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Evaluation of the Acoustic Measurement Capability of the NASA Langley V/Stol Wind Tunnel Open Test Section with Acoustically Absorbent Ceiling and Floor Treatments

by
M.A. Theobald

(NASA-CR-165796) EVALUATION OF THE ACOUSTIC MEASUREMENT CAPABILITY OF THE NASA LANGLEY V/STOL WIND TUNNEL OPEN TEST SECTION WITH ACOUSTICALLY ABSORBENT CEILING AND FLOOR TREATMENTS Final Report (Bolt, Beranek, and G3/09 N82-10059 HC A03 | MF A01 Unclas 11472

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by
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for

NASA

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA 23665

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MAY 1978

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1. INTRODUCTION

The test section of the V/STOL wind tunnel at the NASA Langley Research Center is being modified to allow the accurate measurement of noise radiated by model aircraft. This tunnel has been the subject of two previous reports by Bolt Beranek and Newman Inc. (BBN). Report No. 2288 (1971)[1] described the acoustic environment of the unmodified tunnel. It was reported that the unmodified, open test section was semi-reverberant. Hall radii* measured for various directions of propagation at different frequencies were cited. It was recommended that a model study of the tunnel be carried out to ascertain what acoustical treatment was needed to allow measurement of the direct noise field of the aircraft. Report No. 3179 (1975)[2] discussed the findings of this model study. Acoustical treatment was recommended for the floor and raised ceiling of the open test section.

The present study concerns the evaluation of the acoustical environment of the treated test section under the following specific condition: Given the single source location used for helicopter model studies, at what distances and directions upstream of the model may accurate measurements of the direct acoustic field be performed? The method used to answer this question was to measure the decrease of sound pressure levels with distance from a noise source and thereby determine the hall radius as a function of frequency and direction. A summary of the conditions required for accurate measurements of the direct field are given in Ref. 1.

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*The hall radius is the distance from a sound source at which the intensities of the direct and reverberent sound fields are equal.

2. TEST ARRANGEMENTS AND PROCEDURES

The ceiling of the test section had been treated previous to our tests with a 5-inch-thick layer of open-cell acoustical foam (see Figure 1). Two alternate treatments were used on the floor. First, 5-inch-thick acoustical panels consisting of compressed glass fiber mats with glass fiber cloth and perforated metal facing were installed. This treatment was designed to allow the support of concentrated loads while still maintaining good mid- to high-frequency absorption (see Figure 2). The second floor treatment used was a layer of foam identical to the ceiling treatment. All of our tests were performed with the ceiling in the raised position with the open test cell configuration. The tunnel fan did not operate during our tests.

An electroacoustic noise source was suspended seven feet above the floor at the center of the forward test position (nearest the nozzle). Acoustic ray paths were outlined in the forward hemisphere using light twine (see Figure 3 and 4). Propagation distances were indicated on the twine using small flags. A Brüel and Kjaer 4134 pressure microphone, mounted on an adjustable stand, was used to measure the sound pressure levels of 1/3 octave bands of noise as a function of distance from the source. The direct sound waves impinged on the microphone diaphram at grazing incidence for maximally flat response.

Two noise sources were used in order to cover the frequency range of interest (200 Hz to 10 kHz) with a sufficiently high signal-to-noise ratio. Noise in the one-third octave bands from 200 Hz to 630 Hz was produced using a loudspeaker system consisting of a regular, twelve-sided polyhedron with an 8-inch-diameter

FIGURE 1

Acoustical Foam Treatment Installed on Raised Ceiling of Test Section

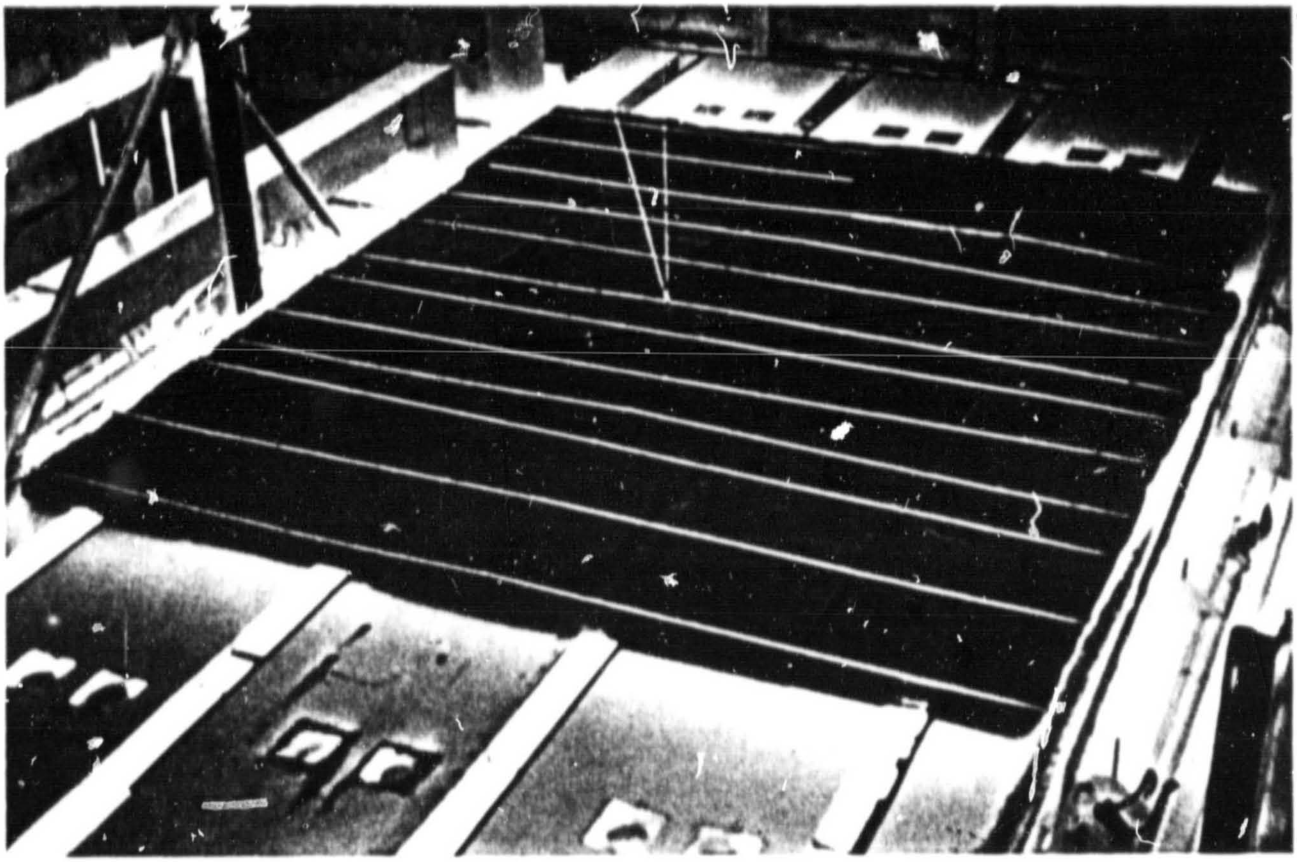


FIGURE 2

Floor Treatment Consisting of Glass Fiber Covered With Perforated Metal (Polished Surface) Installed in Test Section

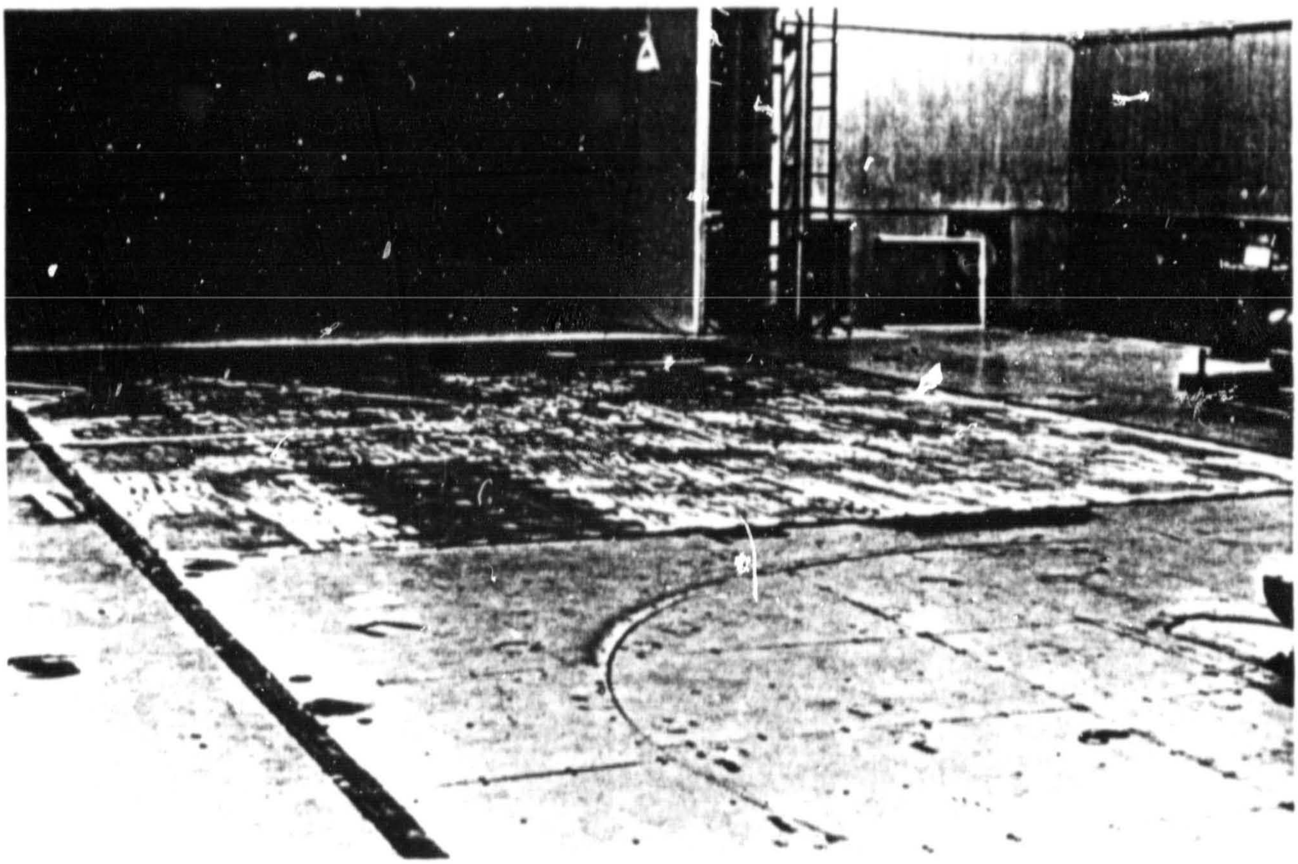
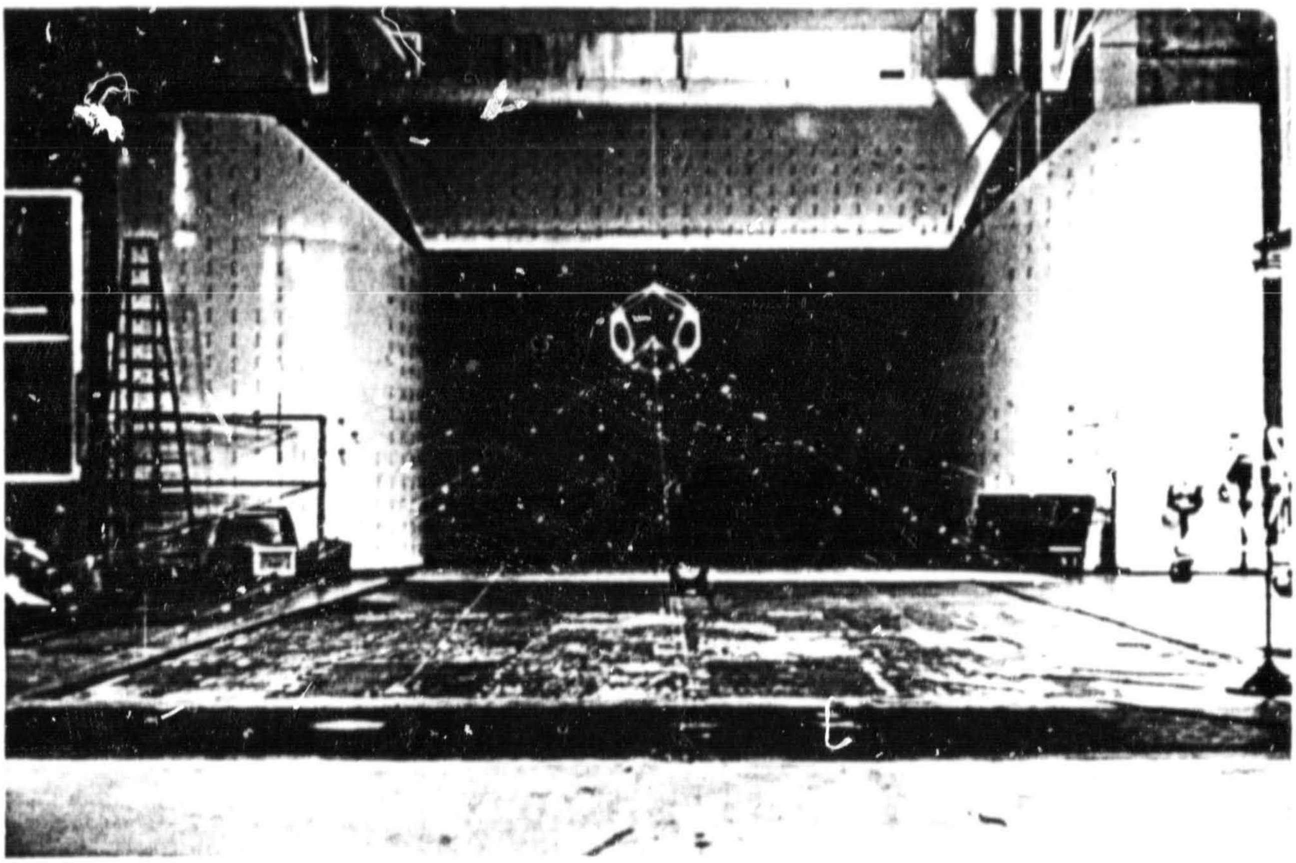
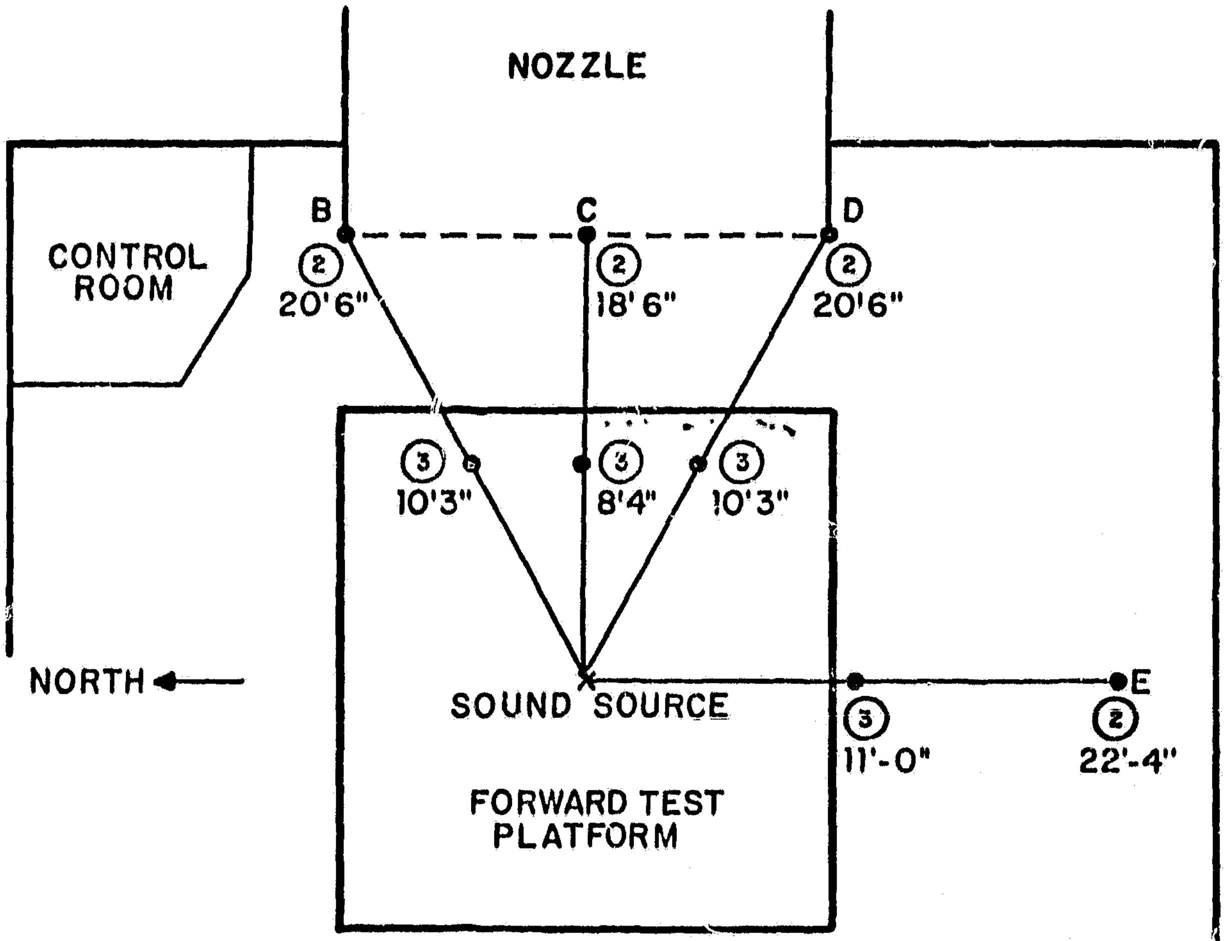


FIGURE 3

Dodecahedron Sound Source Suspended in Tunnel With Ray Paths Outlined by Strings (View from Nozzle of Tunnel).

