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EXPERIMENTAL STUDY OF NOISE TRANSMISSI
INTO A GENERAL AVIATION AIRCRAFT

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Section

1. INTRODUCTION

The reduction of cabin noise in aircraft has been a continuous effort of several research projects funded by NASA. The previous research work by the authors at Columbia University has been mainly devoted to theoretical noise studies. Significant progress has been made in verifying some of the theoretical predictions by comparison with experimental results. The objective of the present report is to provide needed experimental data and to evaluate a variety of sidewall treatments for noise control in a light aircraft.

The test article for these experiments is the fuselage of a 1957 Aero-Commander (model 680) aircraft. This aircraft has been used for a number of tests to investigate the structural dynamic and noise transmission characteristics. Even though the aircraft is relatively old, it is believed that the structural sidewall design characteristics are similar to those of many aircraft now in service. The previous experiments included ground, taxi and flight tests performed at the Langley Research Center, NASA [1-4]. The noise transmission experiments under static conditions (ground) were performed for a variety of inputs such as those generated by speakers, exponential horn and actual propellers with rotational speeds up to 2600 rpm [1,5]. In addition, a series of experiments were conducted in the laboratory to measure the structural dynamic parameters such as the modal frequencies, modes, damping and transfer functions [6].

The experimental results presented in this report are obtained for diffuse and localized noise pressure inputs. The diffuse noise inputs are generated utilizing two speakers while the localized noise inputs are produced by an acoustic guide setup wherein a speaker and a noise path isolation device are used. The noise transmission data are obtained for a variety of aircraft sidewall treatments. These treatments include honeycomb panels, damping tapes, nonload carrying mass, acoustic barriers, multilayered septum and trim panels. Furthermore, noise transmission through aircraft windows has been measured for several conditions of different acoustic interiors.

The primary objective of the present work was to evaluate a number of candidate treatments to be used for the optimization of interior noise in light aircraft. The experimental results of noise reduction and insertion loss are presented. A summary of the test cases is given first. Subsequent to this summary is the test description and the numerical results.

2. SUMMARY OF TEST CASES

This report includes results for the following test cases.

Inputs: Diffuse and localized sound pressure levels.

Baseline Structures: Noise transmisson into the untreated aircraft for diffuse and localized noise pressure inputs.

Honeycomb Treatment: Effect of honeycomb stiffening on noise transmission.

Damping Tape: Effect of damping on noise transmission.

Porous Acoustic Blankets: Acoustic blankets for noise absorption and noise transmission control.

Noise Transmission Through Aircraft Windows: Localized inputs are utilized to measure noise transmission through single and double wall aircraft windows. The effect of interior absorption on the transmitted noise is estimated.

Noise Transmission Through Multilayered Treatments:

- Noise Barriers
- Acoustic Foams
- Vinyl Septa
- Acoustic Blankets
- Trim

Vibration of Structure: Acceleration measurements were obtained for a number of selected points on the aircraft sidewall.

Miscellaneous Tests:

- Effect of Rear Baggage Barrier on Noises Transmission
- Noise Distribution Inside and Outside of the Acoustic Guide

3. TEST DESCRIPTION

This section of the report describes the test set-up, add-on treatments used for noise reduction, data acquisition and data reduction.

3.1 Test Set-up

The test specimen is a 1957 Aero-Commander (model 680) aircraft shown in Fig. 1 but with the wings and a portion of the tail, landing gear and nose gear removed. The fuselage of this aircraft was loaned to Columbia University by the Langley Research Center, NASA, for research to expand the data base obtained in Refs. 1-6. The aircraft is supported by a sling type cradle. The sling straps support the fuselage underbody just aft of the pilot side window and just aft of the door. For some tests, the front end of the aircraft was lifted slightly by attaching a hoisting device. It was assumed that the support mechanism does not affect the local structural dynamic properties of the fuselage. Figure 2 shows the aircraft in its cradle support. Prior to testing, the interior of the cabin was stripped of all the original treatments (fiberglas blankets, cloth trim, carpeting) and thoroughly cleaned. Figures 3 and 4 show the panel identification scheme. The letter identification symbols S and P indicate the starboard and port sides, respectively.

The diffuse sound inputs were generated by two large speakers elevated at two feet from the ground and positioned at about four feet from the fuselage as shown in Fig. 5. The location and direction of the speakers were adjusted until a relatively uniform sound pressure distribution at the exterior aircraft sidewall was achieved. The localized noise inputs were obtained using an acoustic guide device as shown in Fig. 6. The basic features of the acoustic guide design include a high quality acoustic speaker and a slowly diverging rectangular duct. The walls of the guide are constructed from 3/8 in. thick plywood. To minimize noise leakage from the interior enclosure of the guide, two layers of noise barriers each with a surface density of 1 lb/ft^2 were added to the exterior surfaces of the guide. The noise barrier designated as #101 is composed of a protective polyester film facing, impervious barrier layer, foam decoupling layer and a pressure sensitive adhesive backing. At the contact between the guide opening surface and the aircraft sidewall, soft isolation material (foam) ranging in thickness foam about 2 in. to 4 in. was installed around the periphery of the guide. The detailed features of the acoustic guide construction are given in Figs. 7 - 12. The present design of the guide includes two sections. The section without extension has an opening area of 20 x 20 in.^{2} and it is primarily employed to generate noise inputs for windows and small panels. The section with extension has an opening area of 30 x 30 in.^{2} and it is used to produce inputs for the larger stiffened panels. The acoustic guide is a very useful device for generating noise inputs over localized areas of the sidewall. Such a procedure is needed to find paths through which noise is being transmitted into the aircraft. The construction of the guide is relatively simple and different attachments can be added to increase its versatility.

3.2 Instrumentation

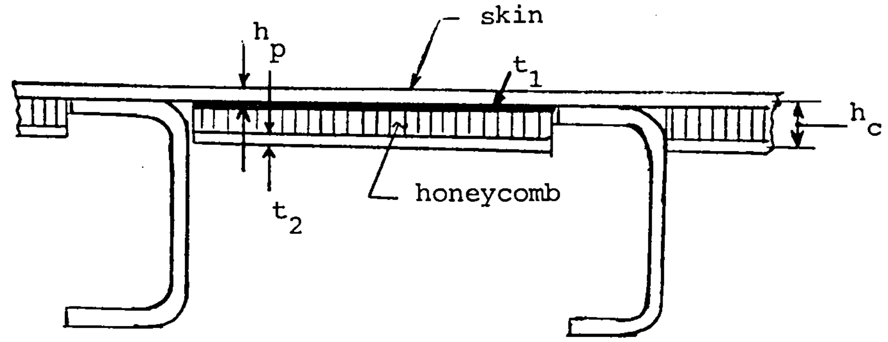
The instrumentation set-up is shown in Fig. 13. The loudspeakers were driven by the amplified signal of a random noise generator. A spectrum equalizer was used to shape the noise spectrum distribution. The noise measuring system included exterior and interior microphones. The output signals of the microphones are amplified and fed into a real-time spectrum analyzer. The resulting input/output spectra and the noise reduction (difference between the input and output spectra) are plotted by an X-Y plotter. The measurements include the narrow band, one-third octave and overall sound pressure levels.

3.3 Add-on Treatments

The add-on treatments used in the experimental study can be divided into two basic categories. In the first case, the treatments are attached directly to the interior side of the sidewall skin (honeycomb panels, damping tapes, non-load carrying mass) and have a marked influence on the structural dynamic characteristics of the sidewall. In the second case, the treatments are not attached to the skin (acoustic blankets, foams, noise barriers, trim panels) and it is assumed that these treatments do not affect by much the vibration characteristics of the aircraft sidewall. The properties of the add-on materials are presented in Table 1. Figure 14 illustrates a typical general arrangement of the multilayered treatment. Noise transmission tests were obtained for a variety of treatment combinations. The different treatment configurations tested are described in the sections that follow.

3.3.1 Honeycomb panels

Aluminum honeycomb panels were attached to the interior side of aircraft skin between the stiffeners as shown in the sketch below. Tests were performed for honeycomb constructions



with single ($t_1 = 0$) and double facings. In both of these cases, the honeycomb panels were glued to the aircraft skin using a high strength epoxy compound. A honeycomb panel constructed from a core and two facings is very stiff and difficulty arises when attaching these panels to a curved surface. In this case, the honeycomb panels were cut into smaller sub-panel units. The new transverse stiffness per unit width of the treated panel (elastic skin and honeycomb) can be calculated from [7].

$$D = \frac{E_1 E_2 (t_1 + h_p)\, t_2 h_c^2}{\{E_1 (t_1 + h_p) + E_2 t_2\}\,(1-\nu^2)} \tag{1}$$

where E_1, E_2 are the effective moduli, ν is Poisson's ratio, and h_c is the distance between the effective facing centroids. It should be noted that the formula given in Eq. 1 is only approximate. Furthermore, for panels stiffened by discrete stiffeners in addition to the stiffening with honeycomb constructions, techniques involving transfer matrices [8] or finite elements [9] need to be used to calculate the dynamic characteristics of these panels.

3.3.2 Damping tape

The purpose of adding damping tape to the skin of the aircraft is to reduce the resonant structural vibrations. However, damping tape increases the surface density of the sidewall panels. The result is a higher total mass but lower panel frequencies. The constrained damping tape used in these experiments has a surface density of about 0.296 lb/ft^2 and it is composed of an aluminum skin, 0.25 in. thick foam and synthetic rubber adhesive. The damping tape was attached to the interior facings of the honeycomb panels. In some cases, damping tape was also added to the flanges and webs of the sidewall stiffeners.

3.3.3 Non-load carrying mass

To investigate the effect of added mass on noise transmission, high density materials which have a very low stiffness were used. The typical surface densities of the mass add-on treatments were 1 lb/ft^2 and 2 lb/ft^2. These treatments were added on top of the honeycomb panels and damping tape to simulate a progressively increasing multilayered construction.

3.3.4 Porous acoustic blankets

Porous acoustic blankets were used to absorb the acoustic noise energy as it enters through the sidewall and reflects from the interior surfaces of the cabin. Several layers of the acoustic blankets were used to fill the spaces between the stiffeners. The thickness of a single layer of the blanket is about 0.75 in., surface density 0.040 lb/ft^2 and flow resistivity

$R = 4.23 \times 10^4$ mks rayls/m.

3.3.5 Acoustic foams

Flexible urethane foams containing a thin bonded film facing and a pressure adhesive were used. The thickness of the sheets were 1/4 in. and 1 in. Experiments were carried out to determine the effectiveness of these foams for cabin noise control. Two types of experiments were performed. In the first case, the acoustic foams were cut into sizes to be fitted between the stiffeners on the aircraft sidewall. In the second case, the interior surfaces of the entire cabin (excluding windows and front cockpit area) were covered with the acoustic foam. These foam sheets were attached to the interior flanges of the main frames and longerons. The spaces between the exterior skin and the foam sheet were also filled with acoustic foam.

3.3.6 Septum barriers

Lead impregnated vinyl septum barriers were used to investigate the effect of these treatments on noise reduction. The lead vinyl sheets were installed between the layers of porous acoustic blankets. Lead vinyl having a surface density of 0.26 lb/ft^2 was used for all experiments. The lead vinyl was cut into sheets of the same size as that of the porous blankets and fitted into the regions between the frames and longerons.

3.3.7 Acoustic barriers

Several types of commercially available acoustic barriers were used to investigate their effectiveness for noise reduction. These barriers are constructed from a urethane elastomer, decoupler foam and pressure sensitive adhesive. The acoustic barriers designated by #101, #103 and #104 were used to design a multilayered treatment. The surface densities of a single layer of these barriers range from 0.5 lb/ft^2 to 1 lb/ft^2. The noise barriers were cut into sizes to fit into the regions between the frames and longerons.

3.3.8 Trim

The effect on noise transmission due to different trim conditions was studied. The trim panels selected include a stiff masonite material of thickness 0.25 in. and surface density 1.06 lb/ft^2 and soft-limp materials with surface densities ranging from 0.26 lb/ft^2 to 1 lb/ft^2. The vibrations of these panels were partially isolated from the vibrations of the main frame structure by installing soft foam materials ranging in thickness from 0.5 - 1 in. between the trim panel and frame. To minimize noise leakage from the sides of the foam isolation, strips of the noise barrier #101 were attached around the periphery of the frame-foam contact. Under these conditions, the structural coupling between the frames and trim panel is minimized and the distance between the exterior skin and trim is increased.

4. NUMERICAL RESULTS

4.1 Inputs

The noise inputs to the sidewall aircraft were generated either by a two speaker or acoustic guide set-up shown in Figs. 5 and 6, respectively. The narrow band sound pressure levels are presented in Fig. 15. The diffuse sound pressures were measured in the vicinity of the propeller plane and at a distance of about one inch from the sidewall. This location corresponds to approximately the mid-point of panel No. 6 shown in Fig. 3. The loudspeakers shown in Fig. 5 were positioned in such a way that a relatively uniform sound pressure distribution was achieved over the entire sidewall of the aircraft. The overall SPL varied no more than 3dB over the region extending from the pilot's window to the rear baggage compartment. No attempt was made to measure the exterior noise pressures under and behind the aircraft. The narrow band SPL inside the acoustic guide was measured in the middle of the guide opening plane and at about 1.5 in. from the exterior aircraft skin. All the sound pressure inputs were generated for the upper cut-off frequency of 1122 Hz.

4.2 Interior Noise Measurements

The narrow band and one-third octave band sound pressure levels (SPL) and noise reduction (NR) were measured for all test cases at the so-called optimization position (position 10 in Figs. 5 and 6) and at the middle of the panel that was being tested (for example, positions 9 and 11 in Fig. 6). The exterior SPL were nearly identical for all test cases. For the majority of test cases, the overall noise levels were measured at all 11 positions indicated in Figs. 5 and 6. The measurements were obtained by an interior microphone which was positioned in each case at about 8-10 in. from the sidewall. The vertical location, except for measurements at the immediate panel, was fixed at about the head level of a seated passenger. The noise reduction was obtained by subtracting the interior SPL from the exterior SPL (inside the acoustic guide or the location described in sec.

4.1).

4.3 Baseline Structure

The distribution of the interior noise levels and noise reduction was measured for the untreated aircraft using diffuse and localized noise inputs. A typical distribution of the overall sound pressure levels inside the cabin is shown in Figs. 16-18. As can be observed from the results given in Fig. 16, the interior noise distribution in an untreated cabin with uniform exterior field is relatively uniform. However, for a localized input, the noise levels in the vicinity of the source panel are as much as 8 dB higher than at other locations in the cabin as shown in Figs. 17 and 18.

The results of noise reduction measurements are plotted in Figs. 19-23 for several panels and two windows. The panel designated 5P is a single sheet curved window (pilot's window) while panel unit 7P is a double wall window. For comparison, the noise reduction corresponding to the noise transmitted by the entire sidewall (sound input from two speakers to the port side of the sidewall) is also given in these figures. It should be noted that these comparisons cannot be taken on an absolute basis since for a nonuniform pressure input, the noise reduction is a function of the positions of the interior and exterior microphones. However, these results are reasonable indications of the relative contribution to cabin noise by different panels. The results shown in these figures correspond to the interior position No. 10 (Figs. 5 and 6). The noise reduction measured at two positions is shown in Fig. 24 for Panel 4S.

These results indicate that for most of the chosen frequency range, a position near the noise transmitting panel shows significantly lower values of noise reduction than other positions some distance away from this panel. Thus, noise reduction is also a function of the chosen interior position in the cabin. The results shown in Figs. 19-23 indicate that for frequencies below 100 Hz, noise reduction is significantly less for the sidewall as compared to individual panels. Acceleration measurements tend to indicate that the vibrations below this frequency are dominated by global sidewall motion [6]. A large number of distinct peaks observed indicate strong resonance conditions and relatively low values of damping. Furthermore, due to the limited capability of the instrumentation, the results for low frequencies (below 25 Hz) should not be taken into consideration.

4.4 Honeycomb Treatment

Aluminum honeycomb panels were attached to the interior side of the aircraft skin using a high strength epoxy compound. The honeycomb panels composed of a core and two facings were used for most of the test cases. In addition, noise transmission through Panel 4S was measured for the case where a honeycomb panel constructed from a core and one facing was attached to the interior skin. It should be noted that these panels can be easily attached to a curved surface while a honeycomb panel with two facings is already very stiff and difficulties arise when attaching those panels to even slightly curved surfaces. The geometric properties of honeycomb panels were t_1 = .016 in., t_2 =

.016 in., h_c = 0.125 in. for the first case, and t_1 = 0 in., t_2 = 0.032 in., h_c = 0.25 in. for the second case. The surface densities were about 0.60 lb/ft^2 and 0.66 lb/ft^2, respectively. The honeycomb sheets were cut into sizes to fit between the frames and stringers. All the panels on the port side (except the door) and Panels 4S and 6S on the starboard side were treated and the noise transmission measured.

The narrow band noise reductions are given in Figs. 25 and 26 for the Panel 4S at two interior positions in the aircraft. The add-on treatments in this case are the honeycomb panels with two facings.

The narrow band noise reductions are given in Figs. 25 and 26 for Panel 4S at two selected interior positions in the aircraft. These results indicate that at some frequency values, significant gains in noise reduction can be achieved with honeycomb stiffening. However, there are frequencies at which these gains are only modest or worse, negative. The insertion losses for the two honeycomb treatments are presented in Figs. 27 and 28 on a one-third octave frequency scale. The insertion loss is defined as the difference between the sound pressure levels of the treated and untreated cases. In the frequency range of about 75 Hz - 400 Hz where the noise inputs due to propeller blade passage harmonics are the most severe, the insertion loss due to honeycomb treatments range from 0 to about 13 dB. The effects of both treatments are somewhat similar, but the honeycomb construction with one facing seems to provide better noise attenuation for frequencies above 400 Hz. This can be attributed to stronger bonding conditions between the aircraft skin and honeycomb core.

The noise reduction for Panels 3P and 6S is shown in Figs. 29 and 30, respectively. The effect of honeycomb stiffening for Panel 3P is somewhat similar to that of Panel 4S. However, the results given in Fig. 30 show that for Panel 6S, the honeycomb treatment reduces the noise attenuation at some frequencies. This might be attributed to the fact that Panel 6S is a small and relatively stiff panel and the additional increase in stiffness due to the honeycomb treament would make the panel act more as a single "smeared" unit rather than a discretely stiffened panel. Furthermore, the stiffness of the elastic (frame supports) boundaries might be of the same magnitude as the stiffness of the tested panel. The result is stronger structural coupling with the other panel units that bound the region of Panel 6S. For those conditions, noise is transmitted not only by Panel 6S but also by other adjacent panels resulting in higher transmitted noise.

4.5 Damping Tape Treatment

Damping tape was added to all the interior surfaces stiffened with honeycomb panels. The damping tape was cut to the same size as the honeycomb panels and attached directly to the honeycomb facing as indicated in Fig. 14. Strips of damping tape were also added to the flanges and the web of frames and stiffeners. Such a treatment gives more uniformity in the distribution of the added mass even though the damping gains of the frames and stiffeners might be minimal. The surface density of the damping treatment is about 0.296 lb/ft^2. Thus, the combined surface density of the honeycomb and damping tape treatment is 0.956 lb/ft^2.

The narrow band noise reduction due to combined honeycomb and damping tape treatment is plotted in Fig. 31 for the port sidewall of the aircraft. It should be noted that the door was not treated. Similar results are presented in Fig. 32 but on the one-third octave scale. These results indicate that the additional amount of noise attenuation obtained by this treatment is a function of the frequency. In the frequency range of 75 - 600 Hz, these gains range from 0 to 8dB measured on the one-third octave scale. If these treatments were applied to the door and ceiling of the aircraft, additional gains in noise reduction might have been realized. The narrow band noise reduction for Panel 4S with and without the honeycomb - damping tape treatment is given in Fig. 33. These measurements correspond to a location of about ten inches from the middle of Panel 4S. These results show that substantial amount of noise attenuation is achieved at most frequencies with this treatment. Similar results are presented for Panels 3P and 4S on a one-third octave scale in Figs. 34 and 35. These results indicate that the addition of

damping tape does not increase noise reduction uniformly at all frequencies. At some frequencies, negative increments of noise reduction were measured when compared to the results of panels treated with only honeycomb stiffening (Figs. 24 and 34). Except for the resonance conditions of Panel 4S in the frequency range of 200-300 Hz, damping tape seems to act merely as added mass, shifting the modal frequencies of the panels to lower values. However, in the observed structural resonance region, additional 3-4dB noise reduction was achieved with damping tape treatment. It should be noted that treating the interior surfaces with damping tape would increase the cabin absorption characteristics when compared to those of a bare or honeycomb treated surface. The effect of different treatments on interior walls with absorbing materials will be discussed in later sections.

4.6 Porous Acoustic Blankets

Fiberglass acoustic/thermal blankets were used to estimate their effect on noise transmitted into a cabin treated with porous blankets. These blankets were cut into sizes to fit into the spaces between the frames. The noise transmission was measured for the cases of the cabin treated with one and two layers of blankets. All the interior surfaces of the cabin, except windows, floor and instrument panel, were treated with porous blankets. Carpeting was installed on the floor. The thickness, surface density and flow resistivity of one layer of fiberglass acoustic/thermal blanket are about 0.75 in., 0.04 lb/ft^2 and 4.2 x 10^4 mks rayls/m, respectively.

The narrow band noise reduction of the port sidewall due to a sound pressure input from two speakers is shown in Figs. 36 and 37 for an untreated sidewall and a sidewall treated with honeycomb panels, damping tape and porous acoustic blankets. Similar results are presented in Fig. 38 for a one-third octave scale. From Fig. 31 and these results it can be seen that the effectiveness of porous blankets to reduce cabin noise increases with increasing frquency. Only for frequencies above 300 Hz can a substantial amount of noise reduction be achieved with these treatments. The effect on noise reduction due to the porous blanket treatment occurs at two stages: first, as the noise enters directly through the sidewall and second, as it is absorbed through the interaction of the acoustic waves with the treated surfaces. These effects are discussed in more detail in the following sections.

4.7 Noise Transmission Through Aircraft Windows

A series of experiments has been conducted to assess the significance of noise transmission through aircraft windows. Some results of noise transmission through single and double wall windows were shown in Figs. 20 and 21. Additional tests were performed to determine the noise transmission through the double wall aircraft window Panel 7P shown in Fig. 3 and to establish guidelines for the noise distribution in a cabin treated with absorbing materials. The interior noise measurements were obtained at about 10 inches from the wall for all the positions shown in Fig. 17. The narrow band noise reduction plots are given in Figs. 39-47 for a cabin treated with honeycomb panels,

damping tape and carpeting on the floor. For comparison, the noise measured directly in front of the window (Position 9) is included in those plots. At this particulr position, the noise reduction is usually the lowest. Similar results are presented in Figs. 48-56 for the cases where the interior walls of the cabin (except the windows and floor) are treated with three layers of porous blankets. From these results it can be seen that the noise reduction at a window is a function of the treatment type and location inside the cabin where the noise is measured. As the distance from the source (window) increases, noise attenutation increases but not by a very large amount. This seems to be typical of relatively small cabins. Furthermore, a cabin treated with several layers of porous blankets shows more favorable gains of noise reduction at higher frequencies than a cabin treated with a thin layer of high density acoustic foam.

In addition to damping tape and porous blanket treatments, noise transmission through a double wall window was measured for the case where all the interior walls (except window and floor) were treated with one inch thick acoustic foam as described in Sec. 3.3.5. The one-third octave noise reductions achieved by the three wall treatments are shown in Figs. 57-67. The results shown in Fig. 57 were measured at the location of the window through which the noise is being transmitted. For the three wall treatments considered, the noise attenuation at this position is the lowest. Furthermore, the acoustic foam exhibits better absorption characteristics for frequencies up to about 700 Hz. At most other locations, the porous acoustic blankets seem to show more noise attenuation than the acoustic foams. For frequencies up to about 300 Hz, less noise reduction was observed at some locations for a cabin treated with damping tape and acoustic foam or acoustic blankets than for a baseline condition with damping tape only. This could be attributed to the decrease in the interior volume of the cabin. The reduction is about 2 inches on all sides for acoustic blankets and 3 inches for acoustic foam. The last layer of porous blankets and acoustic foams covered the frames and all other stiffeners.

