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ACOUSTICAL EVALUATION OF X-20A DYNA-SOAR FULL-PRESSURE SUIT ASSEMBLIES

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FOREWORD

This study was initiated by the Biophysics Laboratory, Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The research was conducted by H. C. Sommer and H. K. Hille of the Biodynamics and Bionics Division, under Project 7231, "Biomechanics of Aerospace Operations," and Task 723103, "Biological Acoustics in Aerospace Environments." Acknowledgement is made of the assistance provided by Mr. Donald T. Bowen and Mrs. Lee C. Rock of the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories. Research covered herein was performed in the fall of 1964.

This technical report has been reviewed and is approved.

J. W. HEIM, PhD
Technical Director
Biophysics Laboratory

ABSTRACT

This report presents comparative acoustical data for the "training" model and the "flight-ready" model of the Dyna-Soar X-20A full pressure suit assemblies. For each model the acoustical protection was determined (1) from the subjective measurements of Real-Ear Attenuation at Threshold (REAT) for pure tones and (2) from the objective measurement of transmission loss for wide band noise as recorded outside and inside the helmet at the lip microphone and ear cup positions. Evaluation of the data as measured by the REAT method showed that the training models provide more attenuation than the flight-ready model at the higher frequencies which is the result of a better seal between the ear cup and skull in the training model. The measurement of the transmission loss showed little difference between the two models of the suit assemblies. On the basis of calculated noise levels in the command module of the Dyna-Soar X-20A vehicle, no reduction in speech transmission and reception by the environmental noise is expected for either model.

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

SECTION I

INTRODUCTION

Prior experience of the acoustical performance of X-20A Dyna-Soar suit assembly had been gained and reported earlier by the evaluation of a prototype suit[1,2]. This report presents additional acoustical data for the Dyna-Soar X-20A full-pressure suit assembly. Data on the subjective Real-Ear Attenuation at Threshold (REAT) and noise transmission measurements at the helmet microphone and ear cup were obtained for two models of this suit assembly.

The first models tested and evaluated were called the "training" models and were custom fitted for each of the Dyna-Soar pilots. During the test program, in which the pilots were acting as experimental subjects, the X-20A program was cancelled and only four of the six pilots completed the tests. The results of this evaluation revealed that various features of the assembly were unsatisfactory; therefore, an improved version was fabricated to correct the undesirable deficiencies. From the acoustical standpoint, the assembly was redesigned to eliminate a resonance at 250 cps with the visor open.

This improved second model was called the "flight ready" model. Two members of the Aerospace Medical Research Laboratories served as subjects for the evaluation of the modified version of the suit assembly.

This report describes a comparative acoustical evaluation of the training models and flight-ready models of the suit assemblies. Evaluation consisted of (1) the subjective measurement of Real-Ear Attenuation at Threshold (REAT) and (2) the measurement of transmission loss through the helmet at the helmet microphone and ear cup position.

SECTION II

SUBJECTIVE MEASUREMENT OF REAL-EAR ATTENUATION AT THRESHOLD (REAT) TEST PROCEDURE

The subjective attenuation test procedure measured the threshold shift in free-field hearing induced by the suit and helmet. The mean differences in these values were designated as the amount of attenuation provided by the suit and helmet. With the exception of the number of subjects used, the evaluation was in accordance with American Standards Association Method for the Measurement of REAT[3] for Ear Protectors. In this test program, two Dyna-Soar pilots and

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[1]Rock, Lee C., Performance Parameters of the X-20 Dyna-Soar Prototype Full Pressure Assembly, AMRL-TDR-64-27, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, May 1964.

[2]Bowen, J. D., X-20A Full Pressure Suit Quantative Performance, AMRL-TDR-64-36, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, May 1964

[3]Standard Z24.22-1957. American Standards Association, United Engineering Center, 345 East 47th Street, New York, N.Y.

two members of the Aerospace Medical Research Laboratories served as test subjects for the training models and for the flight-ready models, respectively.

Threshold of hearing data for nine discrete frequencies: 125 cps, 250 cps, 500 cps, 1000 cps, 2000 cps, 3000 cps, 4000 cps, 6000 cps, and 8000 cps were obtained from the subjects in the following conditions: (a) helmet visor open, (b) helmet visor closed, and (c) without helmet. Data were also obtained for the training model with the suit and helmet pressurized to 5 psi.

The threshold values were obtained with airflow off to eliminate the masking noise resulting from the flow of air through the suit. For this purpose the flow of air necessary to allow breathing when the helmet visor is closed and to cool the pilot when the visor is open, was shut off for the time necessary to measure the threshold at each test frequency. The 5-psi condition, which is obtained by restricting the flow of air from the suit to build up the pressure, could not be maintained with airflow off; therefore, masking of the values, and apparent higher attenuation was expected for this condition.

INSTRUMENTATION

The instrumentation for measuring REAT consisted of: an audio oscillator, an electronic switch, an operator's attenuator (110 dB total range in 1-dB steps), a recording attenuator (intensity continuously varied at a rate of 4 dB per second), an audio amplifier, and a 25-watt loudspeaker. The loudspeaker was positioned 4 feet in front of the subject. The harmonic distortion for the entire system was less than 3 percent over the levels and frequency ranges used. The subjects continuously plotted their thresholds of hearing by varying the intensity of the test tone between audibility and inaudibility. Each frequency was plotted for approximately 30 seconds.

RESULTS

The mean subjective attenuation data for four subjects wearing training models and two subjects wearing flight-ready models are presented in figure 1. The broken lines represent the data for the training model and the solid lines that of the flight-ready model. The mean threshold of hearing for all subjects without the helmet (open ear) is represented by 0 dB at all frequencies.

The lower curve of the graph, 5 psi, represents the attenuation when the training model was pressurized to 5 psi; however, the airflow necessary to maintain the pressure was expected to mask threshold of hearing, particularly at the lower frequencies. The apparent attenuation, shown on the graph for this condition, is an artifact resulting from the method applied. The real figures for attenuation at the 5-psi condition would be expected to follow closely those of the visor-closed condition. Therefore, the 5-psi condition was not obtained for the flight-ready model.

Figure 1* shows a resonance occurring at 250 cps for both suit models with the visor open, causing the signal at this frequency to be amplified above the threshold of hearing with bare ears. The attenuations of the training and flight-ready models are almost identical at the lower frequencies. At test frequencies above 2000 cps, the training model provides about 10 dB more attenuation than does the flight-ready model for both the visor-open and visor-closed conditions.

*Figures are at end of report.

SECTION III

MEASUREMENT OF TRANSMISSION LOSS FOR WIDEBAND NOISE AT THE HELMET MICROPHONE AND EAR CUP POSITIONS

TEST PROCEDURE

In this procedure the noise levels generated by a wideband siren were measured both outside and inside the helmet to determine the amount of noise transmitted through the helmet. The same subjects with the same suit assemblies as described under the subjective measurements (REAT) participated in the transmission-loss measurement. One microphone was placed outside the helmet and the other placed inside the helmet at either the position of the helmet microphone (position 1) or just outside the ear cup (position 2) depending upon which measurement was being made. The subject was seated in a chair directly in front of the siren (see figure 2). The noise level at either position 1 or 2 was recorded simultaneously with the noise outside the helmet on a two-channel tape recorder. These data were later analyzed in third-octave bands to determine the noise reduction in each band. The two suit conditions used to obtain these measurements were: (1) airflow, visor closed, and (2) pressurized to 5 psi.

INSTRUMENTATION

The instrumentation used to measure noise reduction consisted of two parts as shown in figure 3: (a) the recording system (only one channel shown), and (b) the analysis system. The recording system consisted of two condenser microphones, with preamplifiers and power supplies. The data were recorded on both channels of the tape recorder. Standard procedure for all measurements included an acoustical calibration before and after each data run to assure accurate knowledge of microphone sensitivities.

For all measurements, microphone A was placed outside the helmet in the same horizontal plane as microphone B, which was mounted at position 1 (helmet microphone) or position 2 (ear cup) inside the helmet. The cable for the power requirement of the condenser microphone mounted inside the suit assembly was brought out through a special adapter inserted in the ventilation hole at the knee. The lead-through was carefully sealed to maintain the suits in the pressurized condition. For each run approximately 60 seconds of data were recorded. The data were later analyzed with the analysis system shown in figure 3.

RESULTS

Figures 4 through 7 present the noise reduction data recorded at positions 1 and 2 of the training model suit for subjects A and B. The curve at the top of the figures represents noise outside the helmet obtained by microphone A. The remaining two curves represent the noise for the airflow and 5-psi condition as recorded by microphone B inside the helmet at positions 1 and 2. These graphs present the actual levels of noise in Sound Pressure Level (SPL) re 0.0002 dyne/cm^2 in third-octave bands for each condition. Figures 8 through 11 present results of the same measurements for the flight-ready model for subjects C and D, positions 1 and 2.

Note that the airflow and the 5-psi conditions as well as the different microphone positions did not indicate a great change in noise transmission. The mean attenuation for the training model suit assemblies is presented in figures 12 and 13 for subjects A and B. For the modified flight-ready model suit assembly, the same data are presented in figures 14 and 15 for subjects C and D. These figures exhibit the actual attenuation differences between the suit assemblies at each microphone location for the airflow and the 5-psi-pressurized condition. A comparison of figures 12 through 15 shows only a slight variation in attenuation. Generally, they all peak (less attenuation) at 500 cps band and again at the 2000 to 2500 cps band, with the most notable dip (more attenuation) approximately in the 200 to 315 cps band.

SECTION IV

CONCLUSIONS

This comparative evaluation has shown that:

(1) On the basis of the subjective measurement of REAT:

(a) A resonance occurs at 250 cps for both suits with the helmet visor open. The resonance amplifies the signal above threshold with bare ears.

(b) The training model provides more attenuation at higher frequencies (3000 to 8000 cps) than does the flight-ready model.