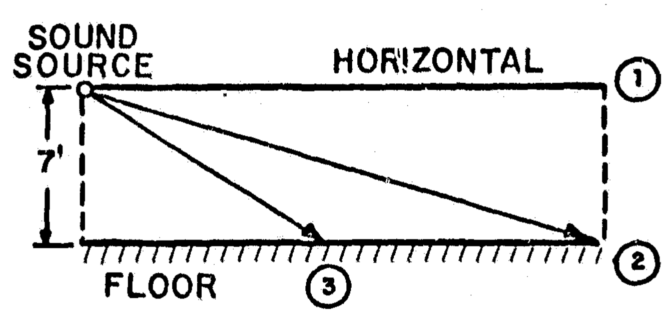




A) PLAN VIEW OF TEST SECTION

RAY PATH DIRECTION LETTERED B-E

RAY PATH NUMBERED 1 - 3 WITH DISTANCES SHOWN MEASURED ALONG FLOOR FROM SOURCE



B) SECTION SHOWING RAY PATHS ALONG DIRECTION E

FIGURE 4. DIAGRAM OF TEST SECTION SHOWING SOURCE POSITION AND ACOUSTIC RAY PATHS

Altec 409B speaker mounted in each face. This system was constructed by Mr. Paul T. Soderman of NASA Ames. A detailed description of the source and its calibration data can be found in Ref. 3. The speaker system is essentially omnidirectional for the one-third octave bands from 160 Hz to 1 kHz. The approximate radius of this noise source is one foot.

The sound source used for the 800 Hz through 10 kHz range was a University ID-60, 60-watt speaker driver having a one-inch (nominal) throat diameter. No speaker horn was used in order to keep the effective source radius small.

The source source was driven by a power amplifier fed by octave bands of pink noise. See Figure 5. The potential across the terminals of the sound source was maintained constant and monitored by means of an RMS voltmeter. The incoming microphone signal was amplified by a B&K 226/B signal conditioner and analyzed by a Spectral Dynamics 312 one-third octave realtime analyzer. The microphone signal was monitored by means of headphones to ensure that intermittent high-level background noise in the tunnel (mainly noise from steam pipes) was not included in the samples. The signal at each position was averaged for eight seconds. The resulting average values were stable with time to within 0.2 dB. The minimum signal-to-noise ratio for all measurements was 20 dB.

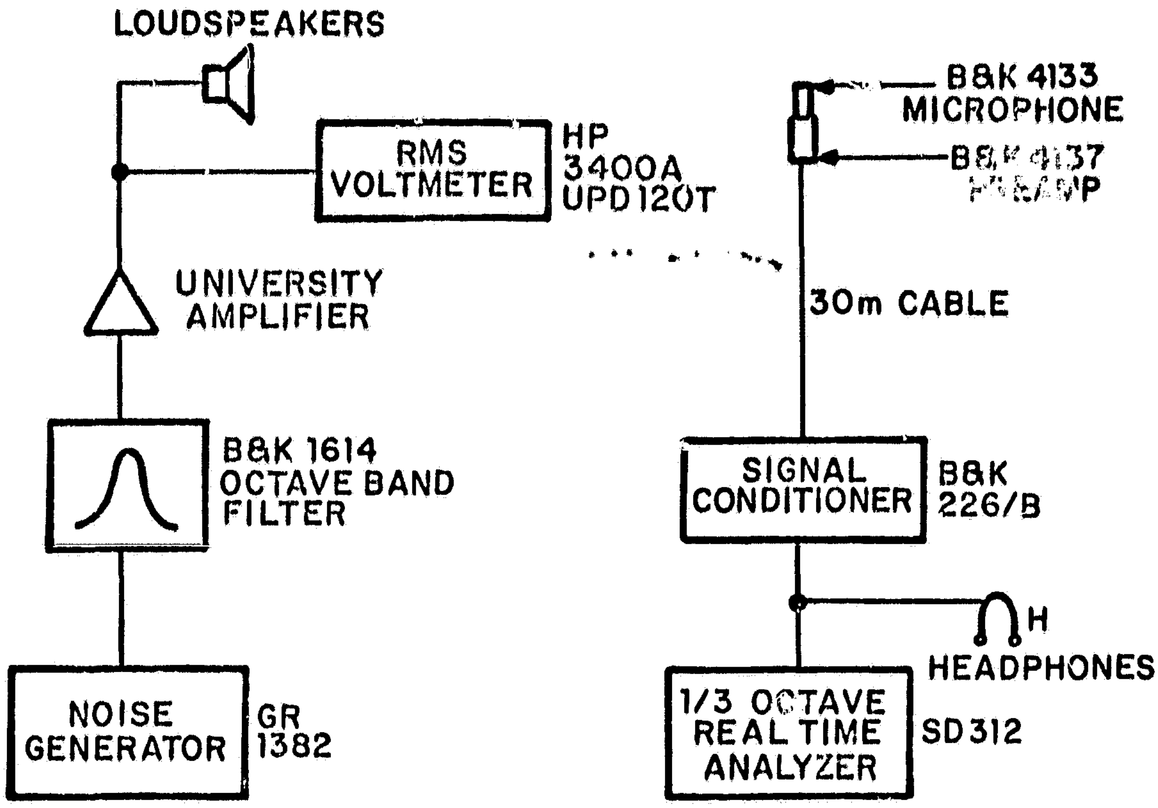


FIGURE 5. BLOCK DIAGRAM OF INSTRUMENTATION

3. RESULTS AND CONCLUSIONS

The measured one-third octave band sound levels were combined to yield sound levels for the 250 Hz, 500 Hz, 1, 2, 4, and 8 Hz octave bands. These sound levels were plotted as a function of distance from the source for each frequency, direction, and floor treatment. It was then attempted to fit the ideal SPL vs. distance curve for a semi-reverberant space through the data. With the tunnel treated, it was difficult to accurately determine a hall radius along each ray path, because the path lengths were limited by the floor, walls, or nozzle, and a sufficient amount of absorptive material was present, the characteristic "plateau" in the SPL vs. distance curves was often not present. That is, when the data approximately follows a -6dB per doubling of distance curve, then only a "minimum" hall radius could be determined. Therefore, the hall radius as a function of frequency was estimated by simultaneously plotting the propagation curves for all directions at each frequency for each floor treatment. These curves are shown in Figures 6-11. The approximate hall radius for each condition is indicated as r_H on the graphs. The estimated hall radii are:

TABLE 1

Hall Radius (feet) - All Directions

Floor Treatment	Octave Band Center Frequency (Hz) 250	500	1000	2000	4000	8000	Average Radius
Foam Floor	25	30	18	25	22	30	25
Glass Fiber Floor	25	25	25	20	20	20	22