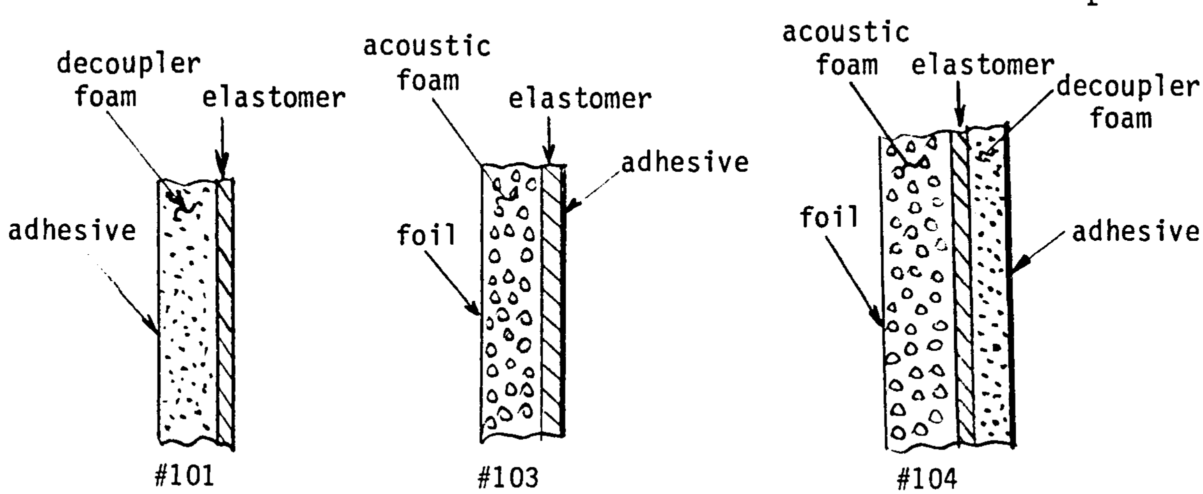
To illustrate the noise variation within the cabin, the measured noise reduction is plotted in Figs. 68-85 for several one-third octave center frequencies. For a typical cruise condition, the propeller blade passage harmonic frequencies would fall within the bandwidth of those selected one-third octave center frequencies. From these results it can be observed that noise reduction is somewhat greater at the rear of the cabin than at the pilot or co-pilot positions. Since the windshield and forward area of the cockpit were not treated, it is to be expected that noise levels will be higher in that vicinity. For high frequencies (about 800 Hz), the noise distribution within the cabin is more uniform than it is at lower frequencies. On the average the source noise (window) is attenuated at the rate of about 2dB/ft along the port widewall. However, at the wall opposite the source (starboard), a lower rate of noise reduction was measured. Similar trends were observed for all three add-on treatments considered in this study.

4.8 Noise Transmission Through Multilayered Treatments

The noise transmitted through a typical panel of a light aircraft treated with several different types of add-on materials was measured. For this purpose, a panel located on the starboard side of the aircraft (Panel 4S shown in Fig. 4) has been chosen. Panel 4S is stiffened with two stringers and supported on all four sides by relatively stiff frames. The noise inputs were generated by an acoustic guide set-up described in Sec. 3.1. The input noise was measured at about the middle of the guide opening and one inch from the exterior skin of the panel. The interior noise was measured at the middle of the panel and about 9 inches from the interior side of the skin. The honeycomb panels and damping tape were permanently attached to the skin and were left intact during all the tests performed. Furthermore, the interior walls including the ceiling (except the windows, floor and instrument panel) were treated with three layers of porous blankets. The narrow band and one-third octave measurements were obtained. To reduce the volume of the reported data, the results corresponding to the one-third octave frequencies are given.

4.8.1 Effect of noise barriers

The noise barrier is a composite of a loaded urethane elastomer bonded to a decoupler foam, and a thin layer of pressure sensitive adhesive as shown in the sketch below. Three types of noise barriers designated by the numbers 101, 103 and 104 were used. The urethane elastomer acts as an impervious



noise barrier while the decoupler foam tends to isolate the elastomer from the vibration of the panels. The front layer of the noise barrier was attached with pressure sensitive adhesive side to the foil surface of the damping tape. The large sheets of the noise barrier were cut into smaller units which were fitted between the frames and stiffeners.

The noise reduction due to single and multilayered treatments are given in Figs. 86-89. For comparison, noise reduction for a panel stiffened with honeycomb and treated with one layer of damping tape is included in these figures. These results indicate that the noise barriers do not provide noise attenuation for frequencies up to about 500 Hz. In many cases, less noise reduction was achieved at some frequencies with the noise barriers installed. However, when several layers of acoustic blankets were added to the 101 type barrier treatment, positive gains in noise reduction were obtained for frequencies above 200 Hz. Since the rubber type elastomer of a noise barrier is separated by soft foam, a double wall noise transmission is introduced. The resulting double wall resonances induce low (or negative) values of noise reduction. For a multilayered treatment, there are multiple values of such resonance conditions which can span a relatively wide frequency band. Furthermore, the noise barriers were attached to the vibrating structures. The result is an added mass effect and shift of the panel modal frequencies to lower values. Such a mass addition is usually beneficial for noise attenuation. However, shifting the panel resonances to lower values could result in a smaller amount of noise reduction at some frequencies for a panel treated with noise barriers than for a panel treated only with honeycomb stiffening and damping tape.

The results shown in Figs. 86 and 87 are for the 101 type barrier treatment. Since, in this case, the elastomer is isolated by a thin layer of soft foam (about 0.2 in.), the double wall resonance frequencies are high and the treatment acts more like added mass in the low frequency region. The results are similar for both the single and the double layer treatments. Only for frequencies above 500 Hz, do the double layer treatments show a clear trend for more noise reduction. When 3 layers of acoustic blankets were added to the 101 treatments, noise reduction increased sharply for frequencies above 200 Hz.

The noise reduction for the 103 type acoustic barrier treatments are presented in Fig. 88. Only for frequencies above 500 Hz were positive gains of noise attenuation observed. In addition, a treatment composed of three layers gives the best results. Similar results were obtained for the 104 noise barrier treatments shown in Fig. 89. From the results presented in Figs. 88 and 89, it can be seen that these treaments would not reduce the noise transmitted into light propeller driven aircraft where the inputs are the highest in the low frequency region.

4.8.2 Effect of acoustic foam (AF)

The acoustic foam selected for the evaluation of the noise transmission is composed of open cell foam, thin polyester film facing and a thin aluminum foil facing. The overall thickness of the foam is 0.5 in. and the surface density is 0.125 lb/ft^2. The polyester film is treated with a pressure sensitive adhesive. The noise reducion for several layers of AF treatments are shown in Figs. 90 and 91. From these results, it can be seen that it is not possible to identify positive trends of noise reduction. In most cases the effect is negative. Only when one layer of the AF was installed as a trim panel, were substantial gains in noise reduction achieved for frequencies above 600 Hz. These results are shown in Fig. 92. In this case, no other layers of AF were installed between the skins structure and trim panel. From these results, it can be seen that double wall resonance frequency is about 250 Hz.

4.8.3 Effect of vinyl septa

The mass septum selected for the evaluation of noise transmission is a lead impregnated vinyl fabric with a surface density of 0.26 lb/ft^2. The vinyl septa was inserted between layers of the fiberglass blankets. Figures 93-97 show the noise reduction for several combinations of multilayered treatments. These results indicate that only for frequencies above 500 Hz is positive noise reduction achieved. In the frequency range below 500 Hz, a number of multiple double wall resonance peaks are produced. A single layer treatment seems to give better noise reduction for frequencies above 300 Hz than multilayered treatments. Furthermore, no clearer trends were observed on the advantages of different geometric combinations of the treatment, such as distance between layers, distance from the skin panel, etc.

4.8.4 Effect of trim

The effect of trim on noise transmission was investigated. The materials selected for this treatment include a relatively stiff masonite sheet and two limp rubber-like materials. The surface densities of these materials are 1.06 lb/ft^2, 1.00 lb/ft^2 and 0.26 lb/ft^2, respectively. The 101 noise barrier and lead vinyl septa were used as the heavy and light trim panels. The stiffness of these materials is very low and these panels can be considered "limp" panels. To isolate the vibration of these panels from the vibration of the frames and stiffeners, strips of 0.5 in. thick soft foam material were installed between the vibrating structure and trim. These strips were glued to the flanges of the frames and stiffeners. To reduce the noise leakage through the foam isolation, a layer of 101 noise barrier was attached around the periphery of the trim panel installation. In addition, two layers of acoustic blankets were installed in the regions between the stiffeners. The trim panel covered the entire region of panel 4S shown in Fig. 4.

Figures 98 and 99 show the noise reduction for the three trim conditions. The results presented in Fig. 98 indicate that noise reduction for the masonite and #101 noise barrier panels is about the same over the entire frequency range. Except for the difference in stiffness, the surface densities of both of these treatments are equivalent. A strong double wall resonance can be seen at a frequency of about 125 Hz. Because of such a resonance condition, negative values of insertion loss are produced in this frequency region. For frequencies above 160 Hz, the insertion loss ranges from about 3dB to 20dB. However, for frequencies between 160 Hz and 500 Hz, insertion loss values average about 7dB. The results shown in Fig. 99 for a light trim panel indicate behavior similar to that of heavy trim panels. However, the values of noise attenuation are different and increases of noise reduction are achieved only for frequencies above 300 Hz. For the critical frequency range of 70-400 Hz for light propeller driven aircraft, a heavier trim which is isolated from the vibrations of the main structure could provide significantly more noise attenuation than a light trim under the same conditions.

5.0 VIBRATION OF THE AIRCRAFT

The vibration of the aircraft was measured at seven locations on the starboard side shown in Fig. 4 and about the middle on both sides of the double wall window unit 7P (Fig. 3). The excitation to the structure was provided by the noise input through an acoustic guide located either at Panel 4S or Panel 7P. The main objective of these tests was to determine the relative motions of the sidewall in comparison to the motions of the panels which are directly excited by the acoustic field from the guide. The measured vibrations were analyzed in terms of narrow band spectra. These spectra were normalized to the input sound pressure spectra. The sound pressures were measured inside the acoutic guide at about one inch from the exterior skin of the sidewall. The ratio, S_a/S_i, of those spectra is denoted as the inertance function. Vibration measurements were performed for the case where the aircraft panels were treated with honey-comb stiffening and a layer of damping tape.

The inertance functions are shown in Figs. 100-105 for seven selected positions on the starboad side of the aircraft. For comparison, results obtained at the middle of Panel 4S are included in all of these figures. Inspection of the data plotted in these figures shows that the inertance function at different locations exhibits different characteristics. The levels at Panel 4S are much higher than the levels at other locations. However, at some locations away from Panel 4S several distinct peaks were observed which are of the order of the motions of Panel 4S. The acceleration time histories for the seven locations on the sidewall are shown in Figs. 106-111. The acceleration time history measured at the middle of Panel 4S is given in each figure. These results show that the motions of Panel 4S are different from the motions at other locations on the sidewall. Panel 4S is directly excited by the airborne sound from the acoustic guide while the motions of the other structural components are due to vibration coupling between Panel 4S and neighboring panels. These results indicate that the vibration levels of a panel excited directly by the noise field generated by the acoustic guide are much higher than the vibrations at other locations on the sidewall.

The vibration levels of Panel 4S are shown in Fig. 112 for the case where three layers of acoustic blankets were added on top of the honeycomb and damping tape treatments. For frequencies between 180 Hz to 350 Hz, the addition of porous blankets to the panel reduces the vibration levels. Since the acoustic blankets are in direct contact with the vibrating panel, mass is added to the structure. However, the most significant effects of porous blankets might be an increase in the panel damping and a change in the transmitted acoustic pressure. Since a thin layer of vinyl material is bounded to each layer of the blanket, the reflected acoustic waves in a multilayered treatment could have an effect on the panel vibrations.

The vibration of a double wall aircraft window was measured utilizing the acoustic guide set-up described earlier. The inertance functions for the exterior and interior sheets of the double window unit 7P are shown in Fig. 113. The interior window is flat while the exterior sheet is curved. The results indicate that the motions of the exterior and the interior windows are strongly coupled through the air cavity that separates them. For frequencies up to about 250 Hz, the acceleration levels of the interior plexiglass sheet are higher than those of the exterior window. However, for frequencies above 500 Hz, the motions of the exterior window are greater than those of the interior window. At a frequency of about 330 Hz, a strong double wall resonance occurs. This corresponds to a dilatational mode where the panels vibrate out of phase. The strong resonance peaks suggest low damping values and the potential to transmit noise at those frequencies.

6.0 MISCELLANEOUS TESTS

6.1 Effect of Rear Baggage Barrier on Noise Transmission

The noise transmitted into the aircraft was measured with and without the rear baggage barrier installed. The baseline design of this aircraft includes a cloth material to cover the opening of the rear baggage compartment. For the present tests, a barrier made from 0.5 in. thick plywood was installed between the rear baggage compartment and main cabin. The experimental set-up is shown in Fig. 114 where the inputs to the aircraft are generated by two large speakers. To minimize the noise inputs at the locations in front of the baggage compartment, two large partitions were installed on both sides of the aircraft as shown in Fig. 118. The overall exterior noise levels measured at both sides of the partition indicate the effectiveness of the partitions. The results shown in Fig. 114 indicate that, on the average, the interior noise levels are about 3dB lower with the barrier installed between the passenger cabin and rear baggage compartment. Thus, for an aircraft driven with a piston type engine where high noise levels are produced by the exhaust engine harmonics in the vicinity of the rear baggage compartment, a proper barrier could provide some improvements in cabin noise levels.

6.2 Noise Distribution Inside and Outside of the Acoustic Guide

Several tests were performed to investigate the noise distribution generated by the acoustic guide. The noise distribution at the opening plane of the guide and acting on a flat surface was measured with a flush mounted microphone as shown in Fig. 115. From these results it can be seen that the noise guide produces a relatively uniform sound field. The noise distribution on the exterior surface of the guide is given in Fig. 116. These overall noise levels are lower by about 27dB when compared to the noise levels generated on the aircraft surface inside the acoustic guide. Thus, the noise guide provides relatively high sound pressure inputs over an isolated region of the sidewall.

7. CONCLUDING REMARKS

The noise transmission into the cabin of twin engine propeller-driven aircraft has been measured in a laboratory for a variety of sidewall treatments. The following conclusions can be drawn from the data presented:

1. An acoustic guide device can be used to generate noise inputs over localized regions of the sidewall.
2. Interior noise levels transmitted through localized panels or windows are function of measurement position in the cabin and conditions of treated interior.
3. Stiffening skin panels with honeycomb could provide 3-7dB additional noise reduction. However, these gains are functions of panel geometry, installation conditions and frequency. The noise attenuation obtained for the entire sidewall treated with honeycomb panels is less than for some individual panels.
4. Constrained layer damping materials could provide 2-3dB of noise reduction. However, these increases depend on frequency .
5. Porous acoustic blankets (2-3 layers) provide noise attenuation for frequencies only above 300 Hz. The insertion losses reach about 10-12dB at 1000 Hz.
6. A multilayered treatment composed of porous blankets and impervious vinyl septa does not provide additional noise

reduction for frequencies up to about 500 Hz. In the frequency range below 500 Hz, several multiple double wall resonances are observed.

7. Noise barriers composed of urethane elastomer and decoupler foam do not give noise attenuation for frequencies up to about 500 Hz.

8. A treatment composed of several layers of acoustic foams does not seem to provide noise attenuation. However, when a single layer is used as a trim panel, positive gains of noise reduction are achieved for frequencies above 600 Hz.

9. A trim with a surface density of 1 lb/ft^2 panel which is isolated from the vibration of the main structures could provide insertion losses ranging from 3-20dB for frequencies 160-1000 Hz. Negative values of noise attenuation were measured at the double wall resonance frequency of 125 Hz.

10. An acoustic treatment for noise control in this aircraft should be composed of honeycomb panels, constrained layer damping tape, several layers of porous acoustic materials, and limp trim panel which is isolated for the vibration of the main structure. Furthermore, additional stiffening to window supports, some frames and longerons would need to be implemented.

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Table 1. Description of Add-on Treatments

Treatment	Materials and Specifications	Surface Density lb/ft^2
Honeycomb Panels	Aluminum: facing and core	0.60 - 0.66
Damping Tape	dense foam, adhesive and thin aluminum foil	0.296
Acoustic Blankets	Fiberglass/Thermal	0.04 (one 0.75 in thick layer)
Acoustic Foam	Open cell foam with thin aluminum foil facing	0.125 (one 0.5 in thick layer)
Noise Barriers	101: urethane elastomer bonded to decoupler foam 103: urethane elastomer bonded to acoustical foam 104: urethane elastomer bonded to decoupler and acoustical foams	0.5 - 1.0
Vinyl Septa	Lead impregnated vinyl fabric	0.26
Trim	Stiff masonite panel, noise barrier #101, or lead vinyl	1.06, 1.0, 0.26

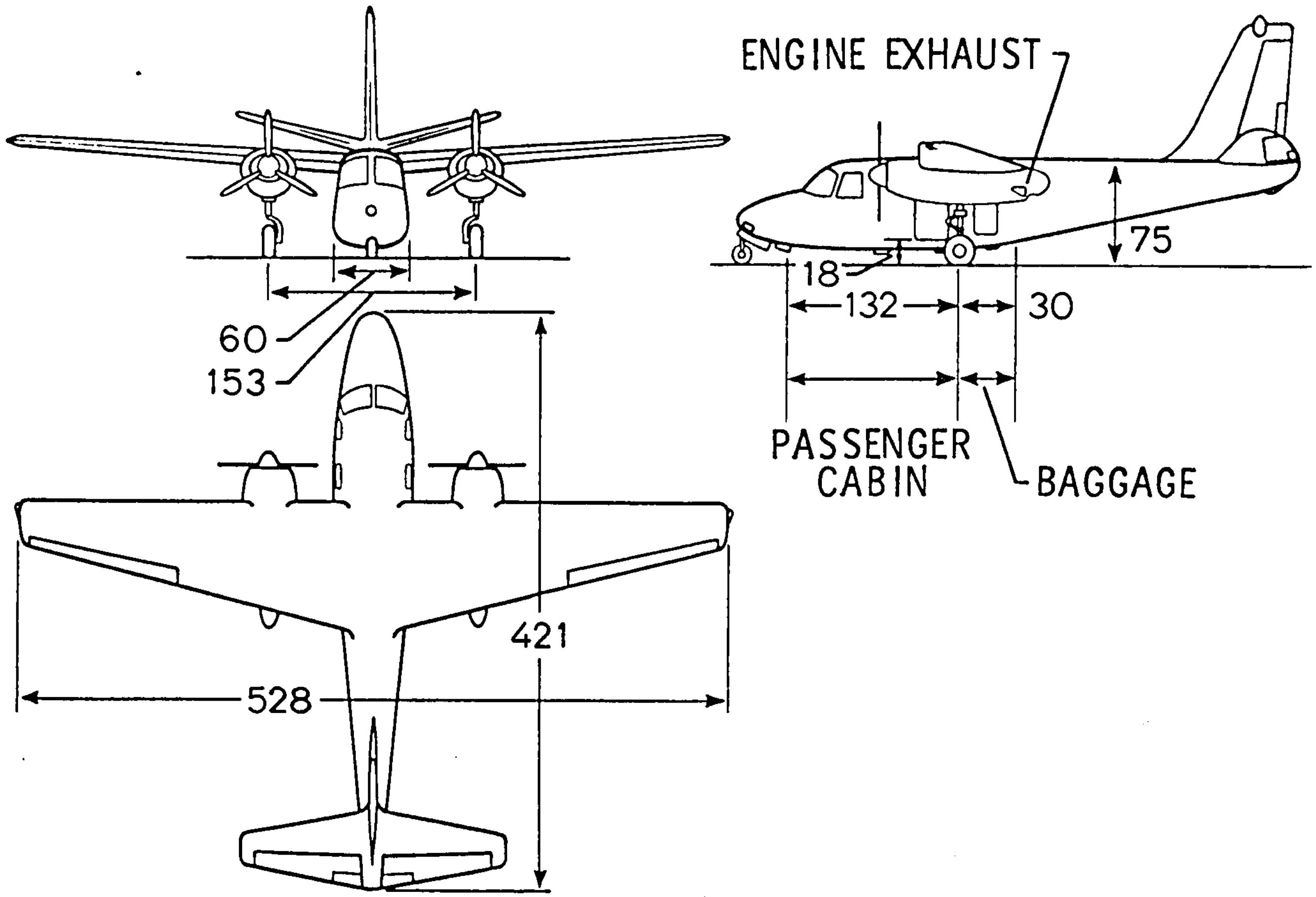


Fig. 1 Twin-engine aircraft used in the experimental study

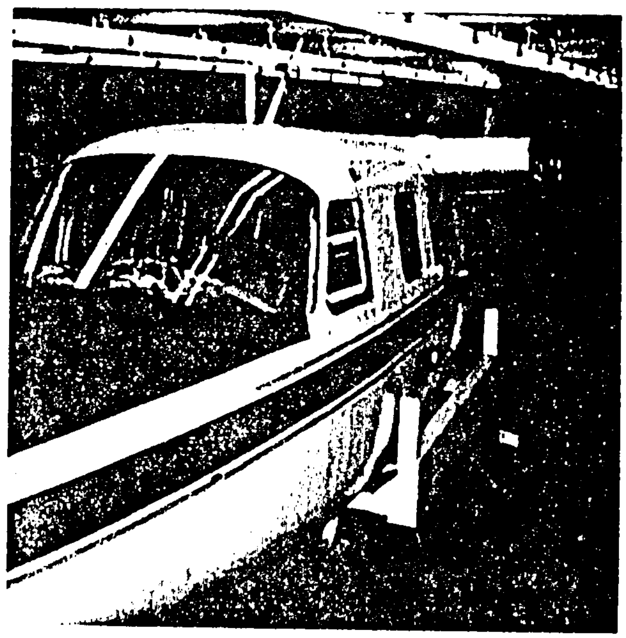


Fig. 2 Aircraft Fuselage in its Cradle Support

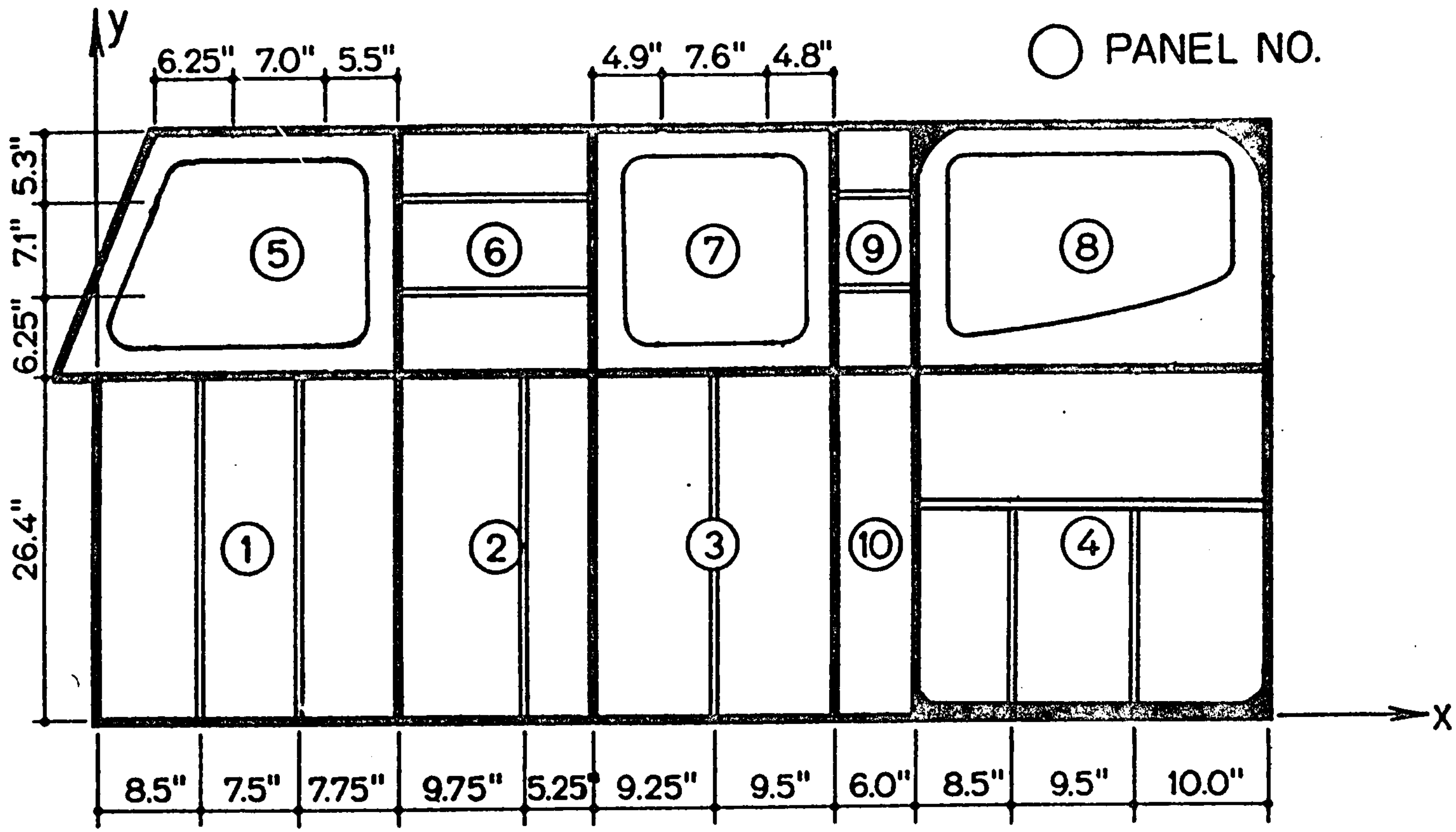


Fig. 3 Panel Identification for Port Side (P)

