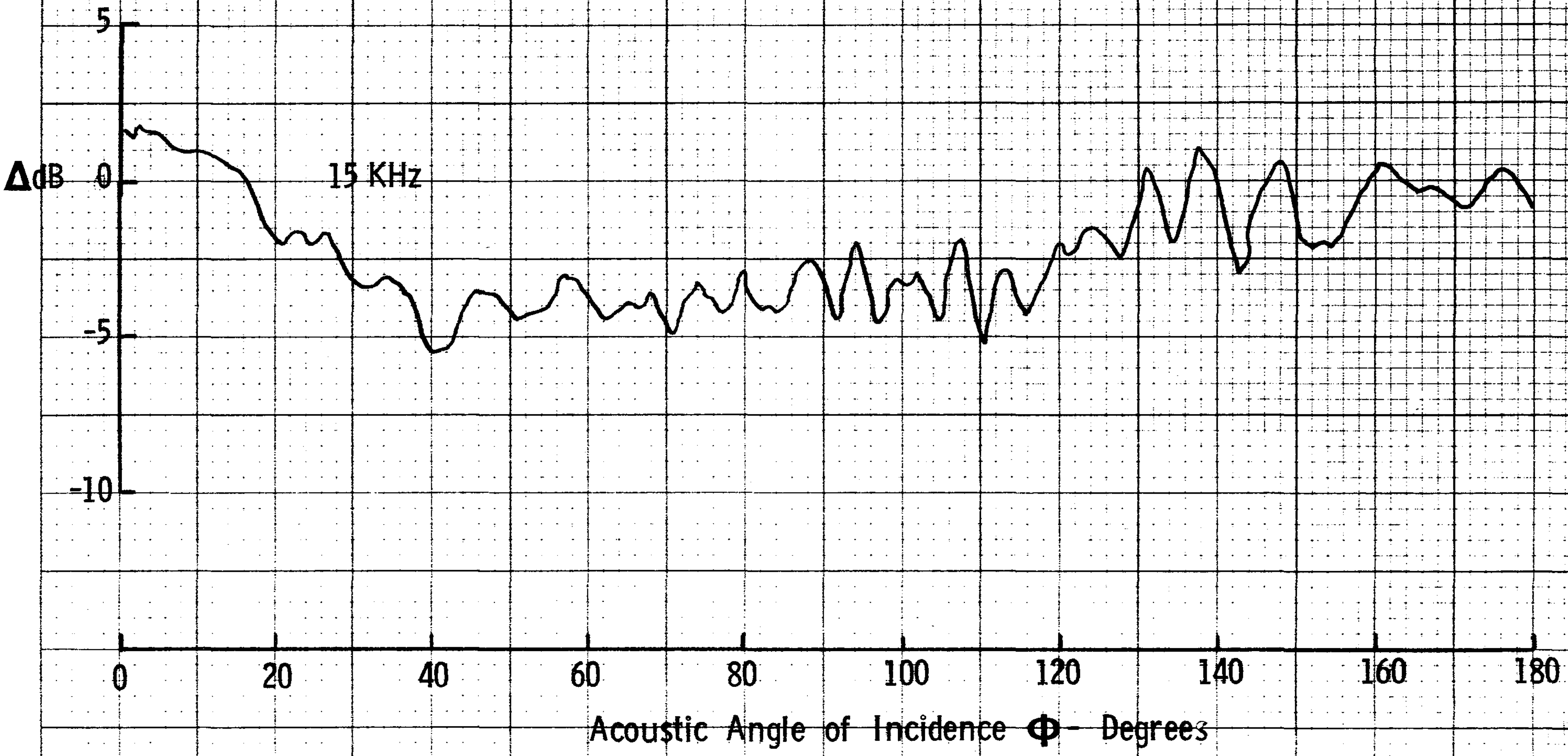


Figure 17h. Concluded.

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15. Supplementary Notes

16. Abstract

The NASA Flight Effects Program has a requirement to compare acoustic data obtained from flyover, static test stand, and wind tunnel tests. This report presents the results of a laboratory study of the acoustic characteristics of the three techniques used to measure noise during these tests. Recommendations are made to allow for a comparison of data obtained with each technique.

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