(c) Both suit models provide 10 to 30 dB more protection with the visor closed than with the visor open.

(d) At 5 psi, attenuation is expected to follow closely the visor-closed condition, although the exact attenuation for this condition could not be measured for the reason given under Results of section II herein.

(2) On the basis of noise reduction at the helmet microphone and ear cup:

(a) Differences in acoustical transmission between suit models and positions are very slight.

(b) Both helmets show resonances (less attenuation) at the 500 cps and 2000 to 2500 cps bands, with maximum attenuation values in the 200 to 315 cps bands.

Comparison of the attenuation obtained by the subjective measurement of REAT and by the measurement of transmission loss are not made since the subjective measurements include the ear cup attenuation. The transmission loss measurements compare only the SPL's outside and inside the helmet, excluding the attenuation obtained through the ear cup. A correlation between these two methods is not made since the attenuation characteristics of the ear muffs were not determined.

The difference in attenuation as shown by the subjective measurement of the REAT was a function of the different helmet liner configuration in the suit assemblies. The helmet liner of the training model was adjustable and when correctly adjusted, provided a good seal between the ear cup and the skull. The helmet liner in the flight-ready model was not adjustable and did not provide as good a seal between the ear cup and skull as in the previous experiments.

Also, the design feature change of the training model of the suit assemblies to eliminate the resonance at the frequency of 250 cps was not achieved in the flight-ready model.

This report does not represent a complete acoustic evaluation of the suit assemblies. To obtain attenuation characteristics of the whole suit assembly, additional data such as measurements at various positions throughout the suit are necessary

Figure 16 presents the expected noise in the pilot compartment of the X-20A Dyna-Soar vehicle[4] during launch and max Q in terms of a design acoustic environment and an estimated acoustic environment. Figures 17 and 18 show the estimated acoustic environment and plot, the estimated sound pressure levels inside the suit assemblies. These SPL's were obtained by subtracting the mean transmission loss values (figures 12 through 15) from the estimated environment in the pilot compartment of the vehicle. These data indicate that satisfactory speech transmission and reception can be expected within the acoustical environment of the X-20A Dyna-Soar Vehicle during launch and max Q of its mission. This report covers the acoustical performance of a special pressure suit assembly. Although variations in acoustical performance will occur with different suit designs, the data reported herein can be applied as general information for a typical pressure suit assembly.

[4]Sutherland, L. C., Boeing Document D2-8109, <u>Preliminary Vibration and Acoustics Analysis Report - Dyna-Soar, Step I</u>

Figure 1. Subjective Measurement of Real Ear Attenuation at Threshold; Training and Flight-Ready Models