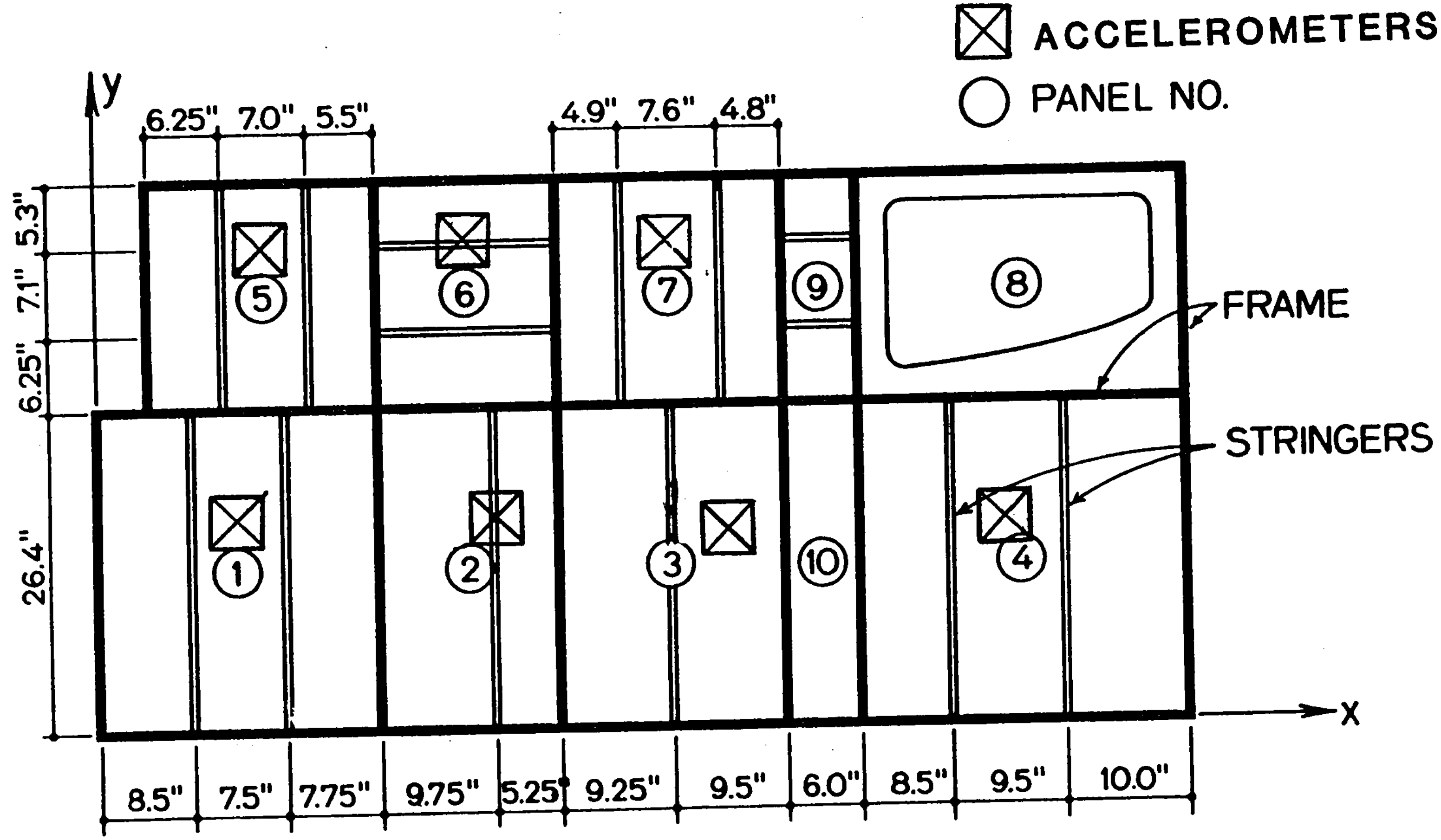


Fig. 4 Panel Identification for Starboard Side (S)

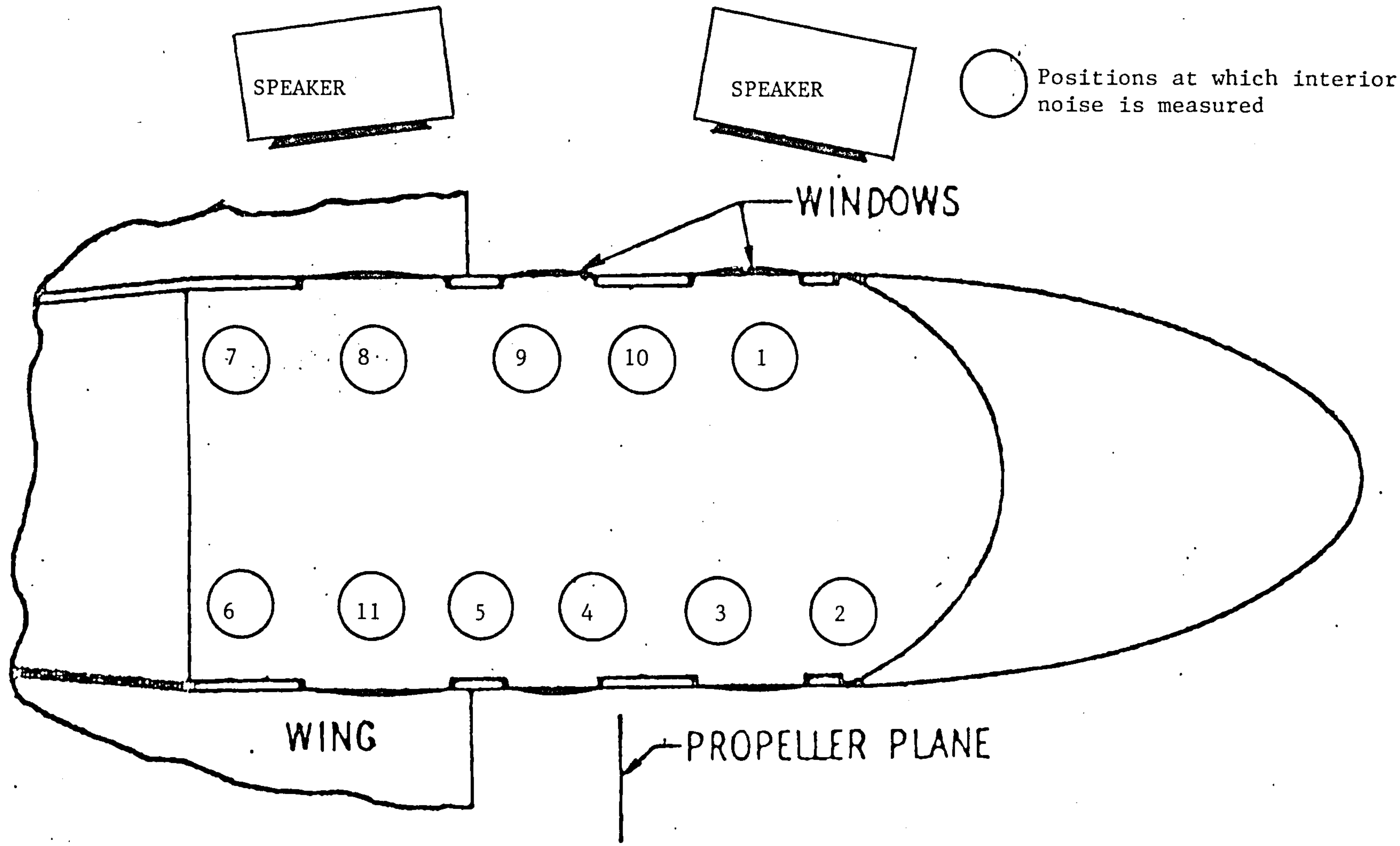


Fig. 5 Experimental Set-up for Noise Transmission through the Sidewall (Diffuse Noise Input)

