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FIG. / DIAG. 14

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Description and Performance of an Anechoic Test Cell for Fan Noise Research

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Summary

A brief description of the fan noise research test cell of the Engine Laboratory is given. Acoustic measurements inside the treated area of the cell showed satisfactory performance of the test area for fan noise research. Noticeable deviations from the inverse square law variations were observed especially at low frequencies near the inlet splitters and flow straighteners, and near the crane rail surface on the ceiling; these surfaces are not adequately treated. The agreement of the measured sound pressure levels with the inverse square law variation was excellent across the width of the cell.

1.0 Introduction

The Engine Laboratory of the Division of Mechanical Engineering is at present engaged in active research programmes on fan noise. Over the last few years several acoustic tests were conducted outdoors on a fan-in-wing model. The model with its drive accessories was installed on a platform 20 ft. above the ground level to shield the noise measurement area from the effects of ground reflections. Testing time was severely limited on account of inclement weather and noise complaints from the neighbouring residents. In addition, there was considerable difficulty in making modifications to the test rig at that height.

A new single-stage fan rig has recently been commissioned in Cell 6 of the Engine Laboratory. This rig permits studying the influence of fan design parameters such as the geometry and number of rotor and stator blades, spacing between the blade rows rotational speed etc. on both the aerodynamic and acoustic performance of the fan. After having experienced several constraints in conducting acoustic tests outdoors, it was decided to convert Cell 6 into an anechoic chamber for fan noise experiments. This report describes the details of the acoustic treatment and calibration of the test cell.

2.0 Anechoic Treatment of Cell

A general arrangement of the research fan rig and the cell acoustic treatment is shown in Fig. 1. Prior to treatment with acoustic materials the test cell dimensions were length 81 ft., width 20 ft. 6 ins., height 18 ft. A 700 HP Sirocco blower (Fig. 2) is situated at the rear of the cell, and exhausts the cell air into a stack through the next level.

The cell inlet has been treated with fiberglas splitters (Fig. 3) and flow straighteners (Fig. 4) to restrict the noise penetration from either side, and to allow the inlet air to flow in a satisfactory manner through the test area.

The treatment of the test area consisted of fibreglas wedges constructed in the form of step pyramids 18" deep. Only that portion of the cell immediately surrounding the fan rig and measuring area was covered with wedges. The rear wall areas were partially covered with 2" fibreglas panels. To limit the penetration of the Sirocco Blower noise into the measurement area a number of vertical splitters were constructed at the rear of the cell and covered with 4" fibreglas panels (Fig. 5).

The fibreglas wedges and panels covering the wall areas were attached to a Dexion steel framework (Fig. 6), which provides a 6" air gap between the cell walls and the fibreglas treatment. The ceiling treatment was attached in a similar manner to a Dexion steel framework which was suspended from a single central crane rail, and attached to the walls. The crane rail itself was covered at its lower surface with 4" fibreglas panels.

The general treatment of the floor (Fig. 7), includes the wooden framework onto which the wedges were placed supporting a steel railing, on top of which was laid a light weight removable aluminium grating; this affords easy access to the test area over the top of the floor wedges. To isolate the fan drive noises from the measuring area, curtains of fibreglas wedges (Fig. 8) were suspended in front of the drive turbine, around and above the plane of the 12" fan. Measured inside the wedges, the treated area dimensions were length 14 ft., width 16 1/2 ft. and height 10 ft.

3.0 Calibration of the Test Cell: Instrumentation and Test Procedure

The method used for measuring the performance of the test cell was to check the inverse square law variations of sound pressure levels with distance from a point sound source. A sound source of a 100 watt driver unit (Fig. 9) was placed close to the fan rig. To get sufficiently high sound pressure levels 3 in. diameter bakealite matching tubes were used as resonators for the low frequency operation of the unit. The aperture of the driver unit or the matching tubes was a point source to a good approximation. The sound pressure level variations were measured by a 1/2 in. microphone suspended from a carriage which could be traversed along an aluminium track at a speed of 5 mm/sec (Fig. 10). The carriage was driven by a pair of synchronous motors. The movement of the microphone along the track was controlled outside the test cell and distances from the source along the track were recorded at 10 cm intervals by means of a microswitch arrangement on the track and the carriage. The signal from the microphone was recorded on a B&K 2203 level recorded through a B&K 2107 constant percentage band width analyser. The driver unit (Fig. 11) was driven by a B&K beat frequency oscillator.

A sound pressure level of 102 db at a distance of 20 cm from the aperture of the driver unit or matching tubes was maintained as a standard condition throughout the experiments.

4.0 Results and Discussions

Figs. (12), (13) and (14) show the sound pressure level variations vis-a-vis the inverse square law along the three axis. Fig. (12) shows the performance of the room along the longitudinal axis from the fan to the inlet splitters and flow straighteners in the frequency range 100-5000 Hz. While there was generally good agreement with the inverse square law, there were large deviations in the frequency range 250-4000 Hz close to the splitters. Since the splitters were treated with 4 in fibreglas panels, they were not expected to give good absorption at low frequencies. The reflections of the sound waves from this area were largely responsible for the deviations from the inverse square law.

Fig. (13) shows good correlations along the horizontal transverse axis of the fan. The room was initially designed to give good performance with the 18 in. wedges down to 250 Hz. There were no marked departures from the inverse square law variations even below 250 Hz. However, there were some deviations near the walls.

Fig. (14) shows the performance of the room to be satisfactory below the fan axis but marked deviations from the inverse square law variations near the ceiling. The 2 ft. surface width of the crane rail which runs along the length of the cell was not provided with fibreglas wedges but was treated with only 4 in thick fibreglas panels. Additional treatment with fibreglas panels would be required to improve the performance near the ceiling.