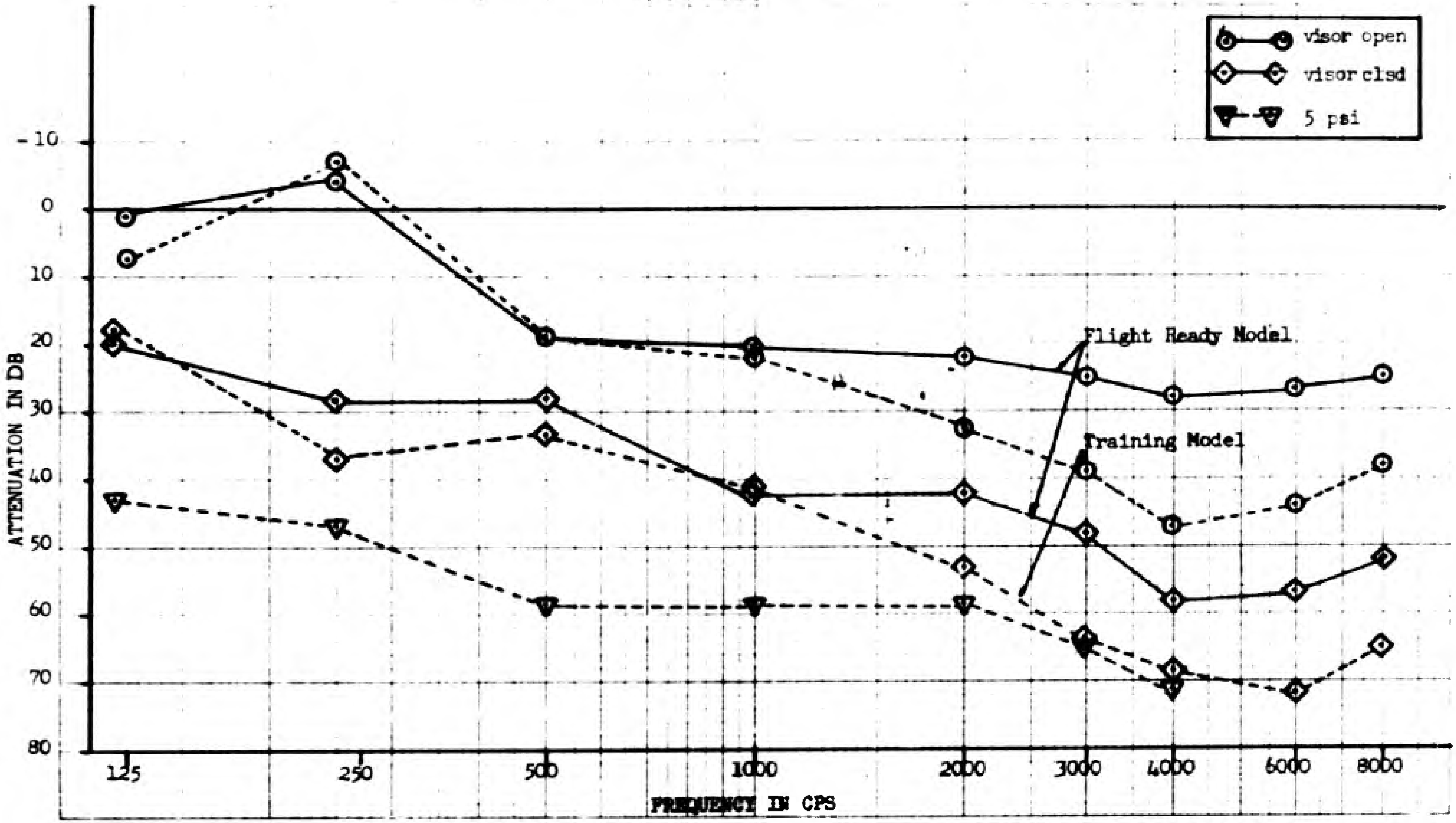

Figure 2. Subject Seated in Front of the Wide-Band Siren

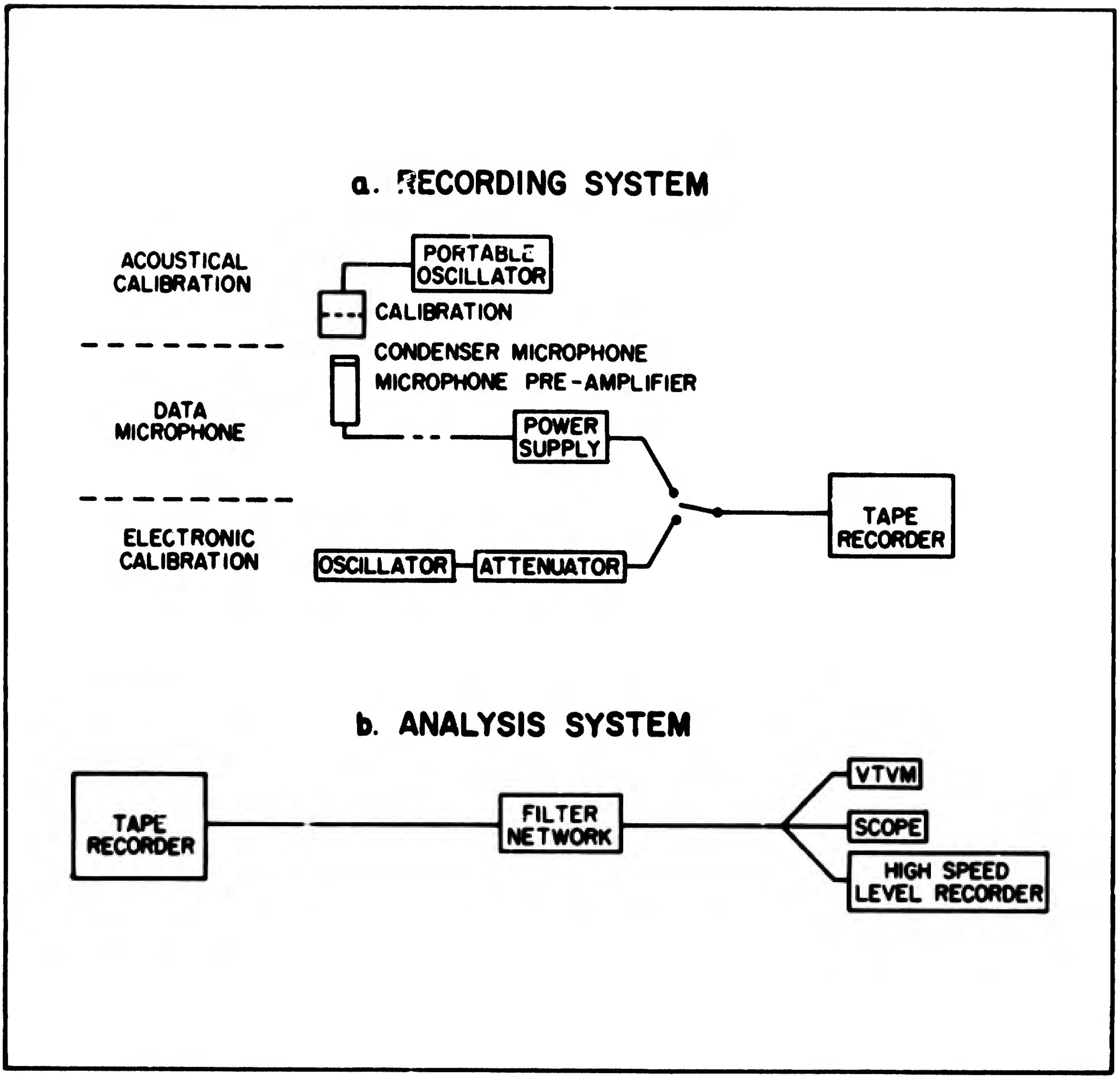

Figure 3. Block Diagram of Data Recording and Analysis Instrumentation

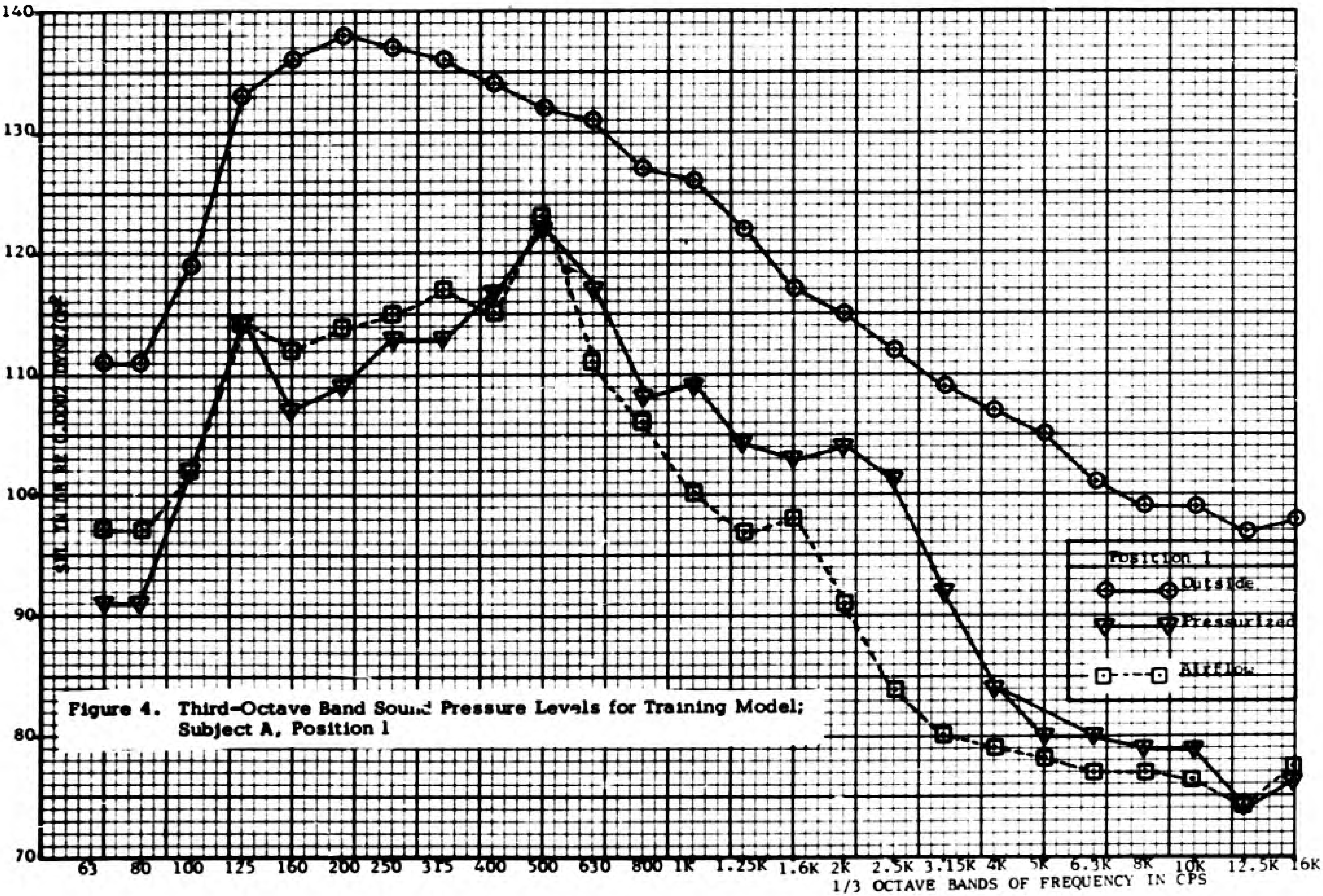

Figure 4. Third-Octave Band Sound Pressure Levels for Training Model; Subject A, Position 1

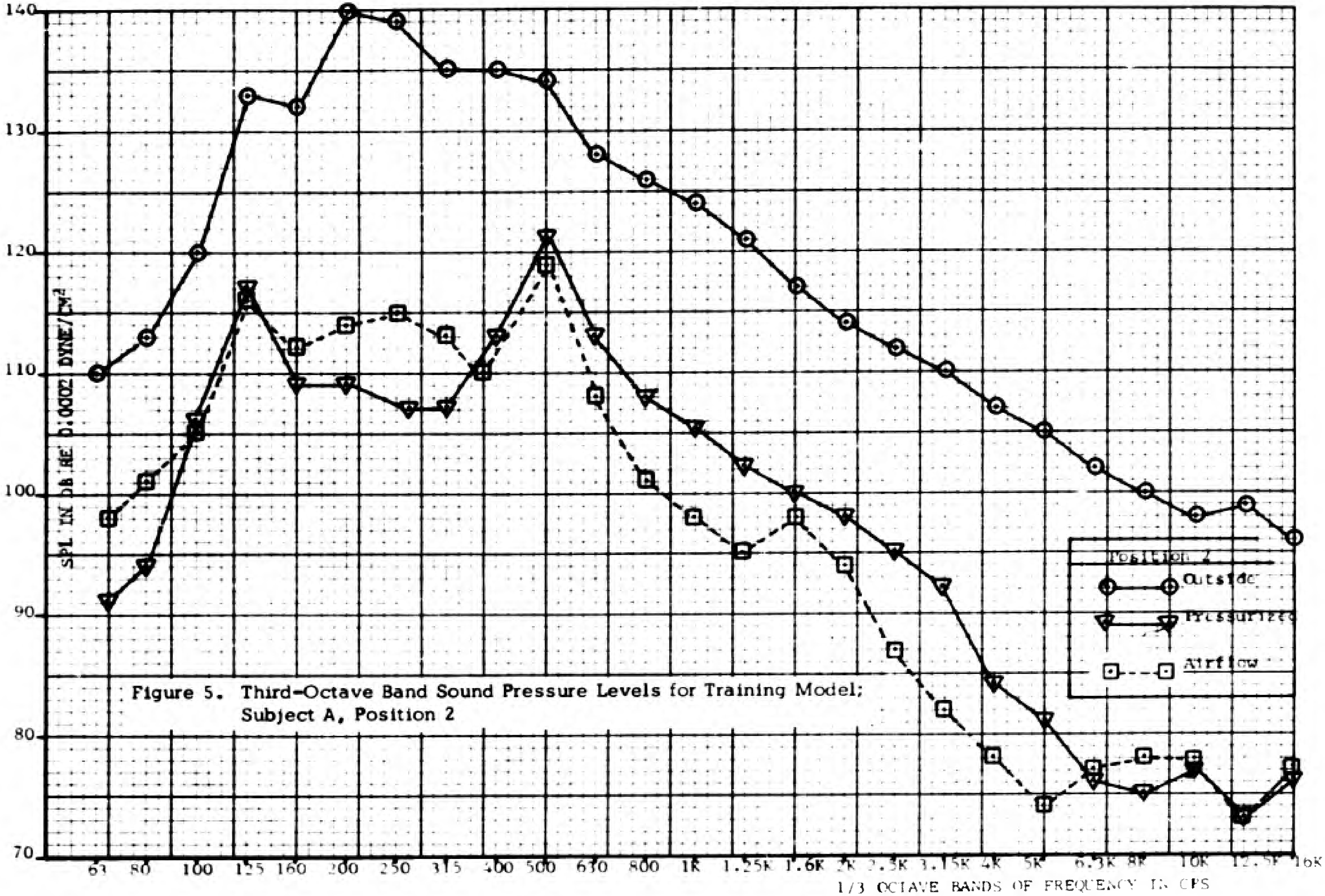

Figure 5. Third-Octave Band Sound Pressure Levels for Training Model; Subject A, Position 2