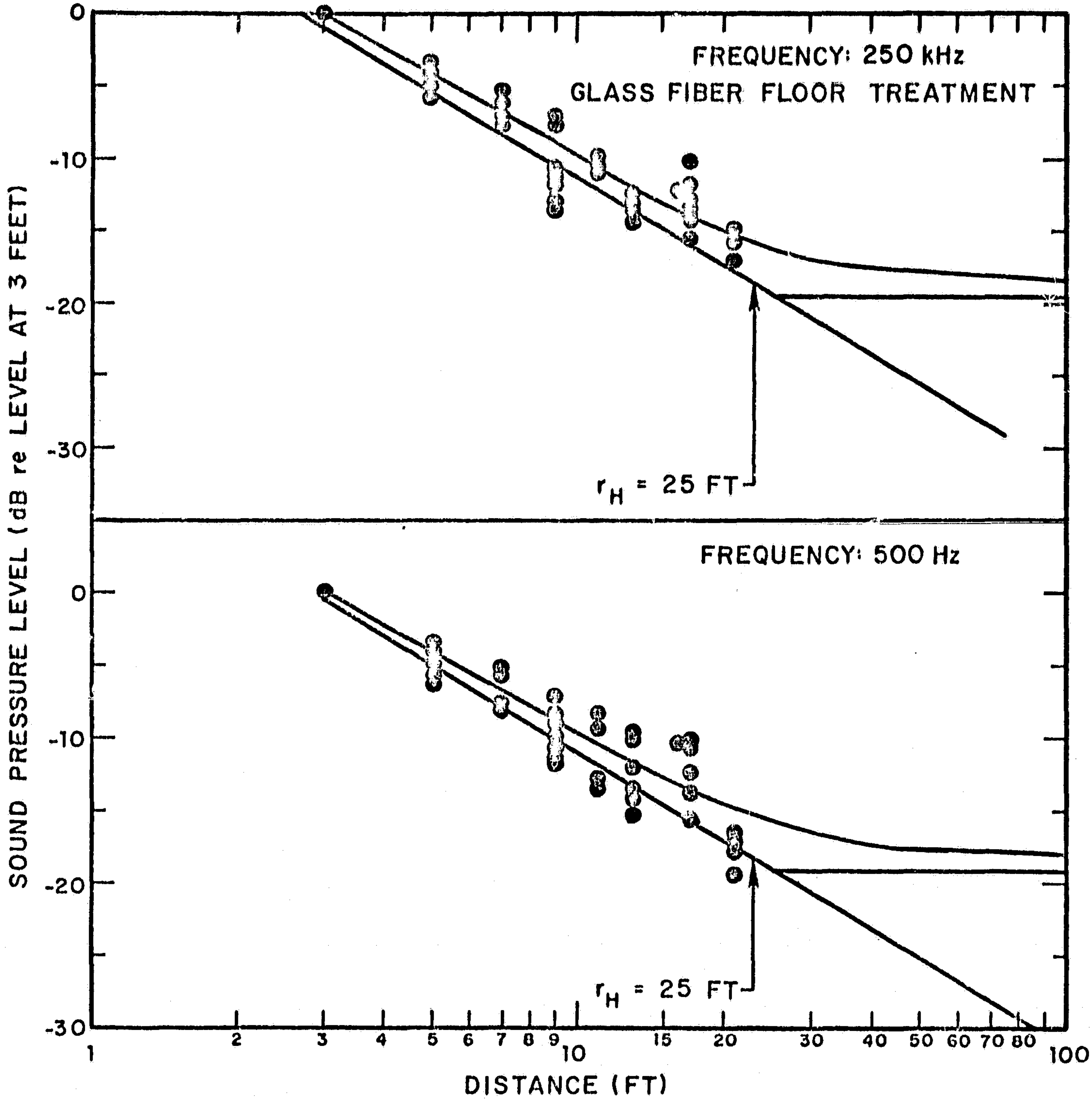


FIGURE 6. DISTRIBUTION OF NORMALIZED SOUND PRESSURE LEVEL VS. DISTANCE DATA IN ALL DIRECTIONS

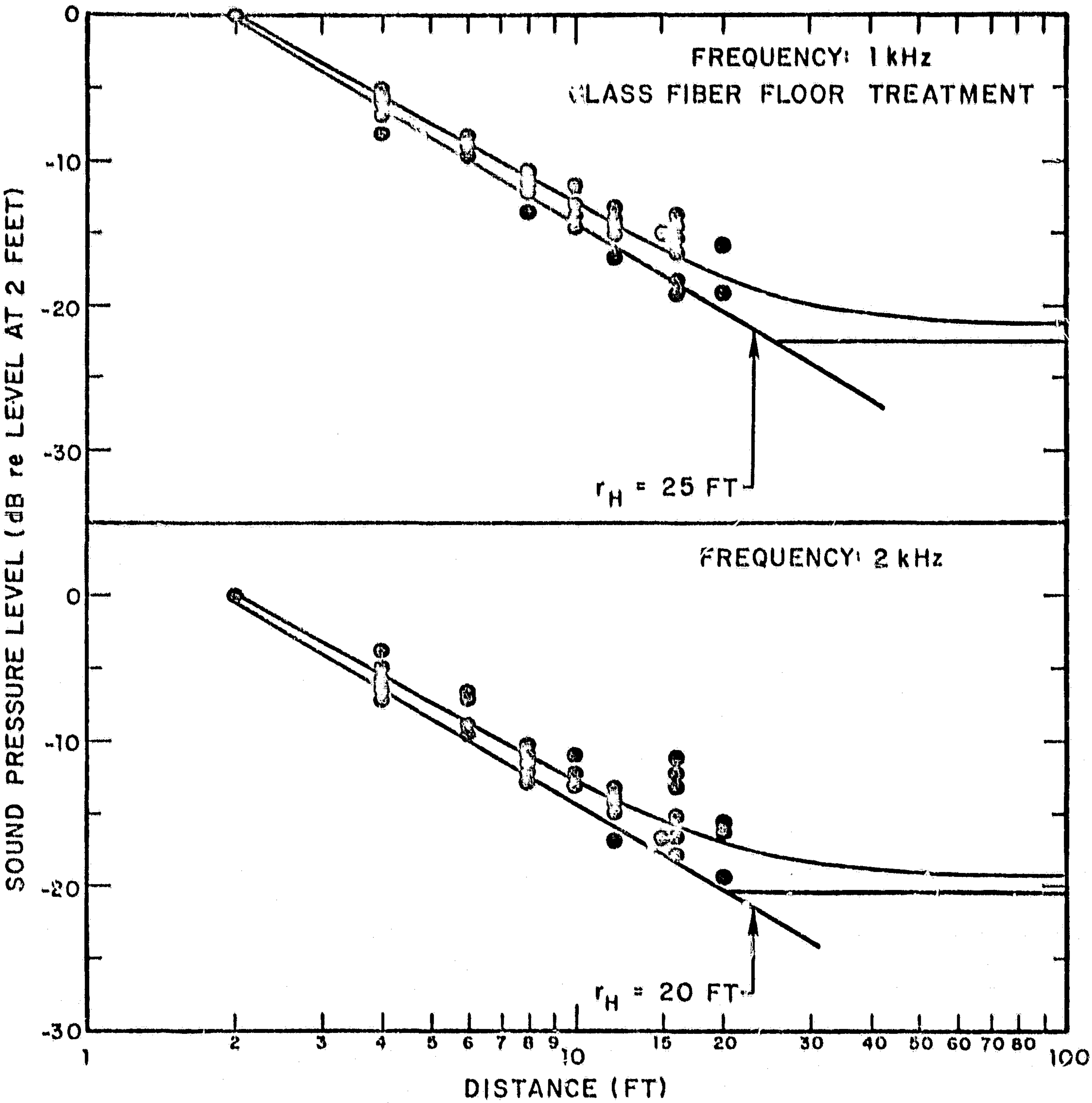


FIGURE 7. DISTRIBUTION OF NORMALIZED SOUND PRESSURE LEVEL VS. DISTANCE DATA IN ALL DIRECTIONS

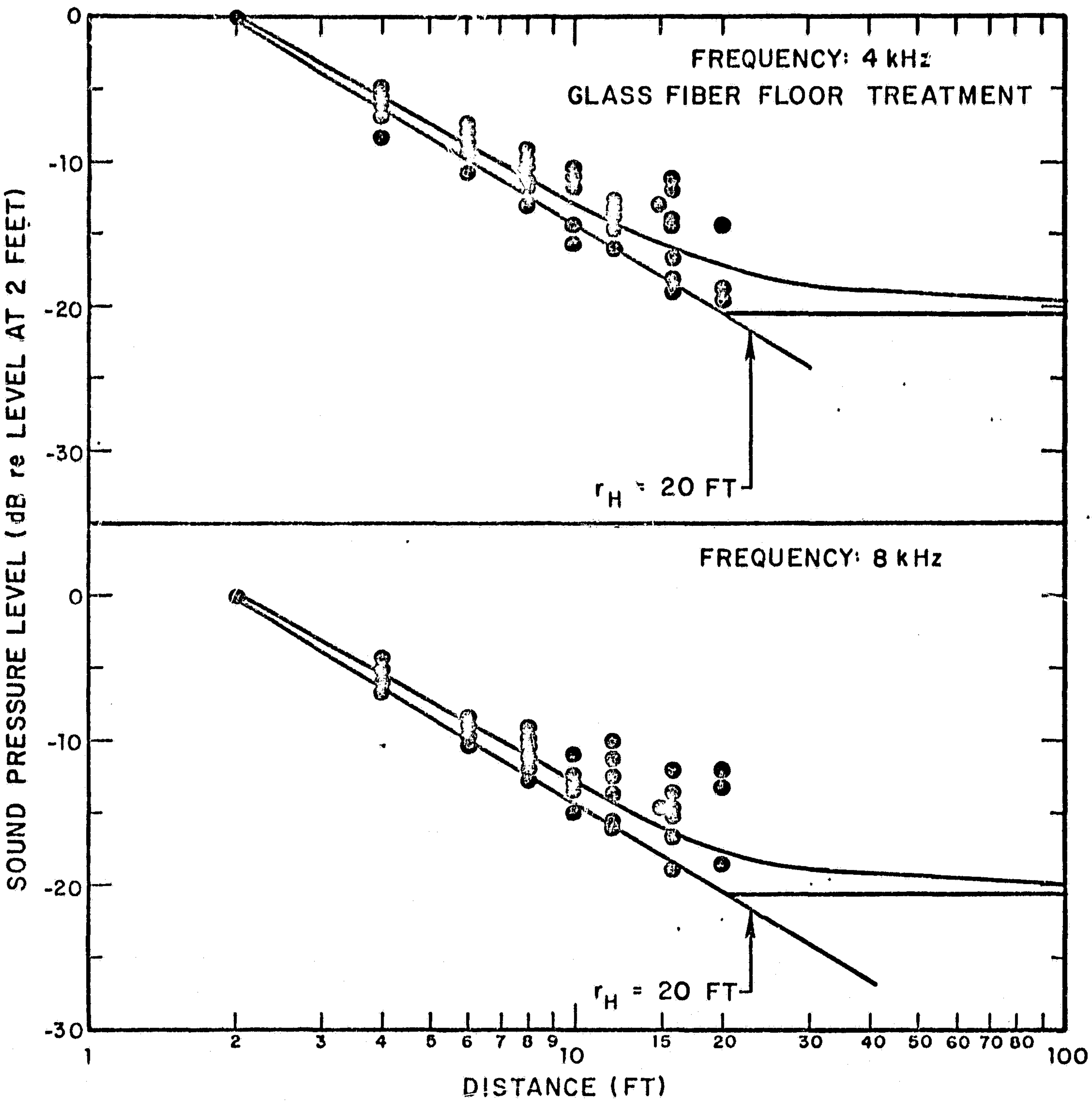


FIGURE 8. DISTRIBUTION OF NORMALIZED SOUND PRESSURE LEVEL VS. DISTANCE DATA IN ALL DIRECTIONS

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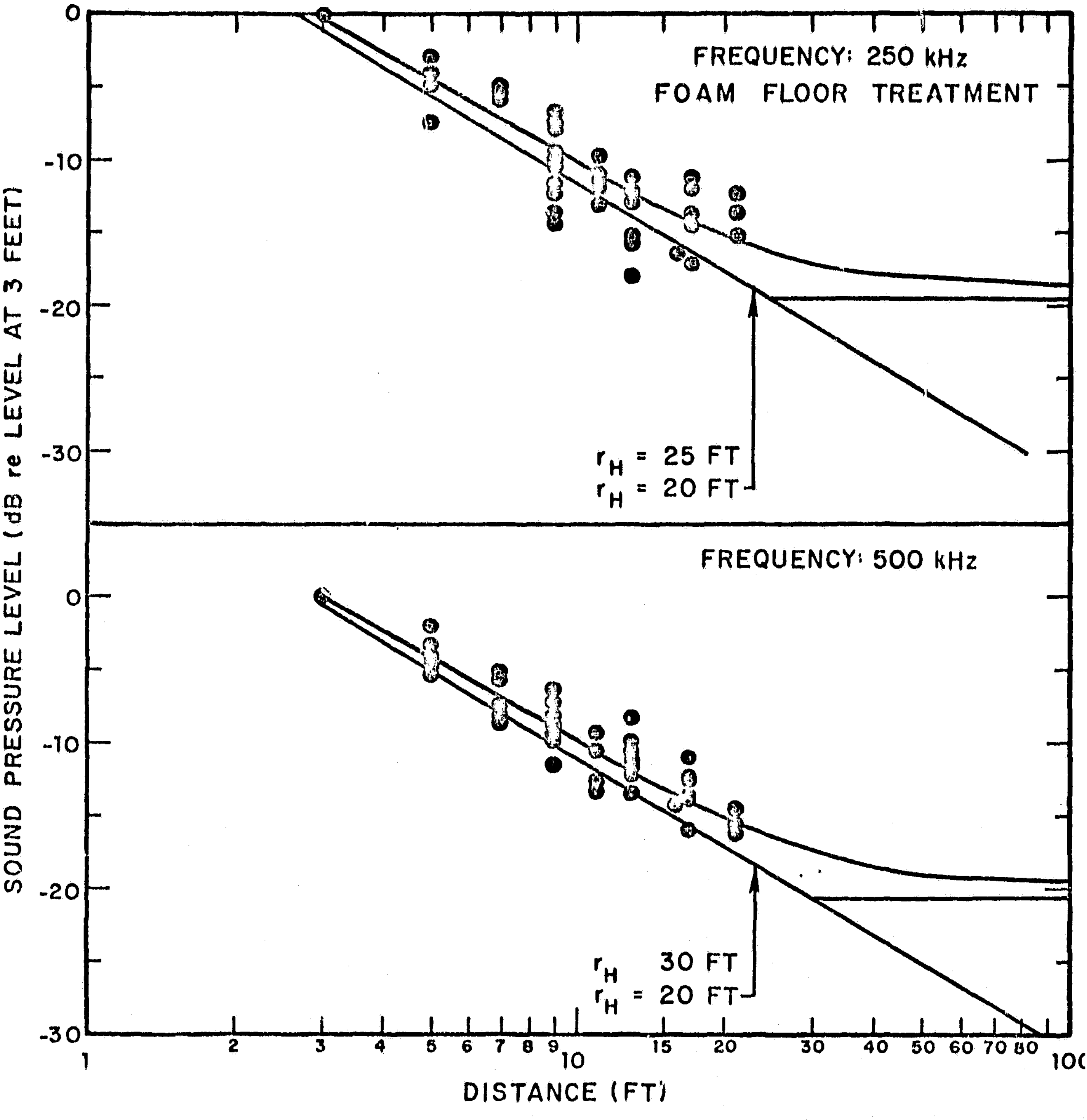


FIGURE 9. DISTRIBUTION OF NORMALIZED SOUND PRESSURE LEVEL VS. DISTANCE DATA IN ALL DIRECTIONS

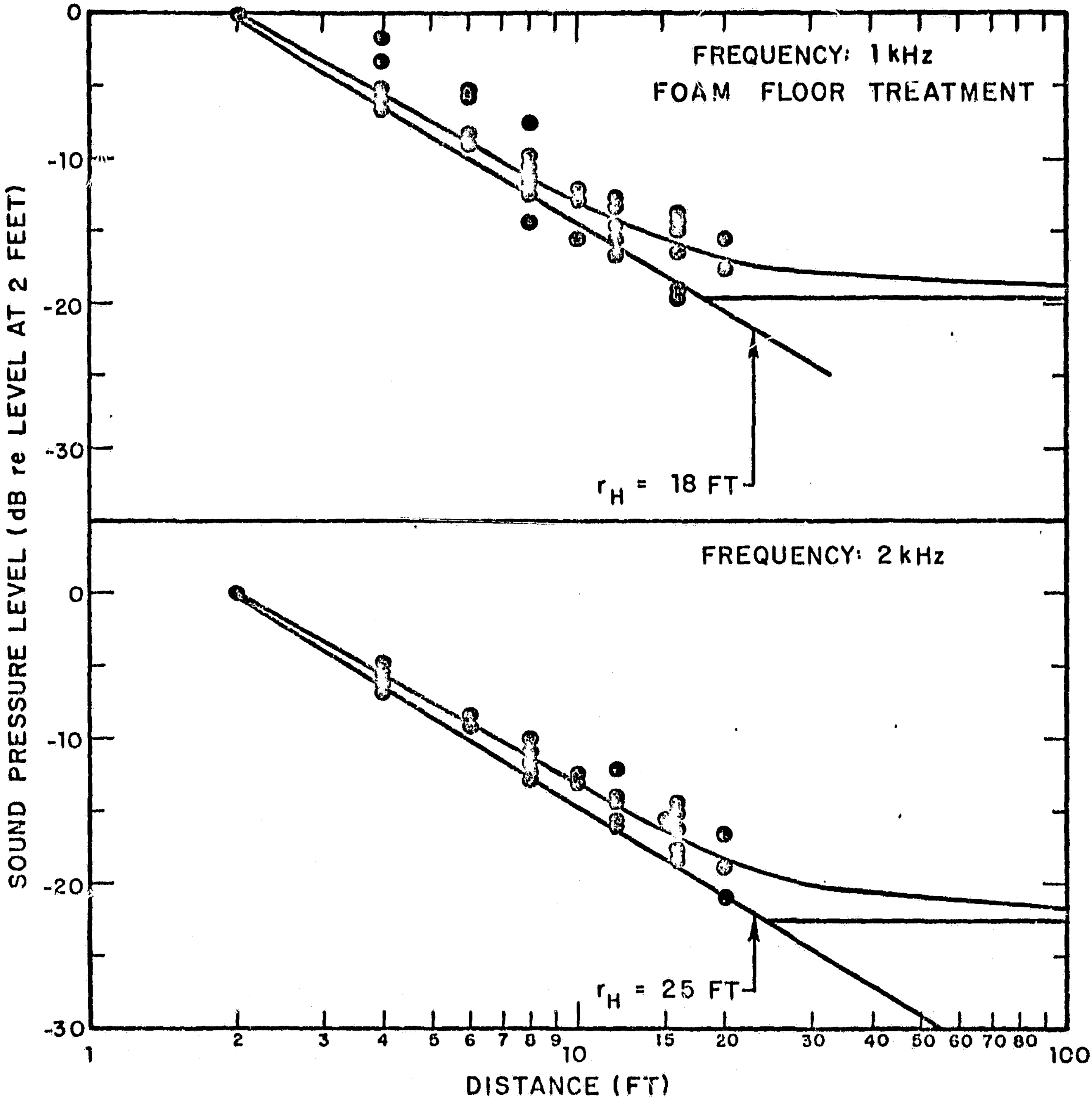


FIGURE 10. DISTRIBUTION OF NORMALIZED SOUND PRESSURE LEVEL VS. DISTANCE DATA IN ALL DIRECTIONS

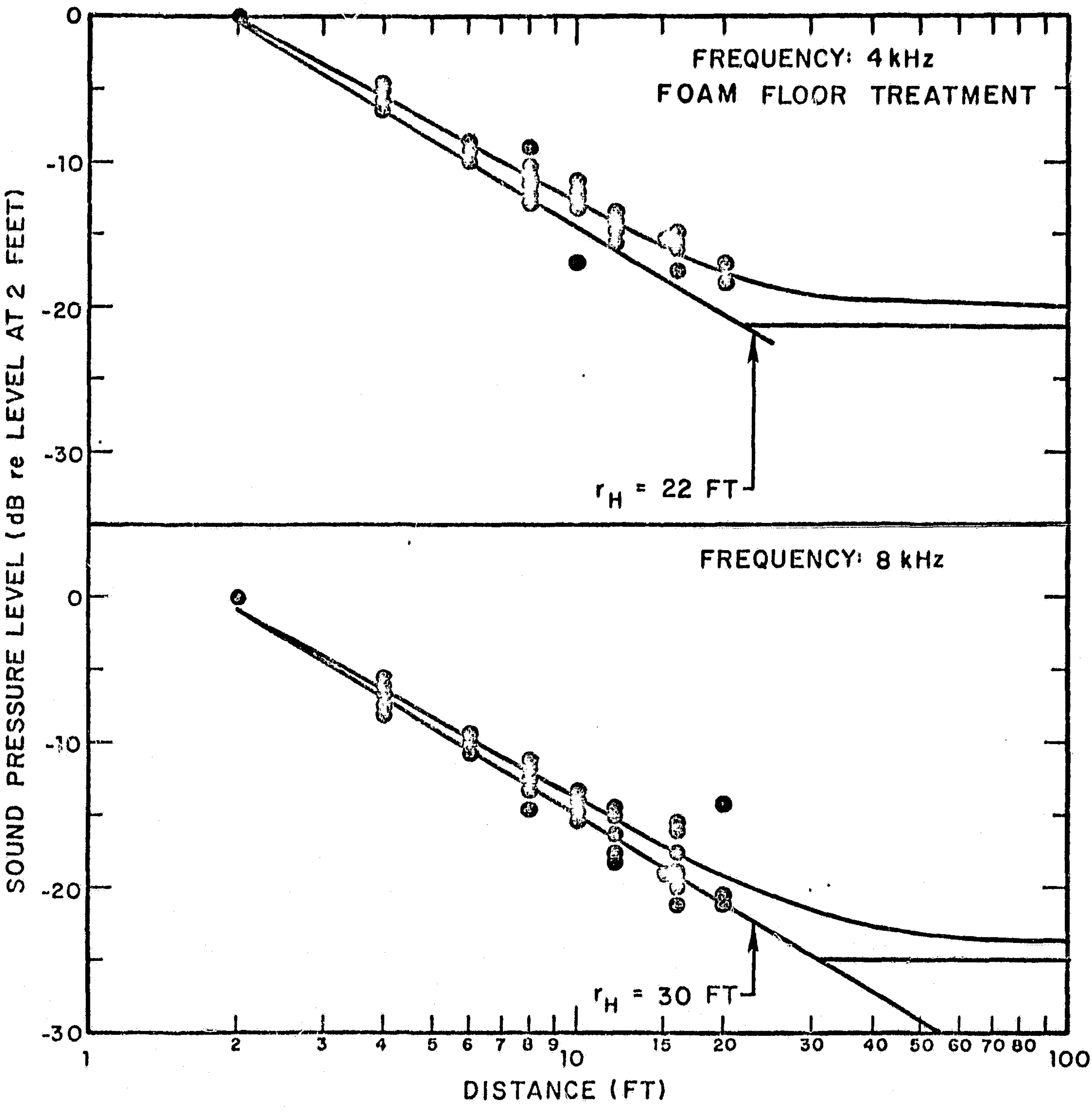


FIGURE 11. DISTRIBUTION OF NORMALIZED SOUND PRESSURE LEVEL VS. DISTANCE DATA IN ALL DIRECTIONS

The average hall radius was 16 feet in the horizontal plane only (where the hall radius should be largest) before the hall was treated.[1] The lengths of the ray paths used for the present study ranged from 11 to 26 feet. Therefore, it is seen that the hall radius for either floor treatment (with the foam ceiling treatment installed) is greater than or slightly less than the available path lengths (see Figure 4) at all frequencies of interest. The foam treatment is more effective than the glass fiber treatment, as expected.

The individual SPL vs. distance curves for each direction, octave band, and floor treatment are given in Appendices A and B. The straight lines corresponding to spherical spreading are shown. These lines were shifted vertically to obtain a "best fit" to the data. The measurement nearest the sound source is the most variable with distance and therefore the most unreliable. The maximum distance along the ray path is indicated by a dashed vertical line (P.L.). These graphs may be used to more accurately estimate the effect of a microphone position on the measured frequency response of a source. The final microphone position for each direction was within 6 to 12 inches of the floor or wall limiting the path length. A 2 to 4 dB increase in SPL is measured for these positions in many cases. Such an increase is often measureable even near "anechoic wedges". It is therefore recommended that microphones be spaced at least one foot from the floor treatment if extreme accuracy is required. One problem with microphone placements near the floor is the self-noise of the perforated treatment with flow present. Due to mechanical problems in the tunnel, the self-noise was not quantified. It is recommended that a section of floor treatment be evaluated for self-noise in a quiet wind tunnel.

Although no reverberation measurements were performed using impulsive sources, the subjective impression is that the flutter echoes between the ceiling and floor have been sharply reduced. The increase in hall radius tends to confirm this observation.

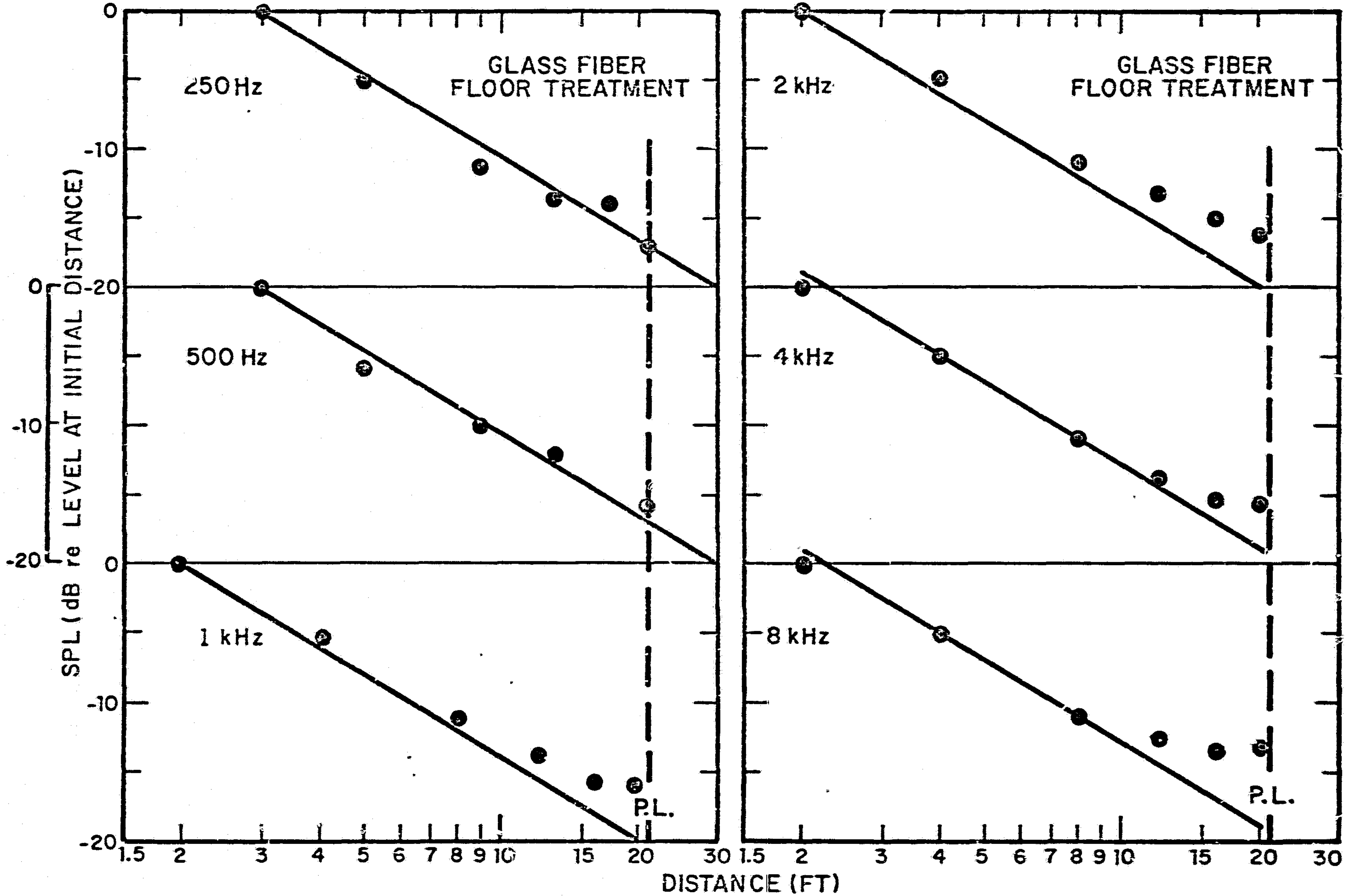
LIST OF REFERENCES

1. Vér, I. L., "Acoustical Evaluation of the NASA Langley V/STOL Wind Tunnel," NASA CR-145087, 1976.

2. Vér, I. L., D. W. Anderson, and D. B. Bliss, "Acoustical Modeling Study of the Open Test Section of the NASA Langley V/STOL Wind Tunnel." NASA CR-145005, 1976.