Fan noise traverses are intended to be made over the 90° arc upwards at a 4 ft. radius. The quality of the room appears to be satisfactory for this purpose. However the performance could be further improved by treating the crane rail surface with addtional fibreglas panels.

5.0 Conclusions

(1) Acoustic calibration of the treated test cell has shown satisfactory agreement with inverse square law.

(2) Departures from the inverse square law have occurred near the inlet splitters and flow straighteners and the crane rail surfaces, as these surfaces are treated only with fibreglas panels.

(3) The correlations are particularly good along the width and towards the floor of the cell.

Appendix A

Description of Instrumentation

6.0 Introduction

The instrumentation used to calibrate the anechoic chamber consisted of a "T" rail about twelve feet long with a carriage to transport a 1/2 inch microphone. The carriage was traversed forward and back along the rail by two electric motors controlled from outside the chamber. As the carriage moved along the rail a signal was received every 10 C.M. which marked the position of the microphone.

The pure tone source was a 100 watt driver which was driven by a Bruel and Kjaer beat frequency oscillator #1014. A half inch Bruel and Kjaer microphone was mounted on the traversing carriage, its output was fed through a Bruel and Kjaer amplifier #2107 and the output was recorded on a Bruel and Kjaer level recorder #2305.

6.1 Method Used to Obtain High Amplitude at Low Frequencies

At frequencies below 500 Hz there was not enough power available in the oscillator to give a high enough sound level and it was necessary to fit to the driver output with various pipes whose lengths would provide resonance and hence a large amplitude signal at the frequencies desired. Six plastic pipes 3 inches in diameter were used with the following combinations giving the required amplitudes.

Frequency	Combination and Length		Pipe Numbers	Length
	Pipe Number	Length		
100	#2	32 1/4"	1	38"
			2	32 1/4"
200	#5 & #6	15 7/8"	3	25 5/8"
			4	19 3/4"
250	#1	38"	5	9 3/8"
			6	6 1/2"
400	#3	25 5/8"		
500	#4	19 3/4		

A nine inch thin wall aluminium sleeve fitted the pairs of pipe together.

6.2 Test Procedure

The "T" rail was first mounted in a horizontal position along the longitudinal axis of the chamber and the sound source or driver was installed at the position where the fan noise originates. The microphone mounted on its carriage was positioned 20 centimeters from the output of the driver or the end of the resonating tube fitted to the driver.

The sound source or driver was actuated by the oscillator and amplitude increased until a reading of 102 db was read on the meter of the B&K 2107 amplifier at the desired frequency. This level was recorded on the Bruel and Kjaer recorder. The carriage was then made to move away from the sound source at a constant rate and each 10 centimeter point was marked on the recording paper giving a profile of the chamber in db level plotted against cell position between the sound source and the splitters at the front of the cell.

To obtain the profile of the chamber in the lateral plane the rail carriage carrying the microphone was mounted in a horizontal position across the chamber with the microphone positioned so that as it passed the driver going from side to side, it just cleared the end of the sound source. The microphone was positioned 20 centimeters one side of the driver, the sound level was raised until the readout was 102 db then the microphone was slowly moved away from the driver again plotting the db levels against microphone position. The same procedure was then conducted on the opposite side of the sound source.

To obtain the profile in the vertical plane the "T" rail was mounted in front of the microphone from floor to ceiling and the microphone was positioned to just clear the sound source; it was then traversed to 20 centimeters above the driver output and the sound level raised until the db reading was 102 db. The microphone was then slowly traversed upward to the ceiling, again having output levels plotted against microphone position. This test was repeated below the sound source down to the floor.

6.3 Description of Instrumentation

A half inch model #4133 free field Bruel and Kjaer condenser microphone with cathode follower was connected to the Bruel and Kjaer 2107 constant percentage band width filter through a 66 ft. microphone cable. The output from 2107 (Fig. 11) was fed to a Bruel and Kjaer 2305 level recorder. Because pure tones were being generated at the sound source the filters of the 2107 were not used. This unit supplied power to the microphone cathode follower and its amplifier was used to drive the level recorder.

A simple circuit connected to a microswitch on the microphone carriage gave a signal every ten centimeters of microphone travel and this signal was transferred to the strip chart of the level recorder.

The Bruel and Kjaer 2107 is a constant percentage band width filter with a step attenuator amplifier and an output flat from 20 Hz to 35K Hz. The constant percentage filter was not used but the microphone cable was connected to the 2107 which powers the cathode follower at the microphone. The output of the 2107 was used to drive the 2305 B&K level recorder which gave the profile of amplitude plotted against microphone position.