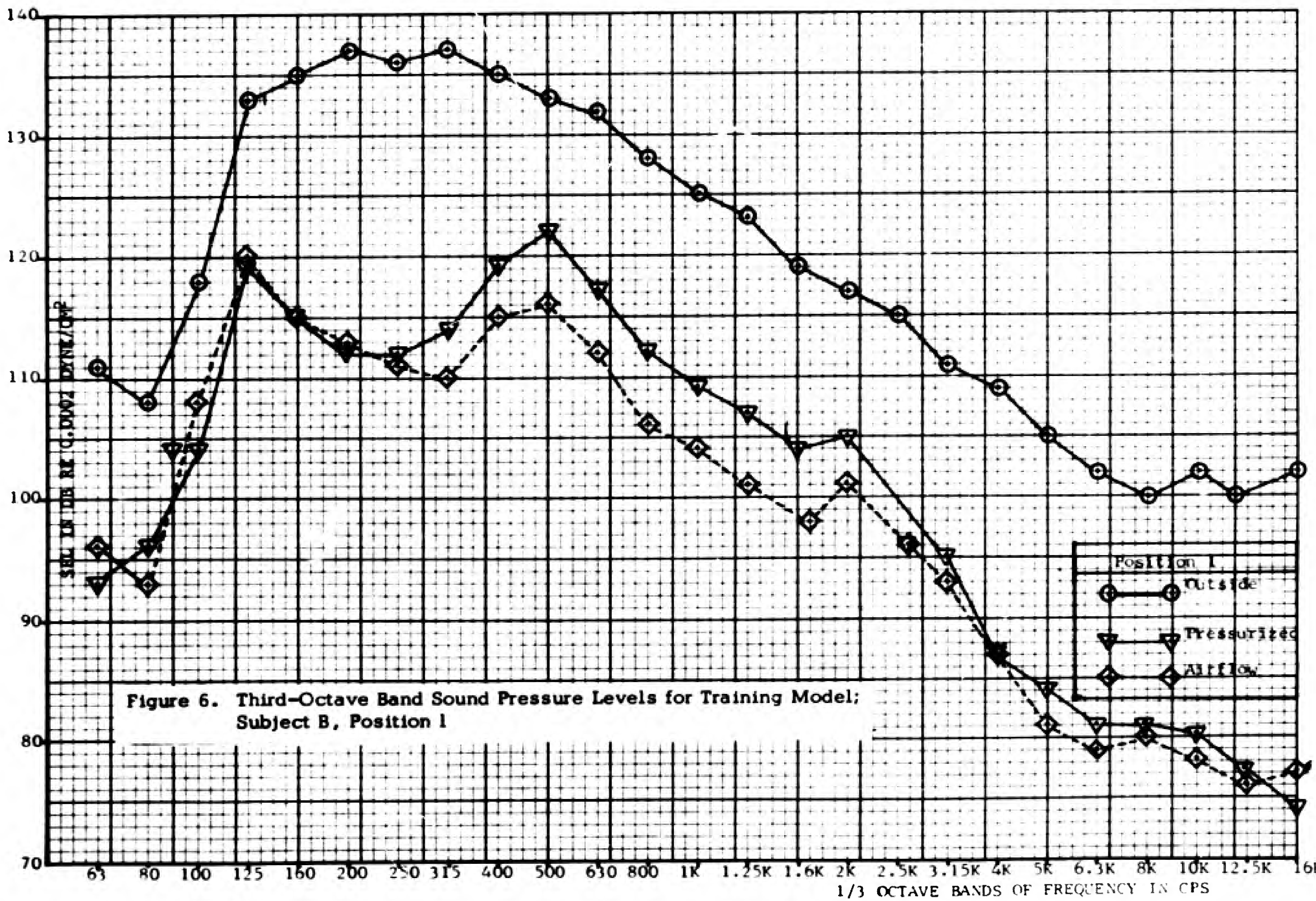

Figure 6. Third-Octave Band Sound Pressure Levels for Training Model; Subject B, Position I

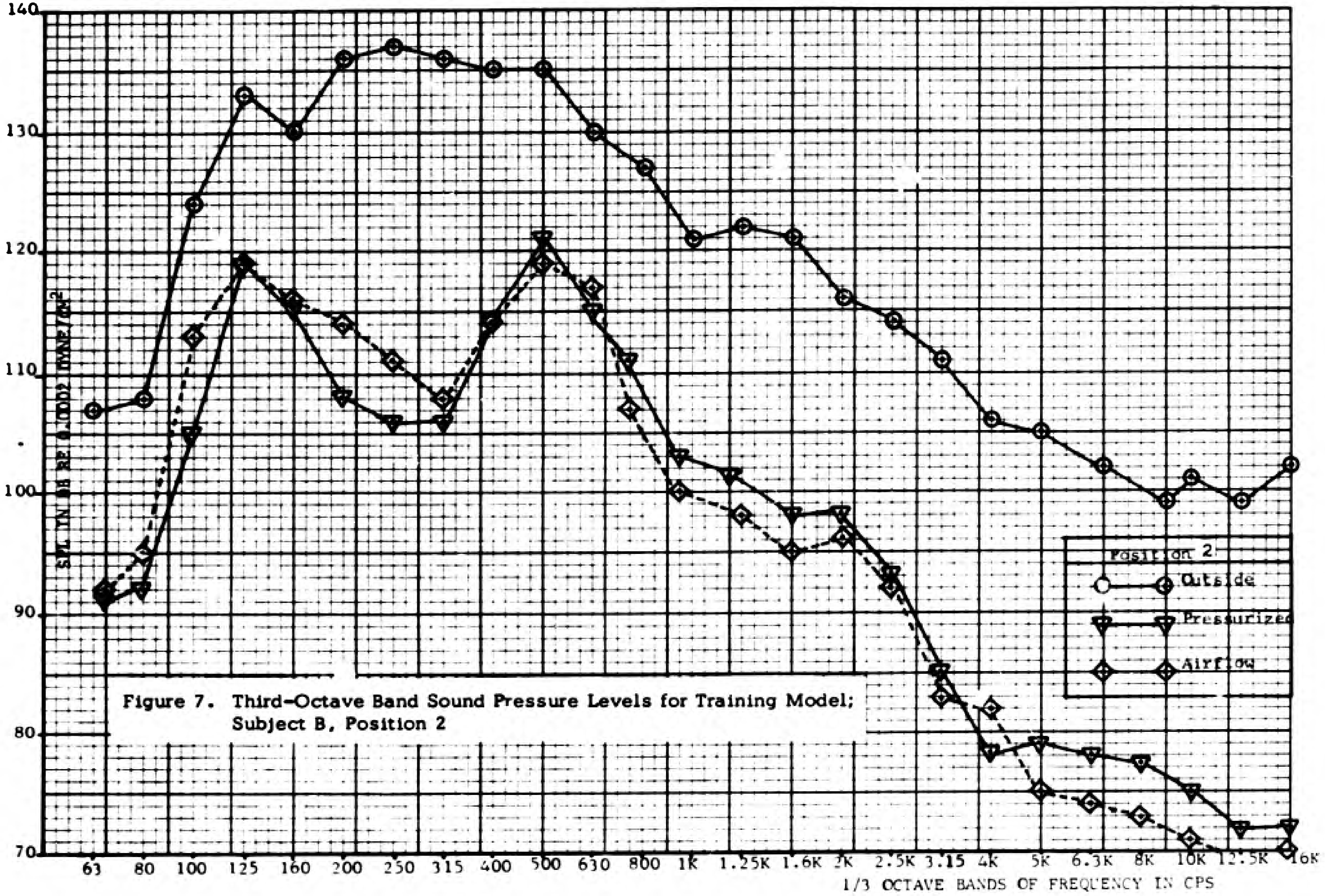

Figure 7. Third-Octave Band Sound Pressure Levels for Training Model; Subject B, Position 2

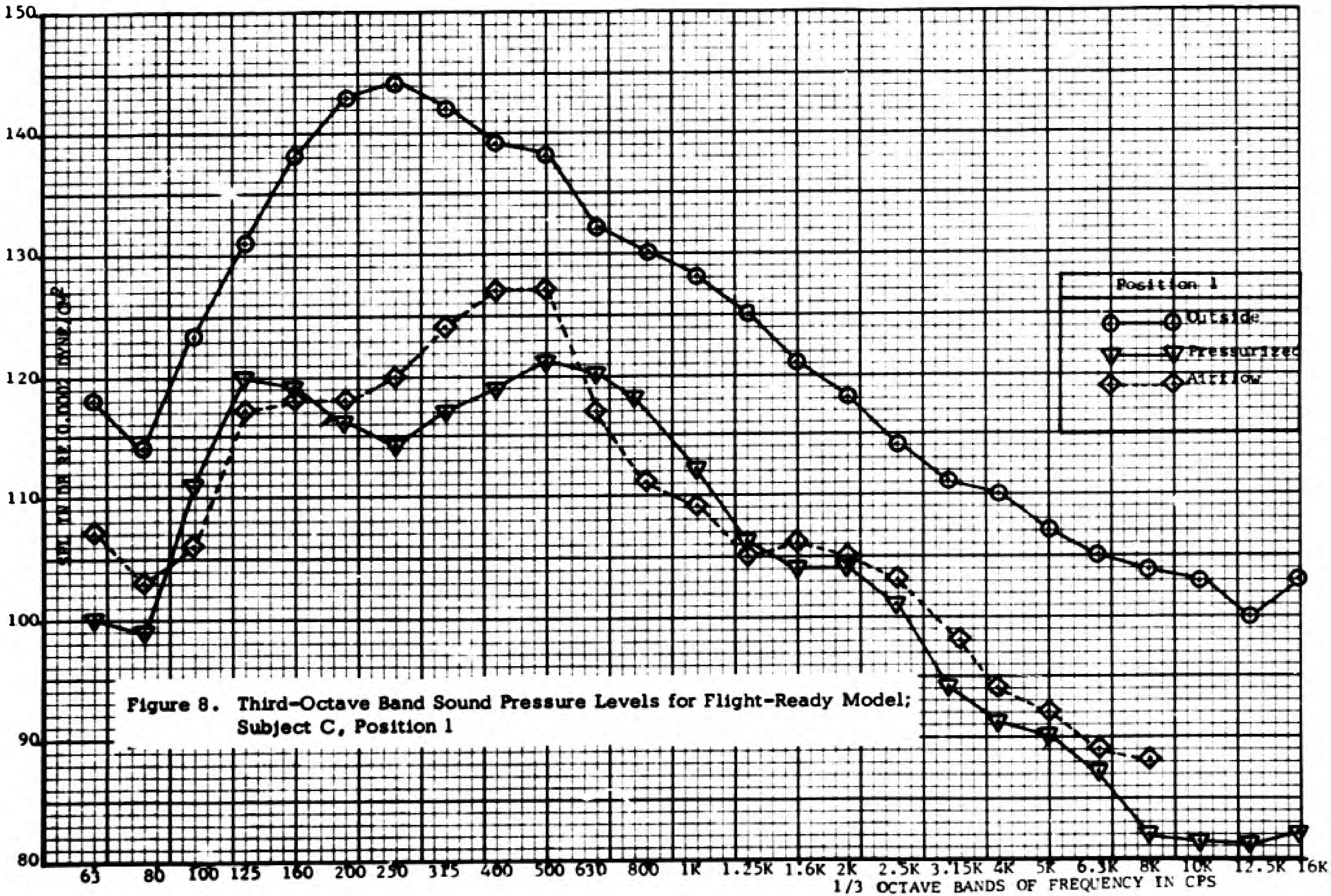

Figure 8. Third-Octave Band Sound Pressure Levels for Flight-Ready Model; Subject C, Position 1