3. Bies, D. A., "Investigations of the Feasibility of Making Model Acoustic Measurements in the NASA Ames 40 by 80 Foot Wind Tunnel," BBN Report 2088, July 1970.

APPENDIX A



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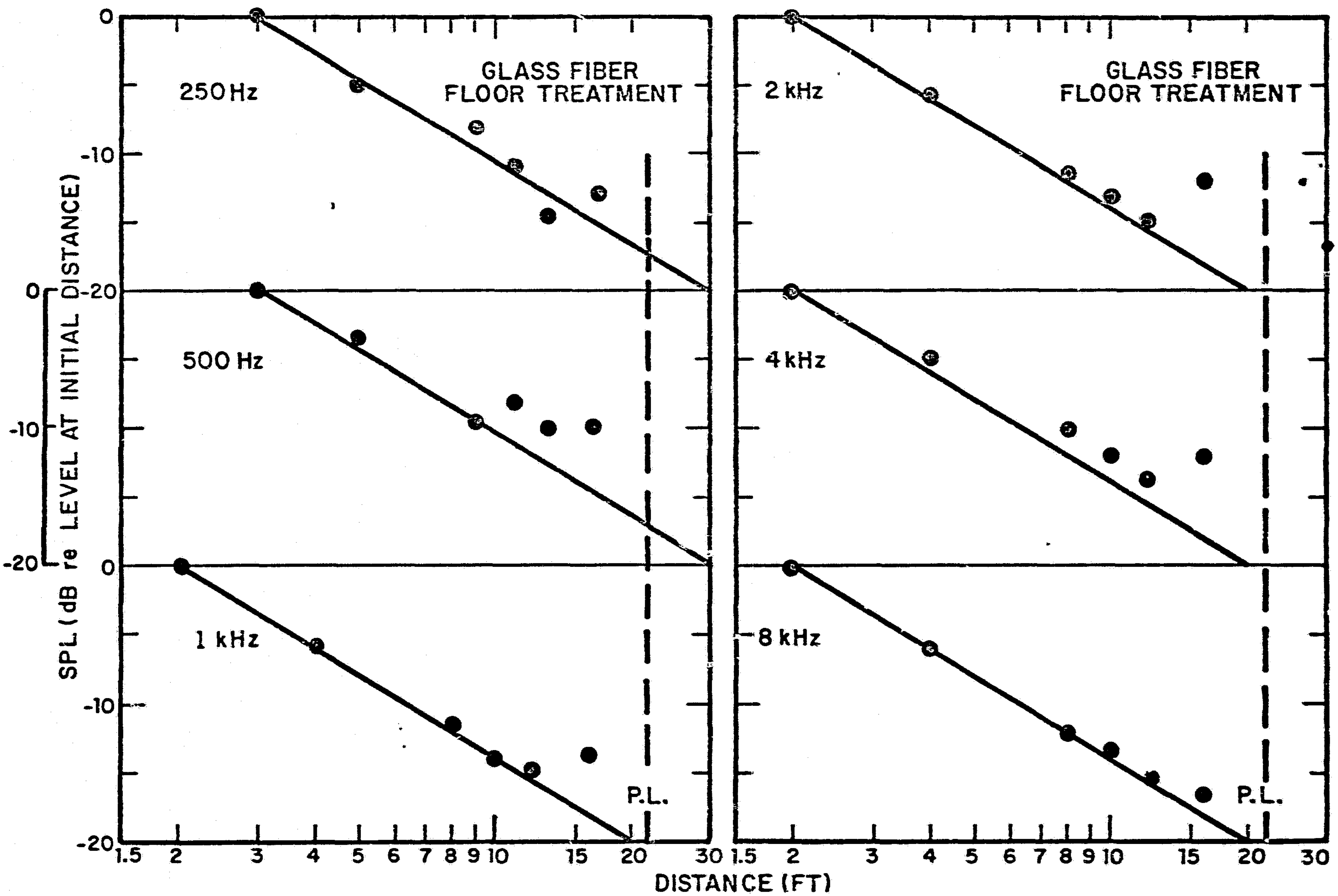

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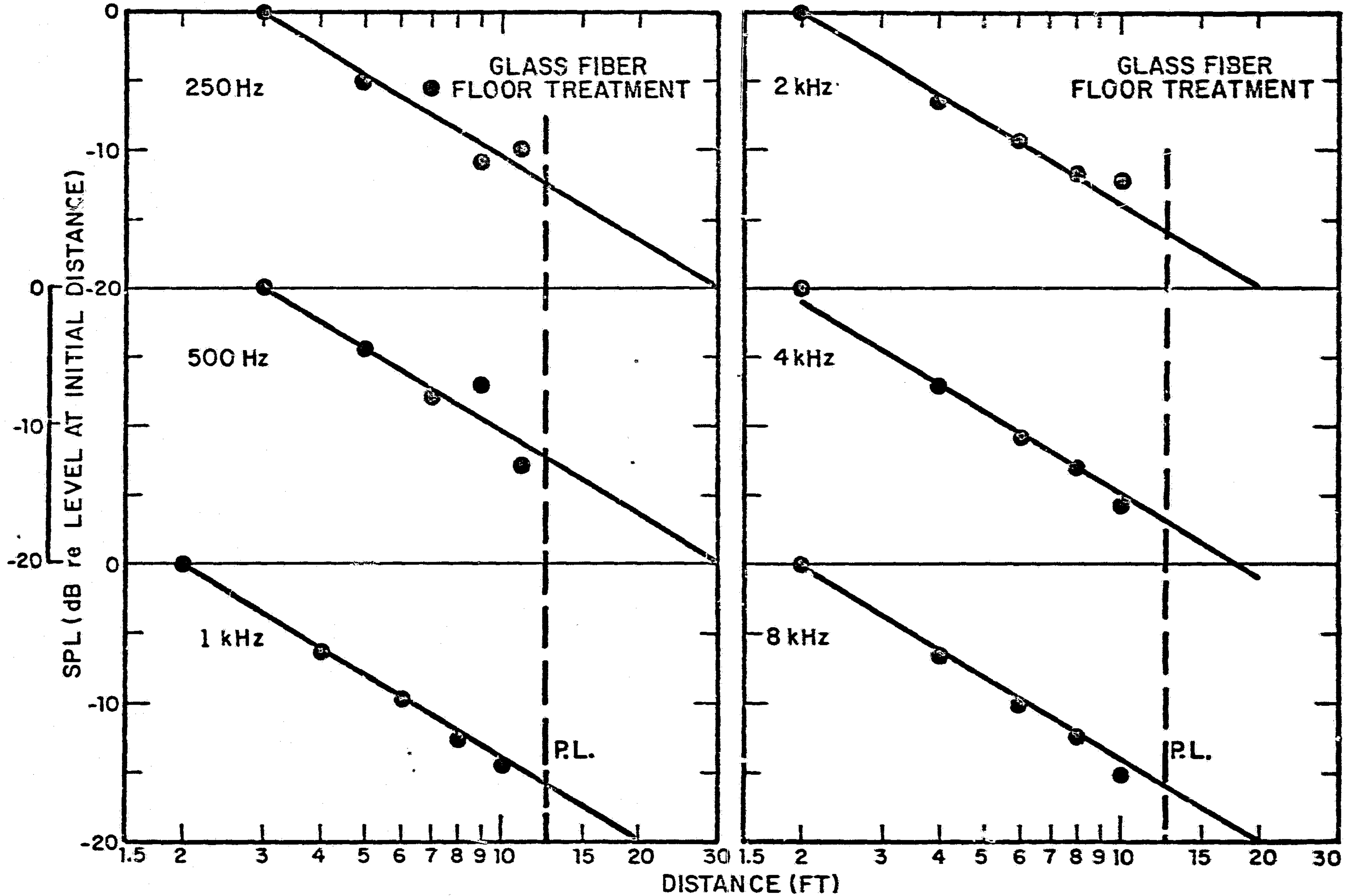

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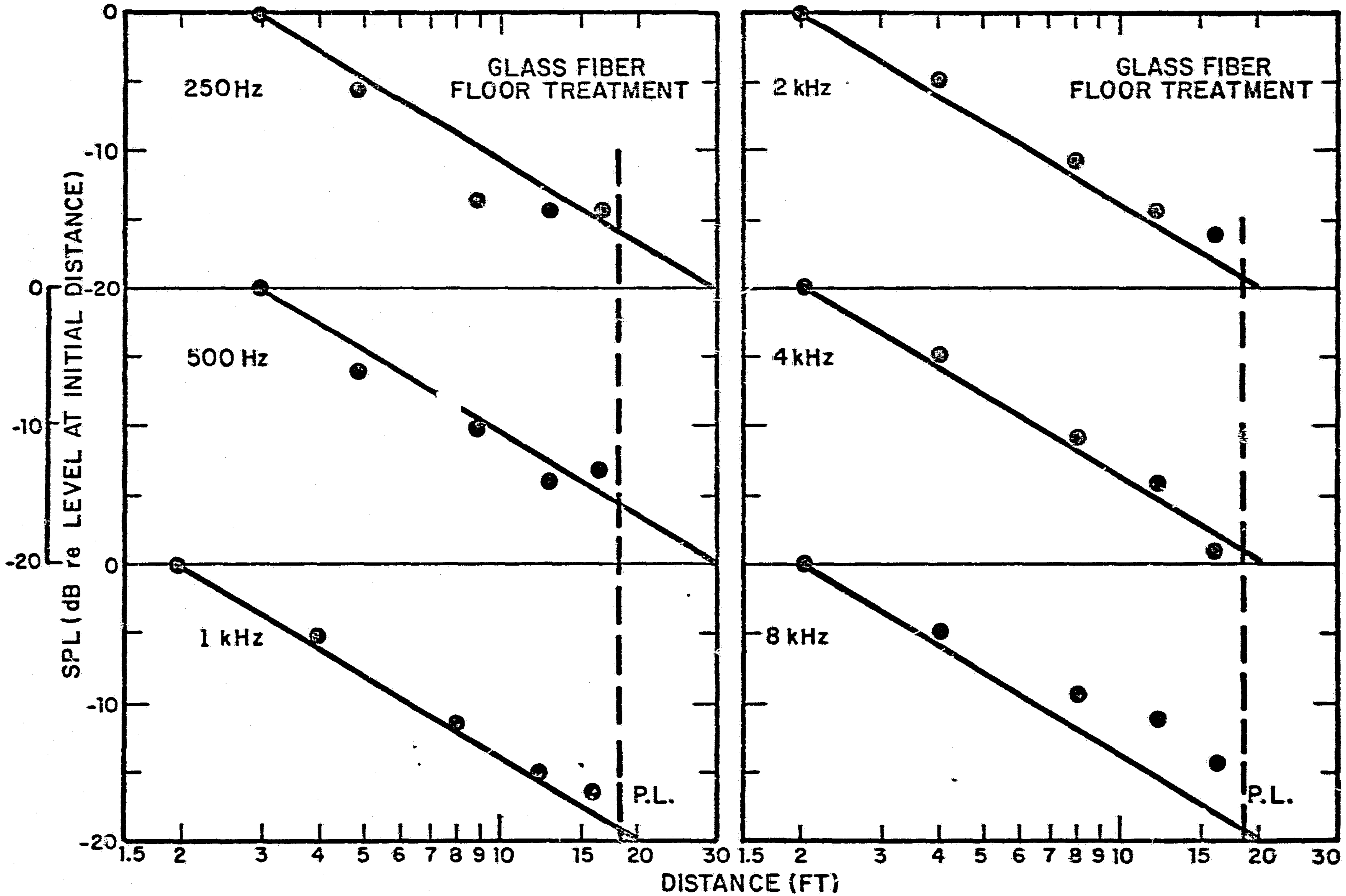

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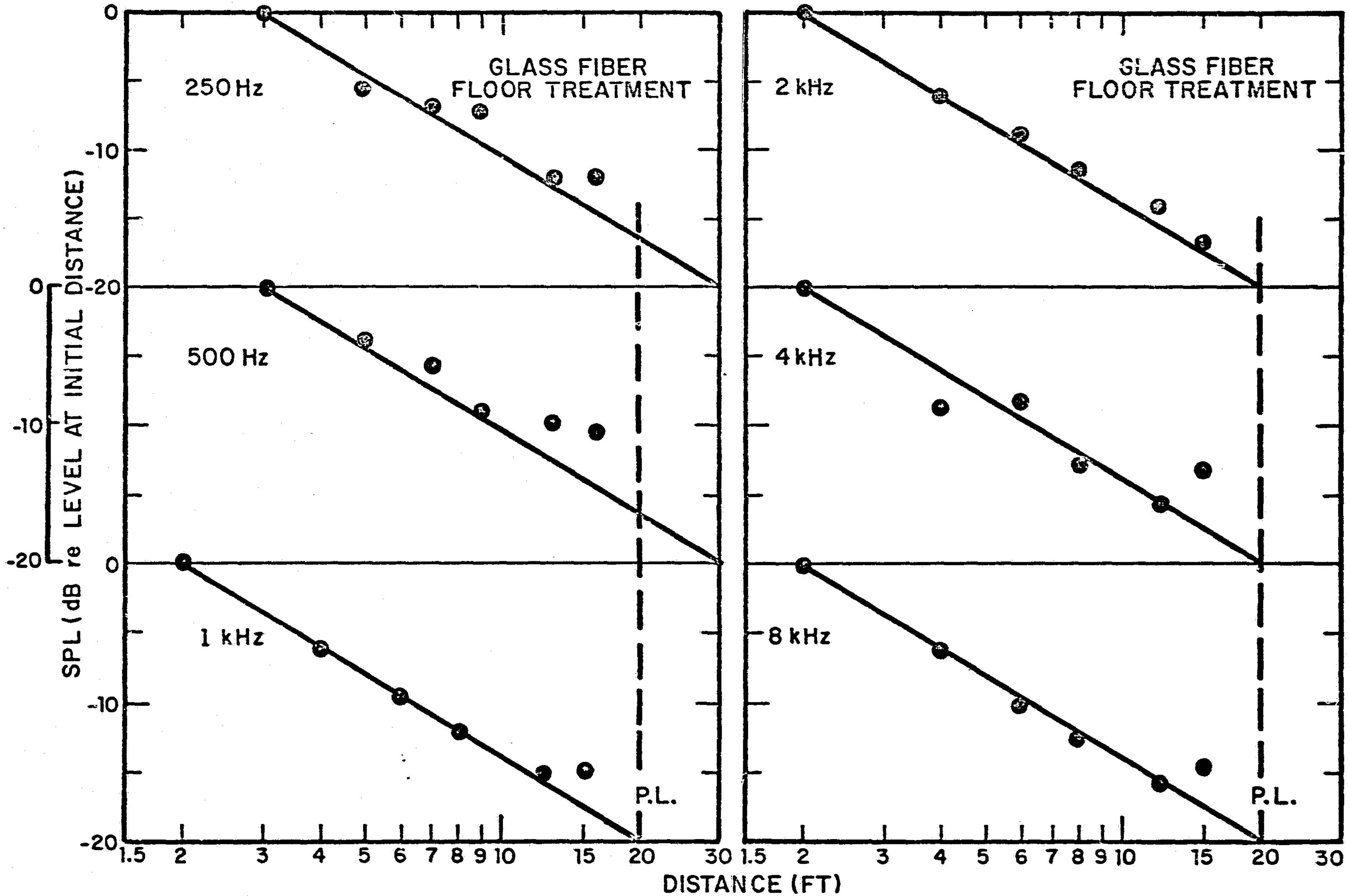