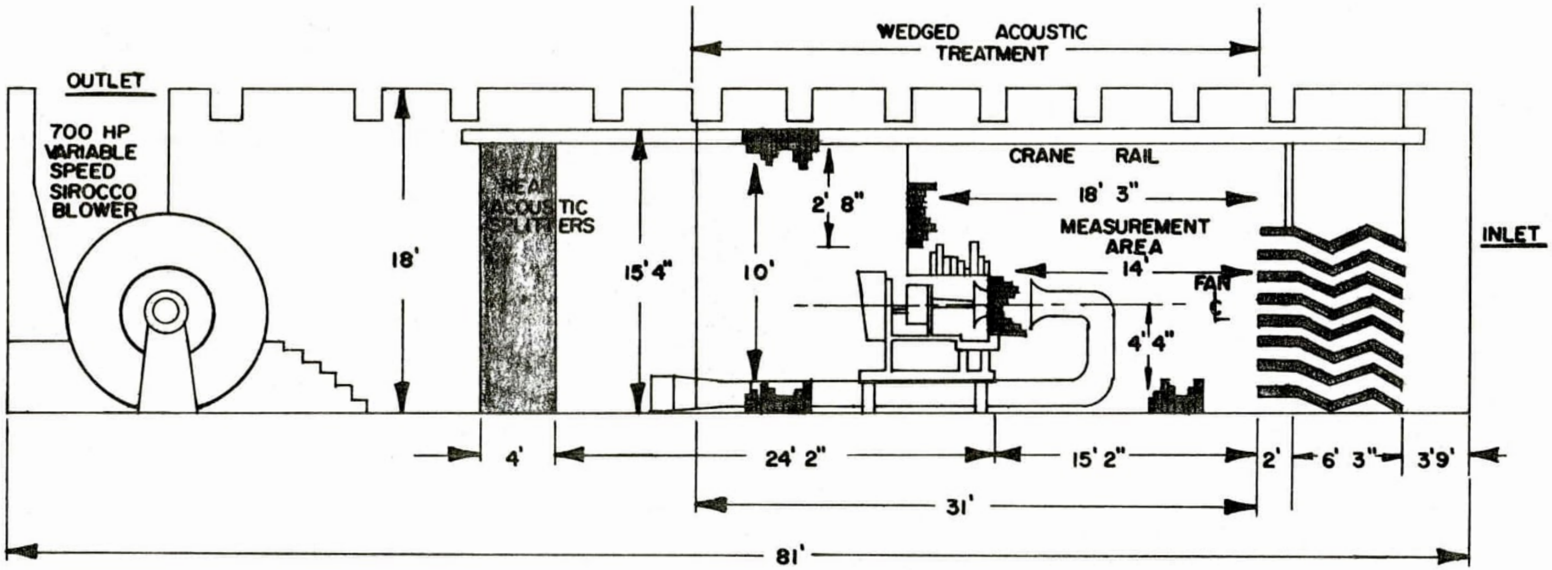

FIG. 1: FAN NOISE TEST CELL WITH ACOUSTIC TREATMENT

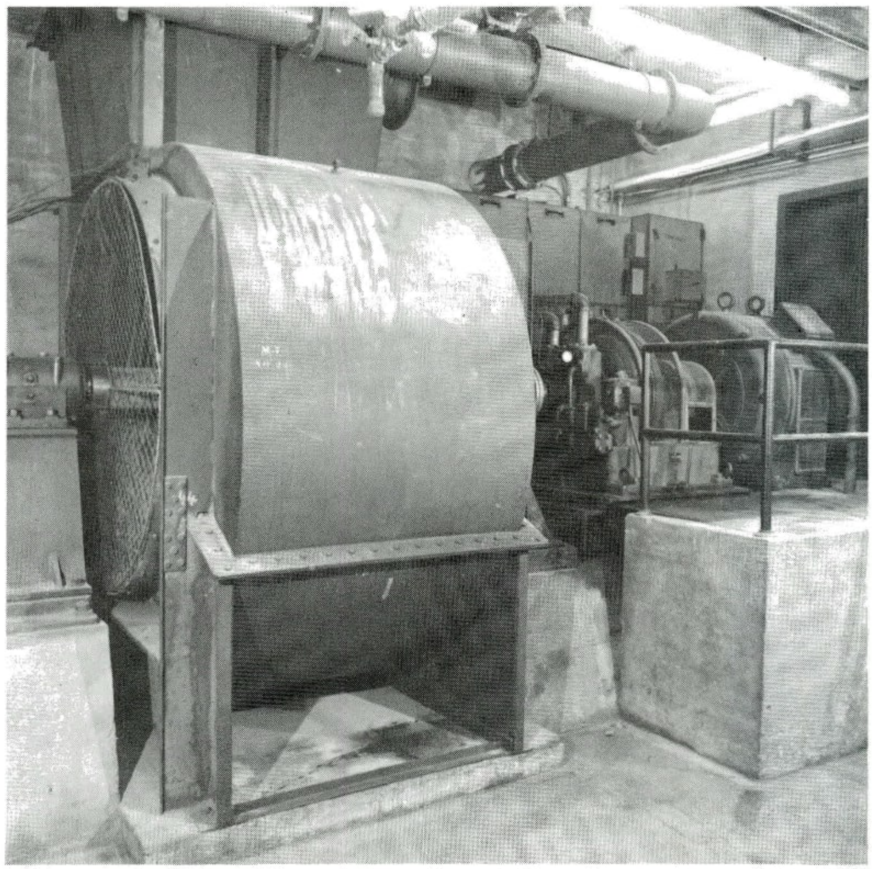

FIG. 2: 700 H.P. VARIABLE SPEED SIROCCO BLOWER

FIG. 3: CELL INLET