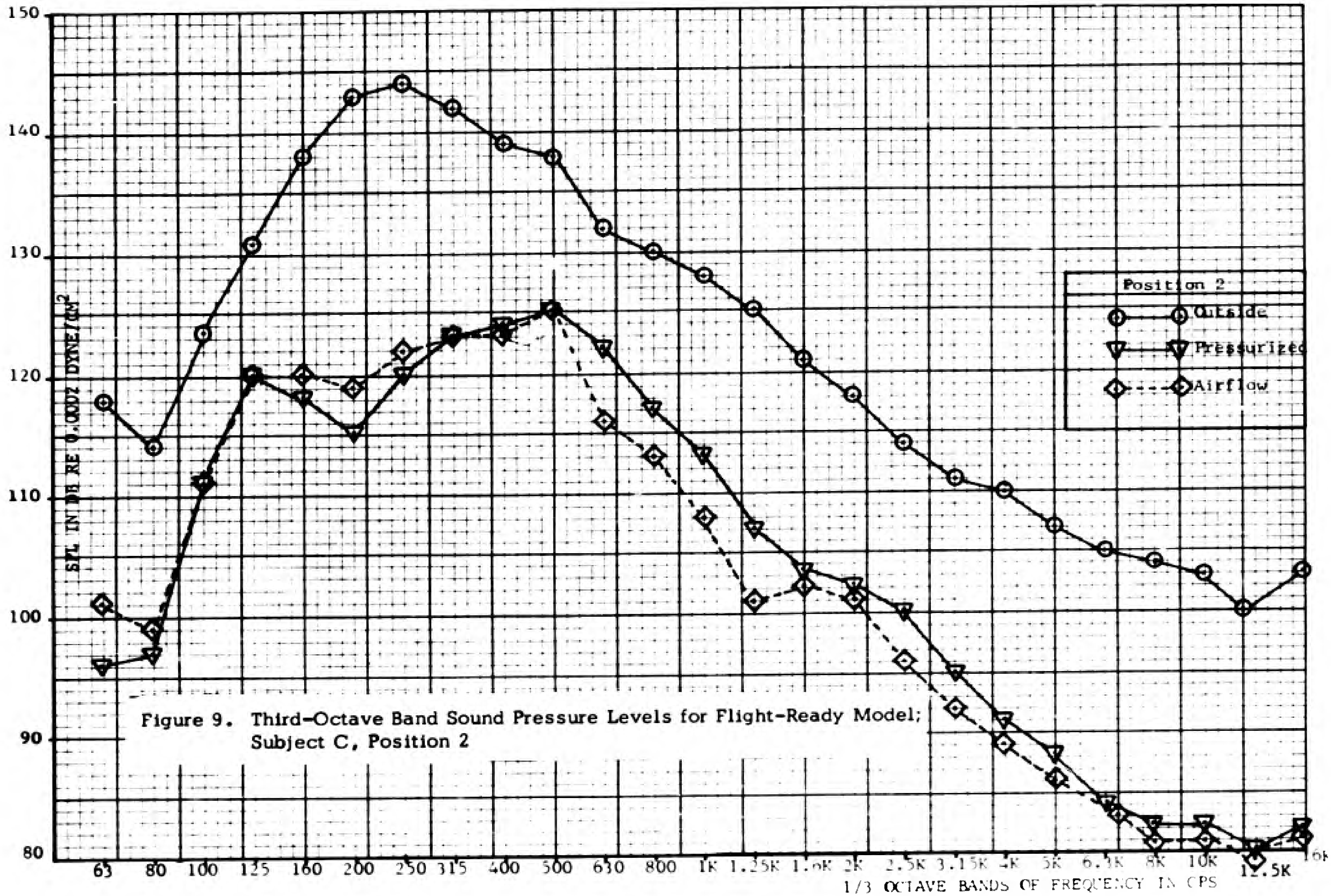

Figure 9. Third-Octave Band Sound Pressure Levels for Flight-Ready Model; Subject C, Position 2

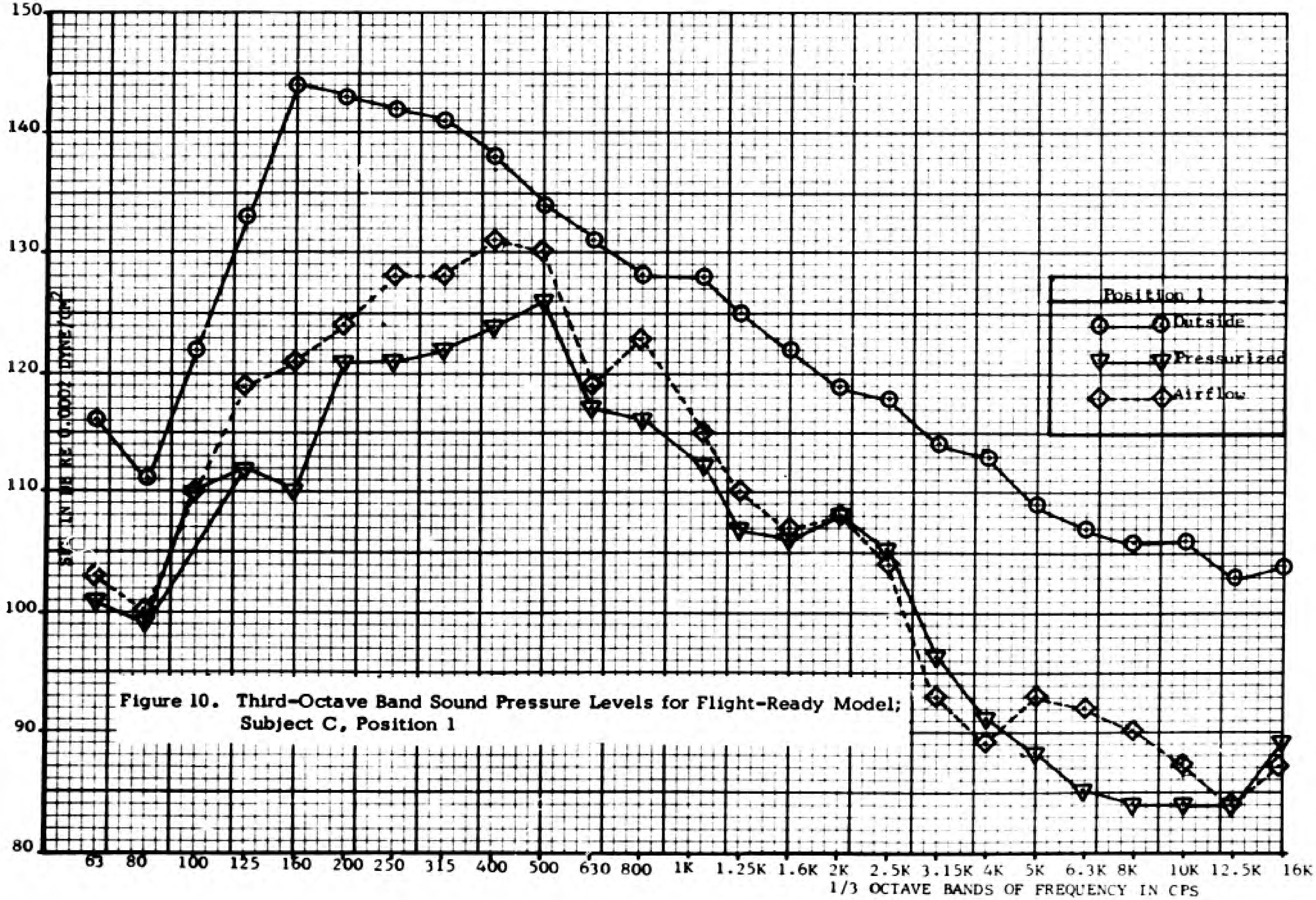

Figure 10. Third-Octave Band Sound Pressure Levels for Flight-Ready Model; Subject C, Position 1