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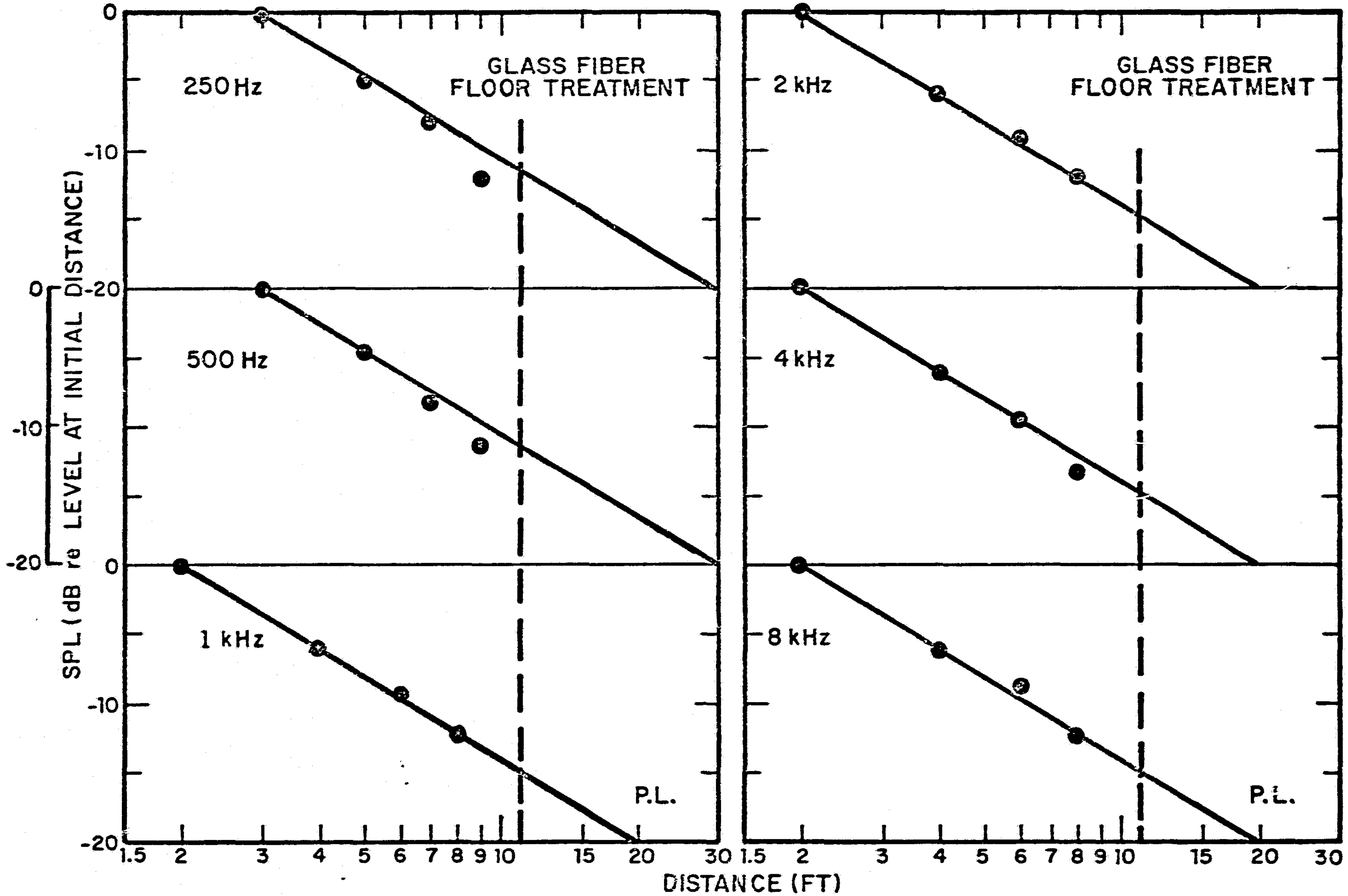

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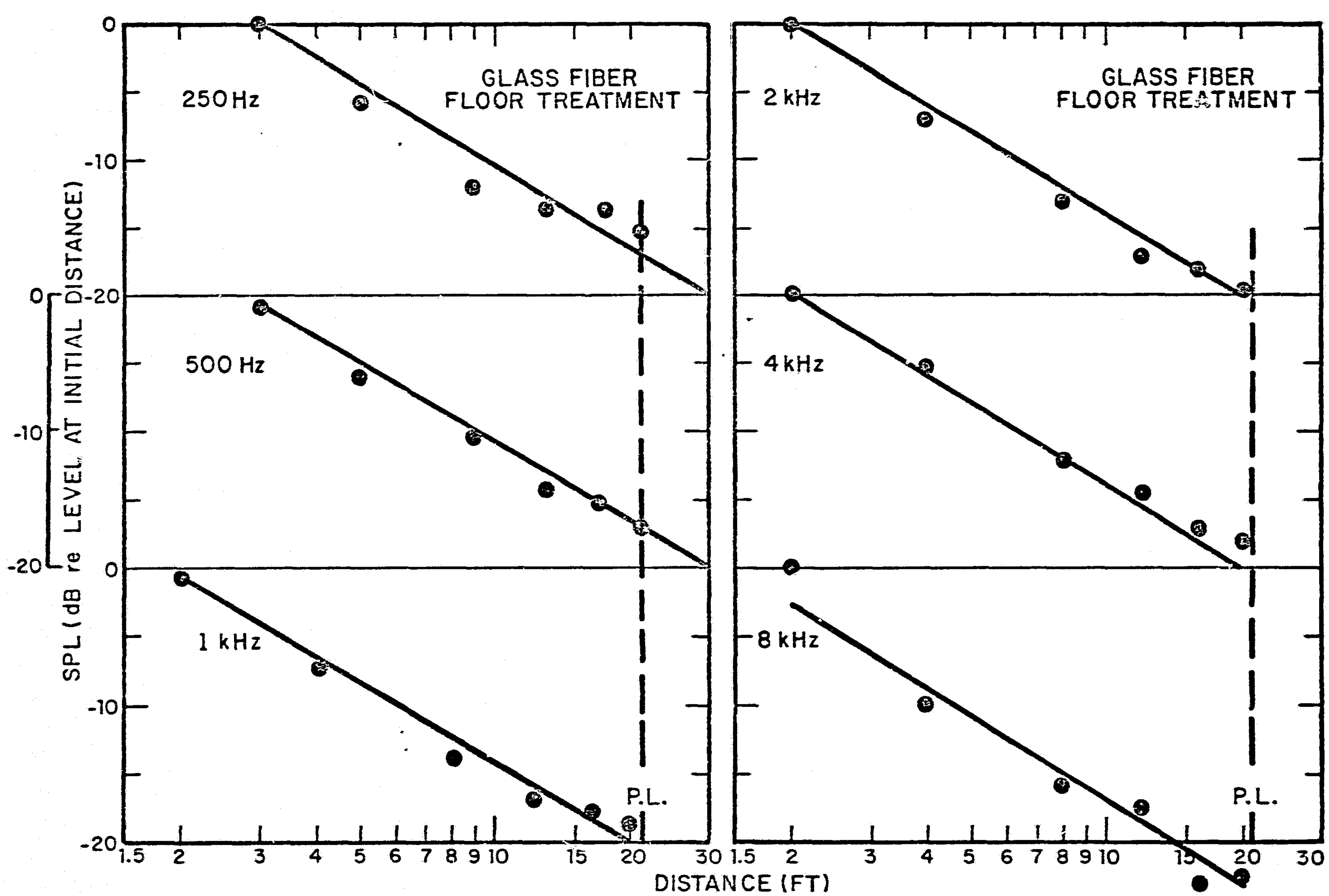

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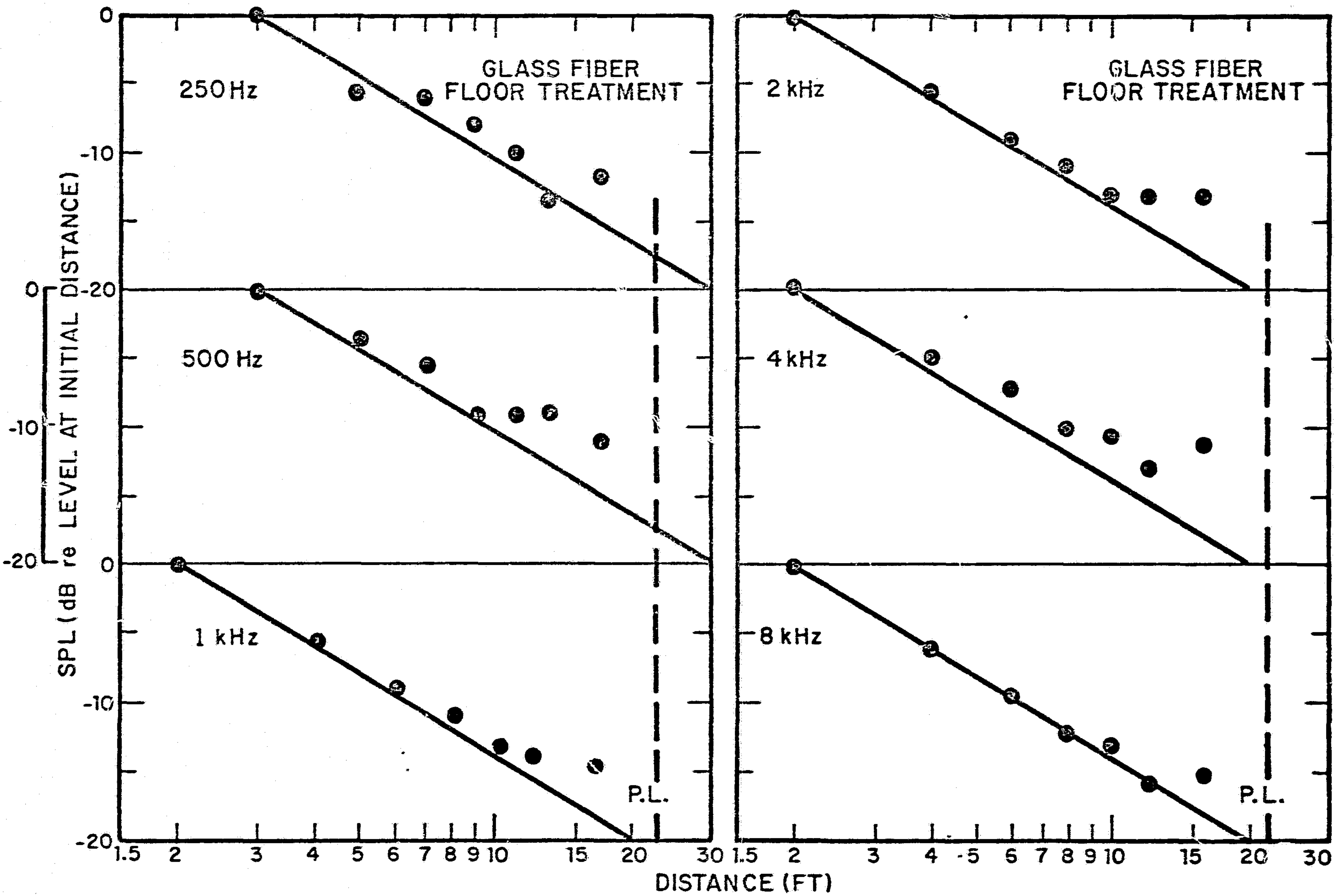

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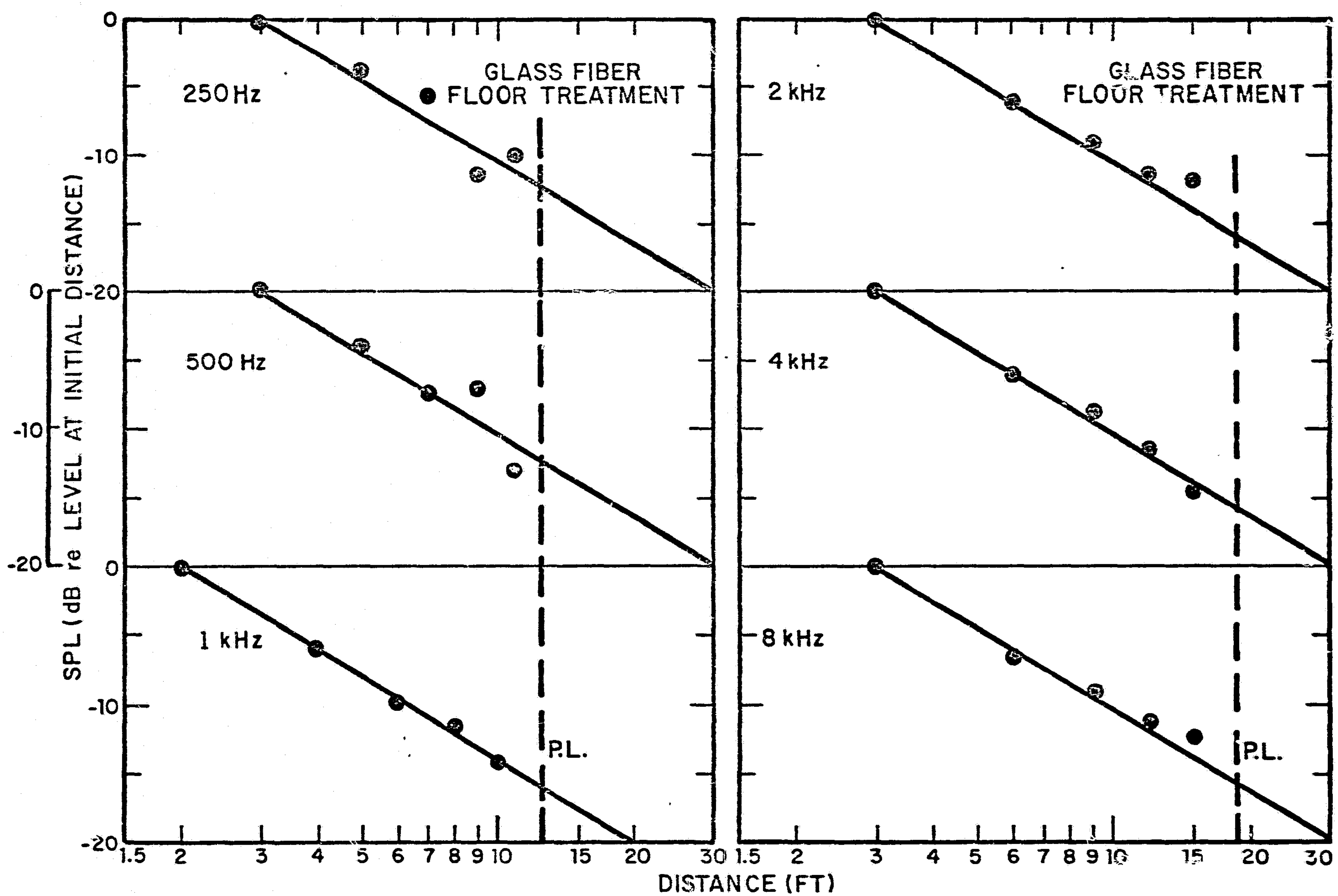

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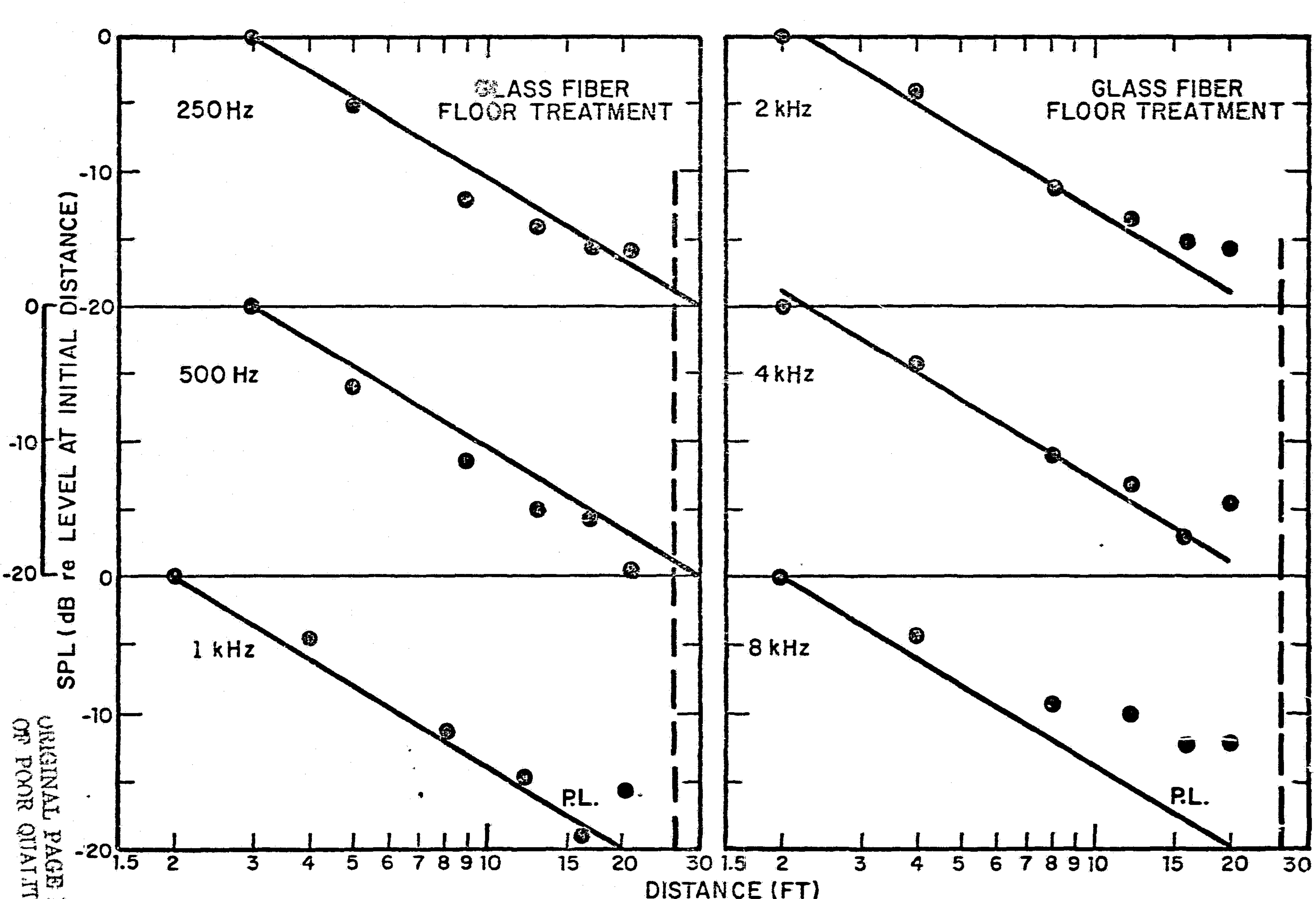