FIG. 4: INLET AIR FLOW STRAIGHTENERS

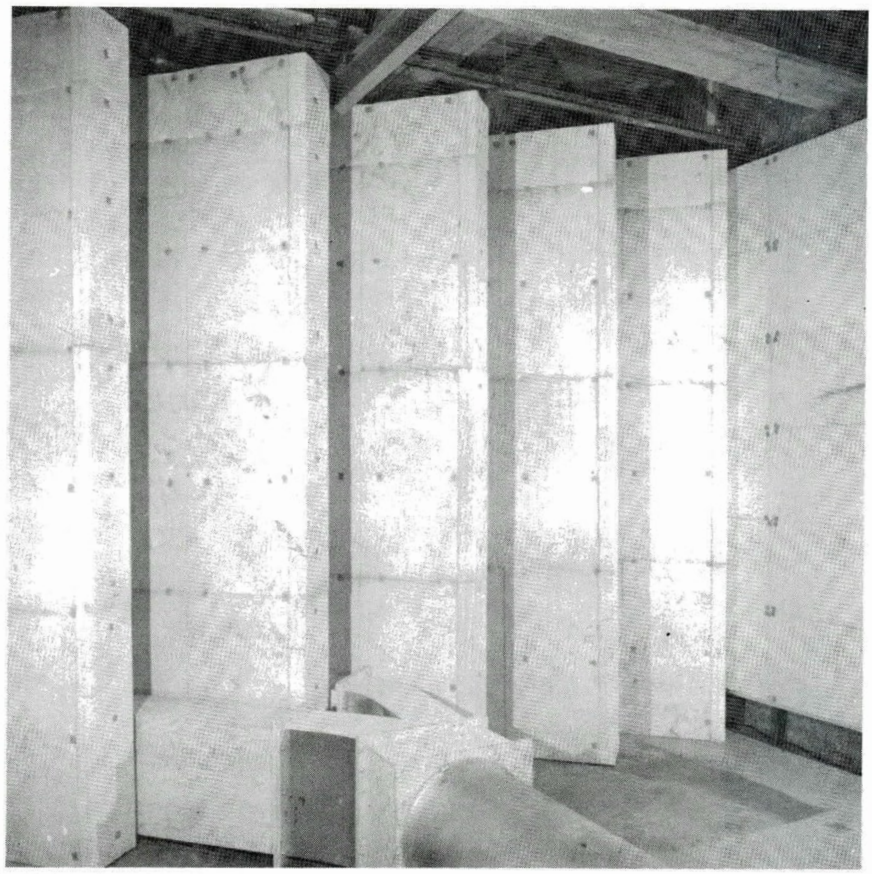

FIG. 5: VERTICAL SPLITTERS AT CELL REAR

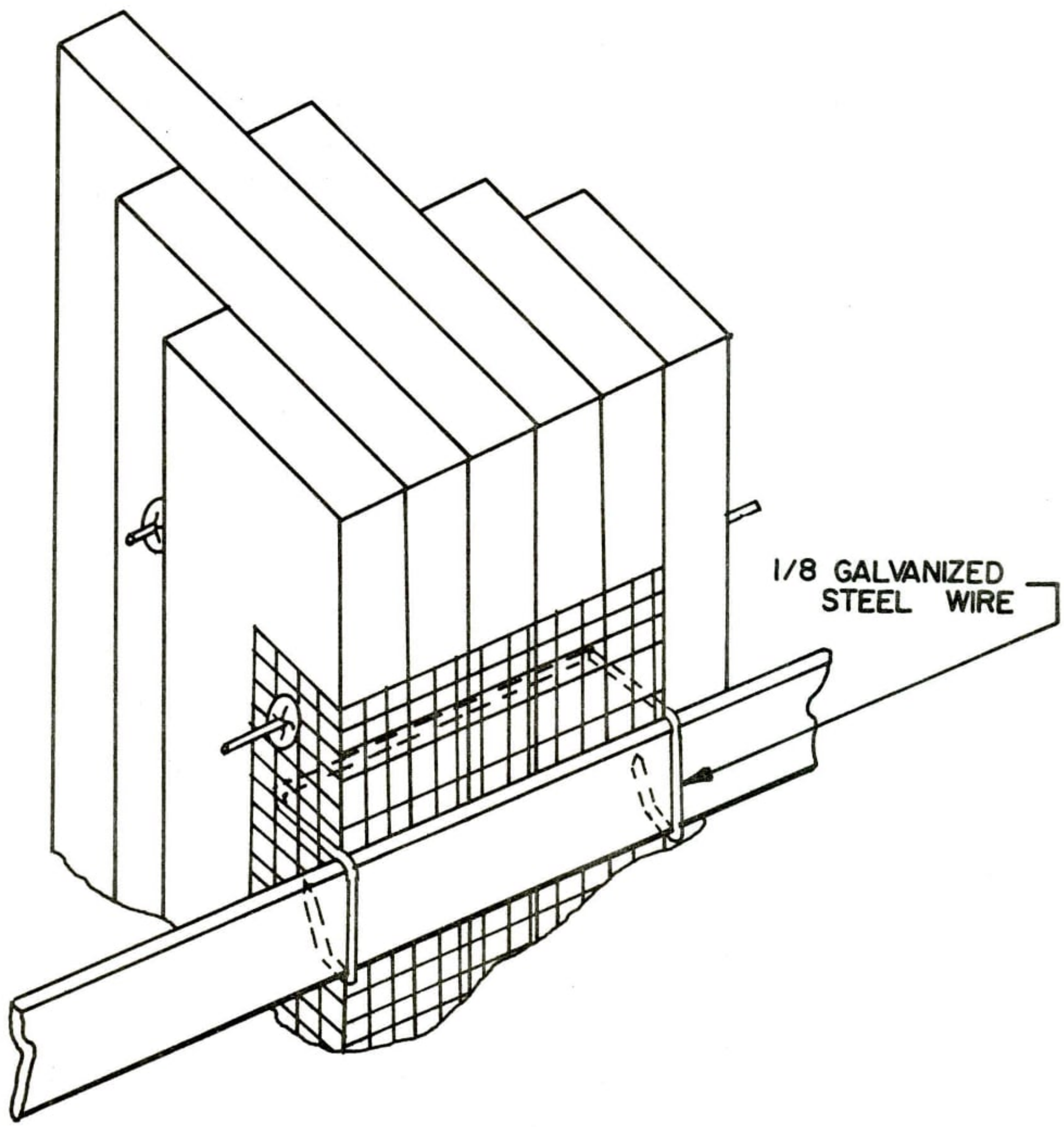

FIG. 6: FIBERGLAS WEDGE & (ATTACHMENT TO DEXION FRAME)