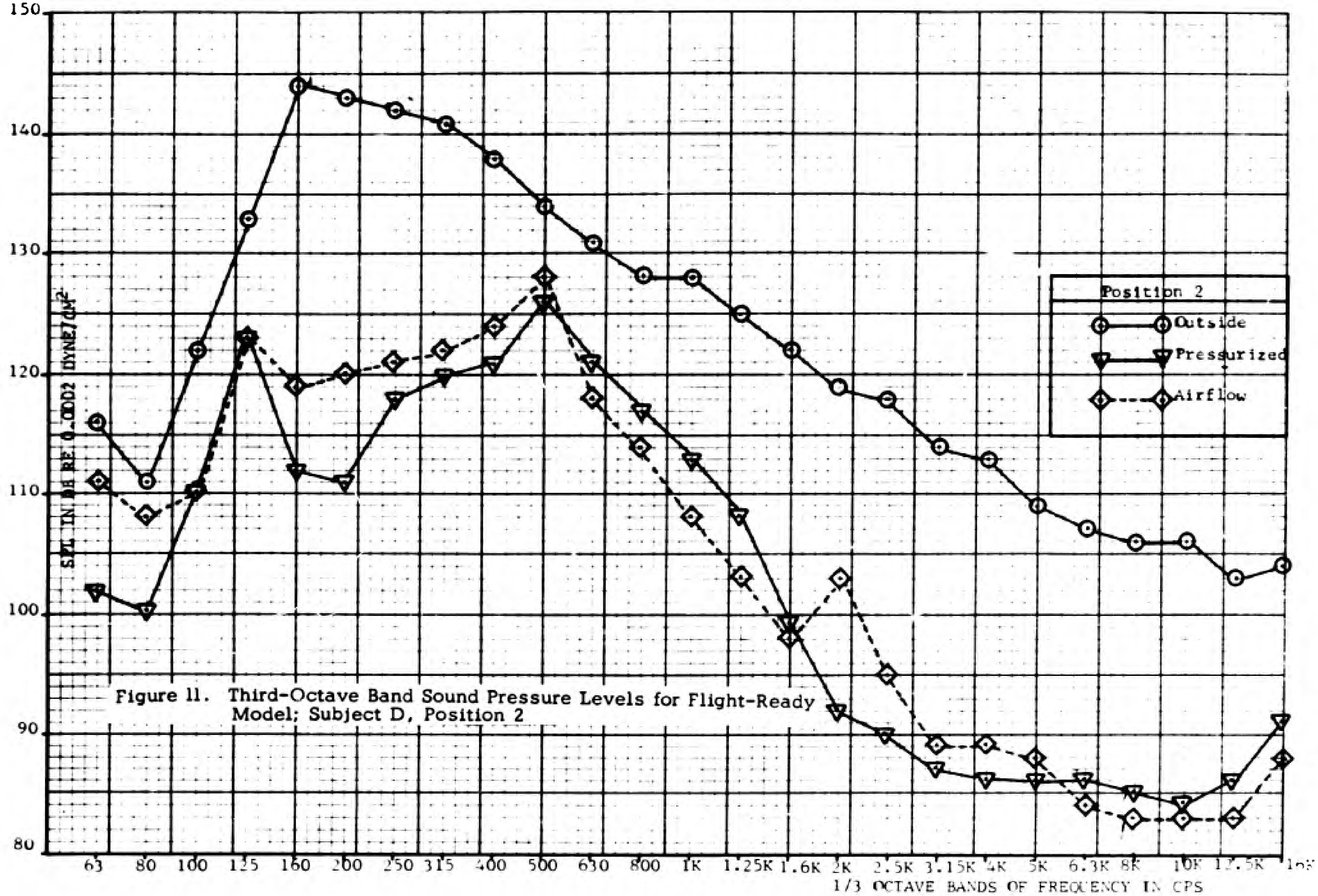

Figure 11. Third-Octave Band Sound Pressure Levels for Flight-Ready Model; Subject D, Position 2

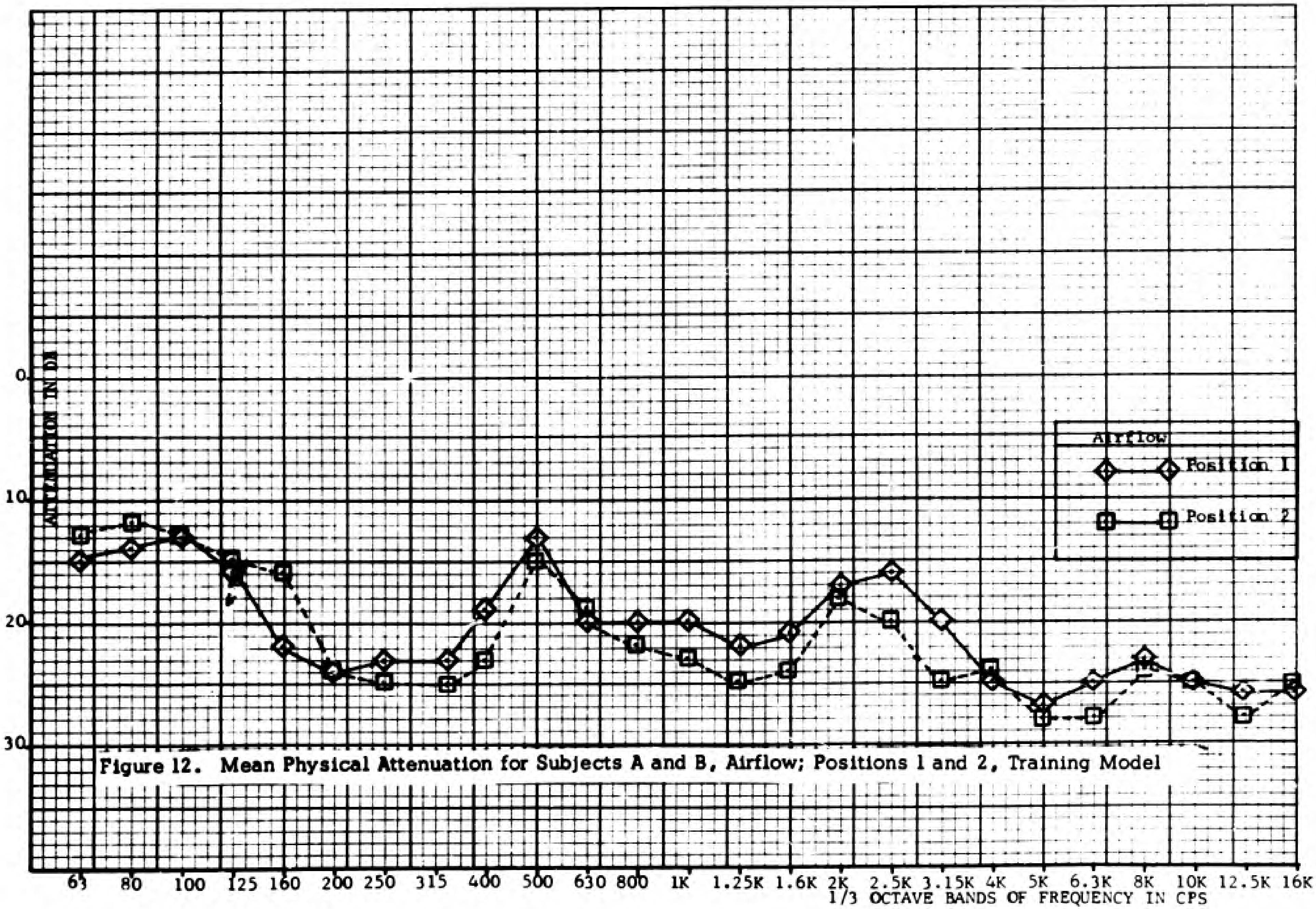

Figure 12. Mean Physical Attenuation for Subjects A and B, Airflow; Positions 1 and 2, Training Model

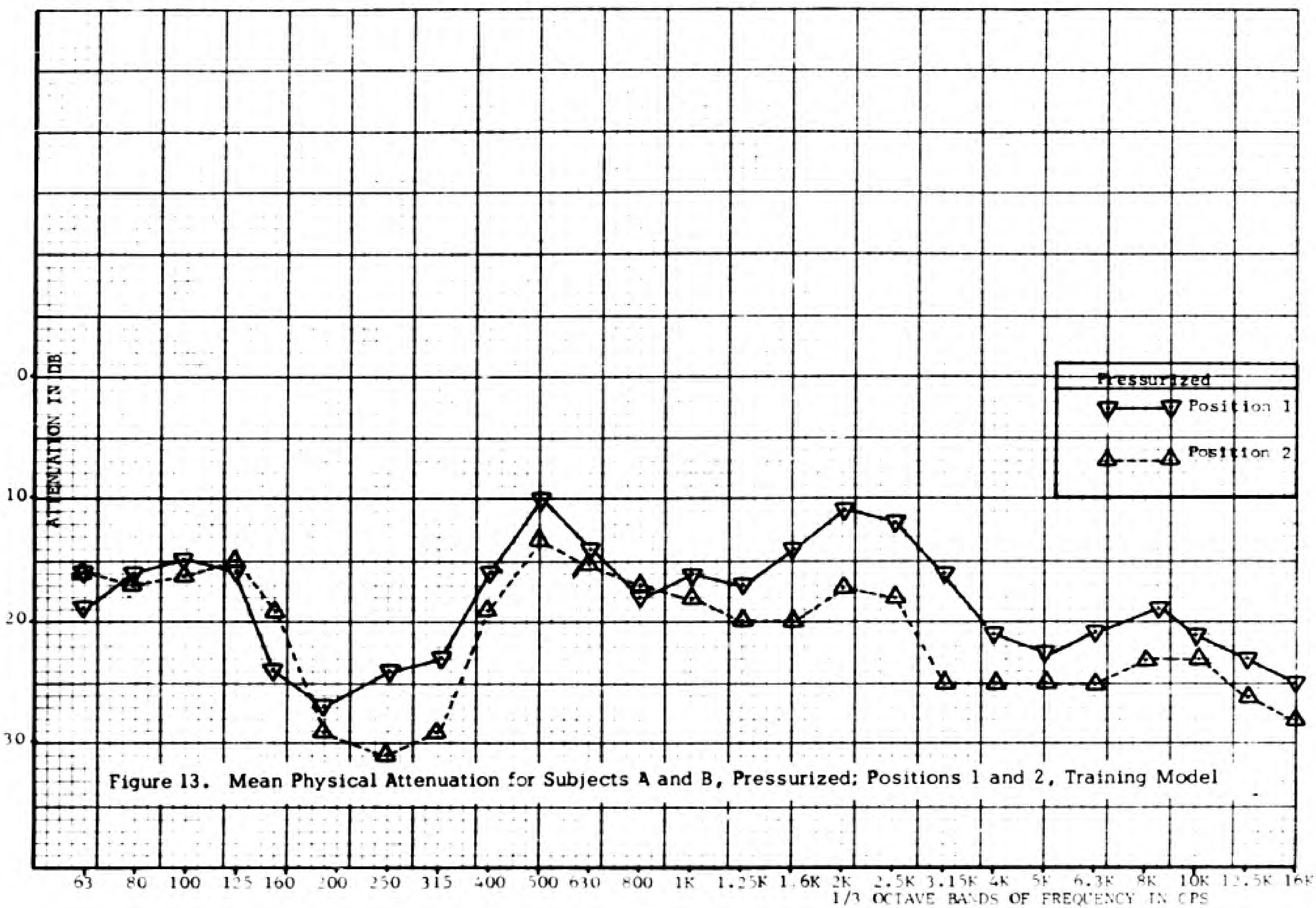

Figure 13. Mean Physical Attenuation for Subjects A and B, Pressurized; Positions 1 and 2, Training Model