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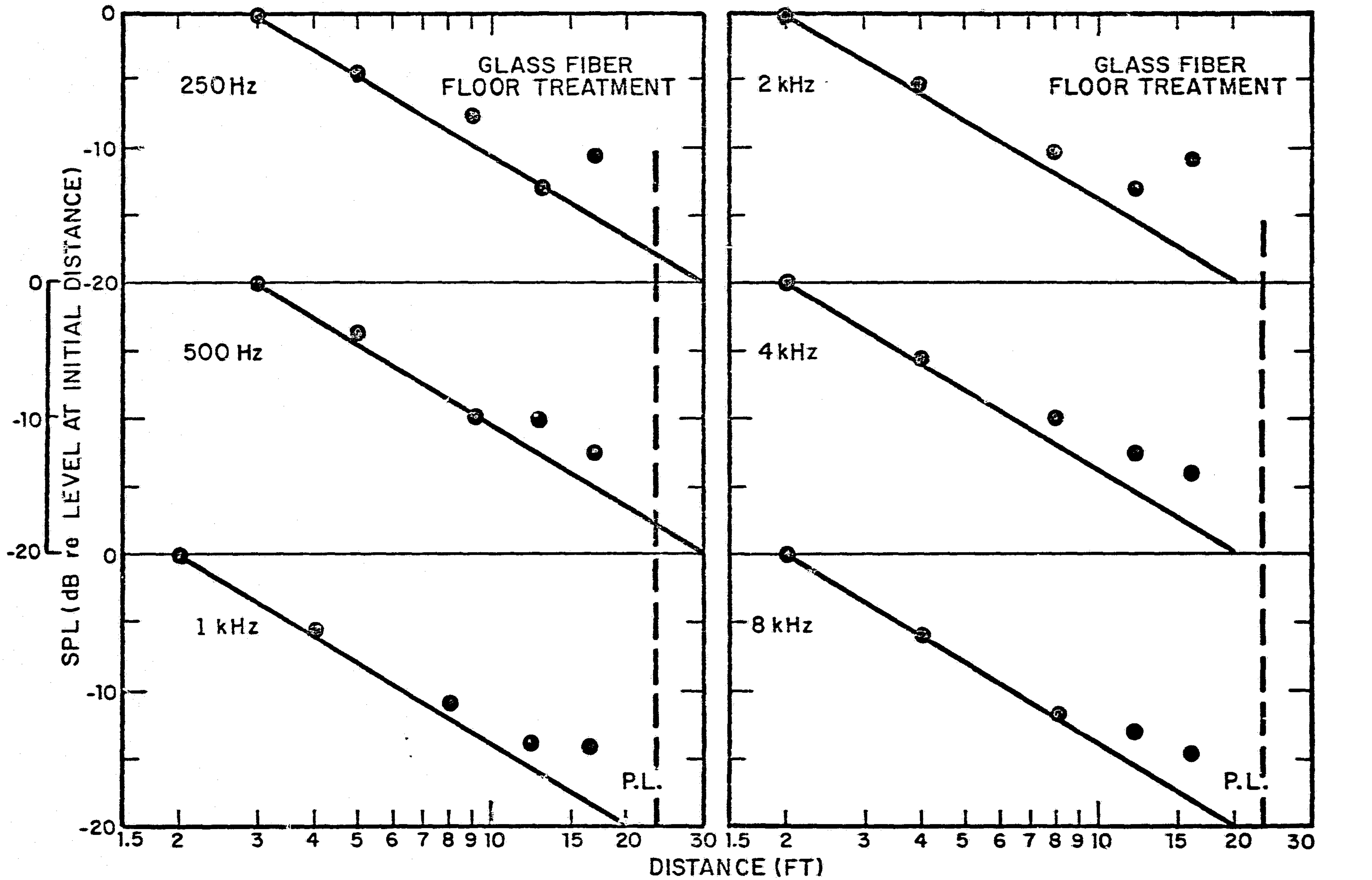

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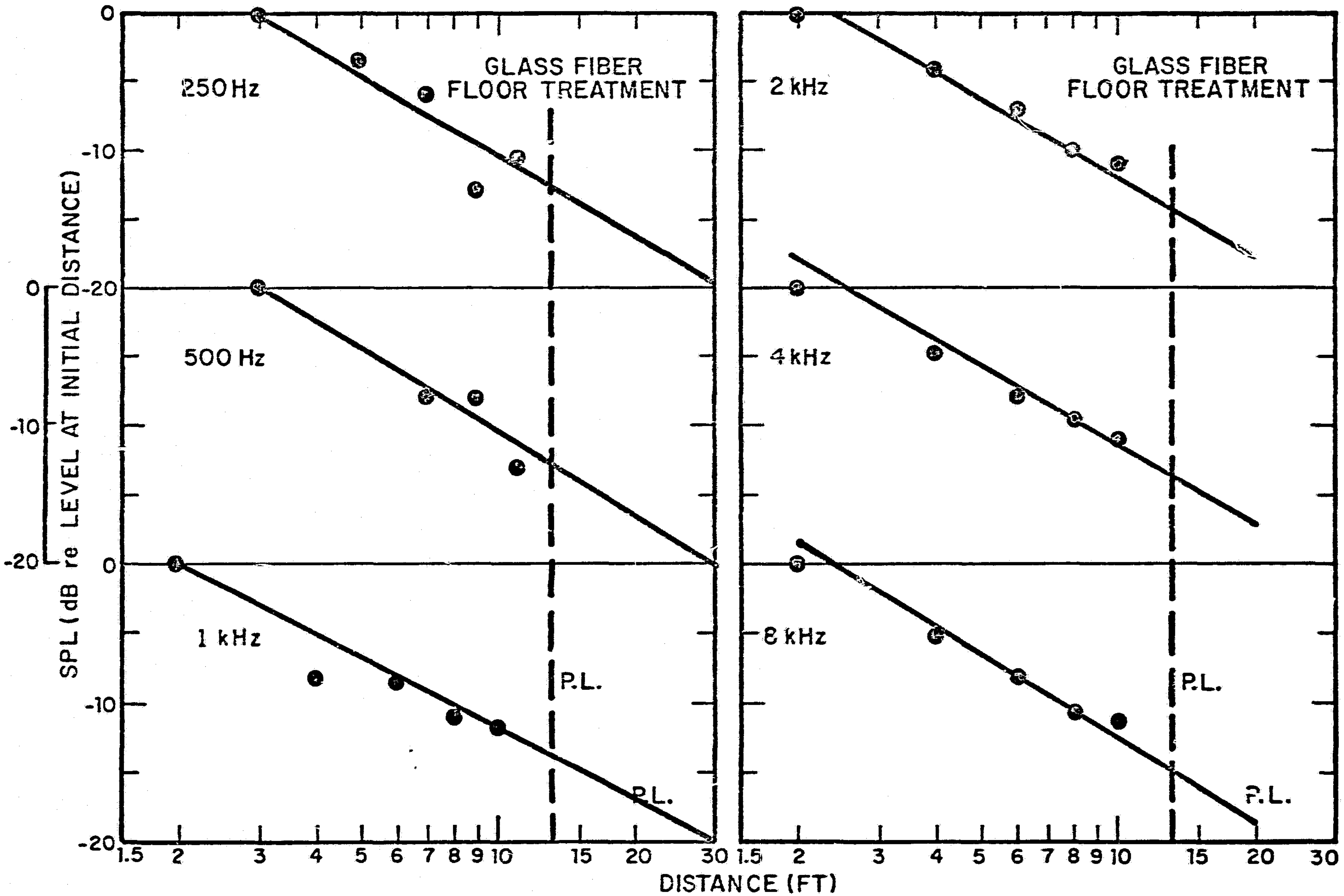
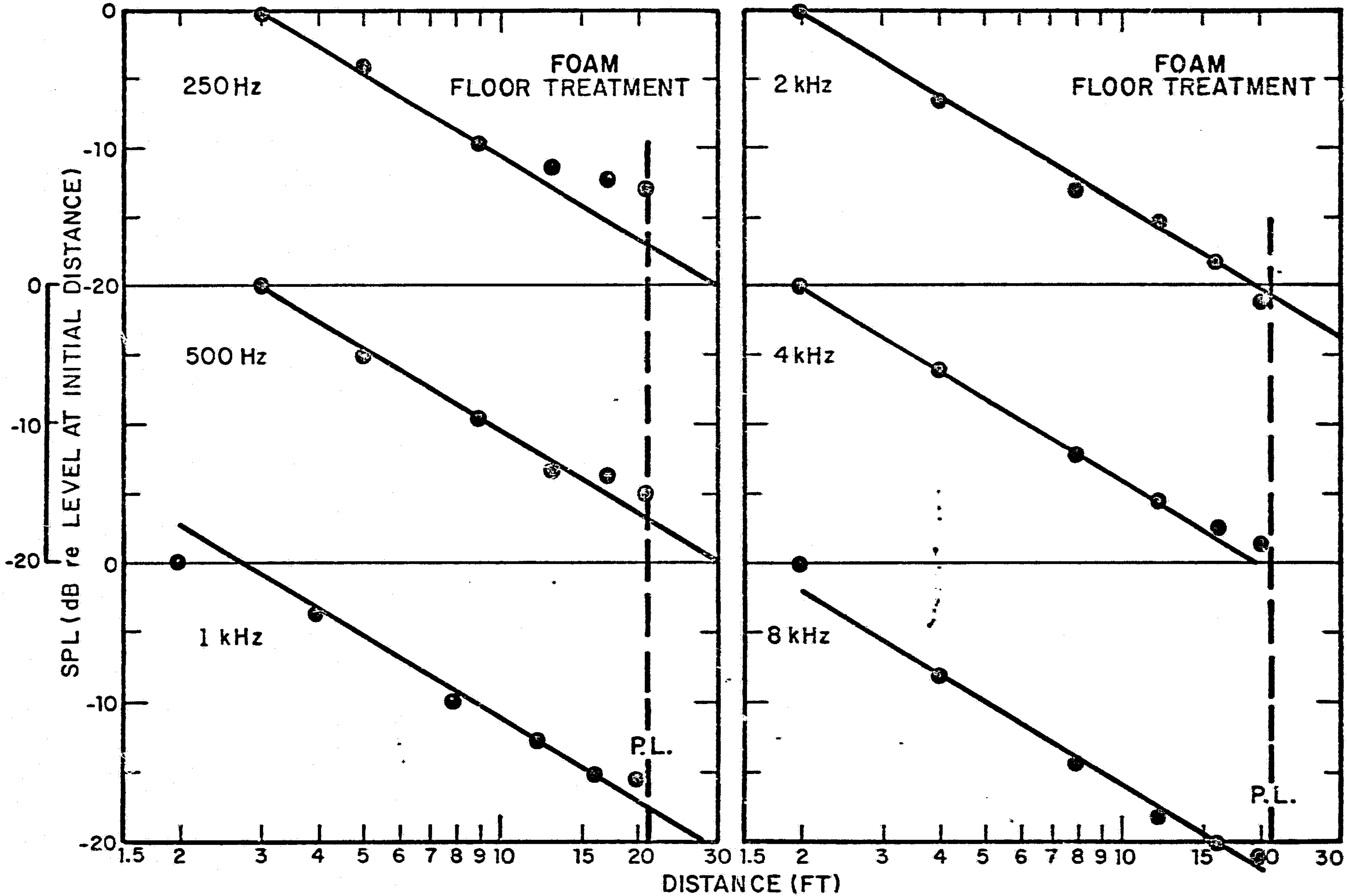


PATH E-3 GLASS FIBER FLOOR TREATMENT

APPENDIX B



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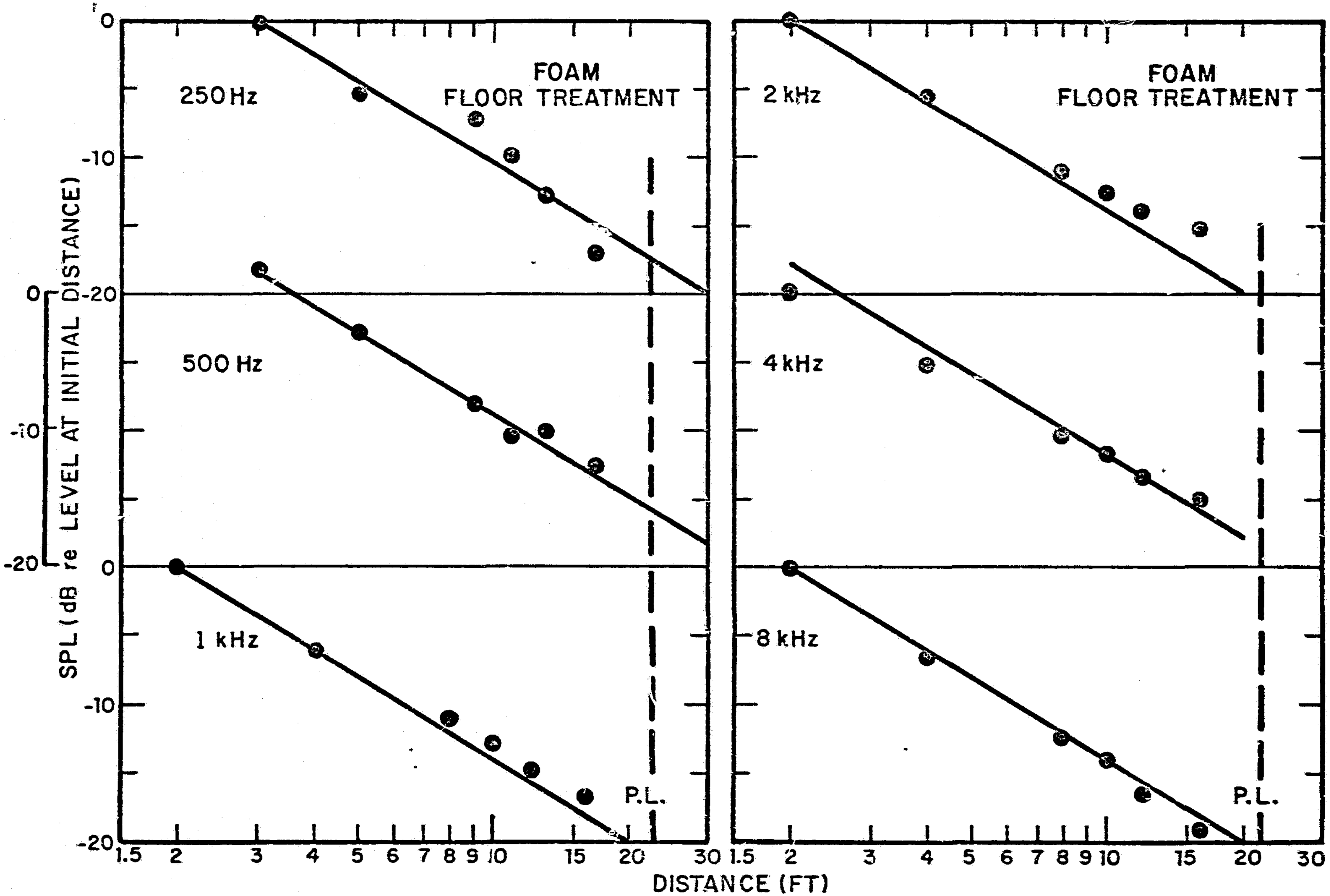

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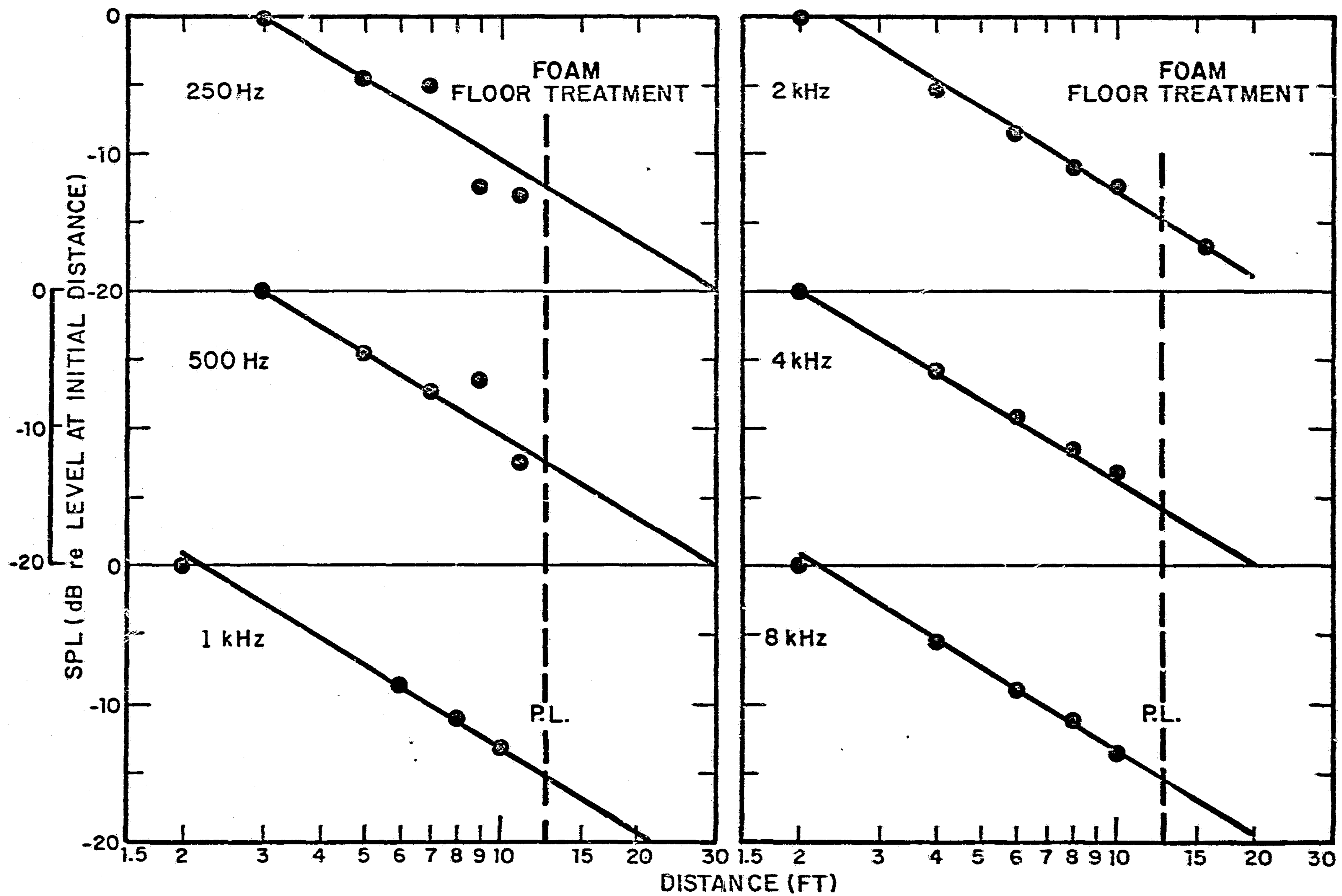