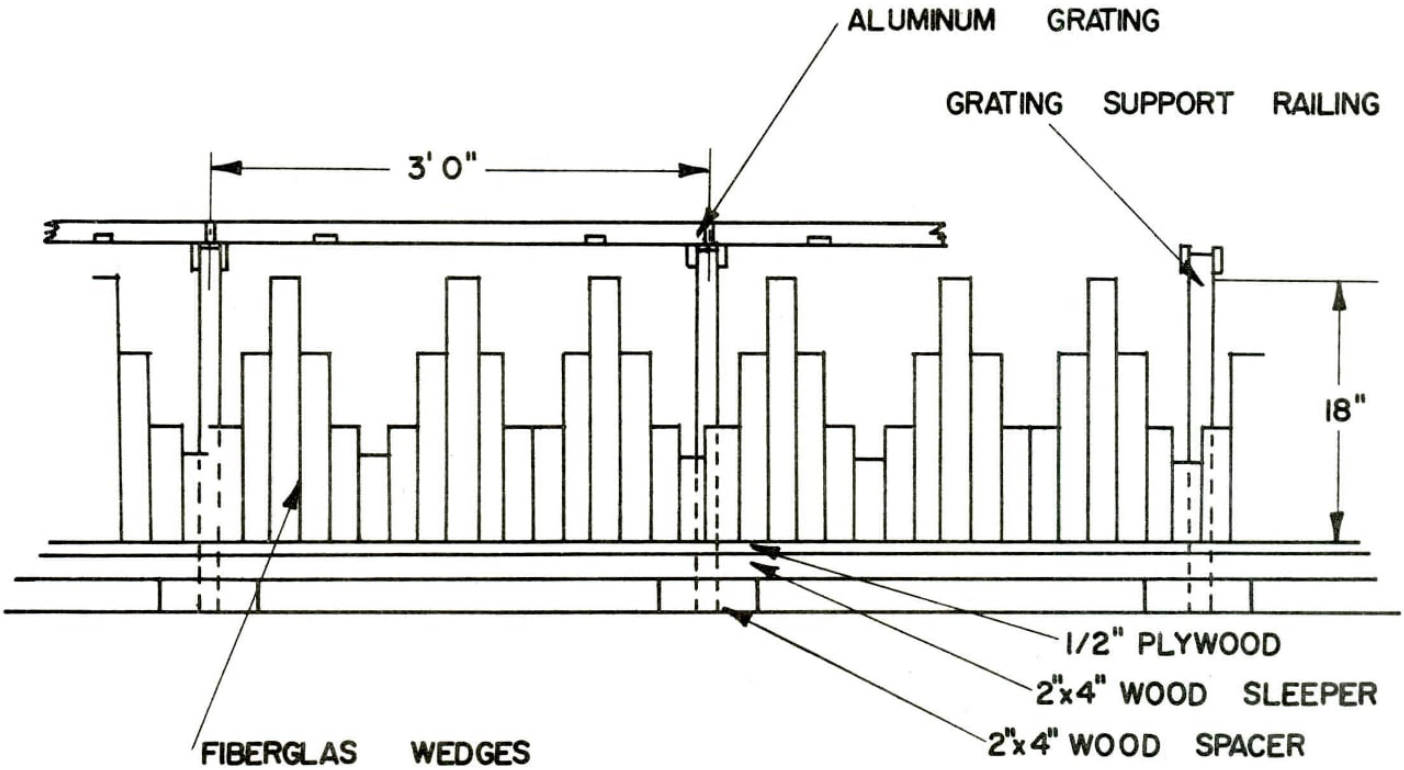

FIG. 7: ARRANGEMENT OF FLOOR WEDGES
WITH REMOVABLE LIGHTWEIGHT GRATING

FIG. 8: ACOUSTIC MEASUREMENT AREA SHOWING 12" FAN AND FIBERGLAS CURTAINS

FIG. 9: 100 WATT SOUND SOURCE