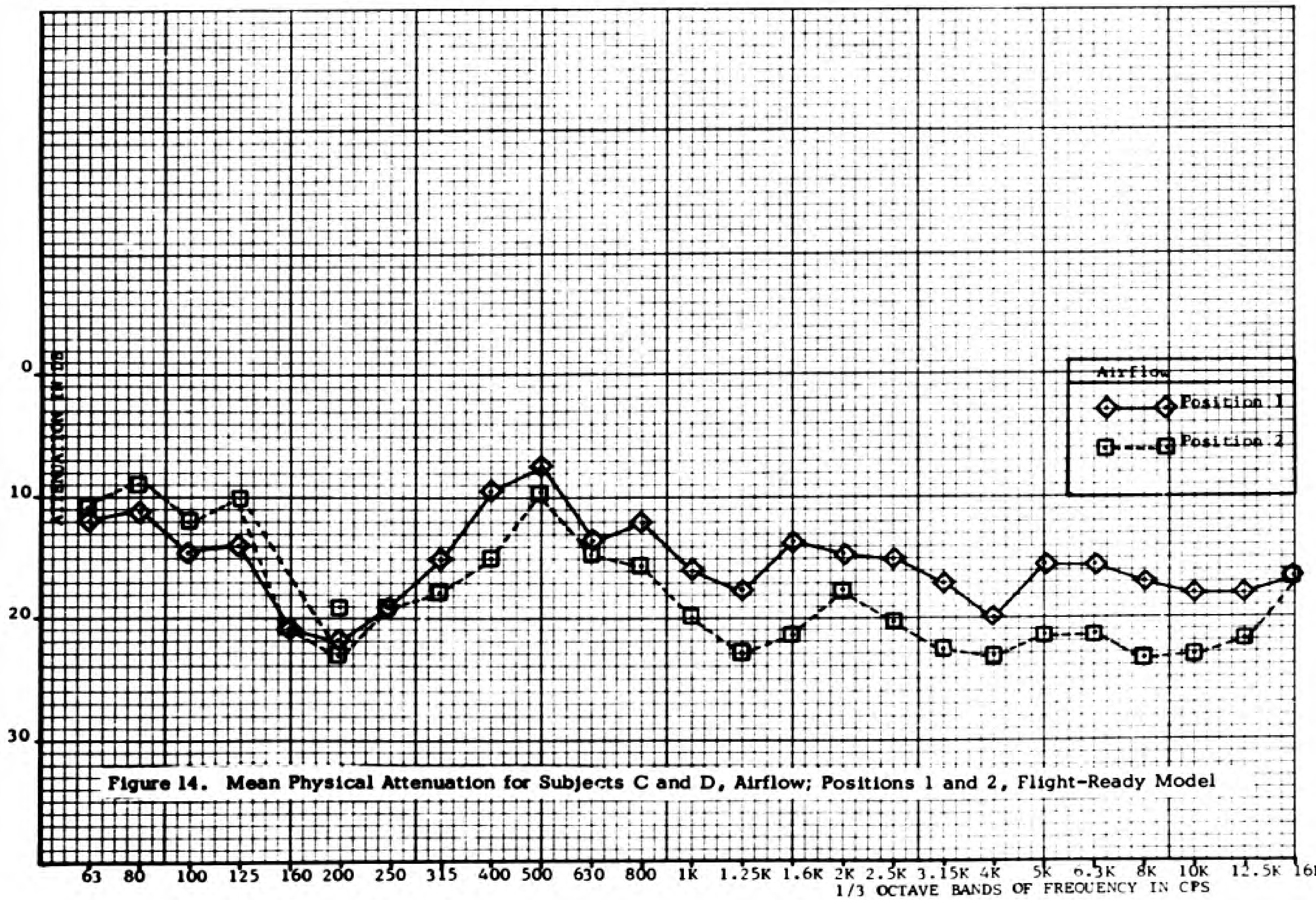

Figure 14. Mean Physical Attenuation for Subjects C and D, Airflow; Positions 1 and 2, Flight-Ready Model

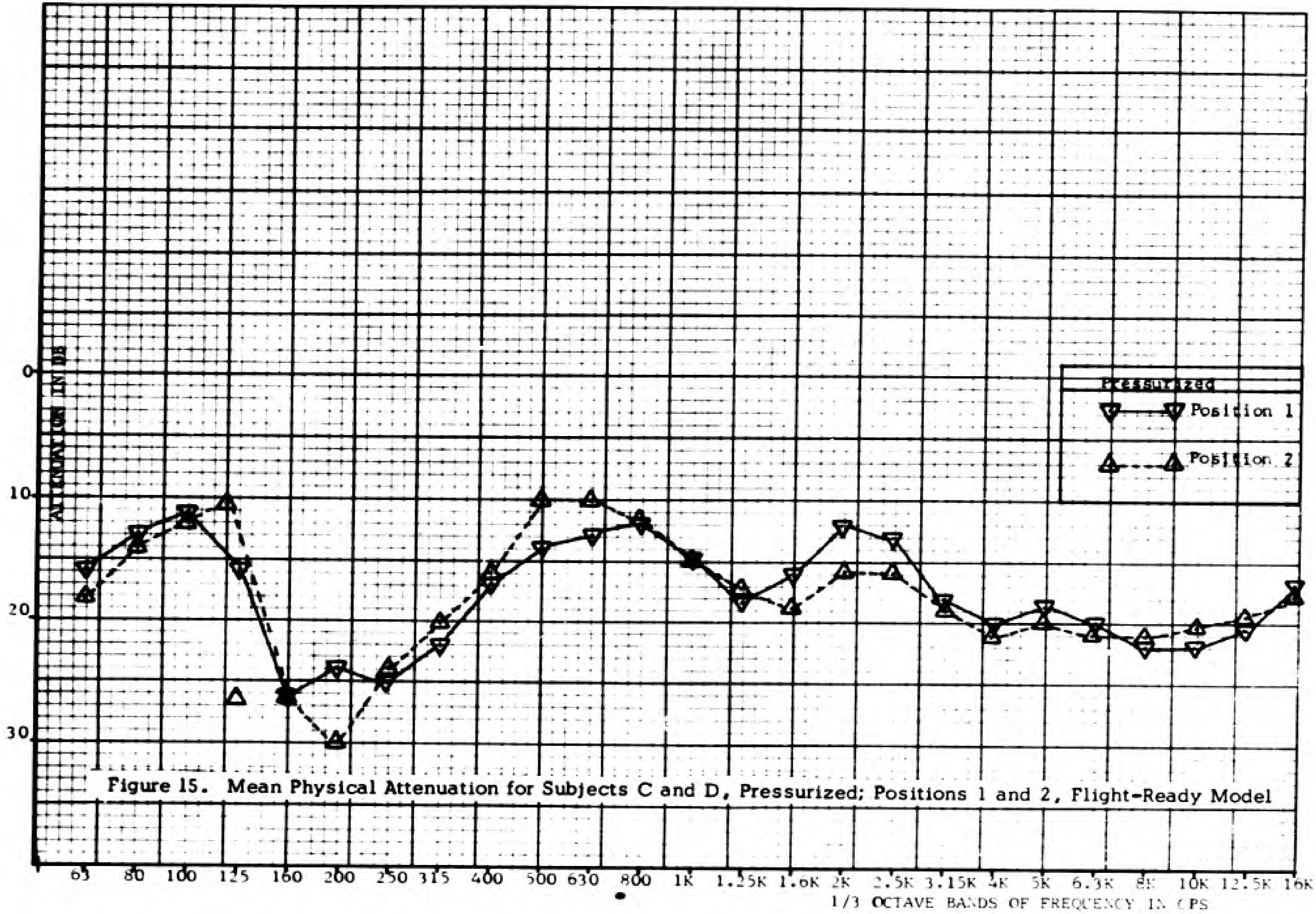

Figure 15. Mean Physical Attenuation for Subjects C and D, Pressurized; Positions 1 and 2, Flight-Ready Model