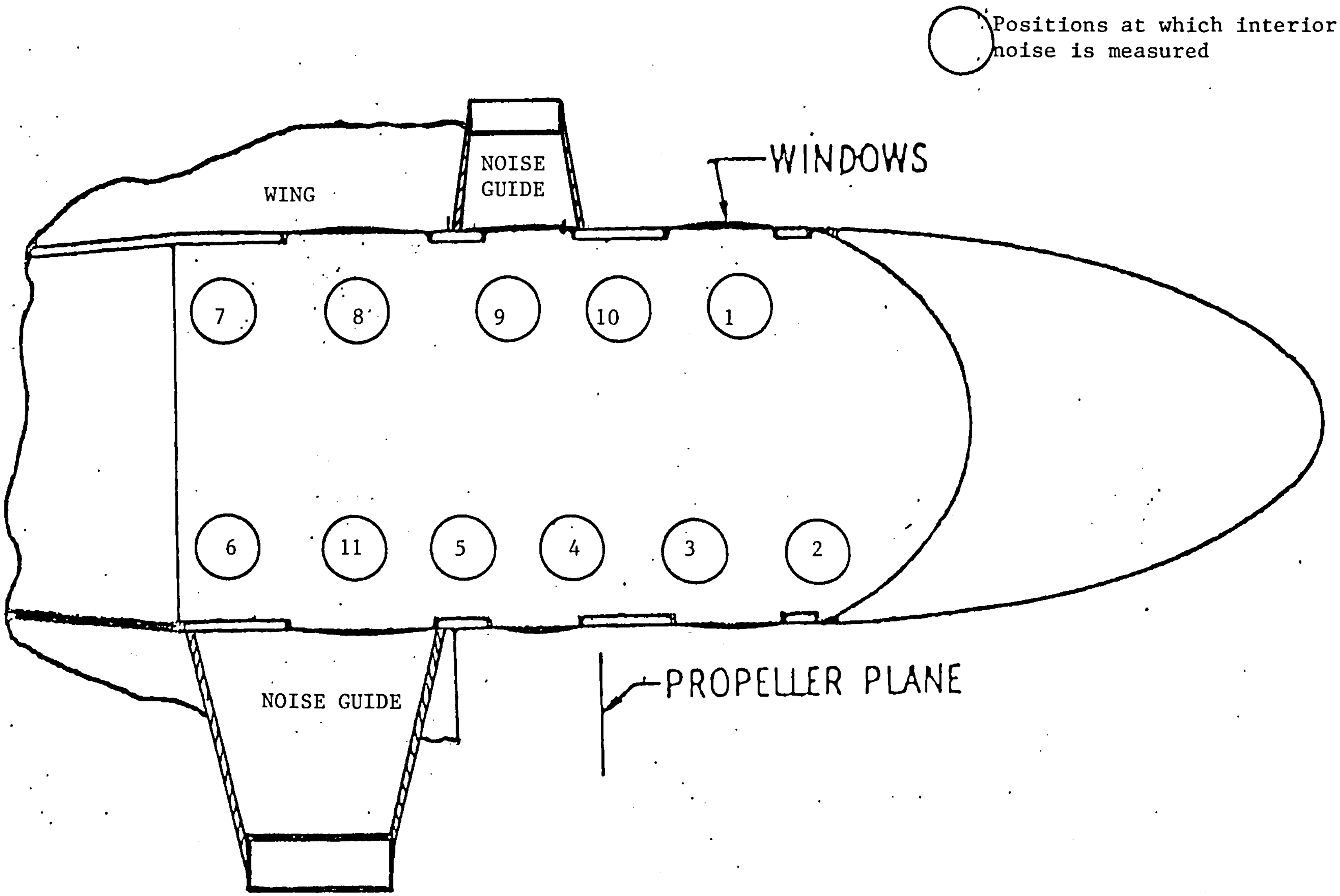


Fig. 6 Experimental Set-up for Noise Transmission through Localized Regions

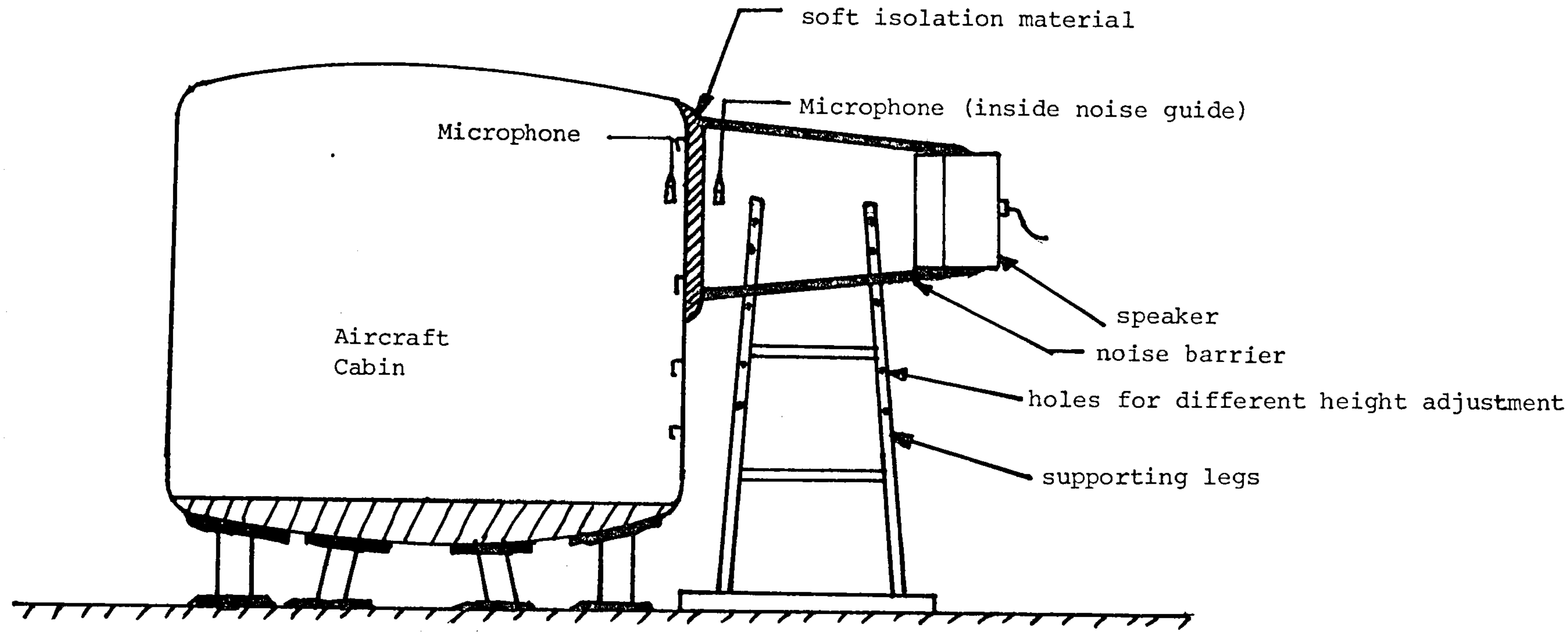


Fig. 7. Basic experimental set-up using a noise guide

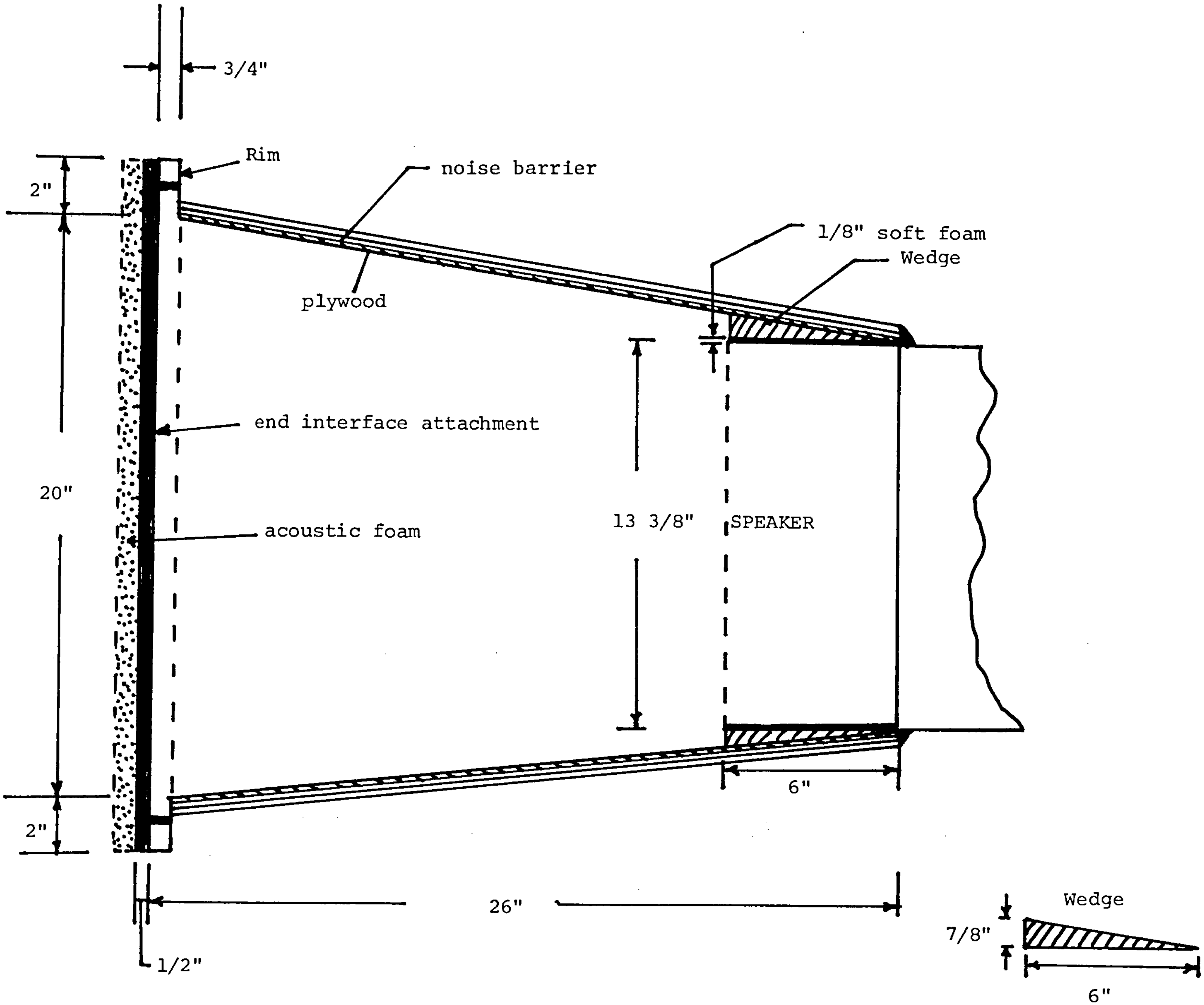


Fig. 8. Side view of the noise guide

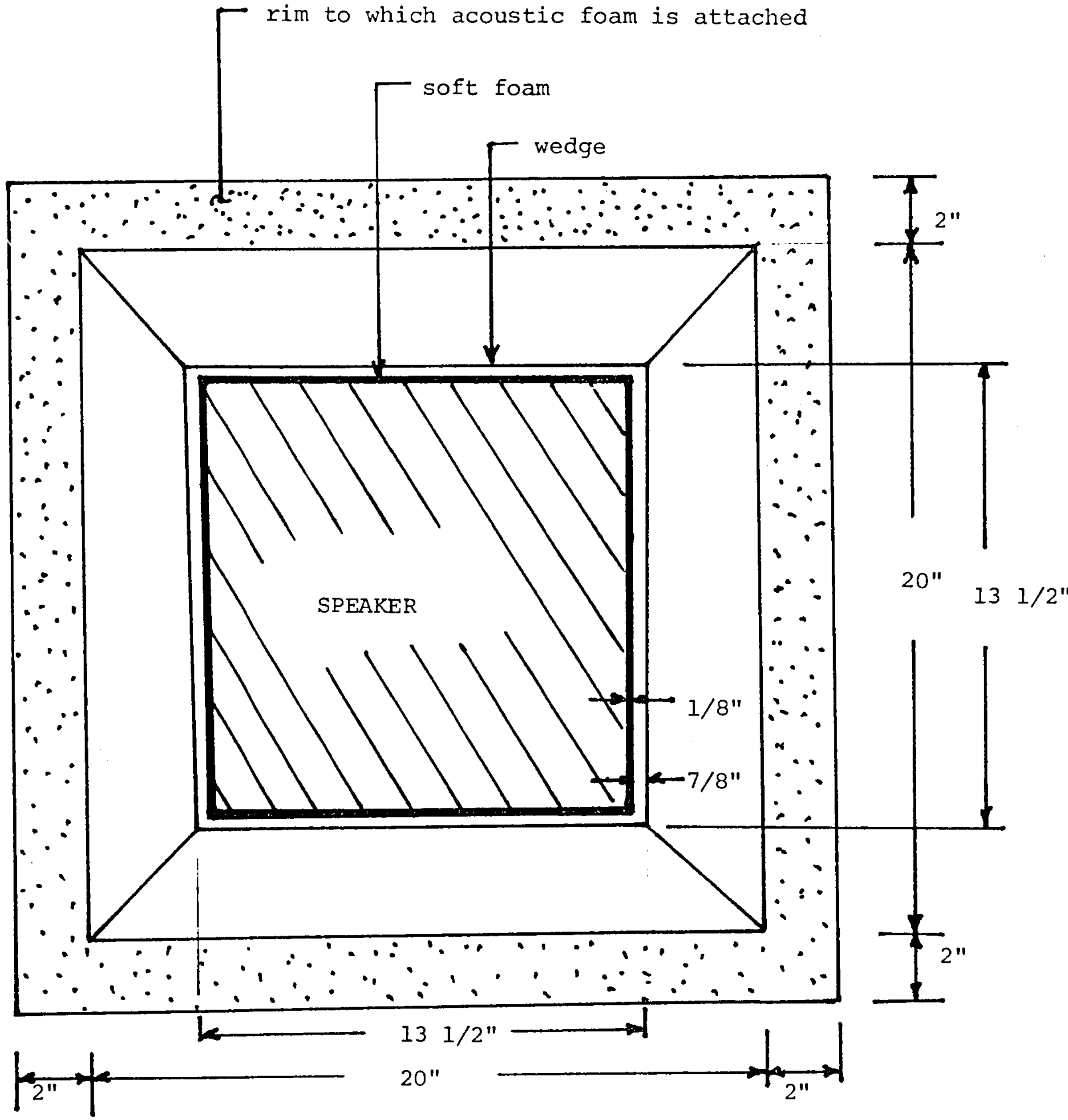


Fig. 9. End view of the noise guide

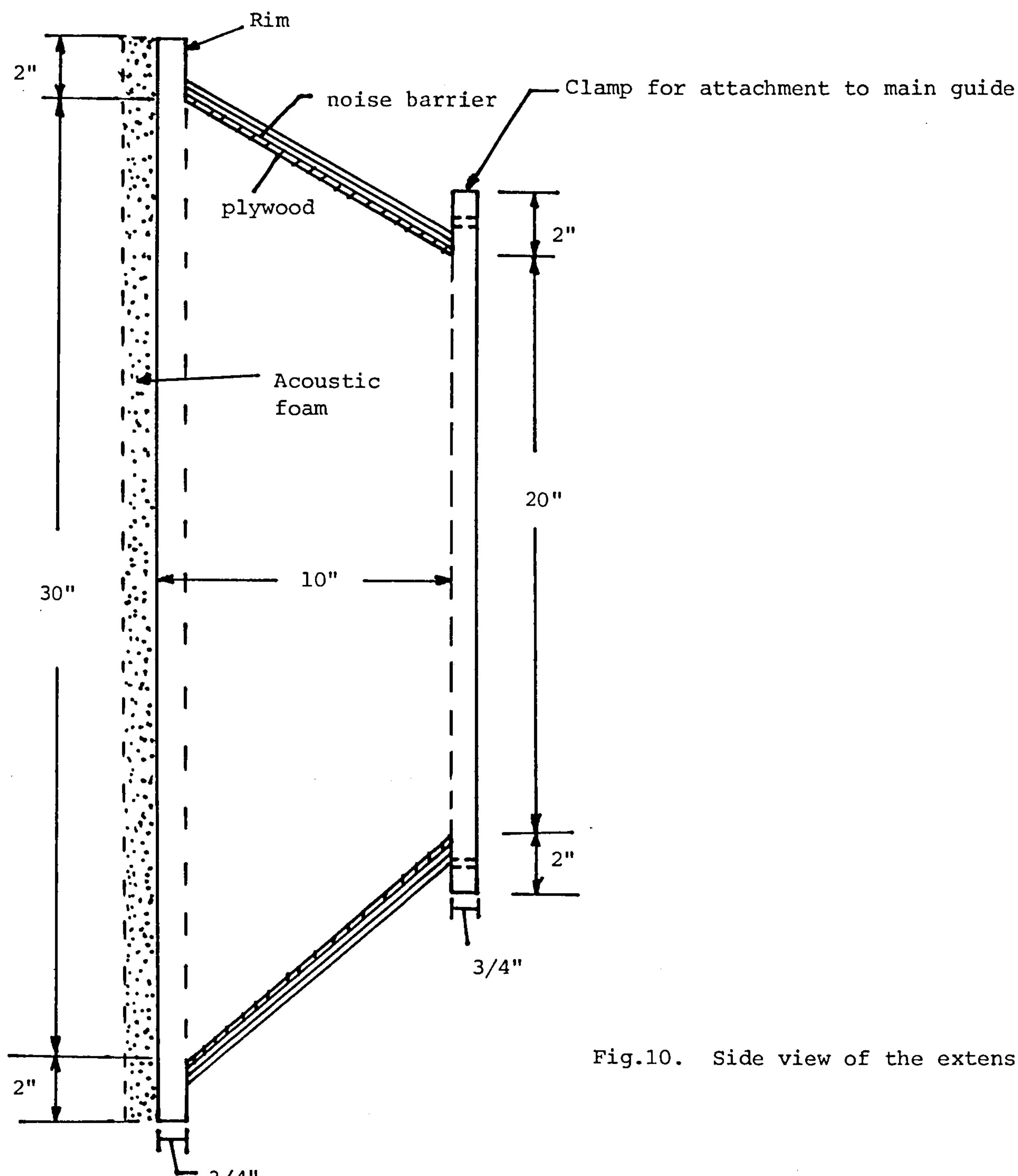


Fig.10. Side view of the extension

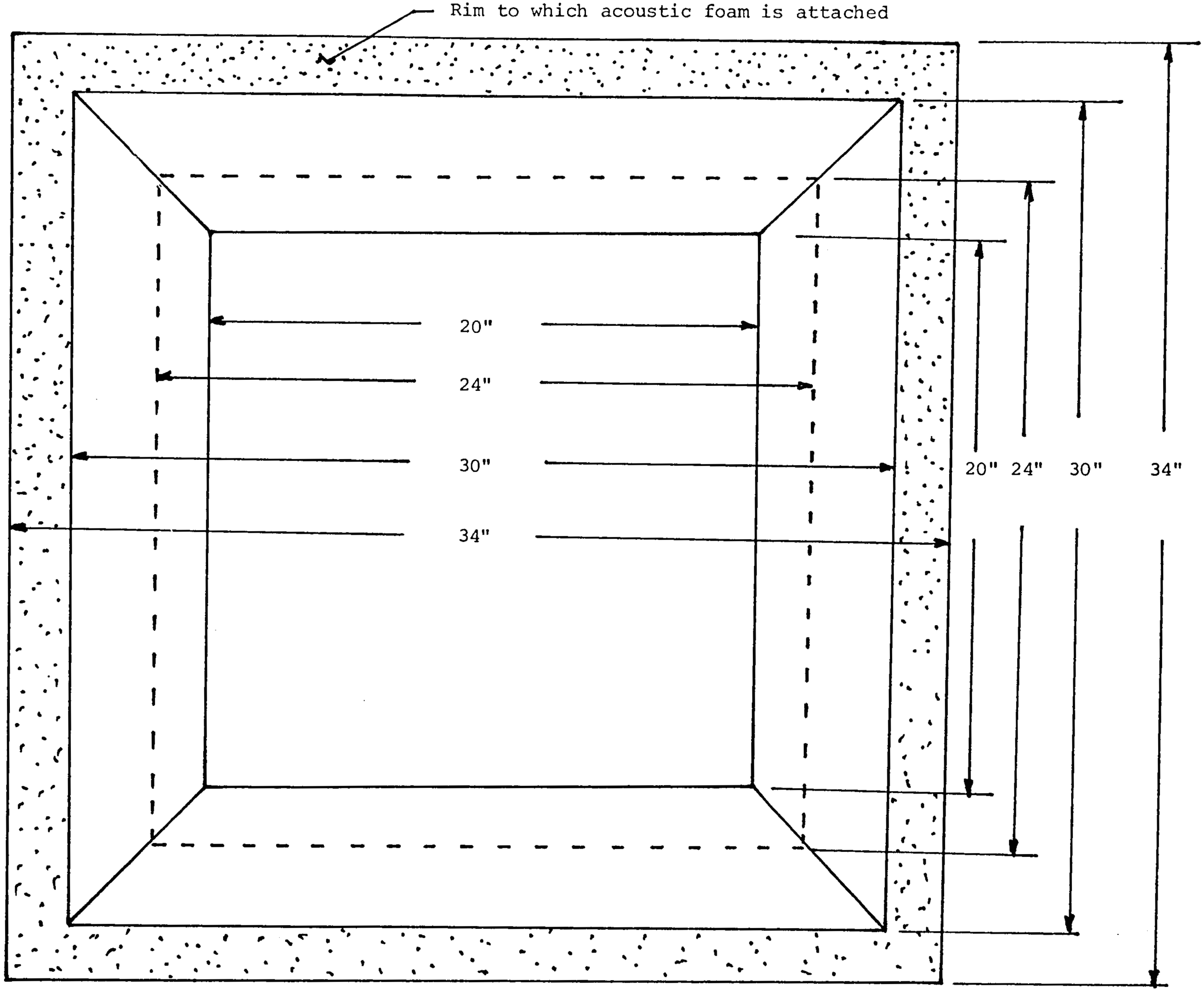


Fig. 11. End view of the extension

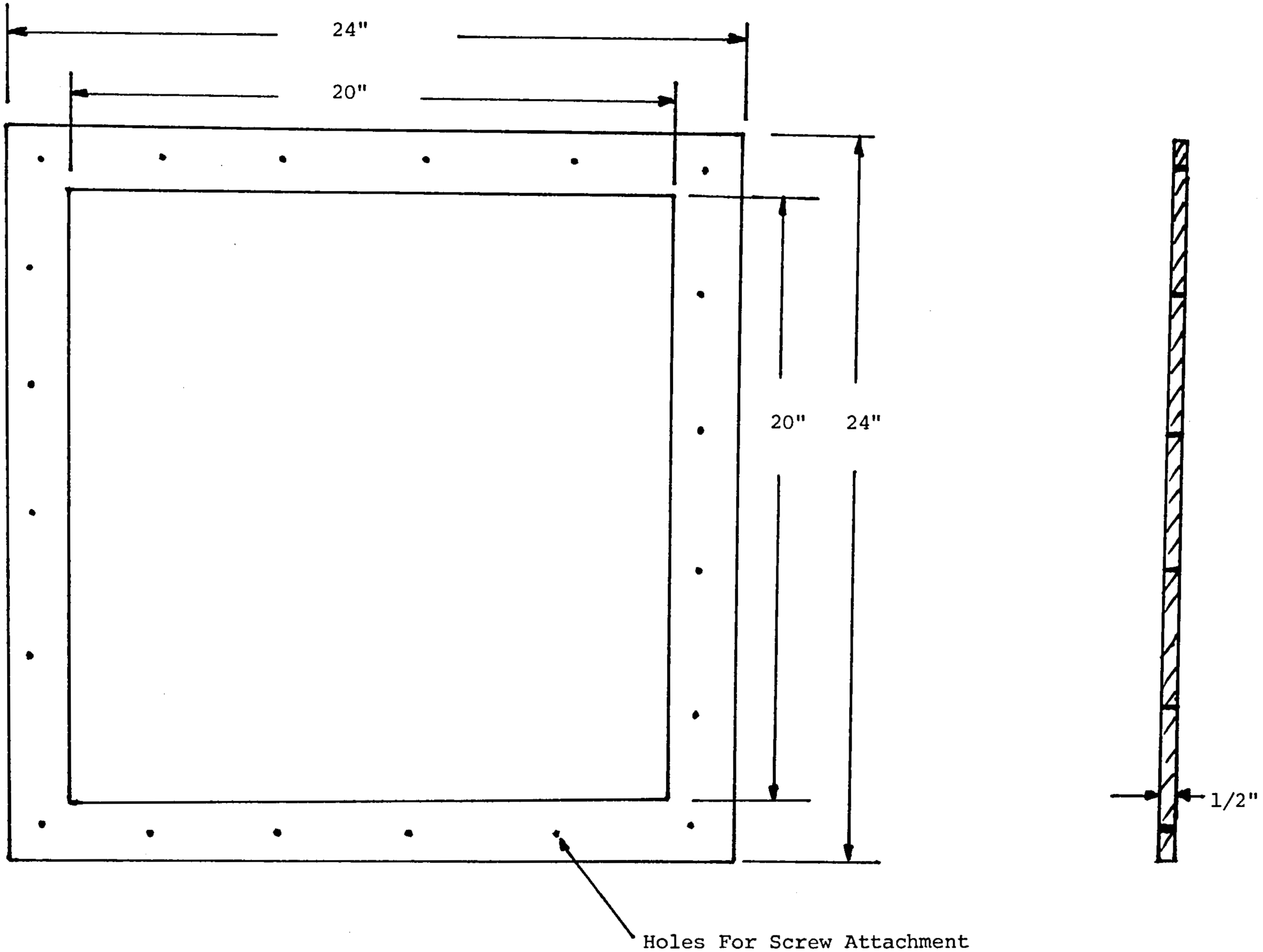


Fig.12. Surface interface to be attached to the end of the guide

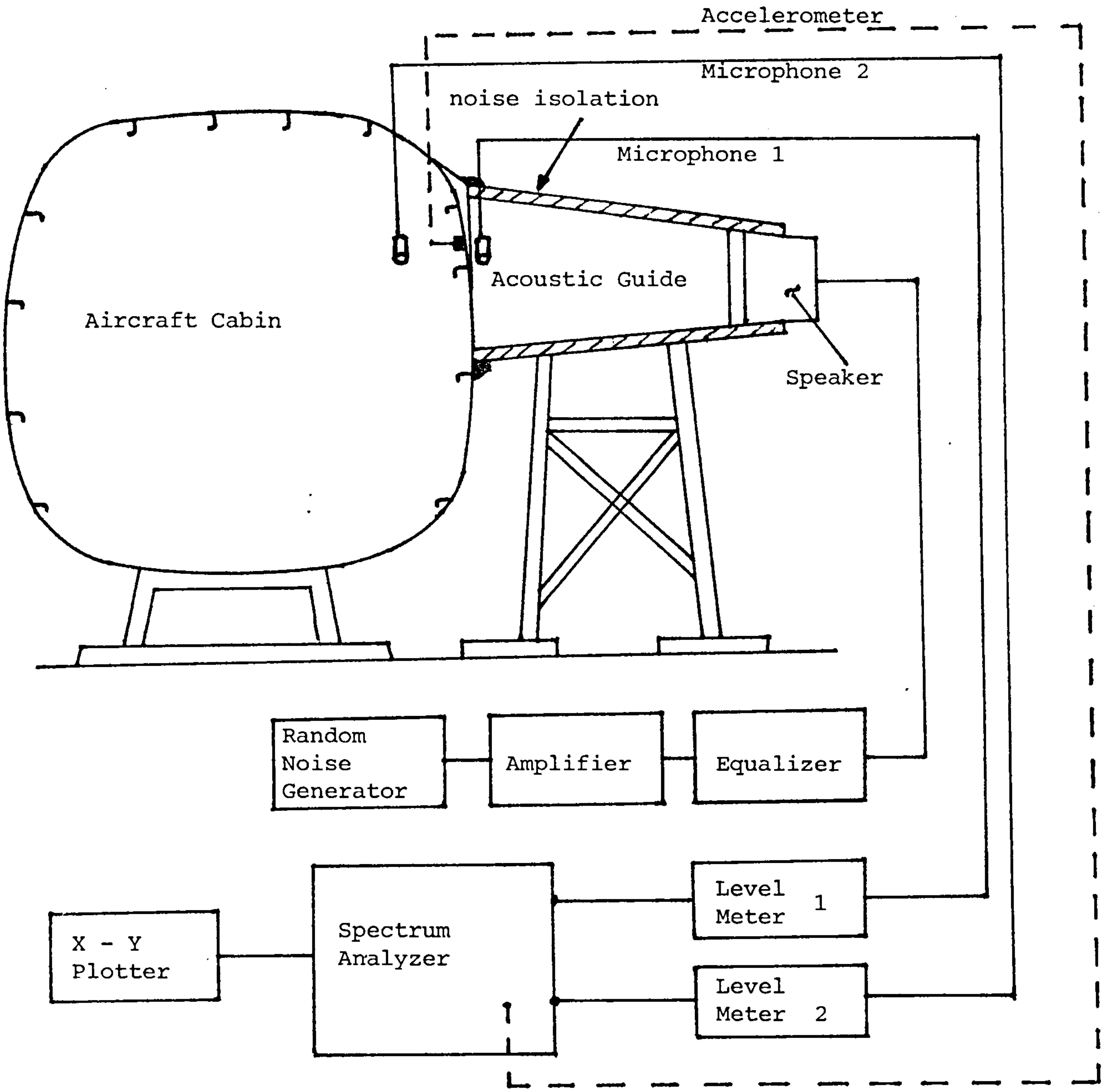


Fig. 13 Experimental Setup for Noise Transmission Study with an Acoustic Guide

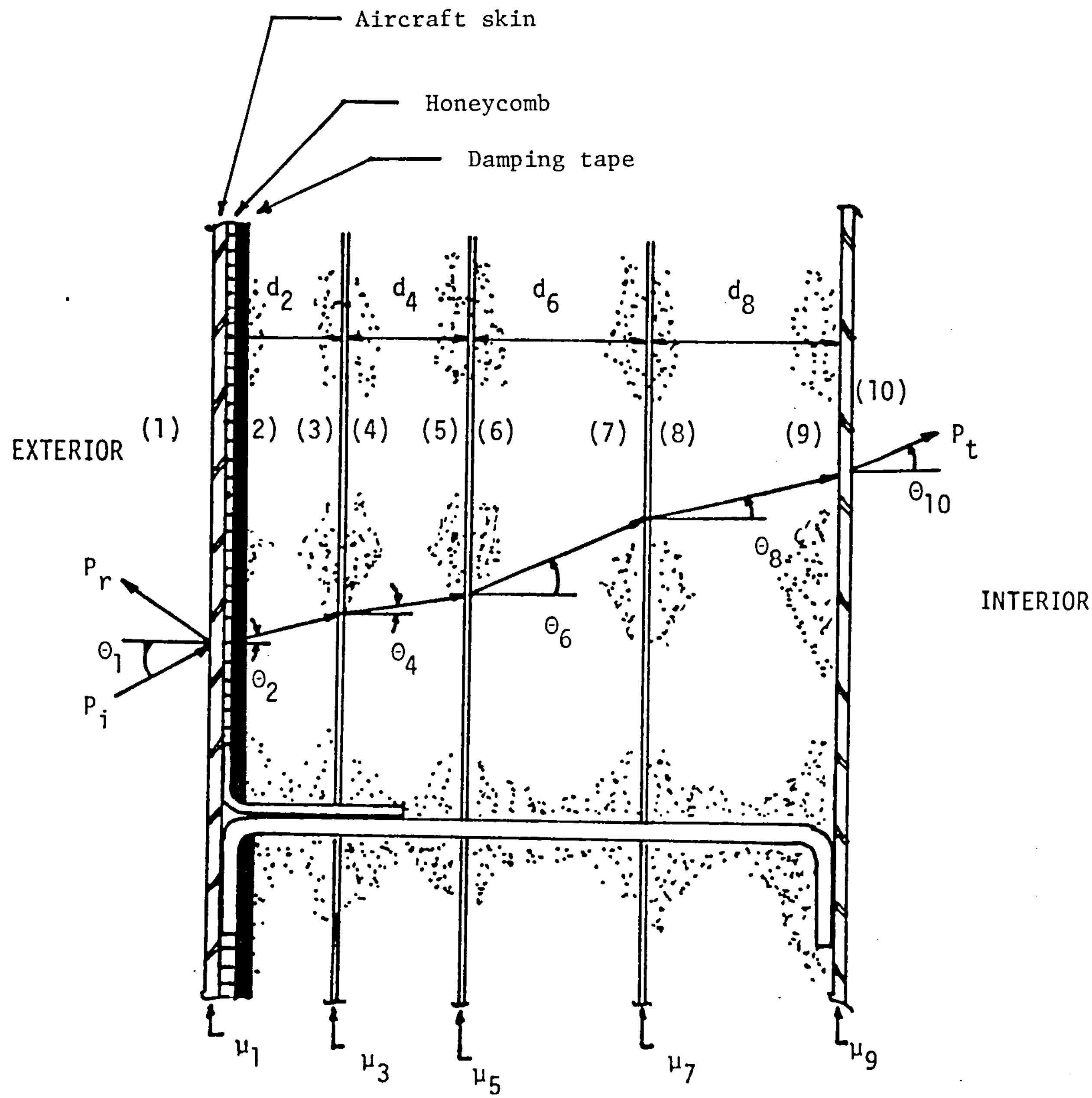


Fig. 14 Geometry of a Multi-layered Add-on Sidewall Treatment