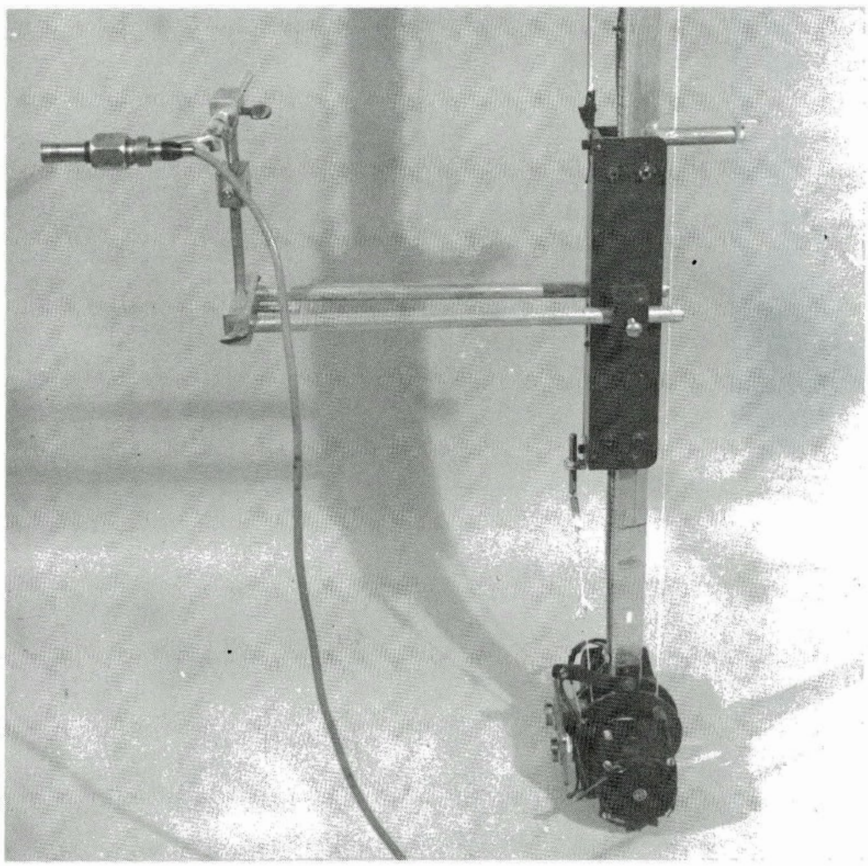

FIG. 10: MOTORIZED MICROPHONE TRAVERSE RIG

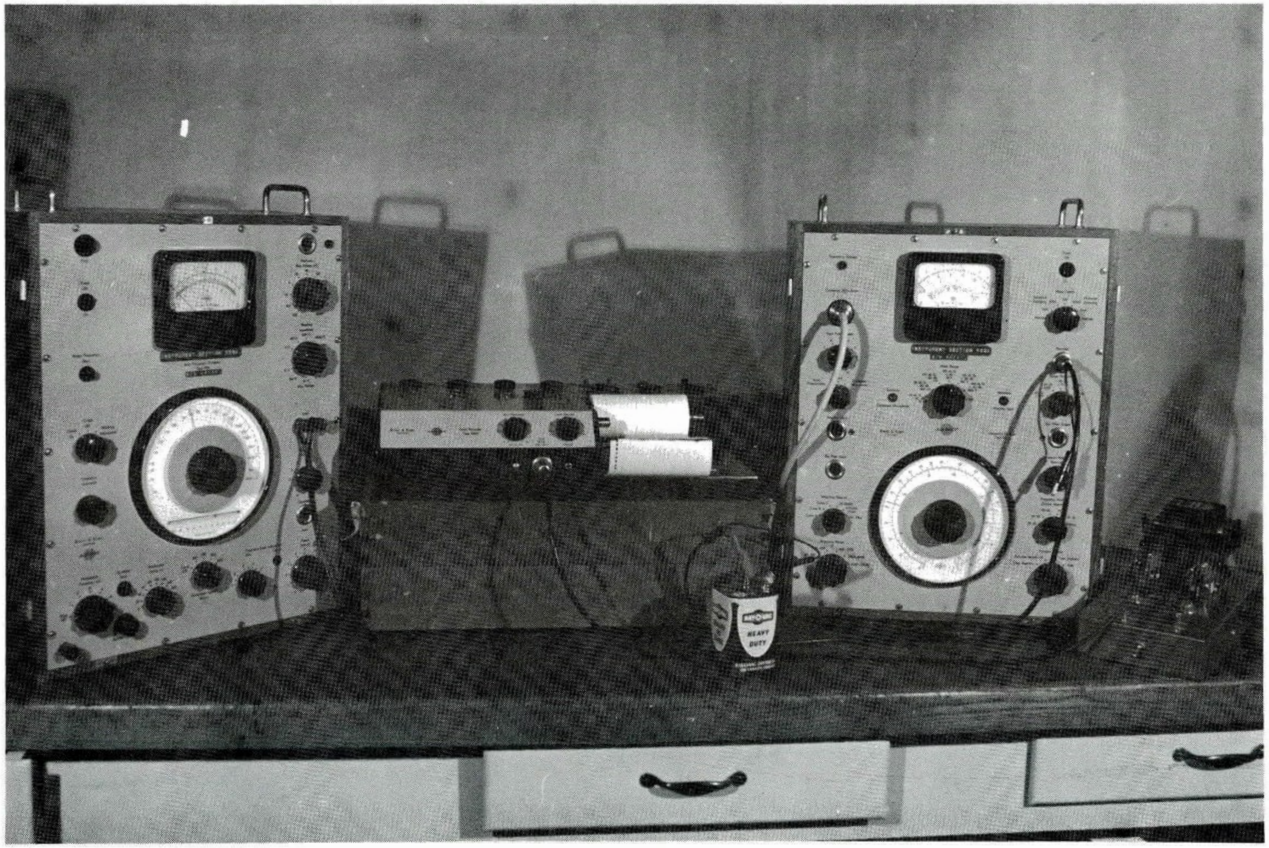

FIG. 11: INSTRUMENTS USED IN TEST, LEFT TO RIGHT OSCILLATOR, LEVEL RECORDER, MIC-POWER SUPPLY & AMPLIFIER.