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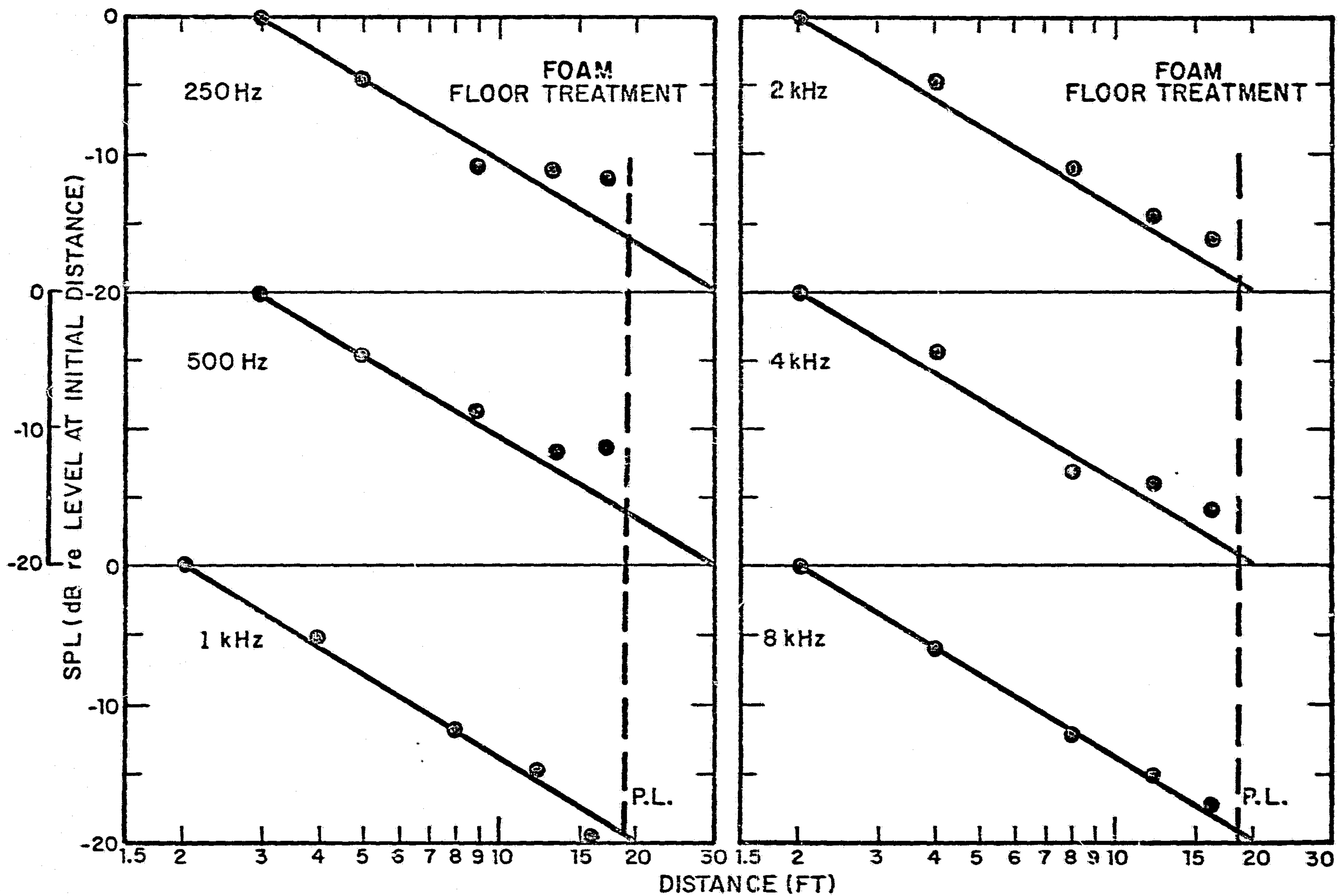

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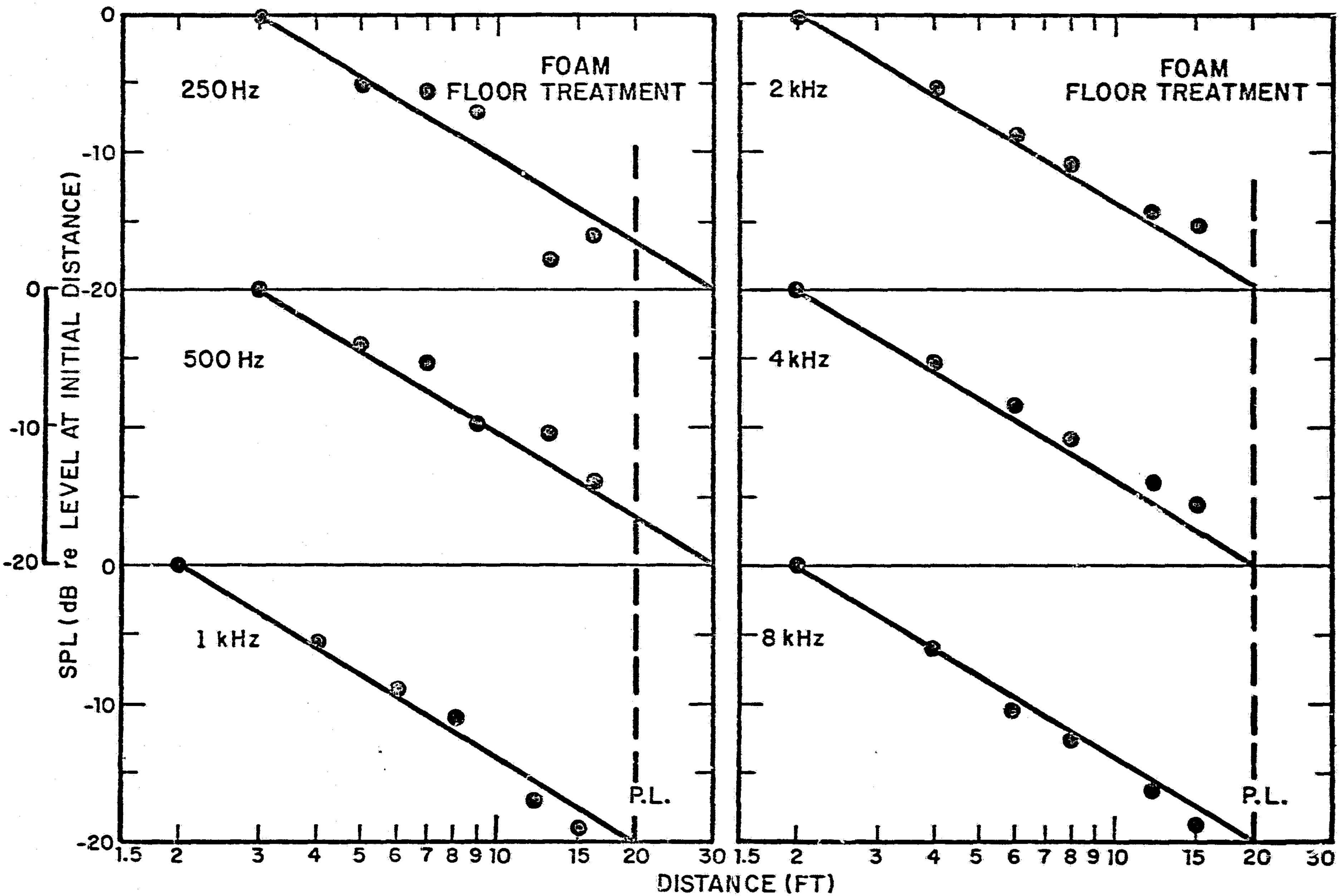

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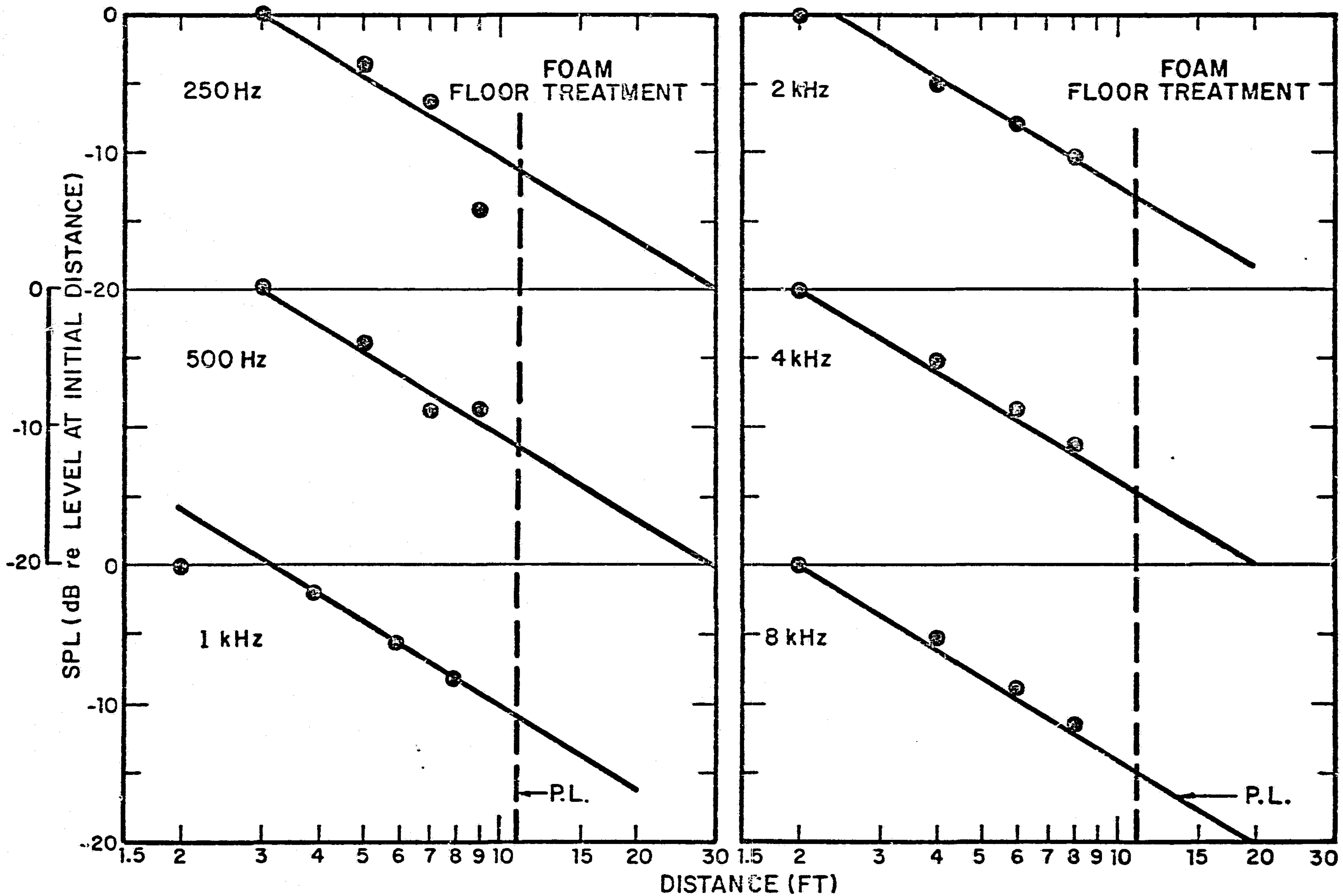

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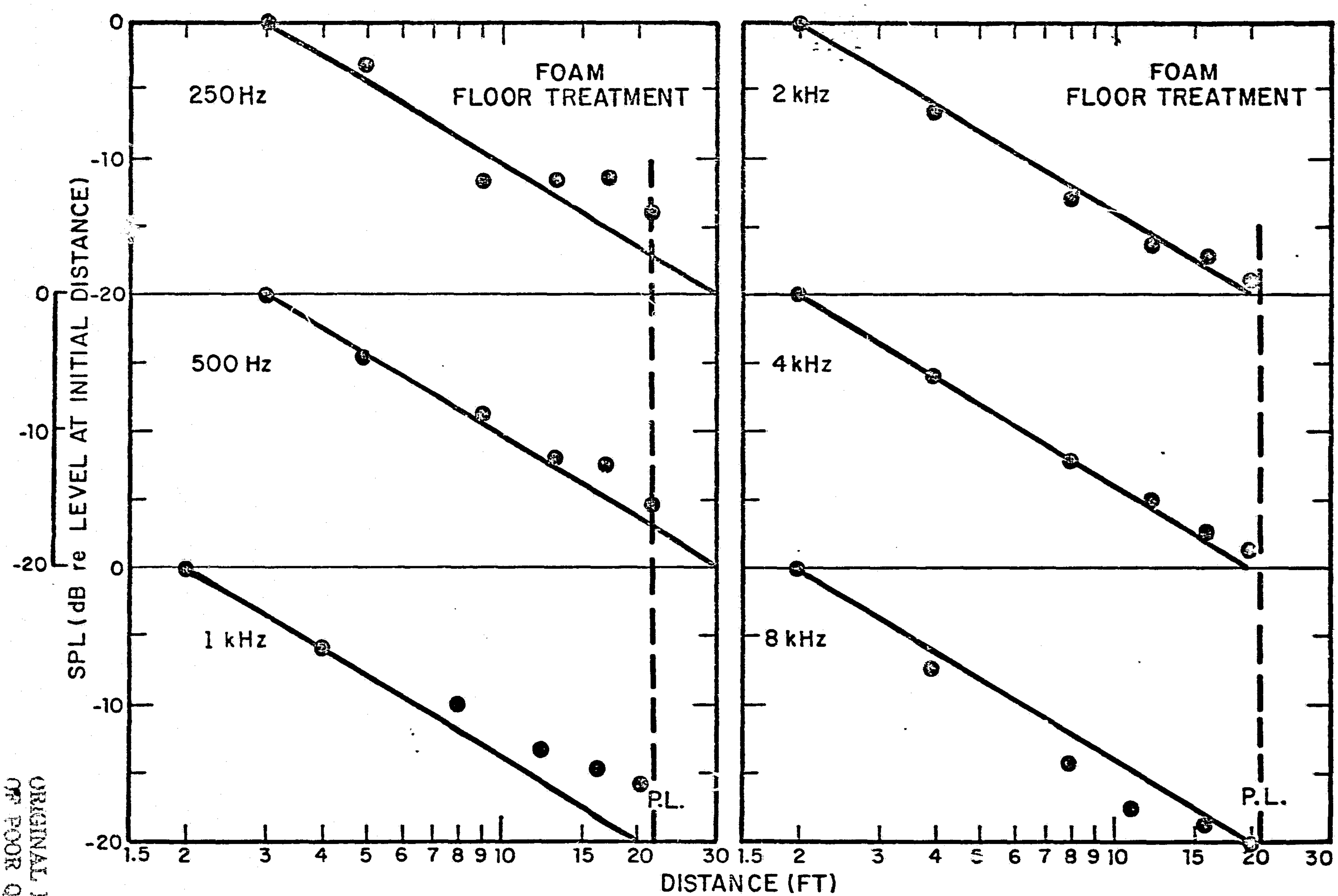