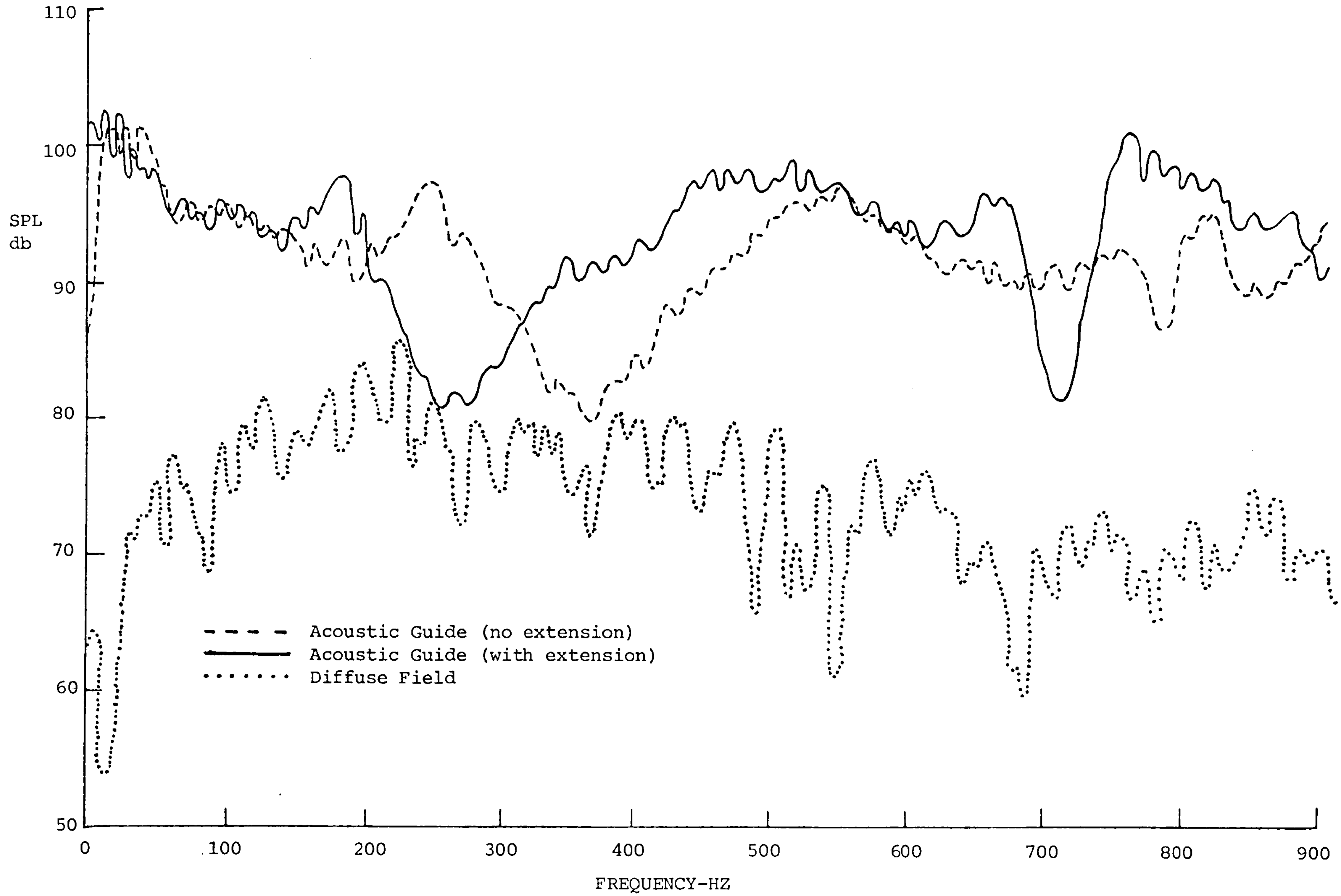


Fig. 15 Sound Pressure Levels for Diffuse and Localized Noise Inputs

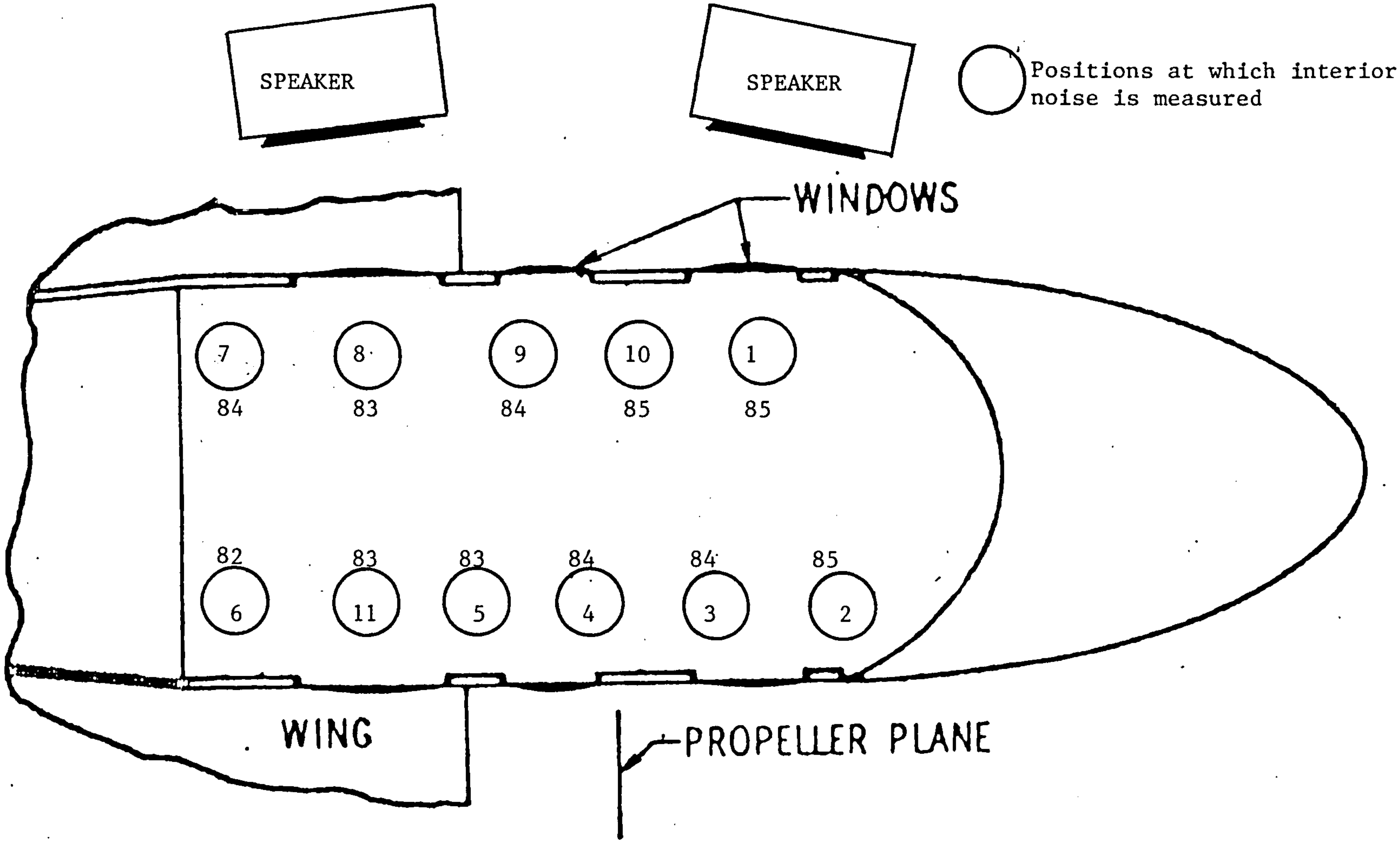


Fig. 16 Interior SPL (dB) for a Diffuse Field Noise Input

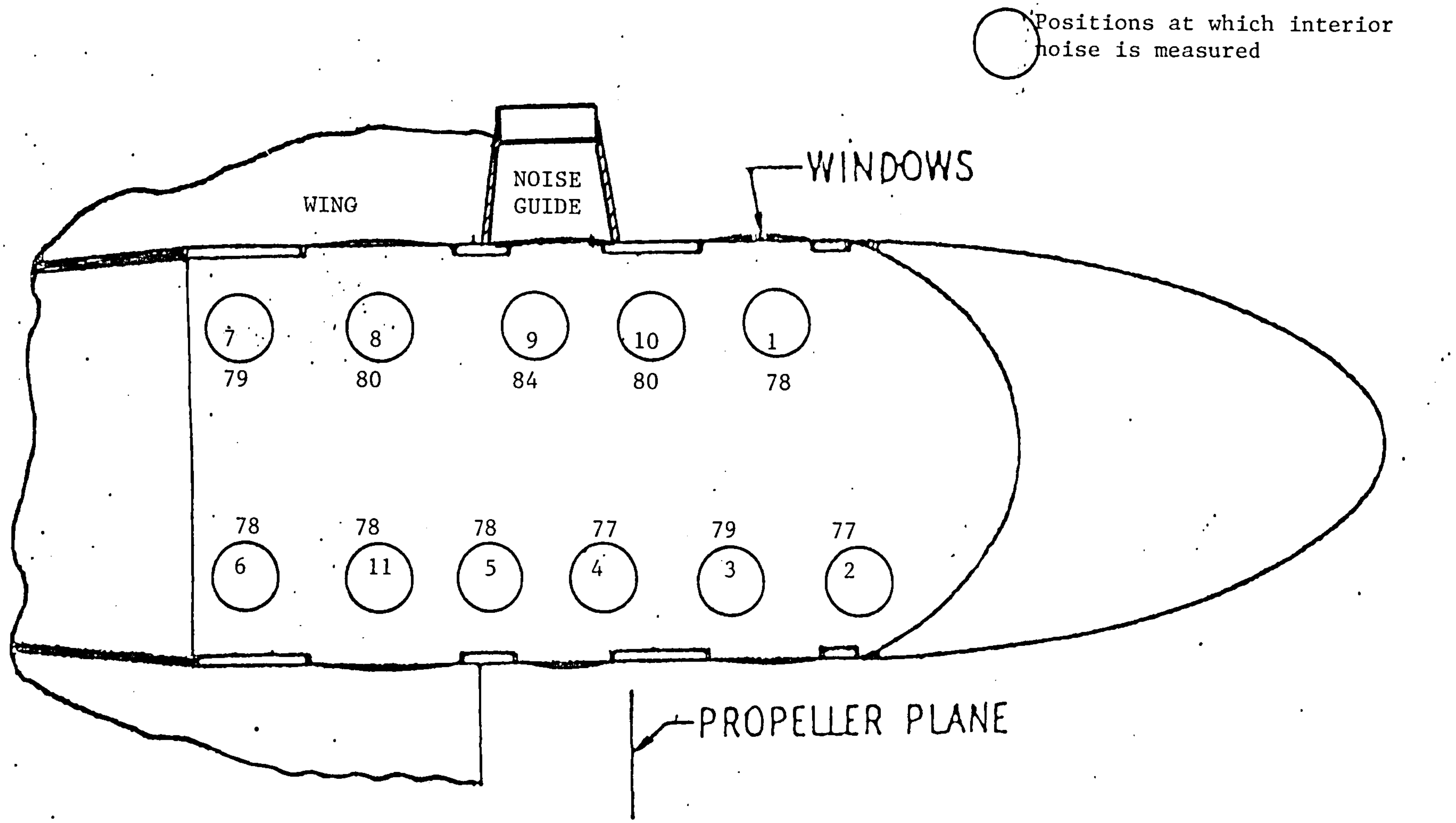


Fig. 17 Interior SPL (dB) for Noise Transmission through a Window

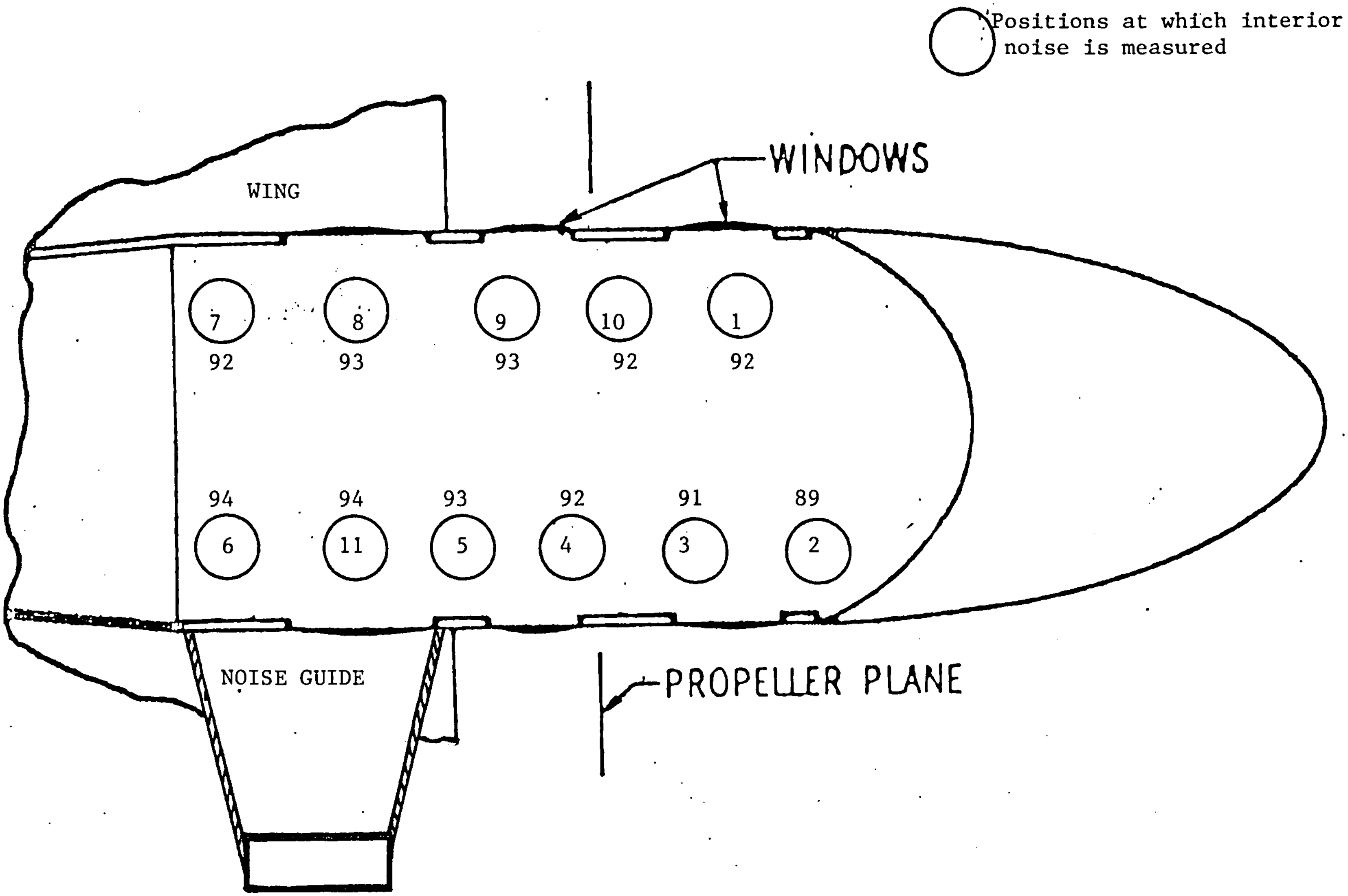


Fig. 18 . Interior SPL (dB) for Noise Transmission through Panel 4S

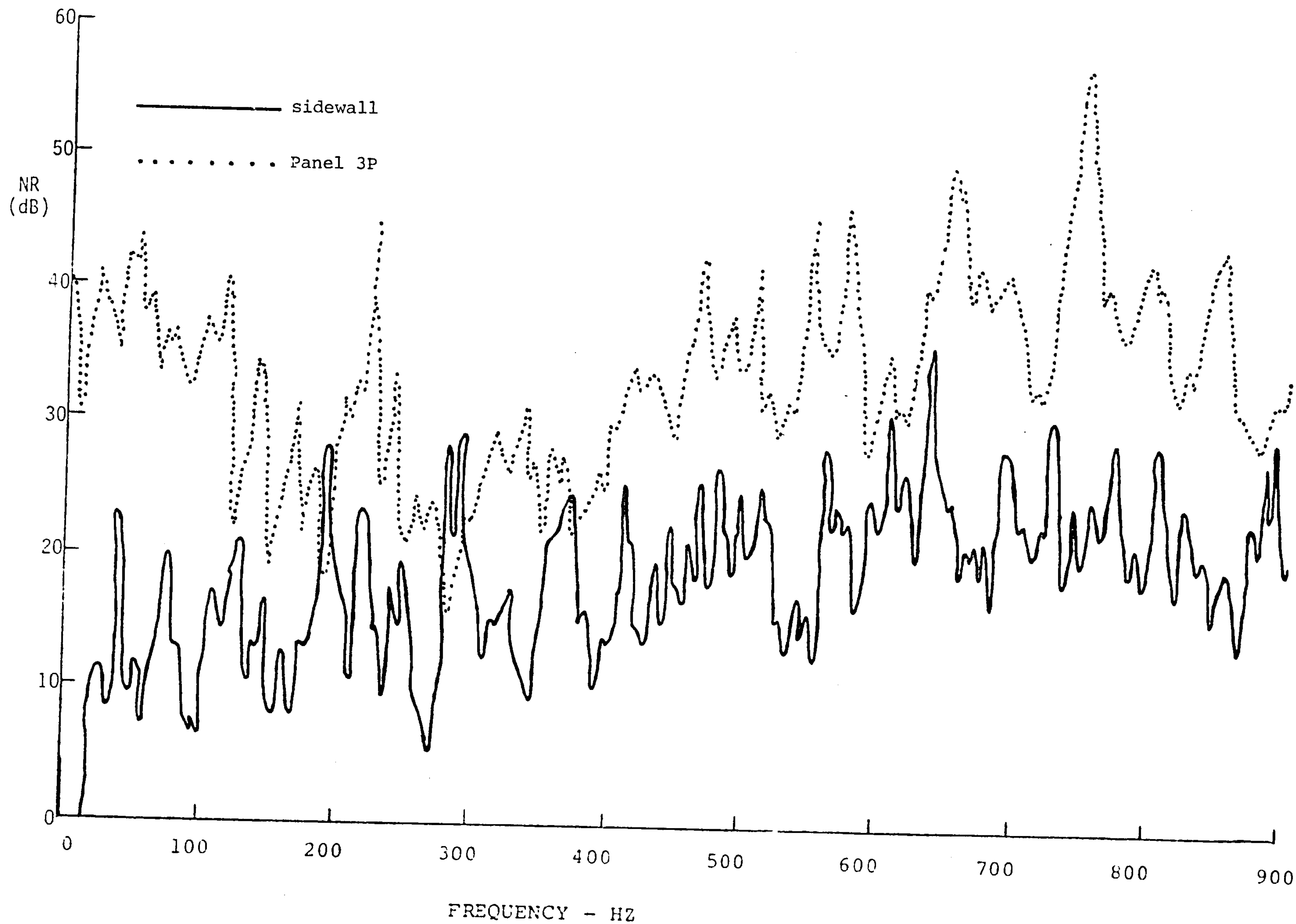


Fig. 19 Noise Reduction for Bare Sidewall and Panel 3P (acoustic guide area 30 in x 30 in)

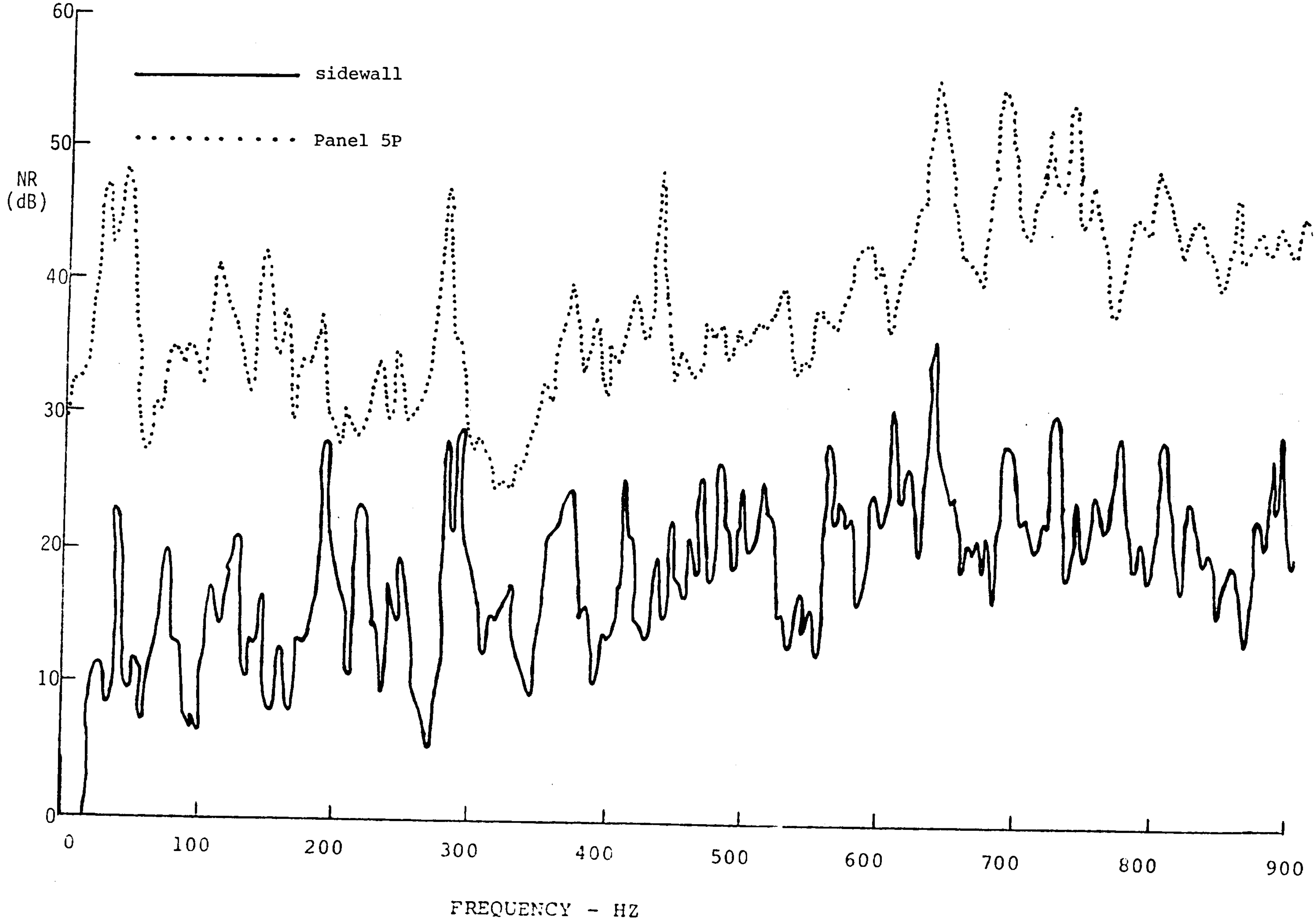


Fig. 20 Noise Reduction for Untreated Sidewall and Panel 5P (window, single pane)

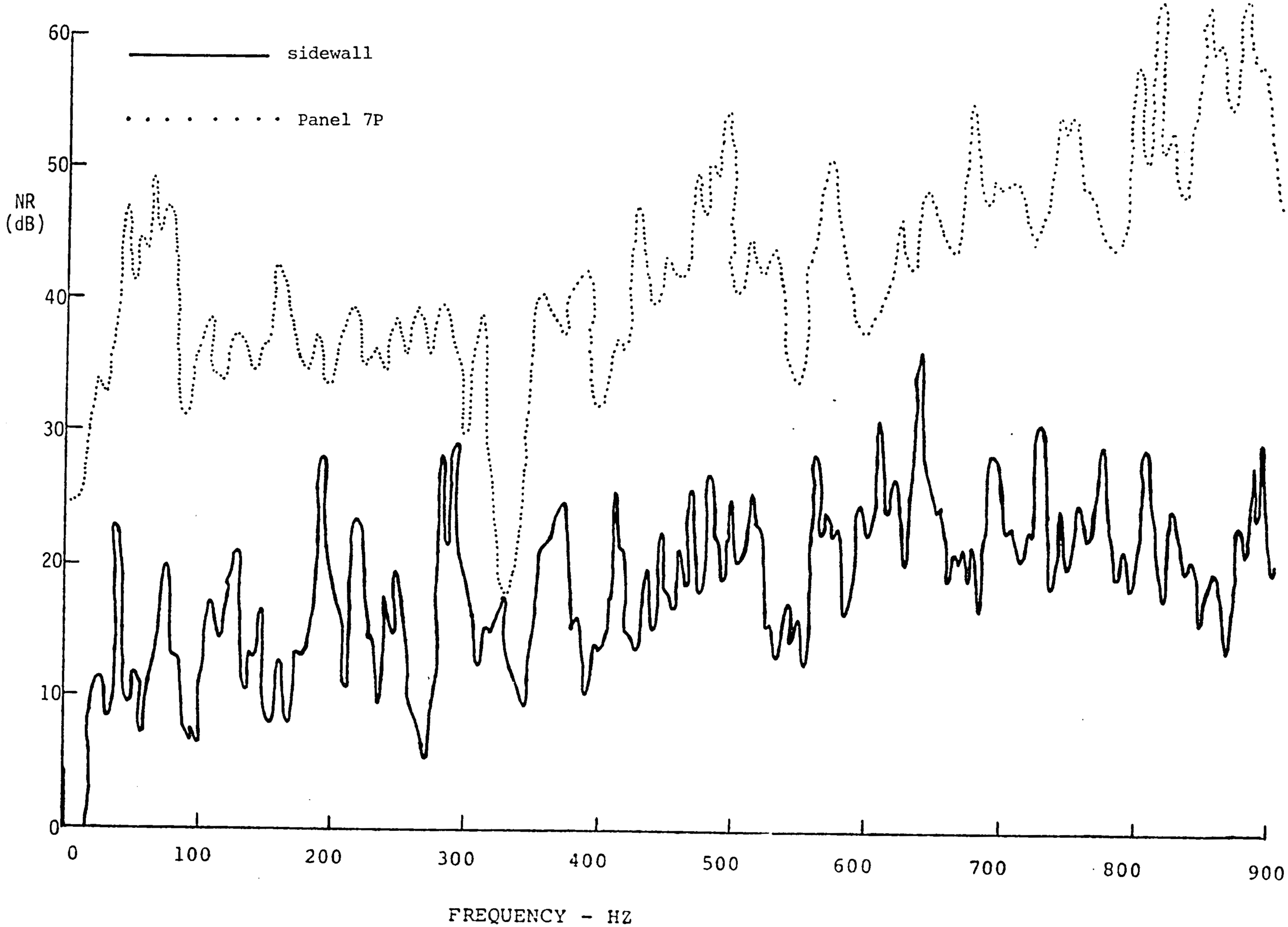


Fig. 21 Noise Reduction for Untreated Sidewall and Panel 7P (double pane window)