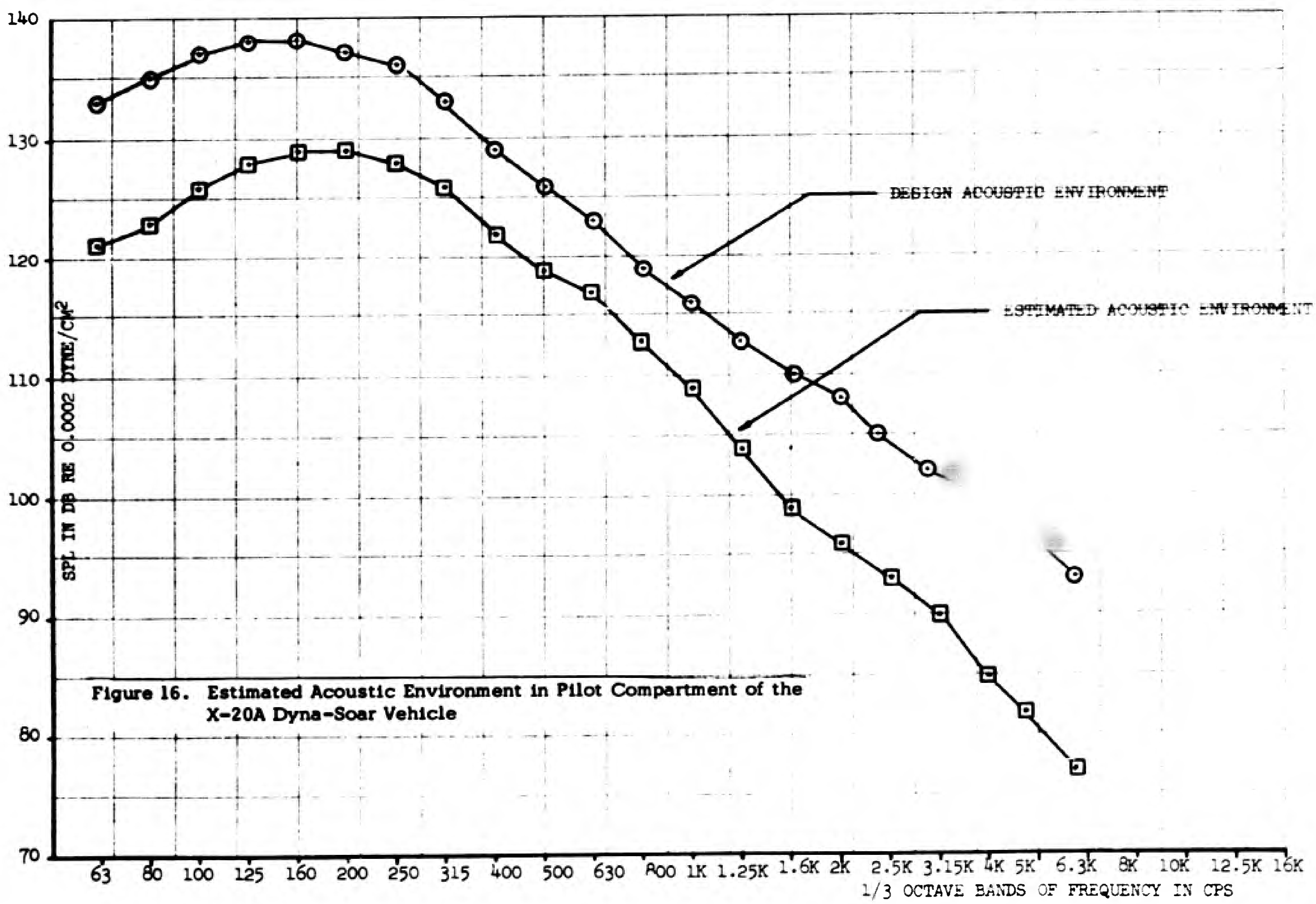

Figure 16. Estimated Acoustic Environment in Pilot Compartment of the X-20A Dyna-Soar Vehicle

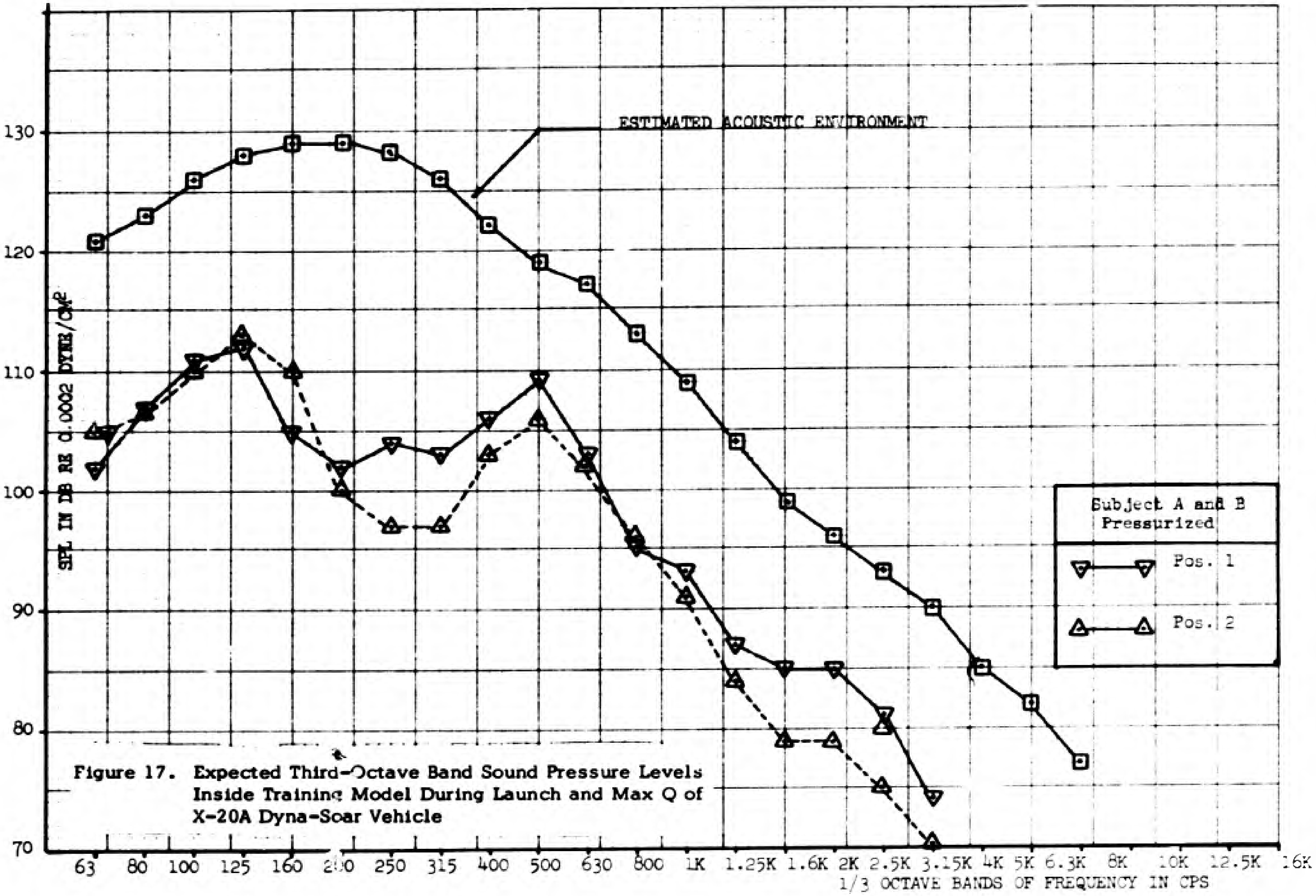

Figure 17. Expected Third-Octave Band Sound Pressure Levels Inside Training Model During Launch and Max Q of X-20A Dyna-Soar Vehicle

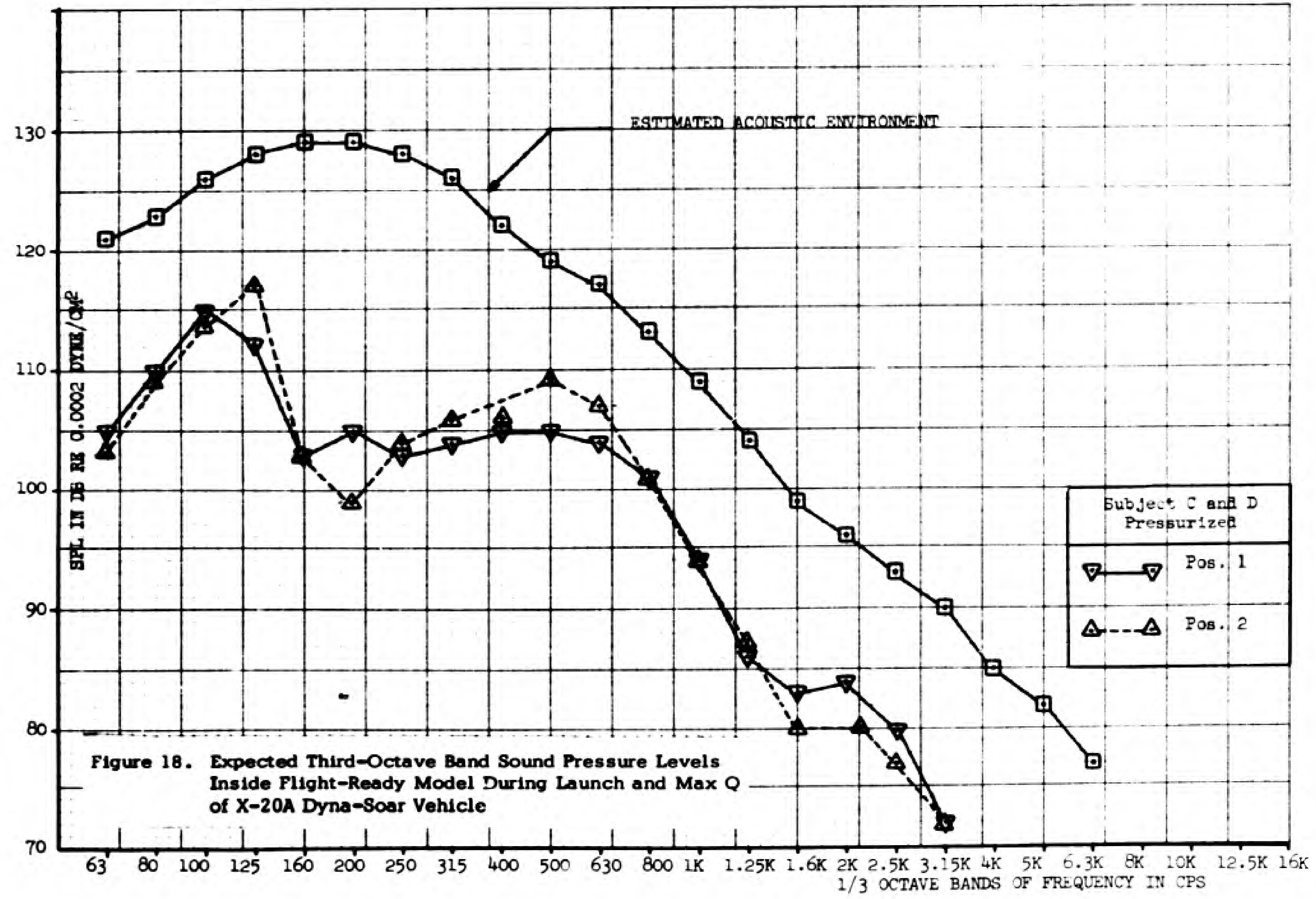

Figure 18. Expected Third-Octave Band Sound Pressure Levels Inside Flight-Ready Model During Launch and Max Q of X-20A Dyna-Soar Vehicle