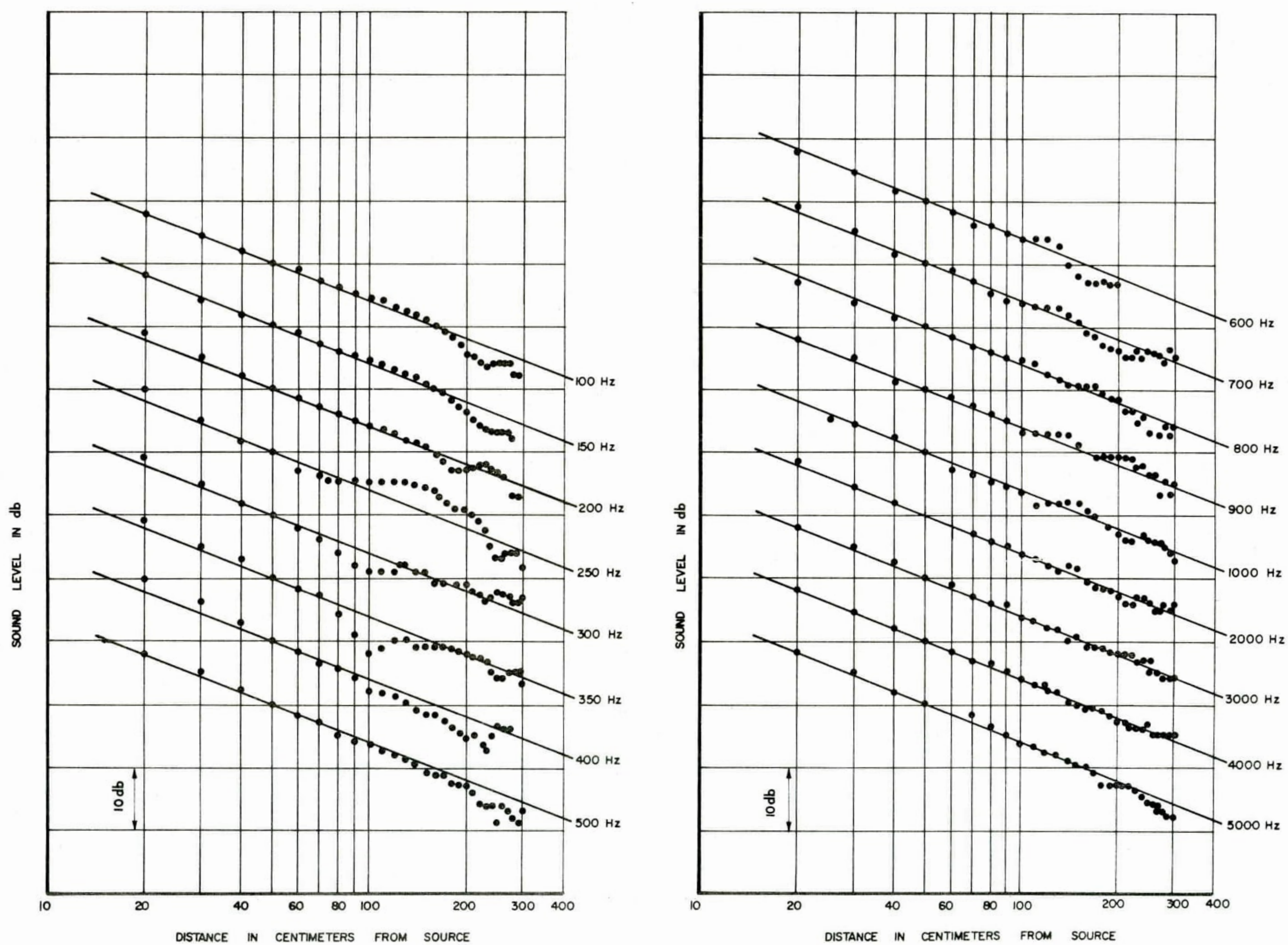

FIG. 12: SOUND PRESSURE LEVEL
VARIATIONS FOR SEVERAL FREQUENCIES FROM 100 Hz – 5000 Hz, WITH THE INVERSE SQUARE LAW ALONG THE LENGTH OF THE CELL FROM THE FAN RIG TO THE SPLITTERS & FLOW STRAIGHTENERS.