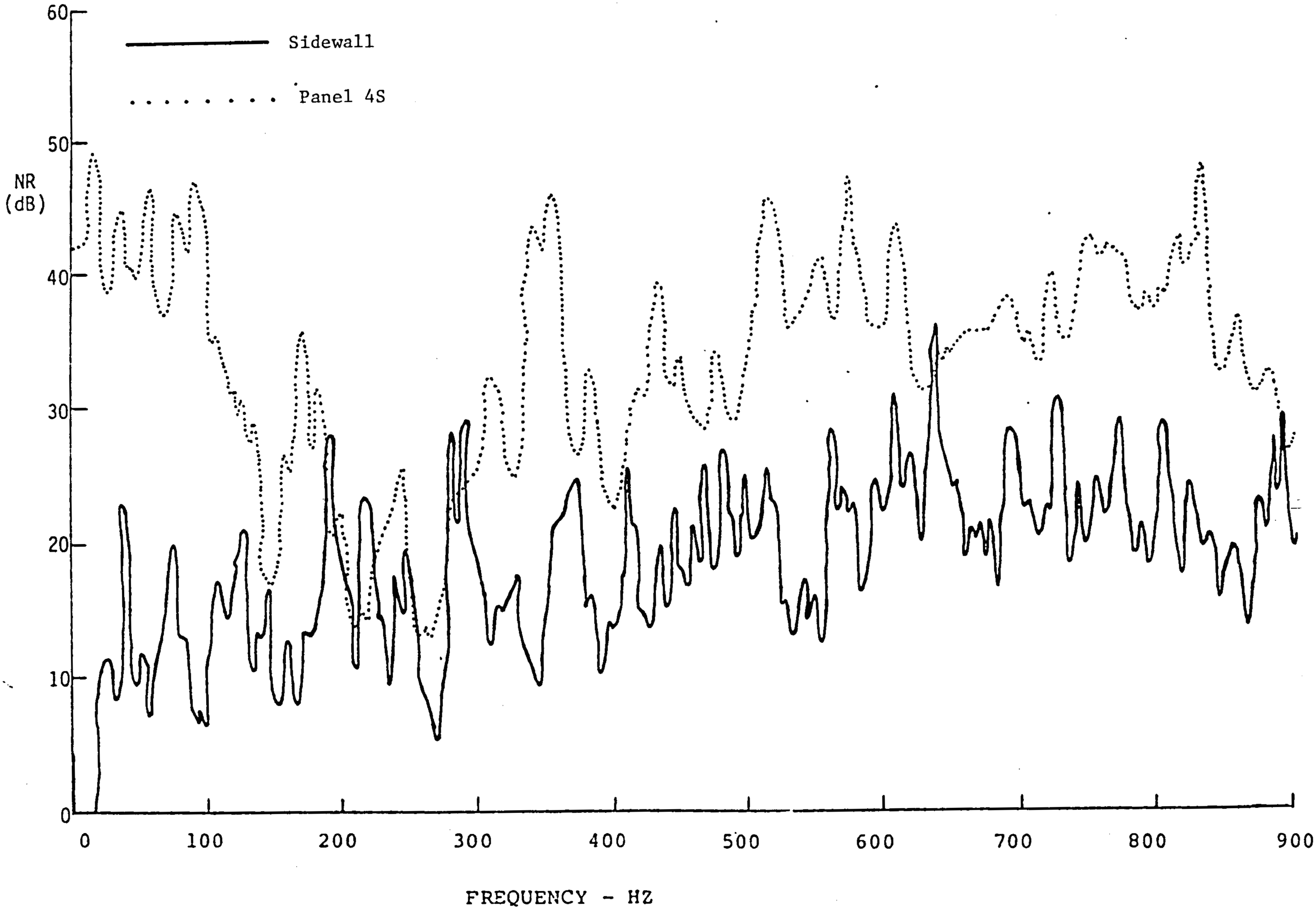


Fig. 22 Noise Reduction for Untreated Sidewall and Panel 4S

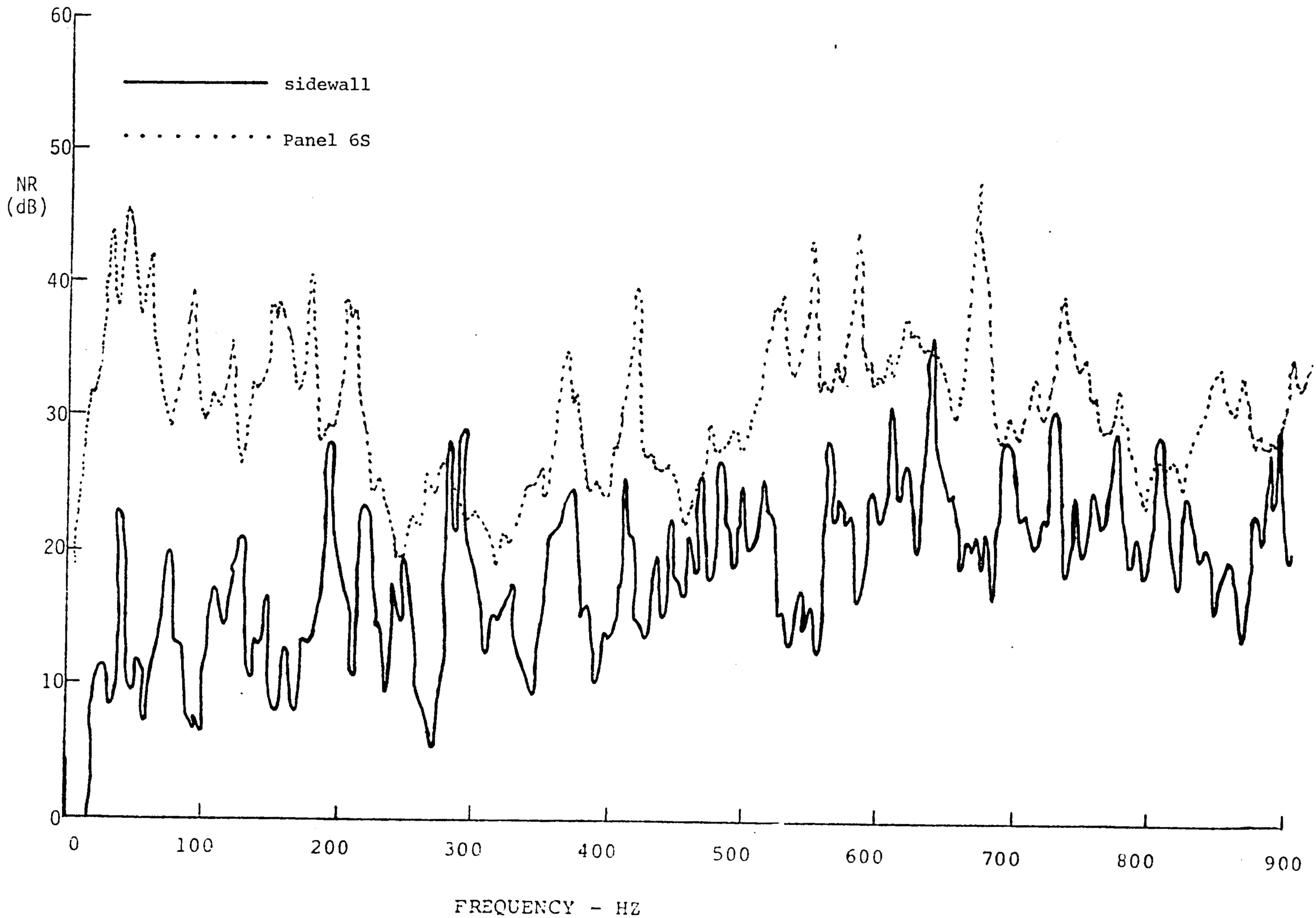


Fig. 23 Noise Reduction for Untreated Sidewall and Panel 6S

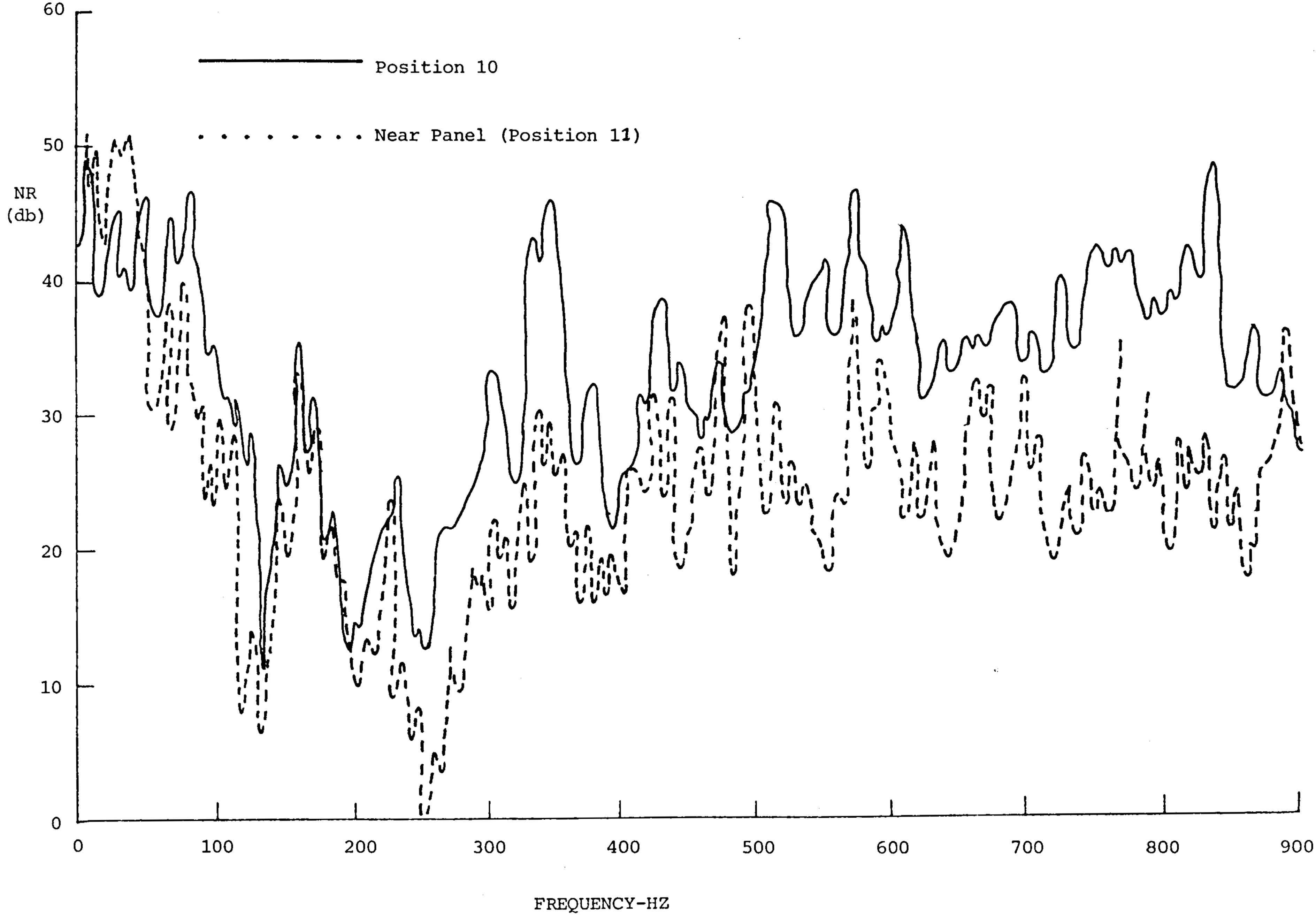


Fig. 24 Noise Reduction for Untreated Panel 4S Measured at Two Locations

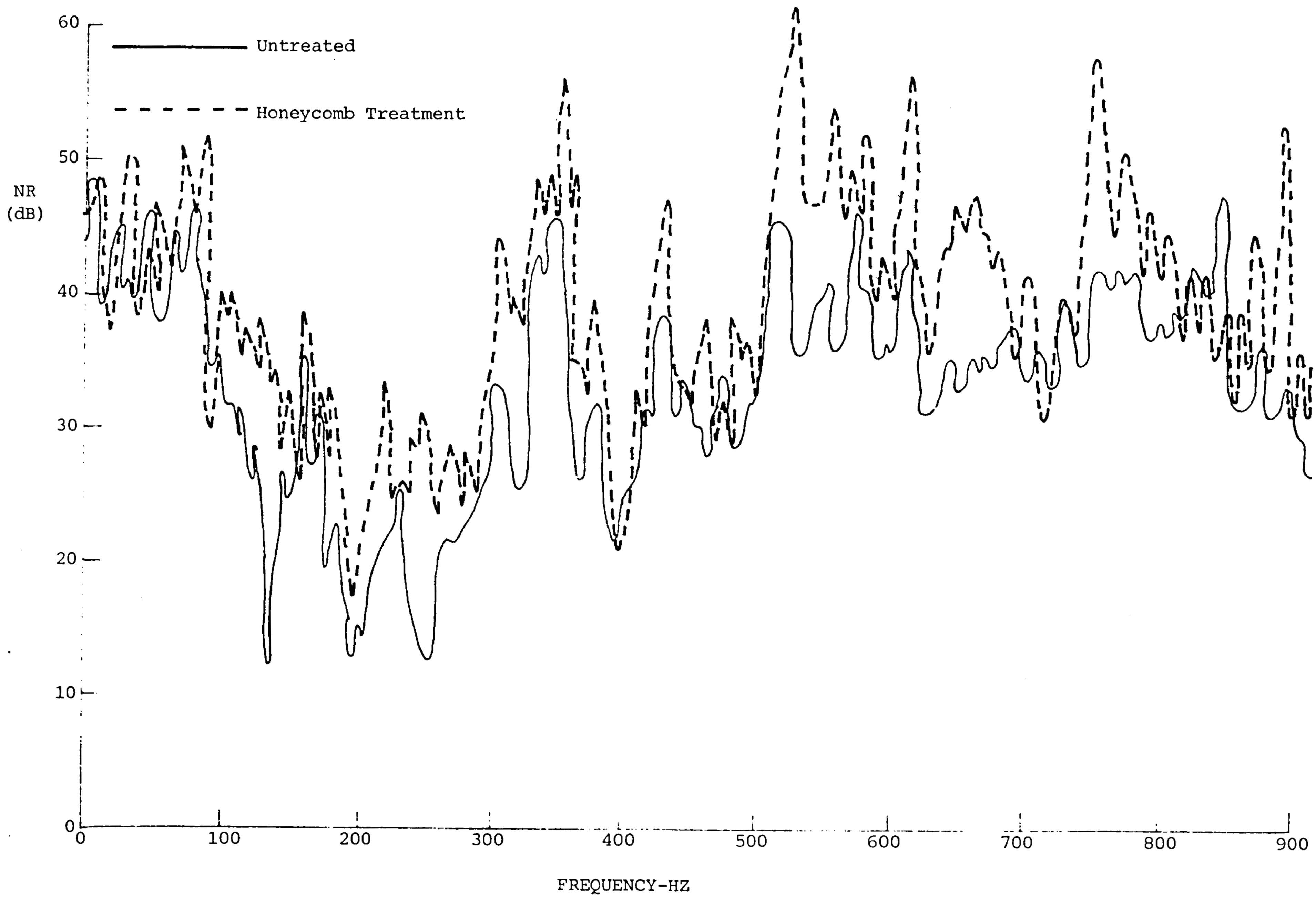


Fig. 25 Noise Reduction for Panel 4S (Position 10)

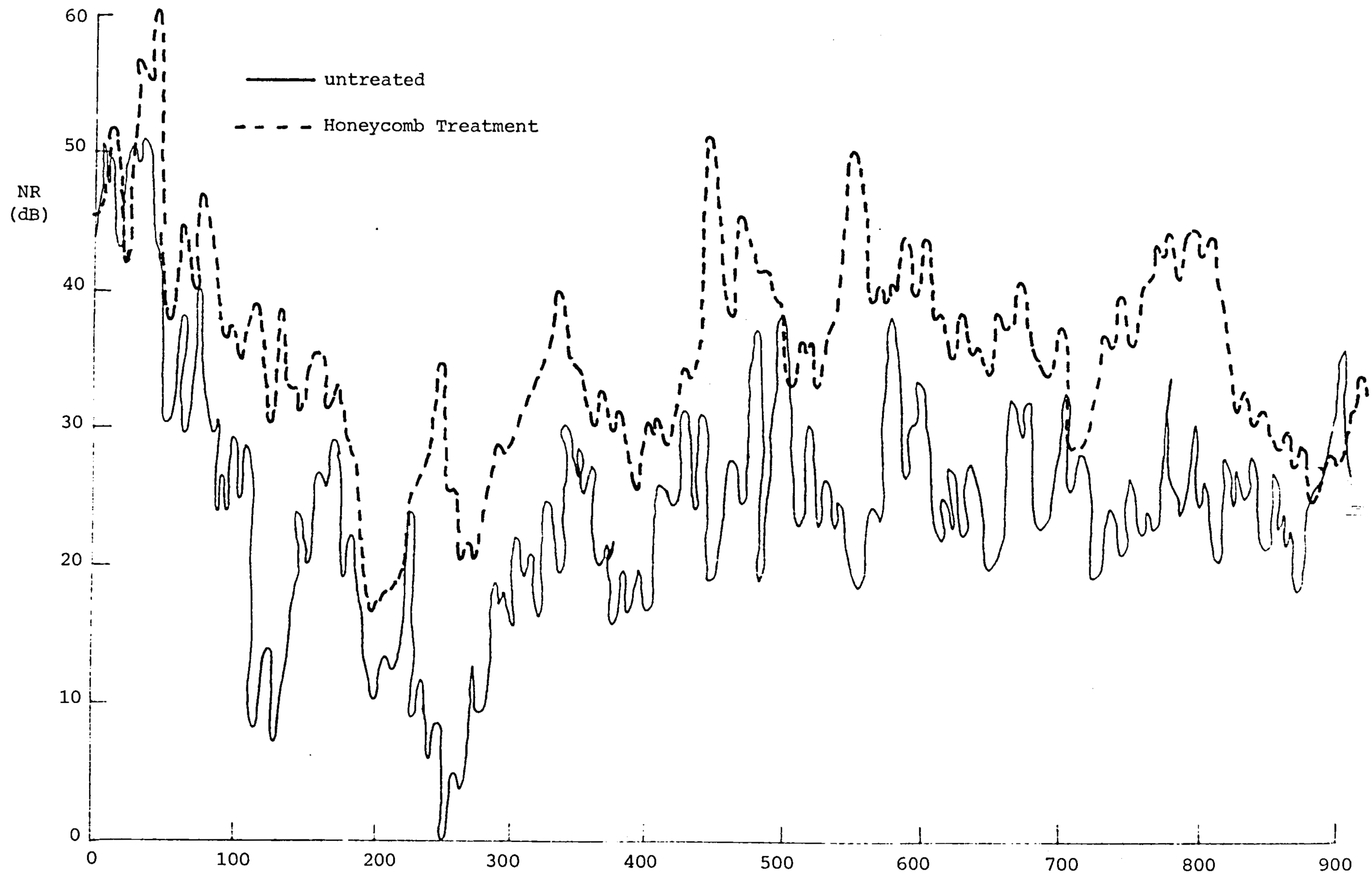


Fig. 26 Noise Reduction for Panel 4S (Position 11)

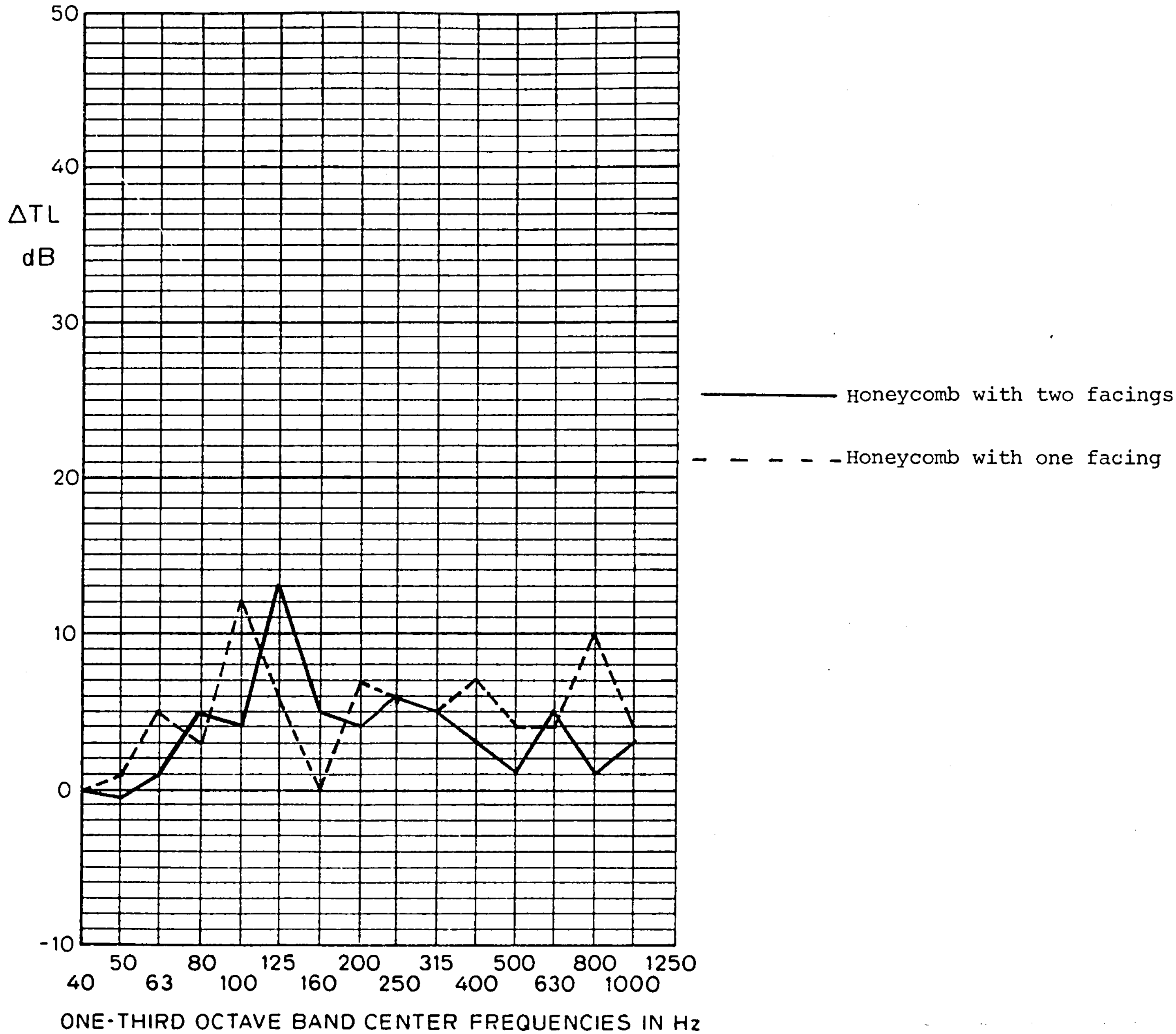


Fig. 27 Insertion Loss for Panel 4S Due to Honeycomb Treatment (Position 10)

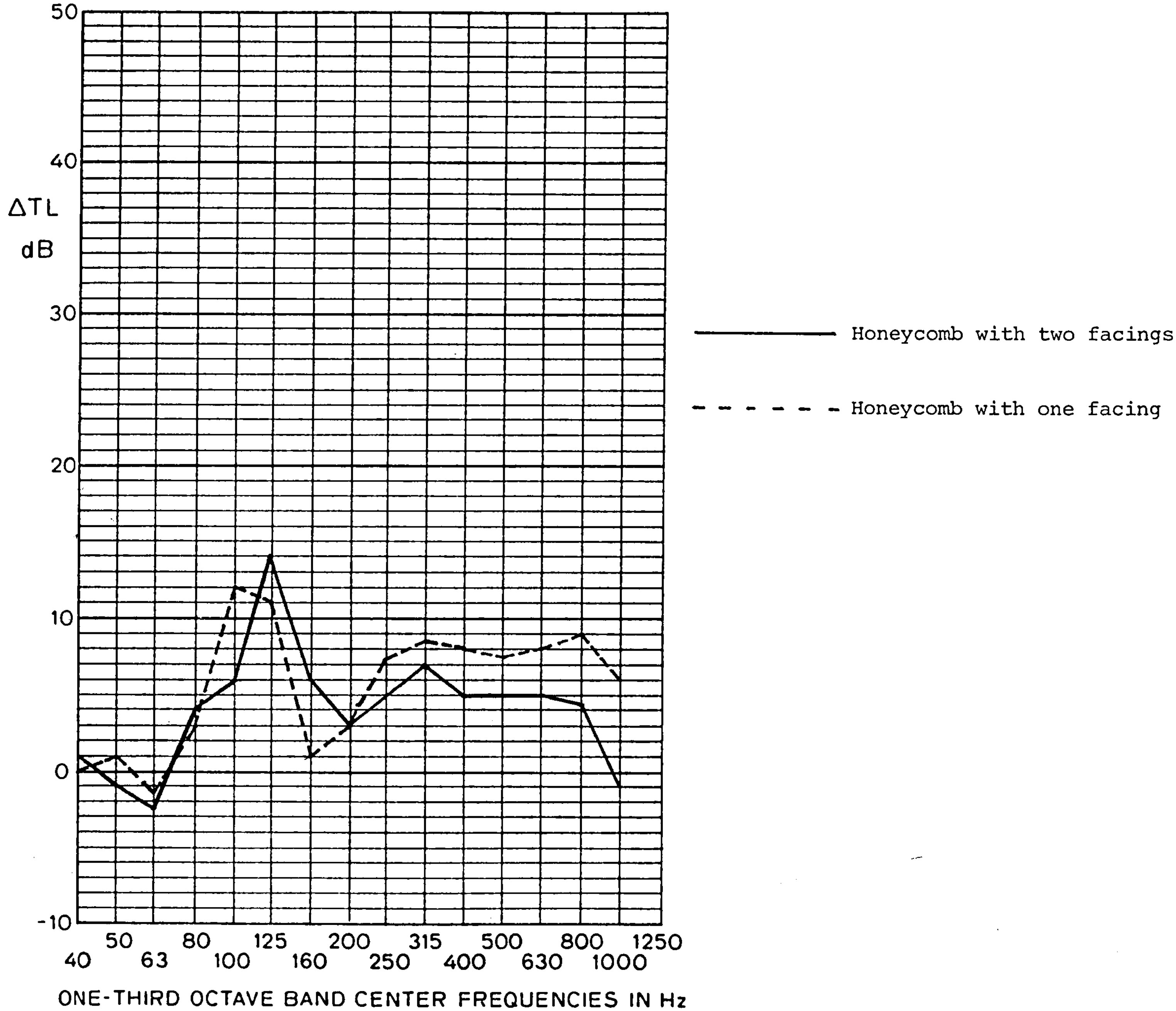


Fig. 28 Insertion Loss for Panel 4S Due to Honeycomb Treatment (Position 11)

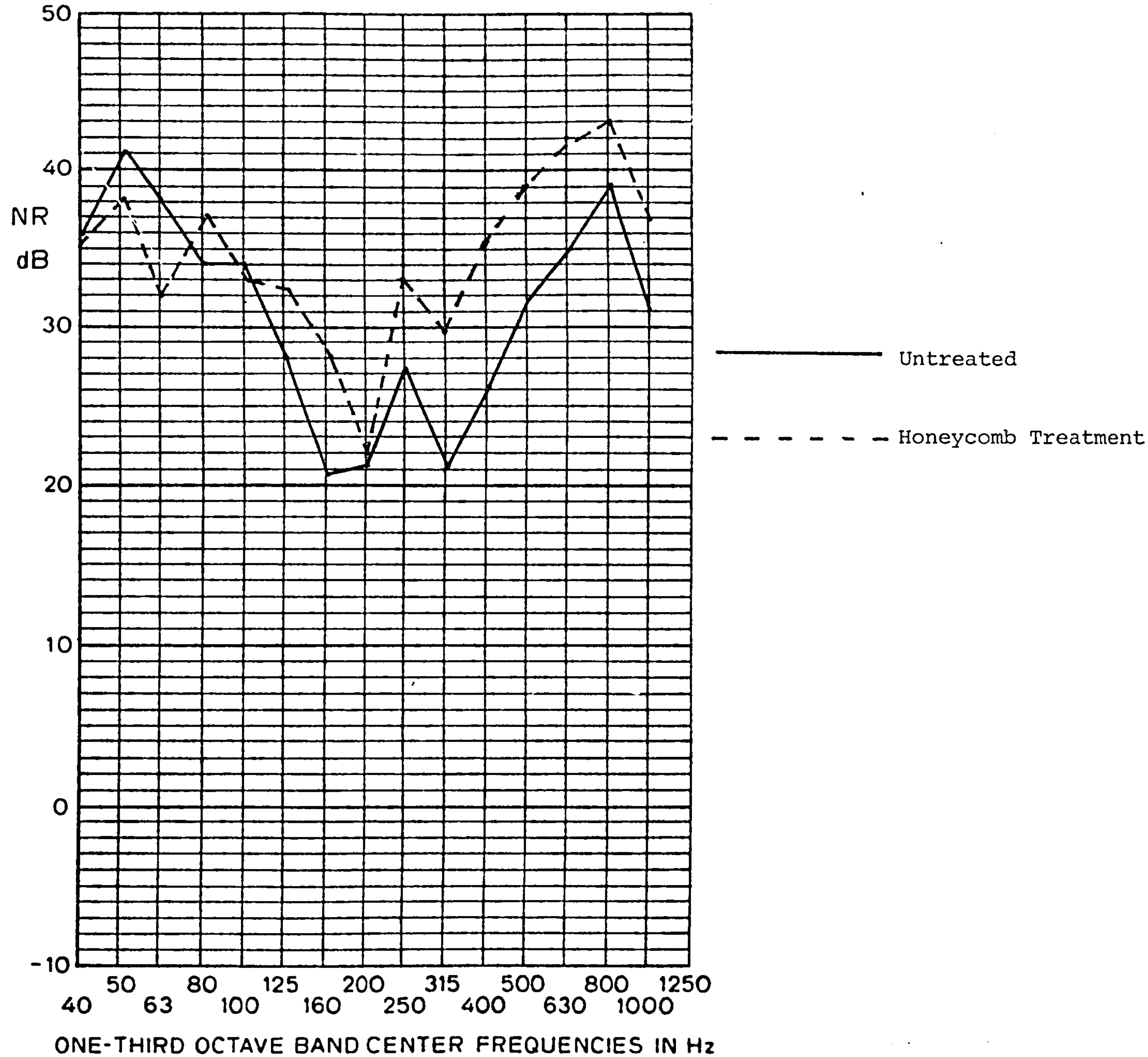


Fig. 29 Noise Reduction for Panel 3P with and without Honeycomb Treatment (Position 10)