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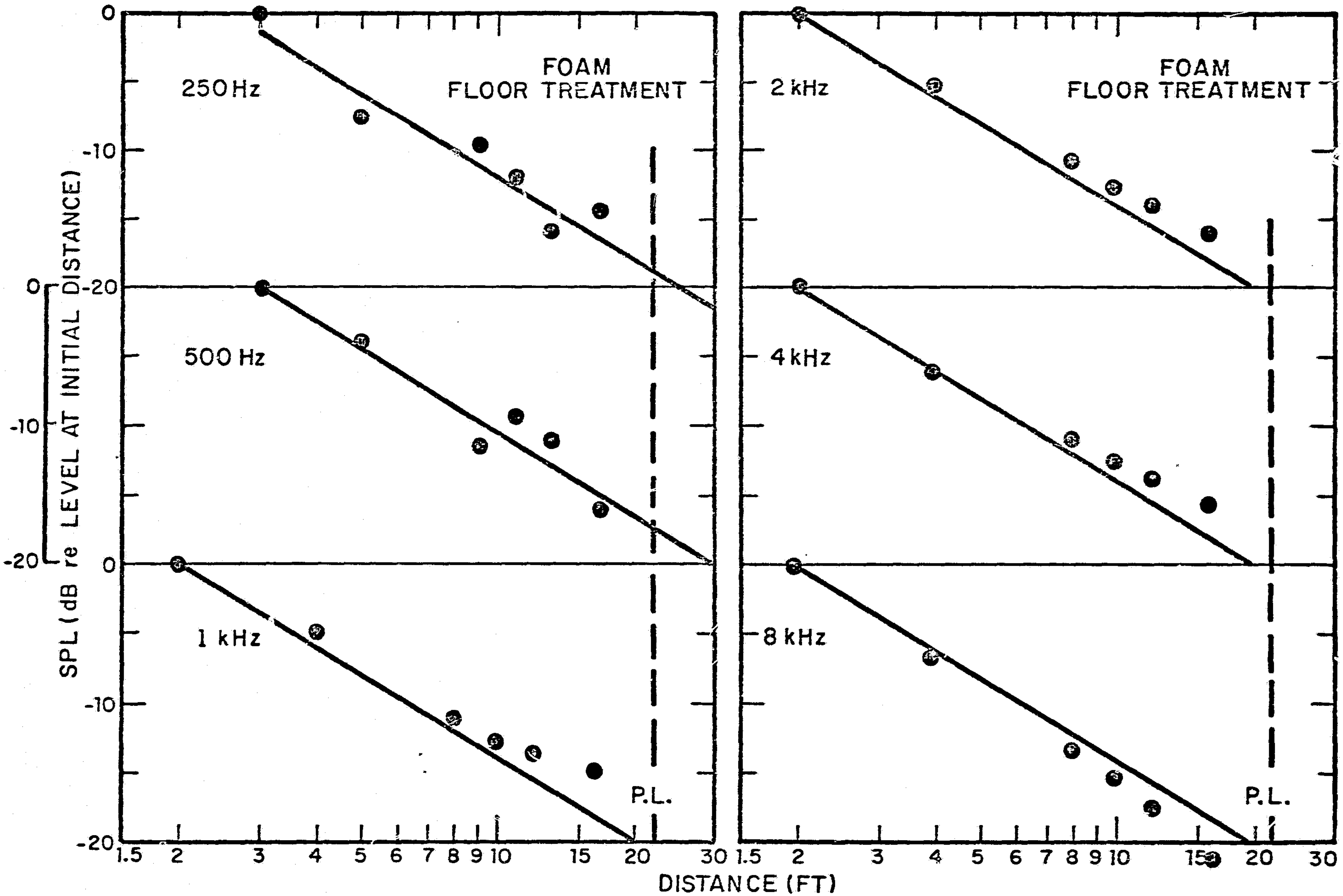

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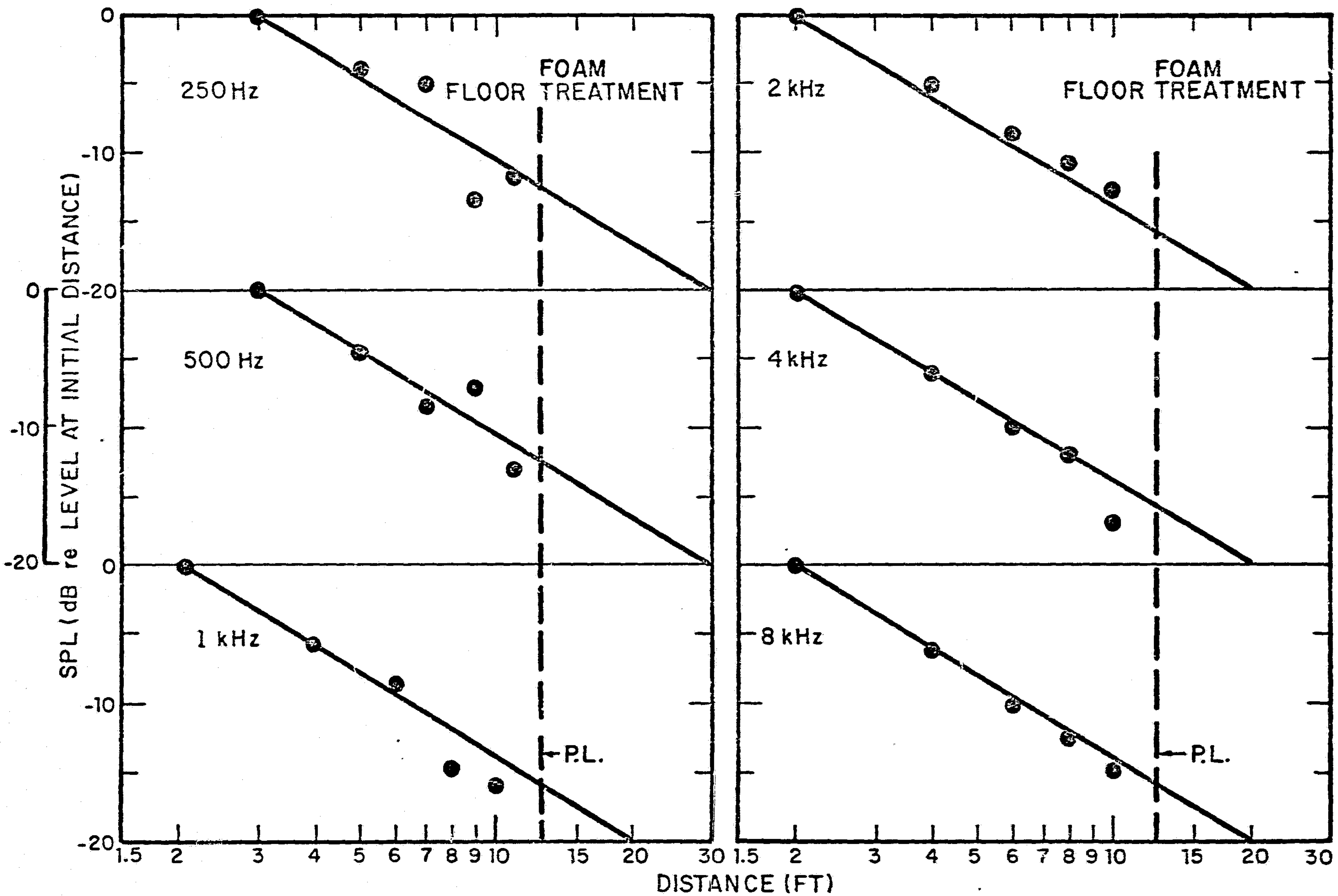

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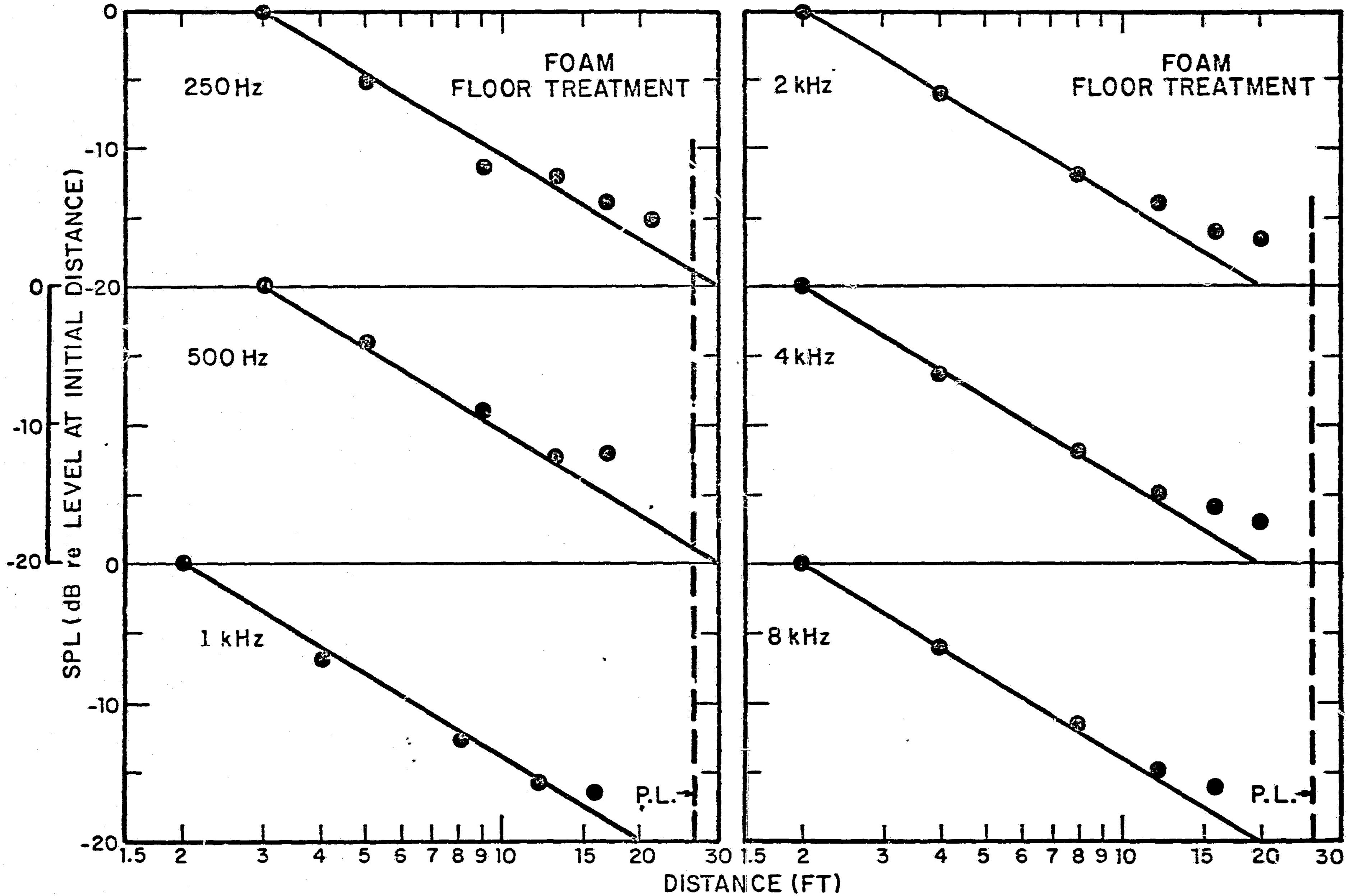

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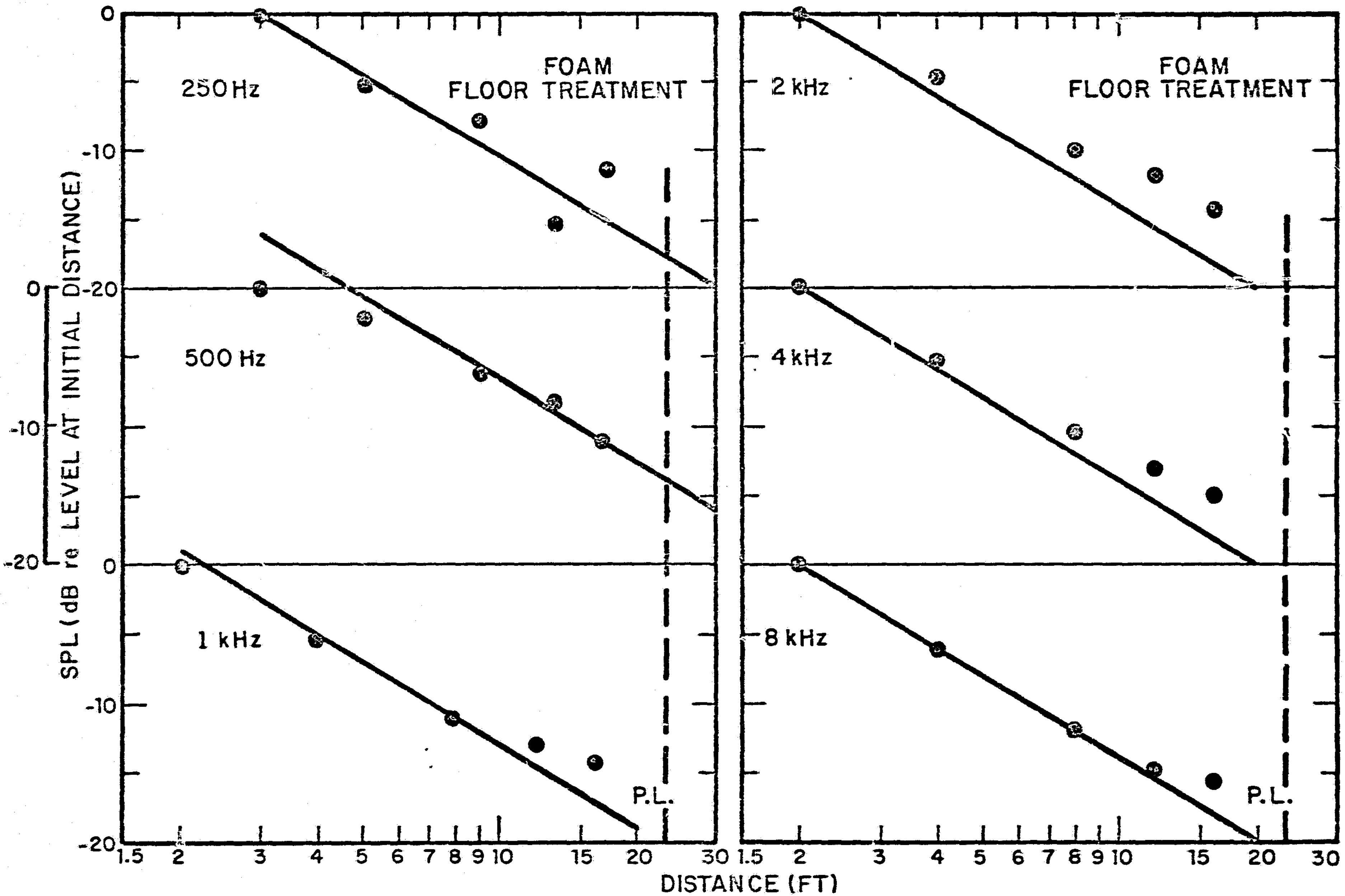

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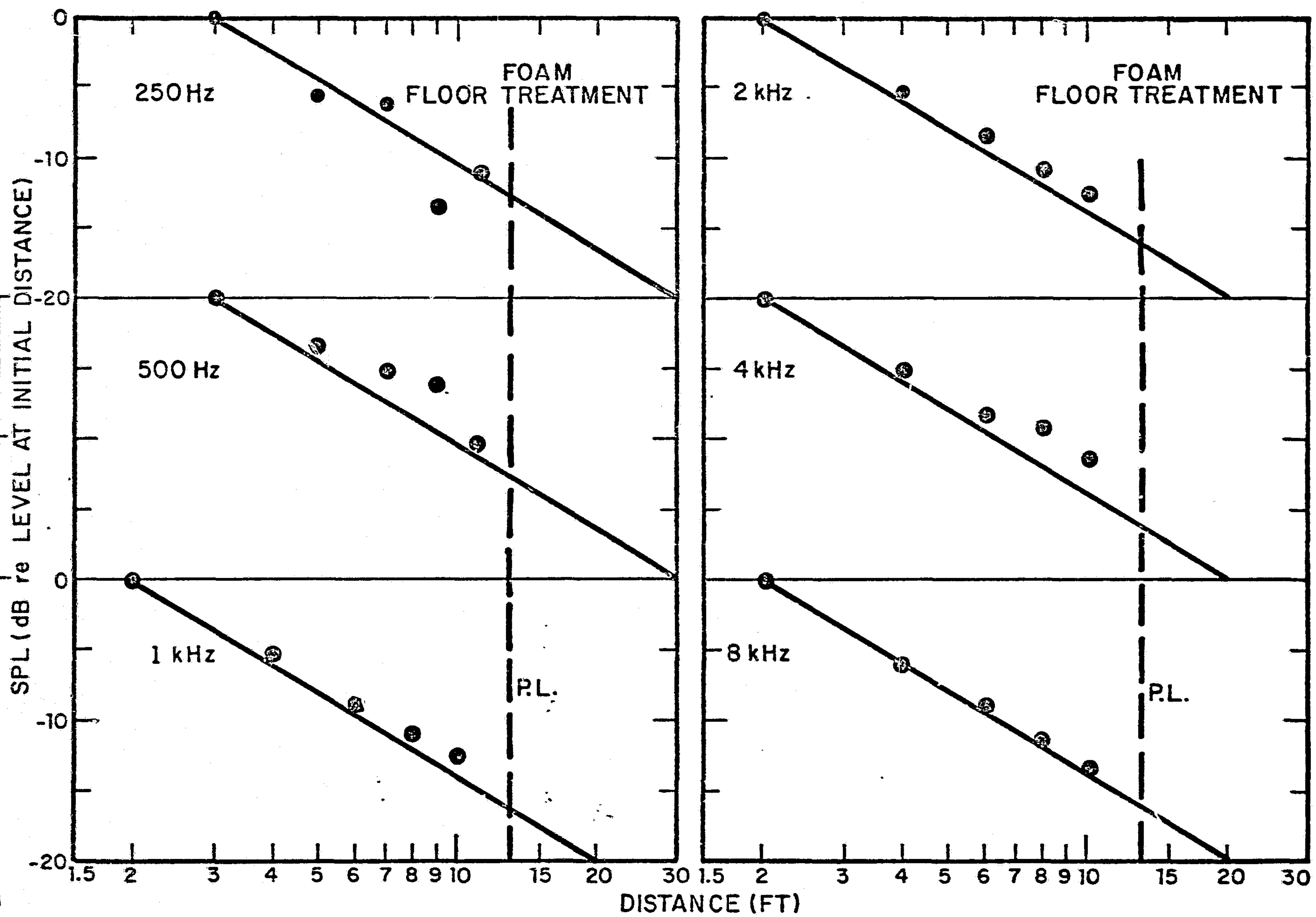

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