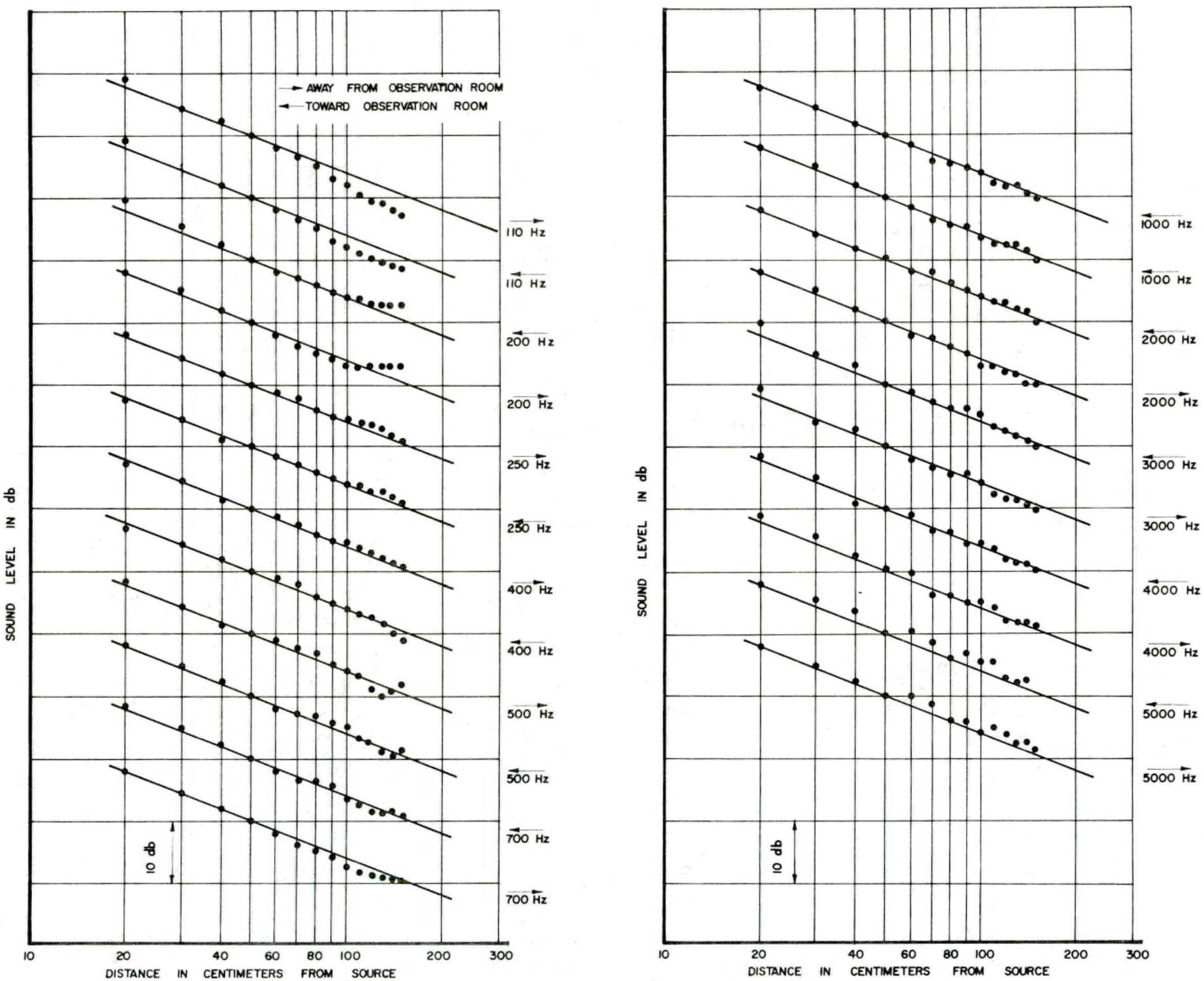

FIG.13: SOUND PRESSURE LEVEL

VARIATIONS FOR SEVERAL FREQUENCIES FROM 100 Hz – 5000 Hz WITH THE INVERSE SQUARE LAW ALONG THE HORIZONTAL TRANSVERSE AXIS OF THE FAN.

MICROPHONE TRAVERSE IN THE HORIZONTAL PLANE.

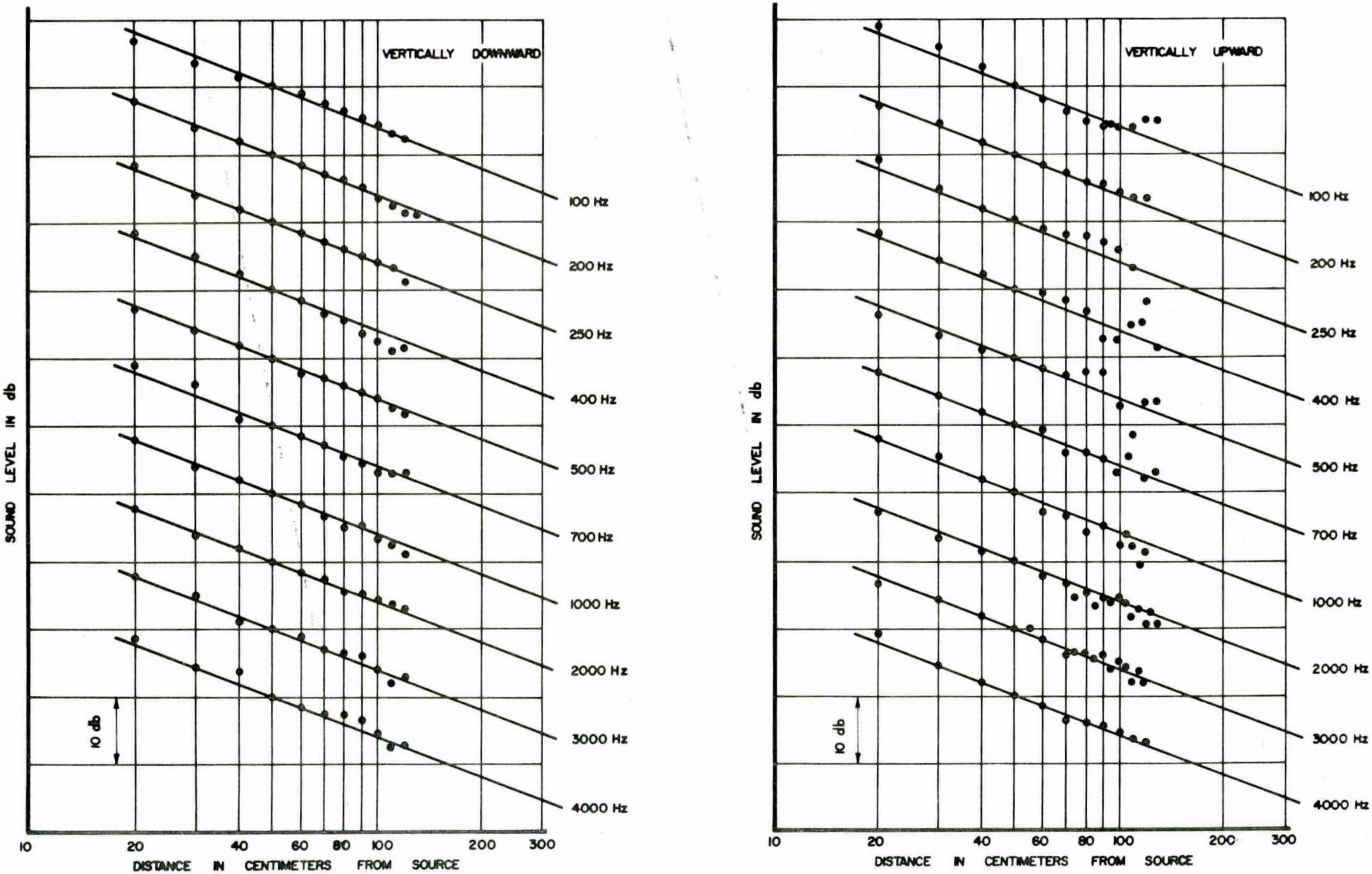

FIG. 14: SOUND PRESSURE LEVEL

VARIATIONS FOR SEVERAL FREQUENCIES WITH THE INVERSE SQUARE LAW FROM 100 Hz – 4000 Hz ALONG THE VERTICAL AXIS.