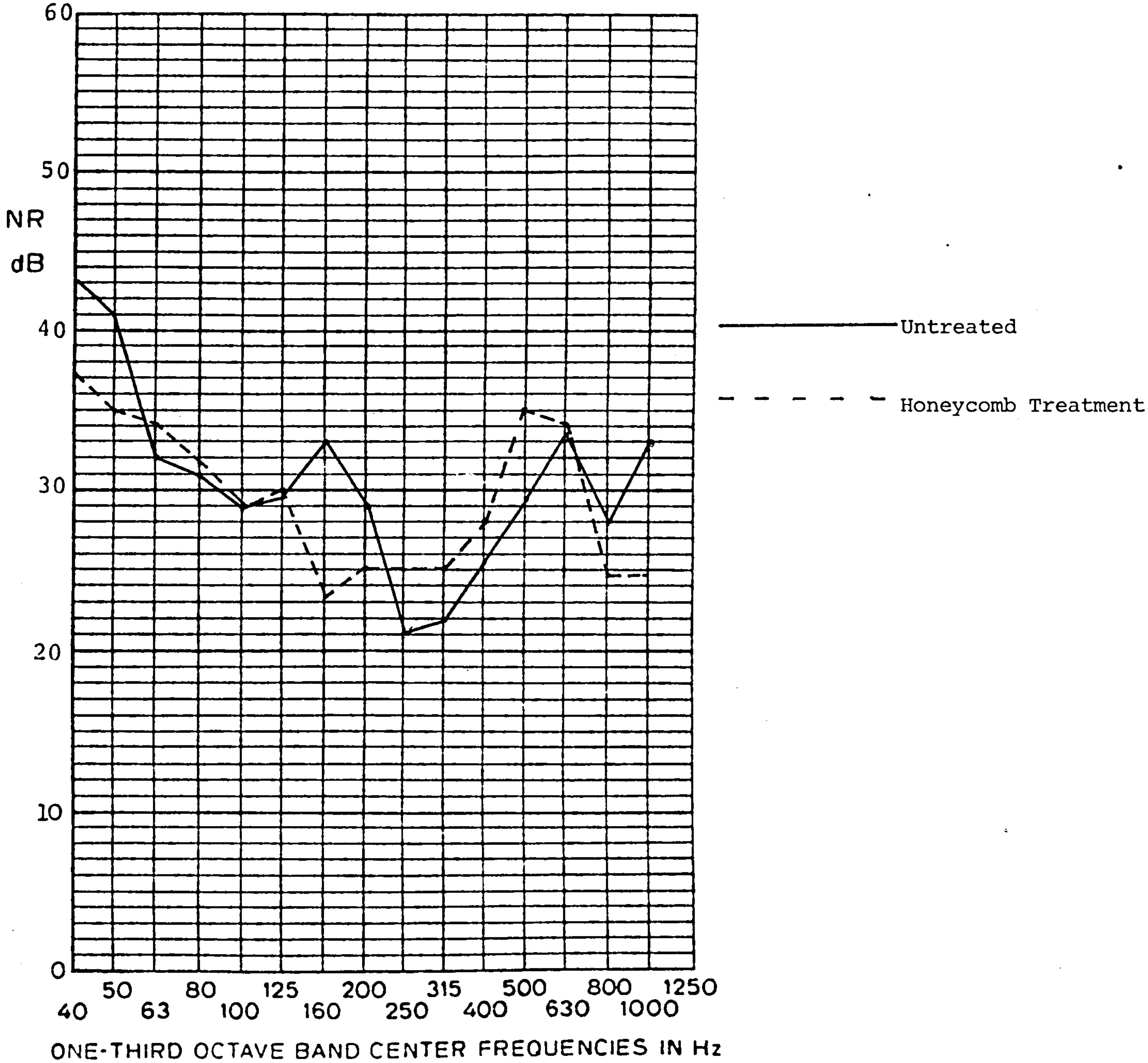


Fig. 30 Noise Reduction for Panel 6S with and without Honeycomb Treatment (Position 3)

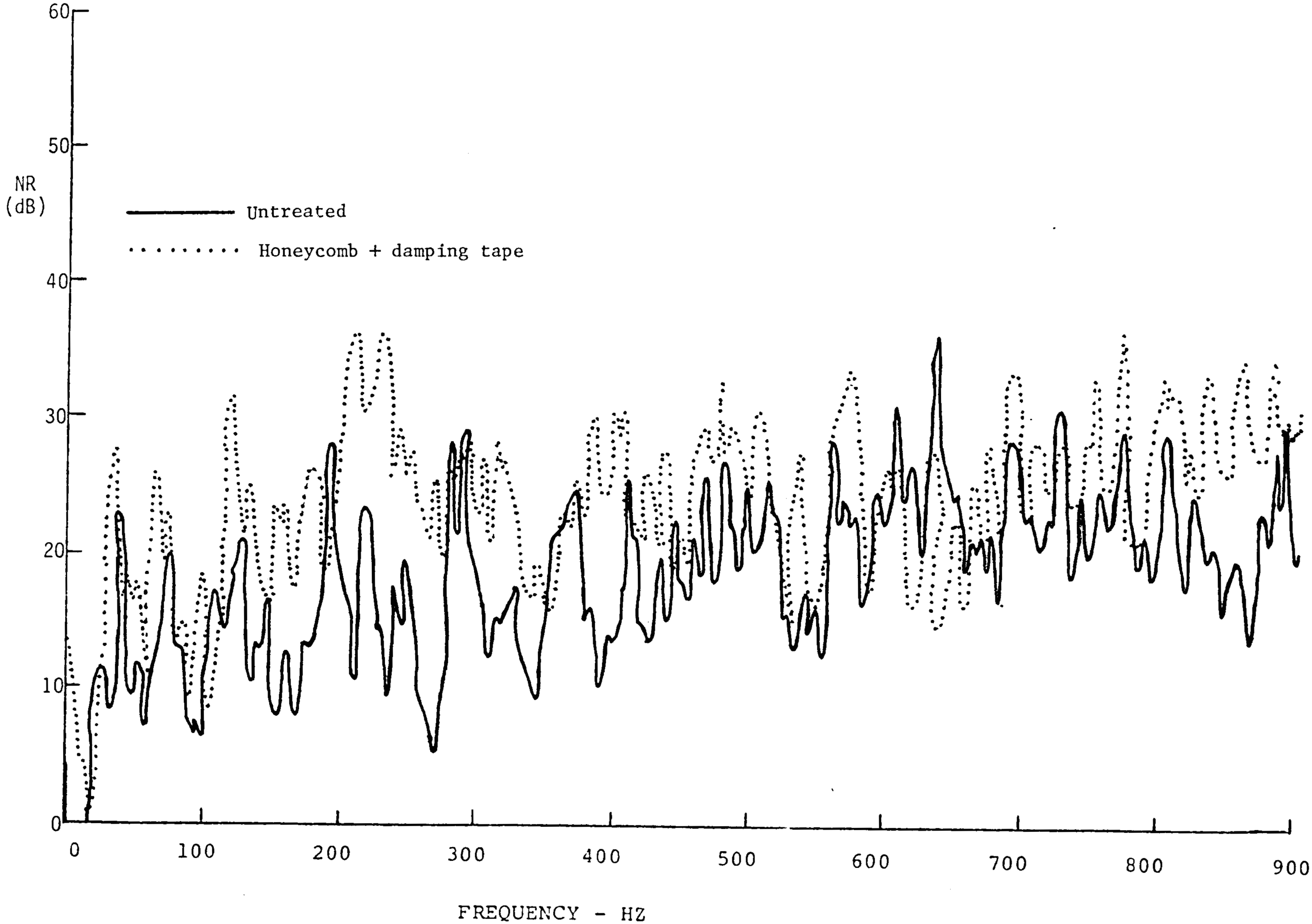


Fig. 31 Noise reduction of a sidewall with honeycomb and damping tape treatment

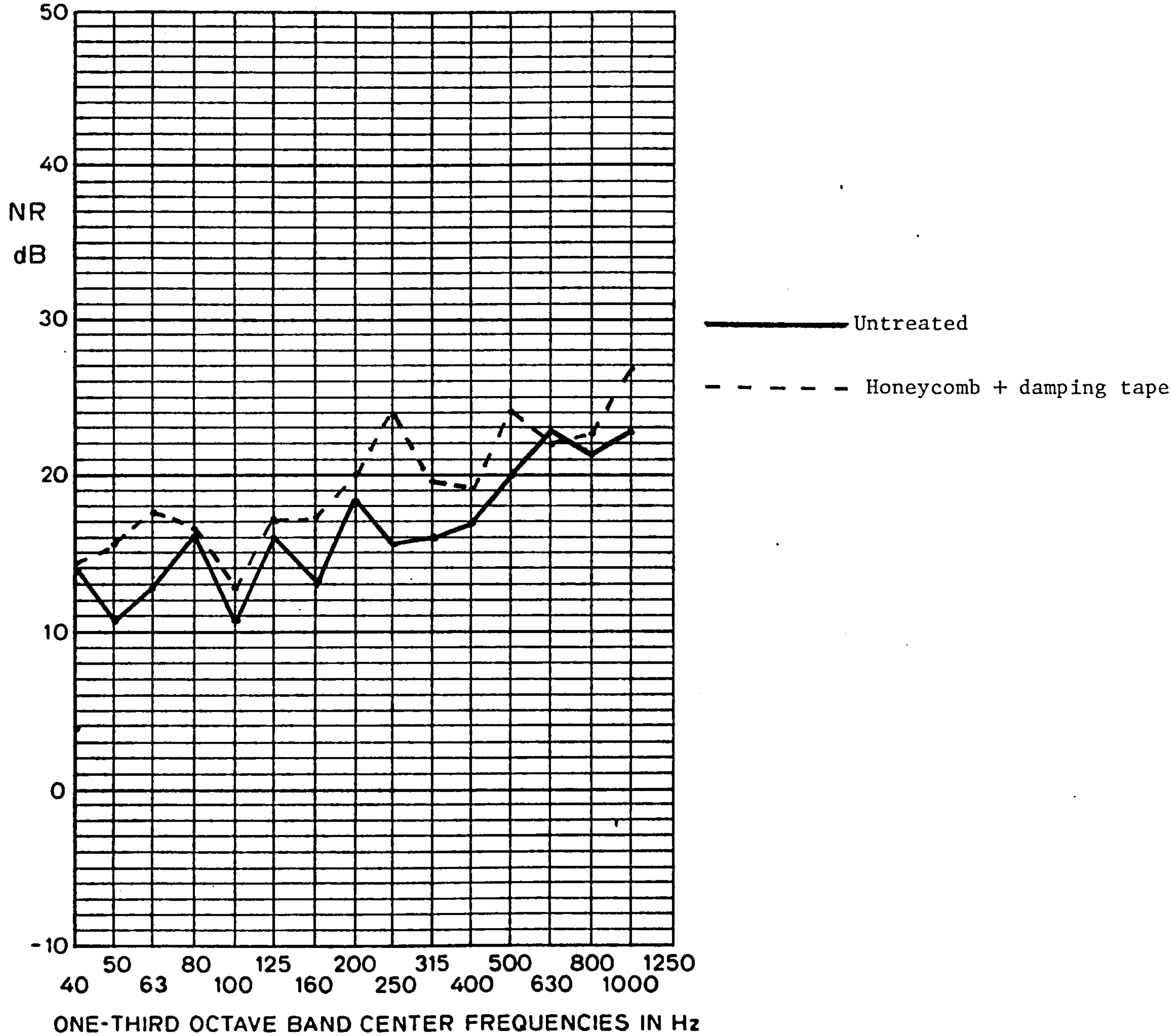


Fig. 32 The one-third octave noise reduction for a sidewall with honeycomb and damping tape treatment

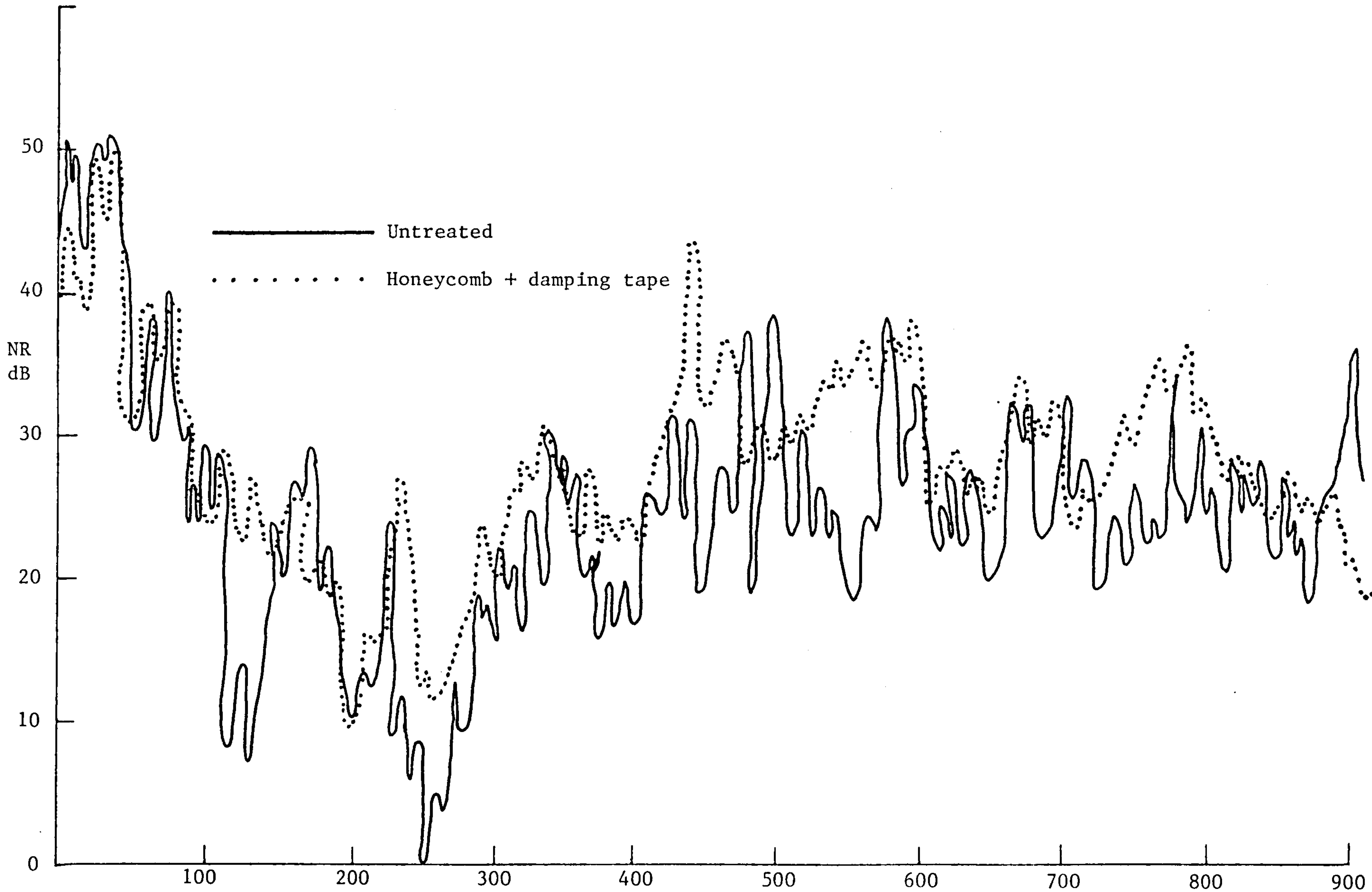


Fig. 33 Noise reduction for panel 4s with honeycomb and damping tape treatment

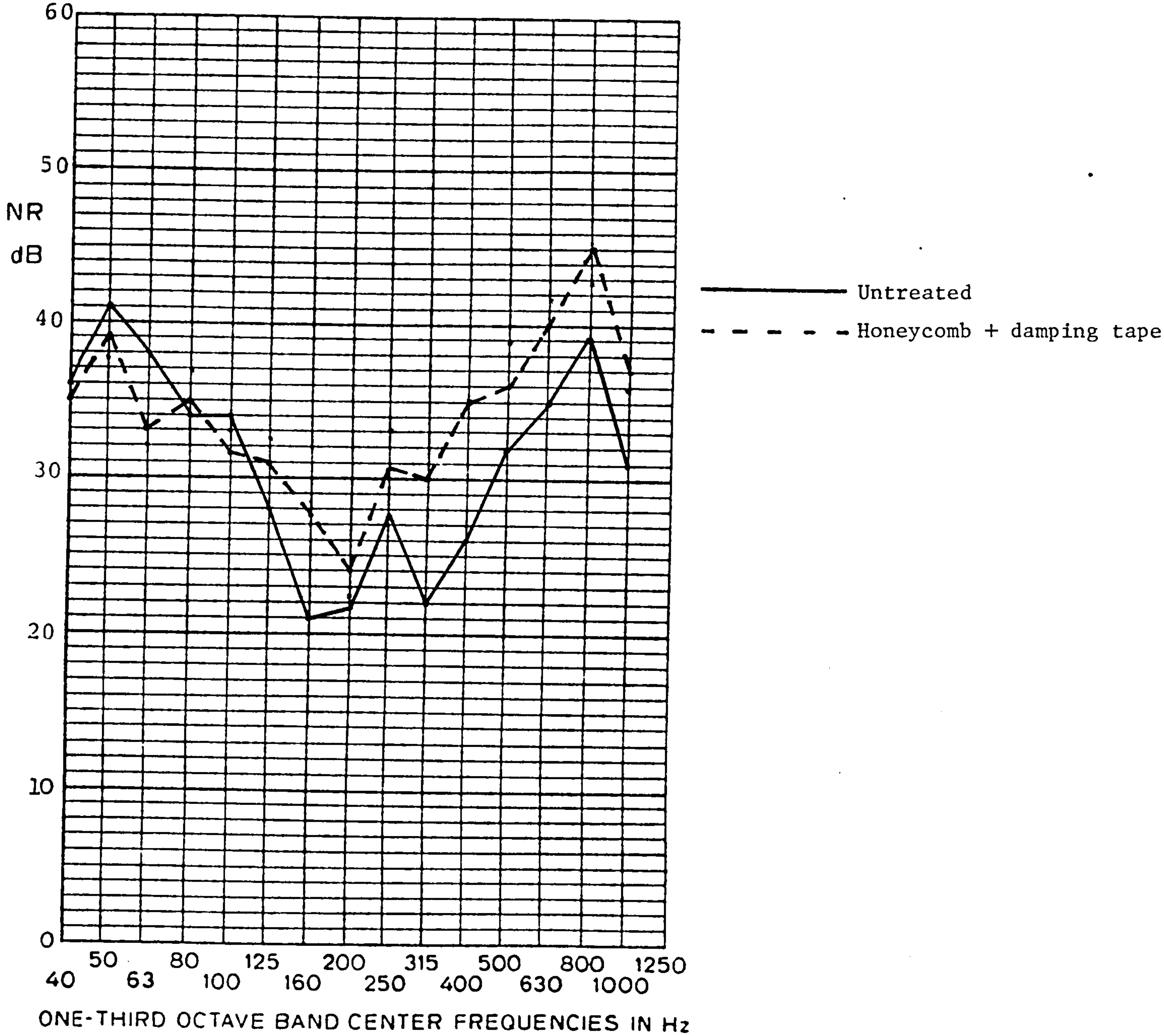


Fig. 34 The one-third octave noise reduction for panel 3P with honeycomb-damping tape treatment

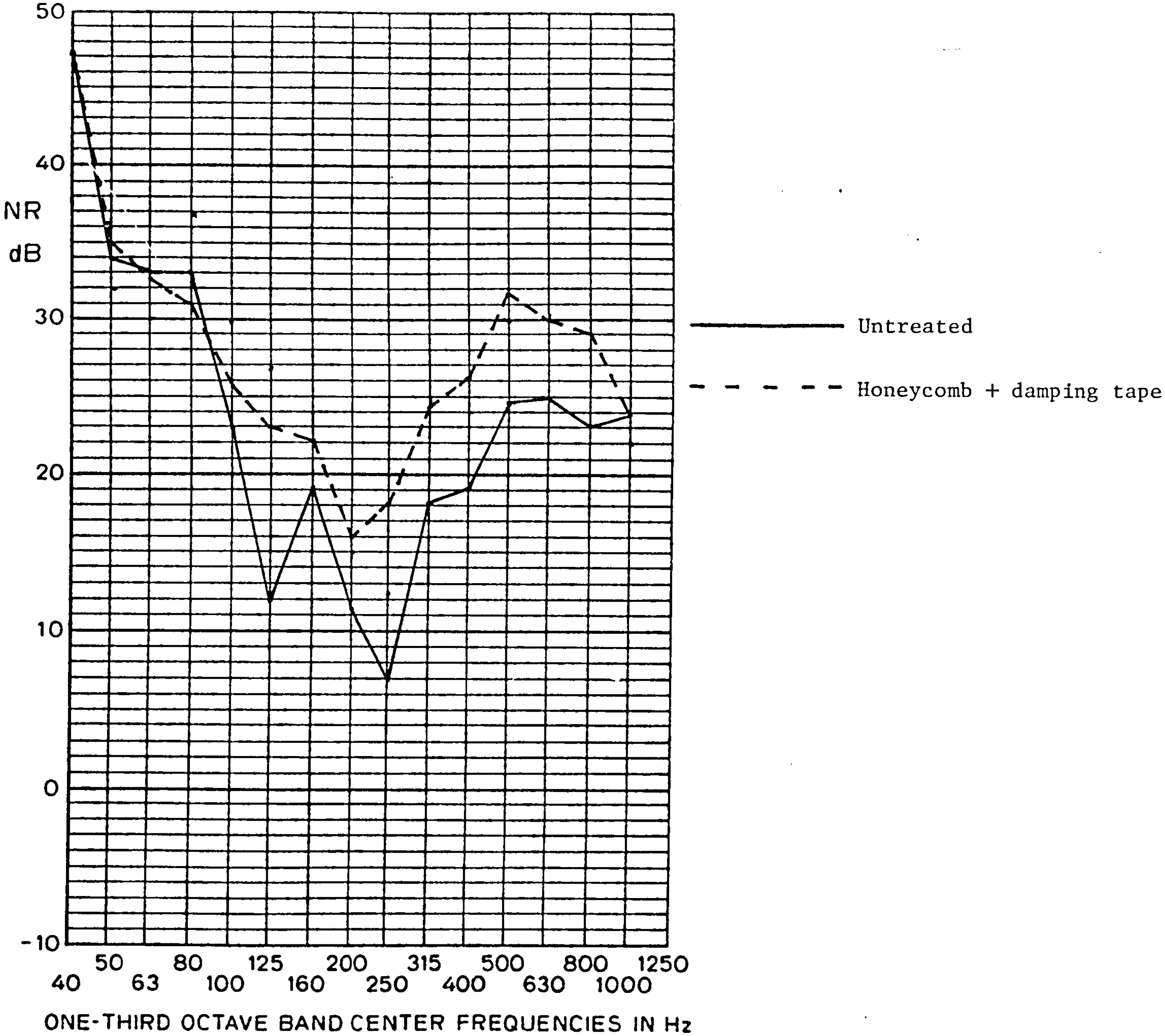


Fig. 35 The one-third octave noise reduction for panel 4S with honeycomb-damping tape treatment (position No. 11)

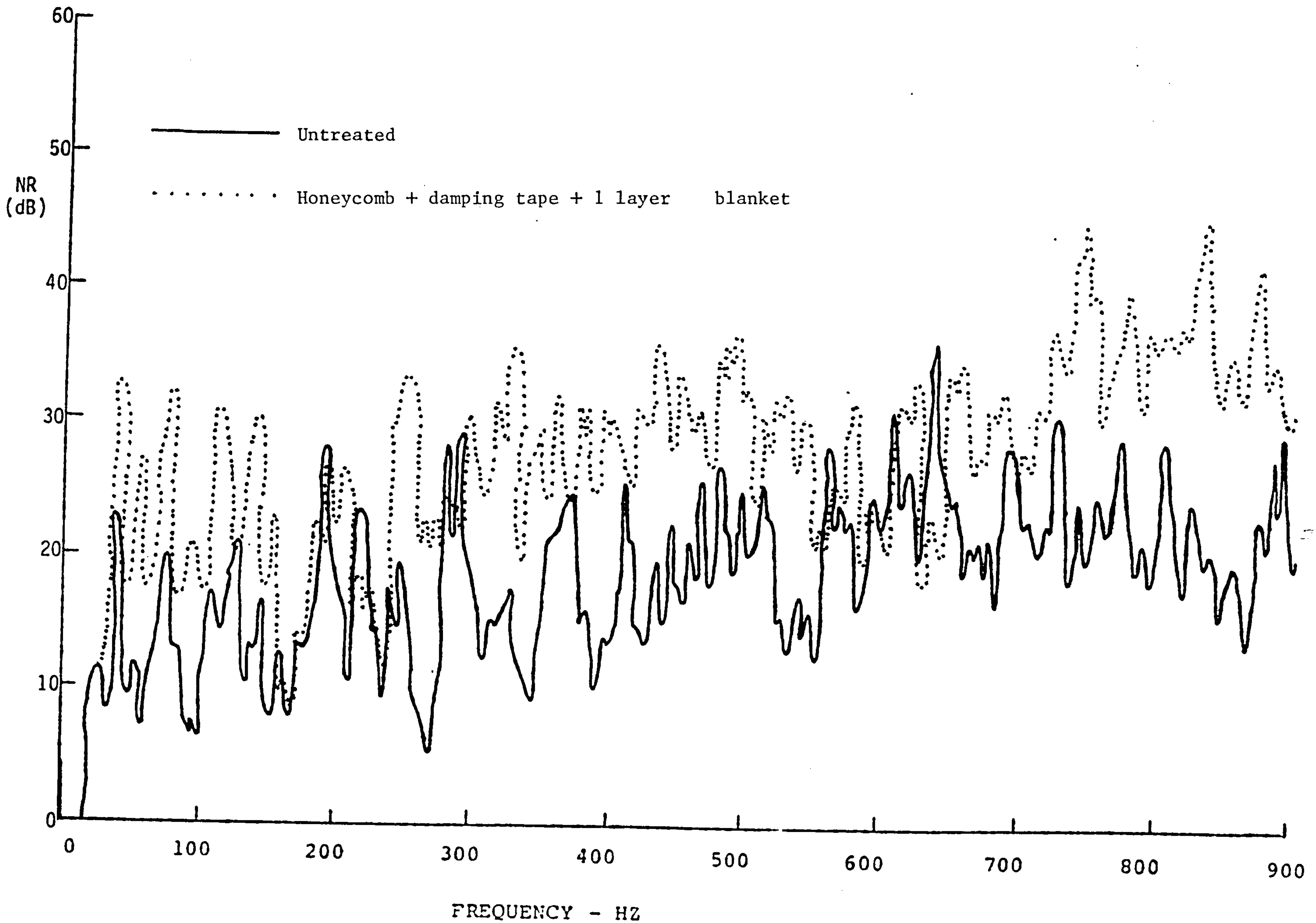


Fig. 36 Noise reduction of a sidewall treated with honeycomb, damping tape and one layer acoustic blanket

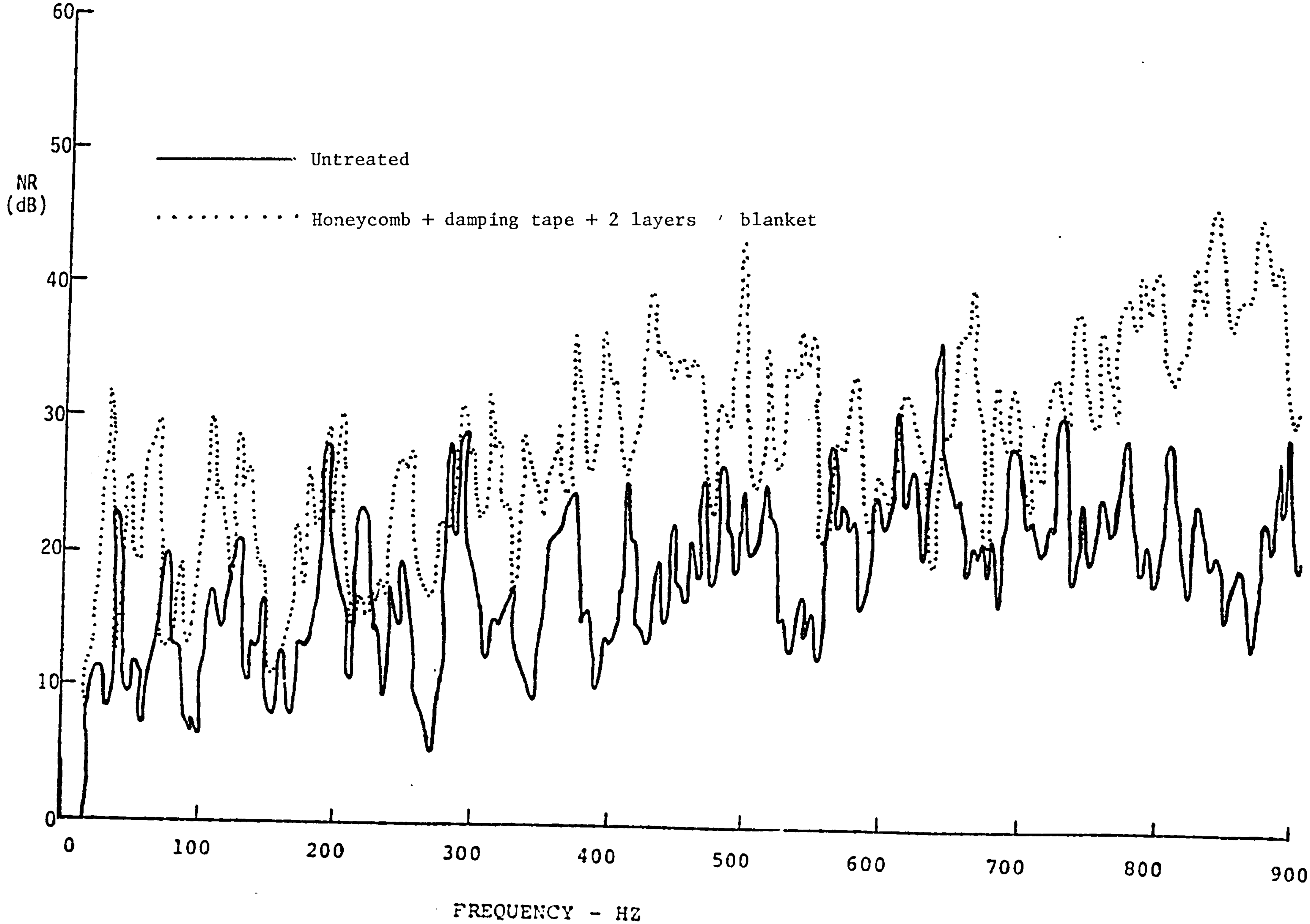


Fig. 37 Noise reduction of a sidewall treated with honeycomb, damping tape and two layers acoustic blankets

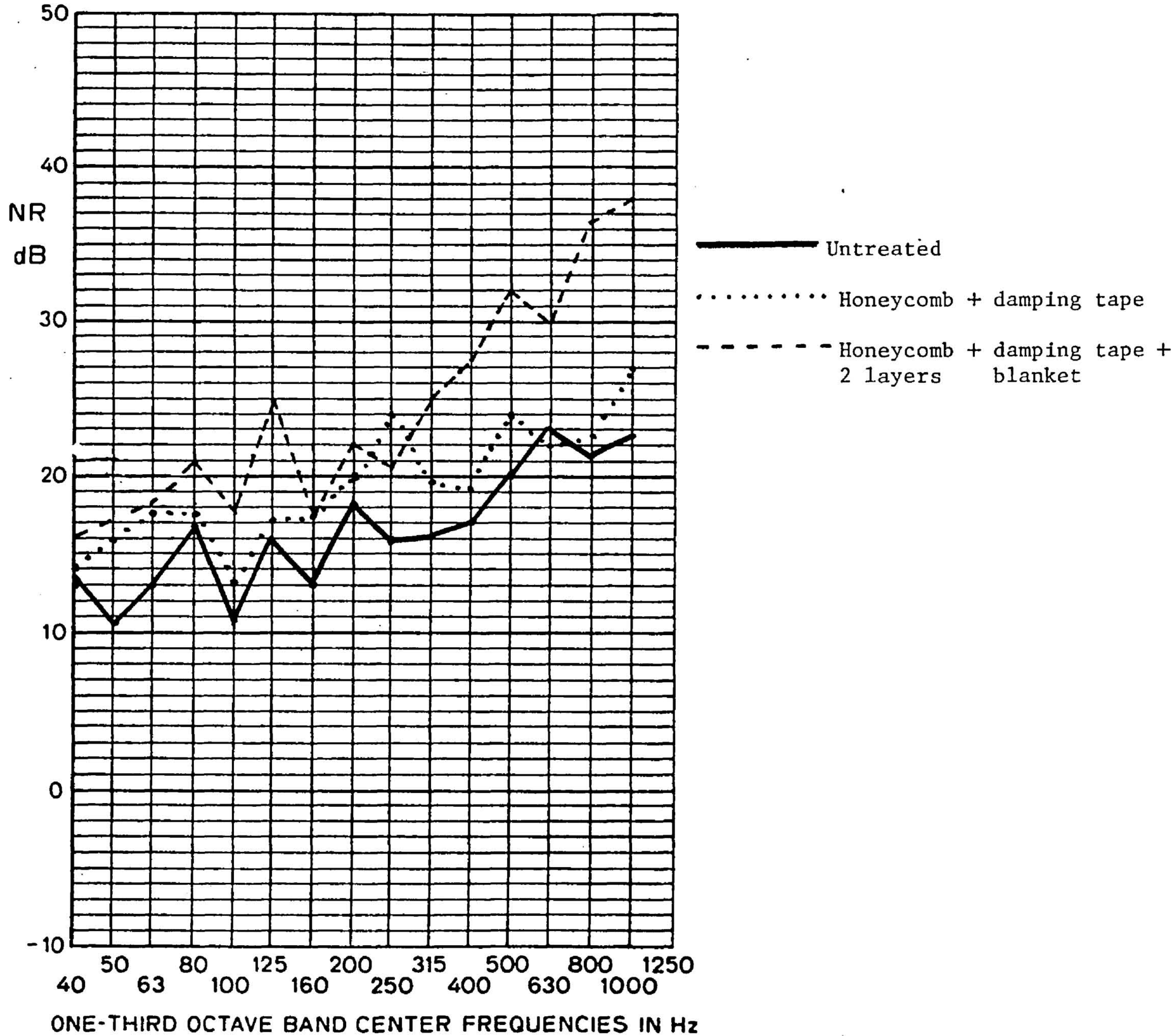


Fig. 38 The one-third octave noise reduction for treated and untreated sidewall

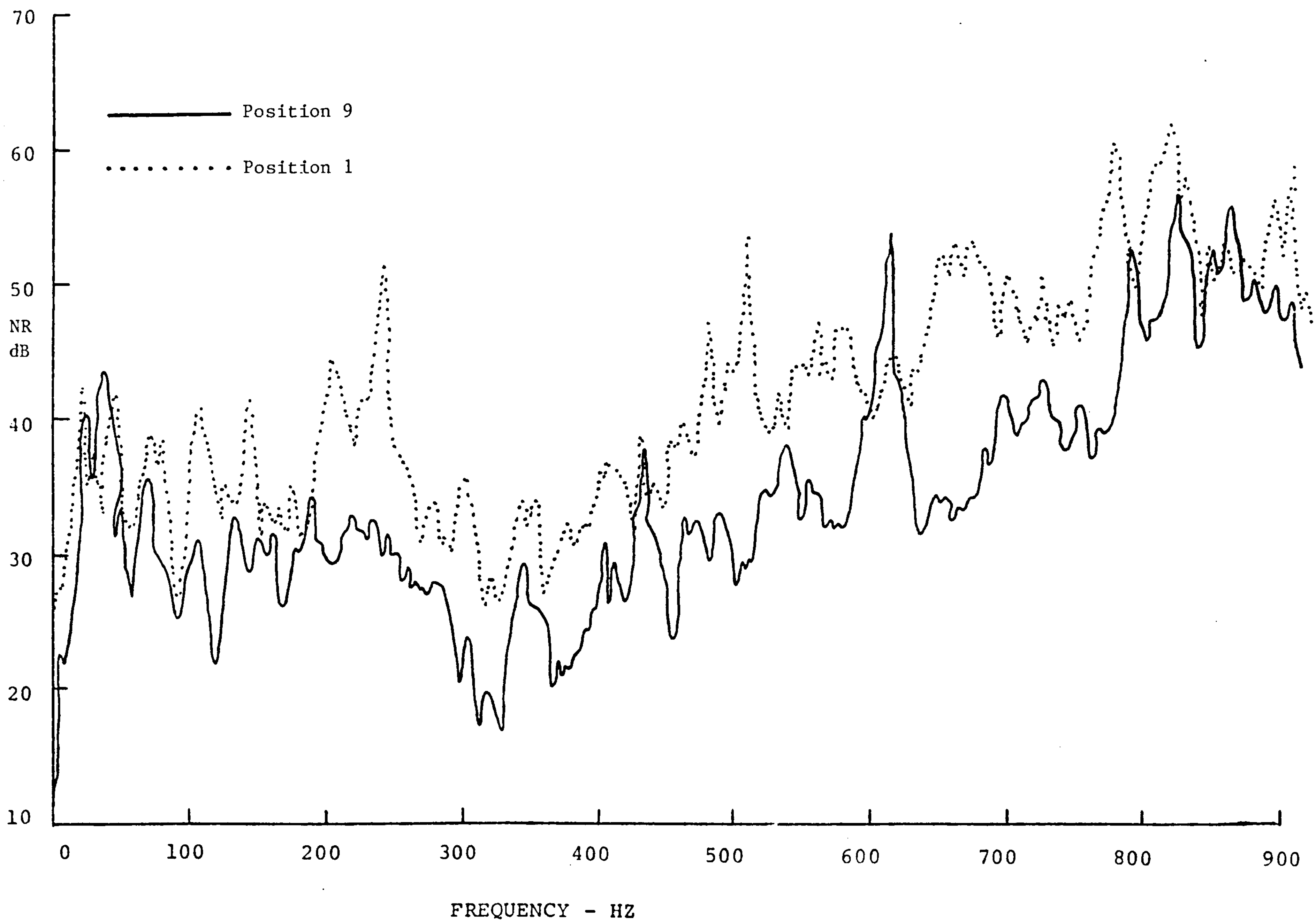


Fig. 39 Noise reduction of double wall window (7P) at positions 1 and 9.

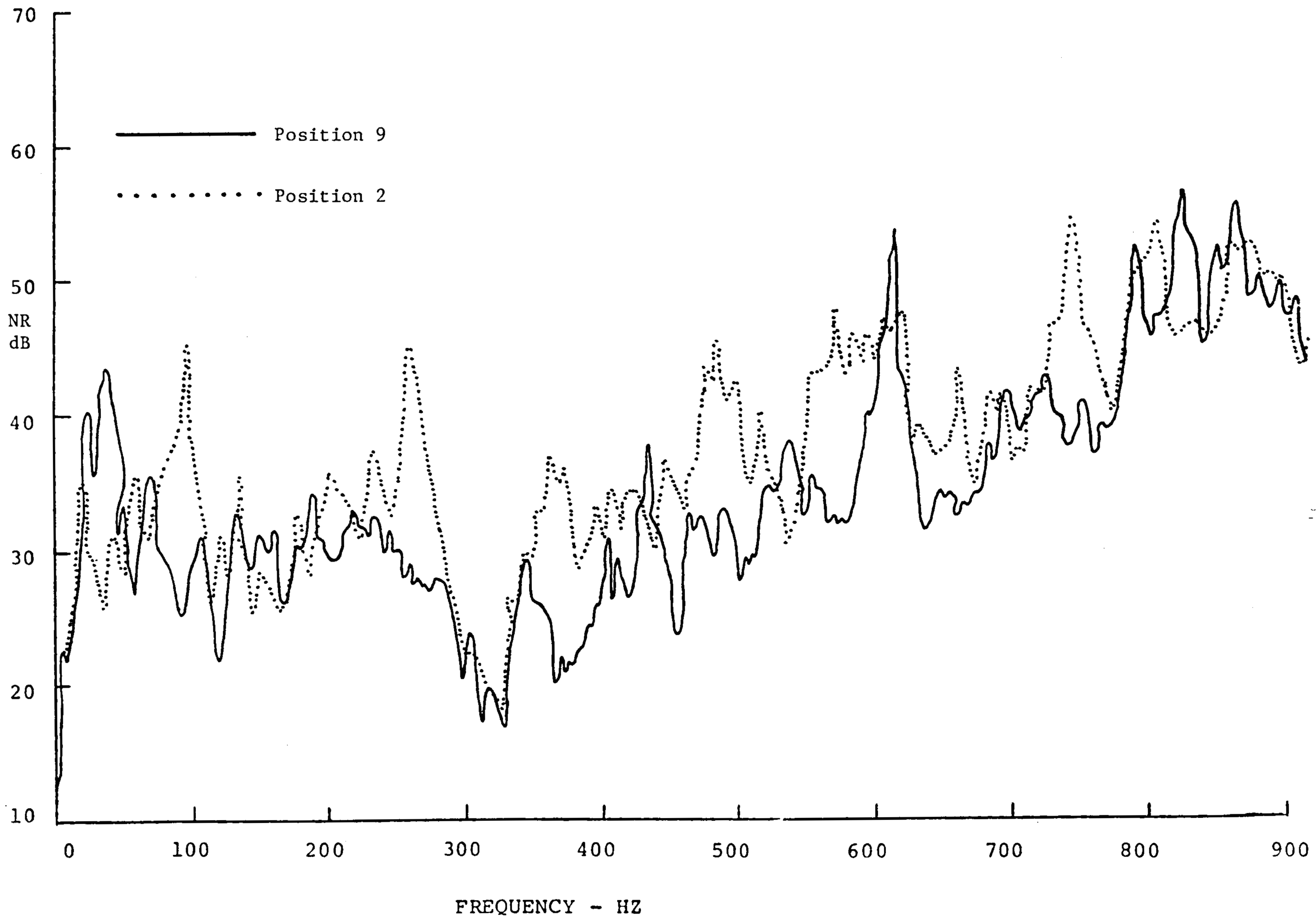


Fig. 40 Noise reduction of double wall window (7P) at positions 2 and 9.

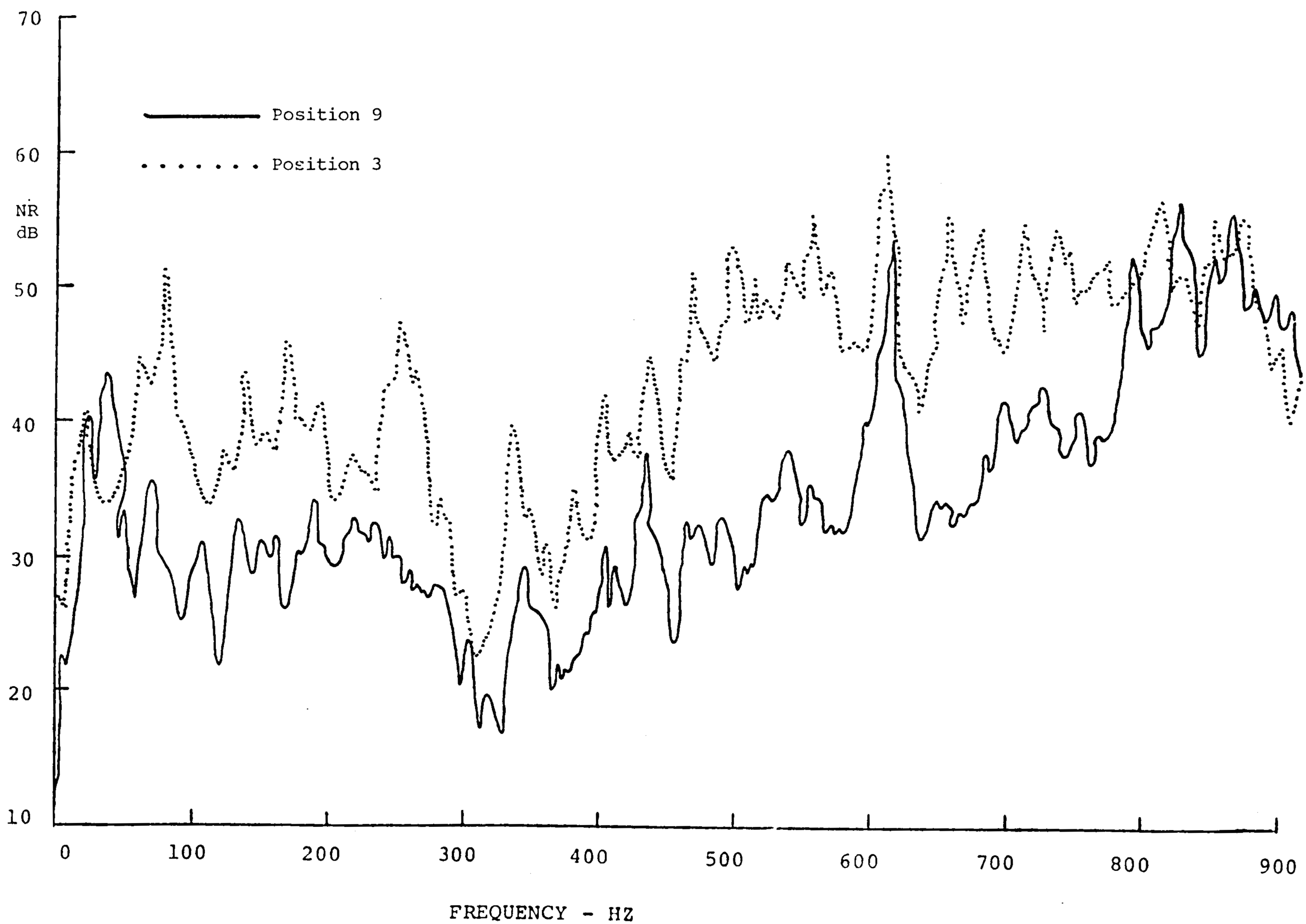


Fig. 41 Noise reduction of double wall window (7P) at positions 3 and 9.

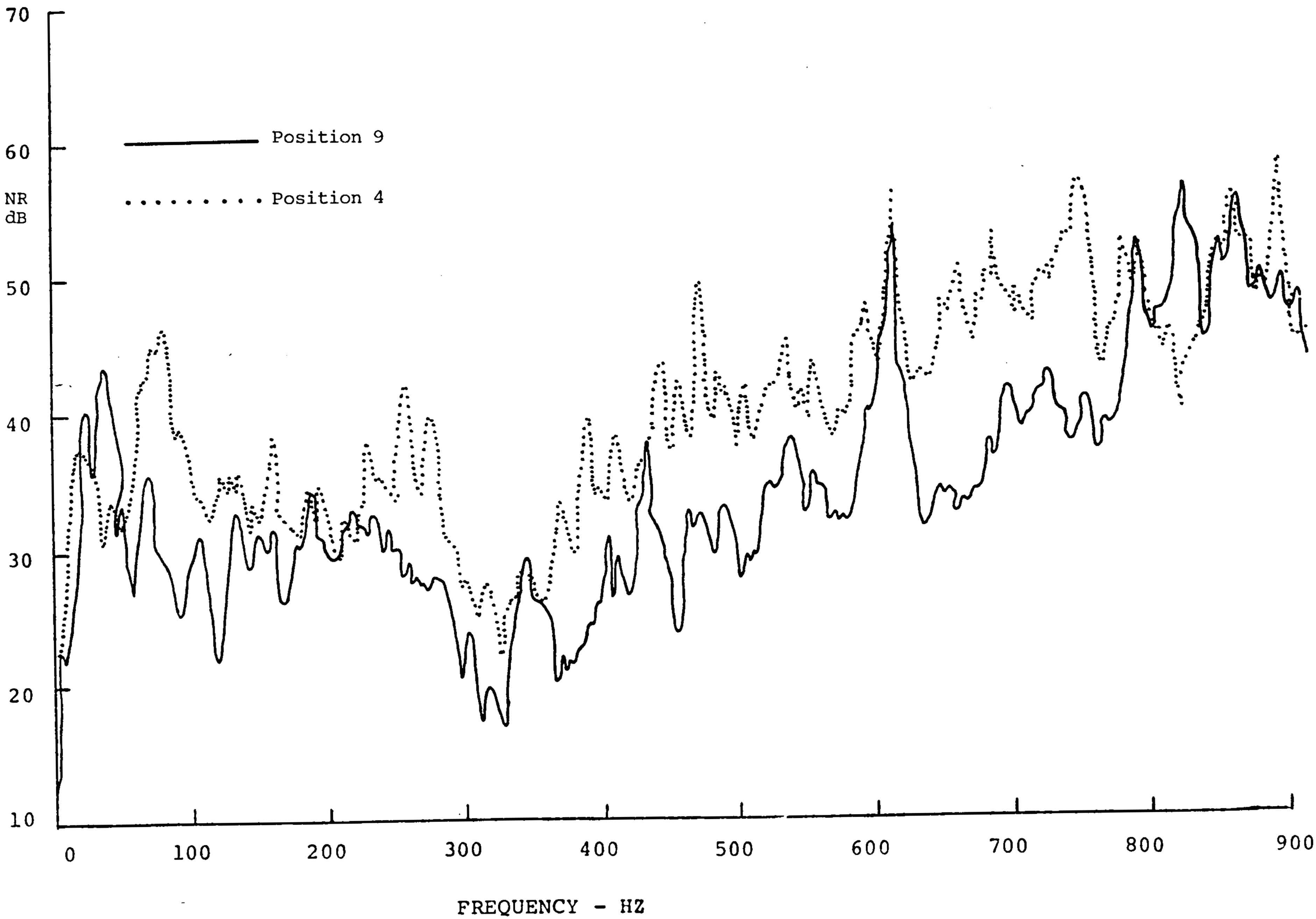


Fig. 42 Noise reduction of double wall window (7P) at positions 4 and 9.

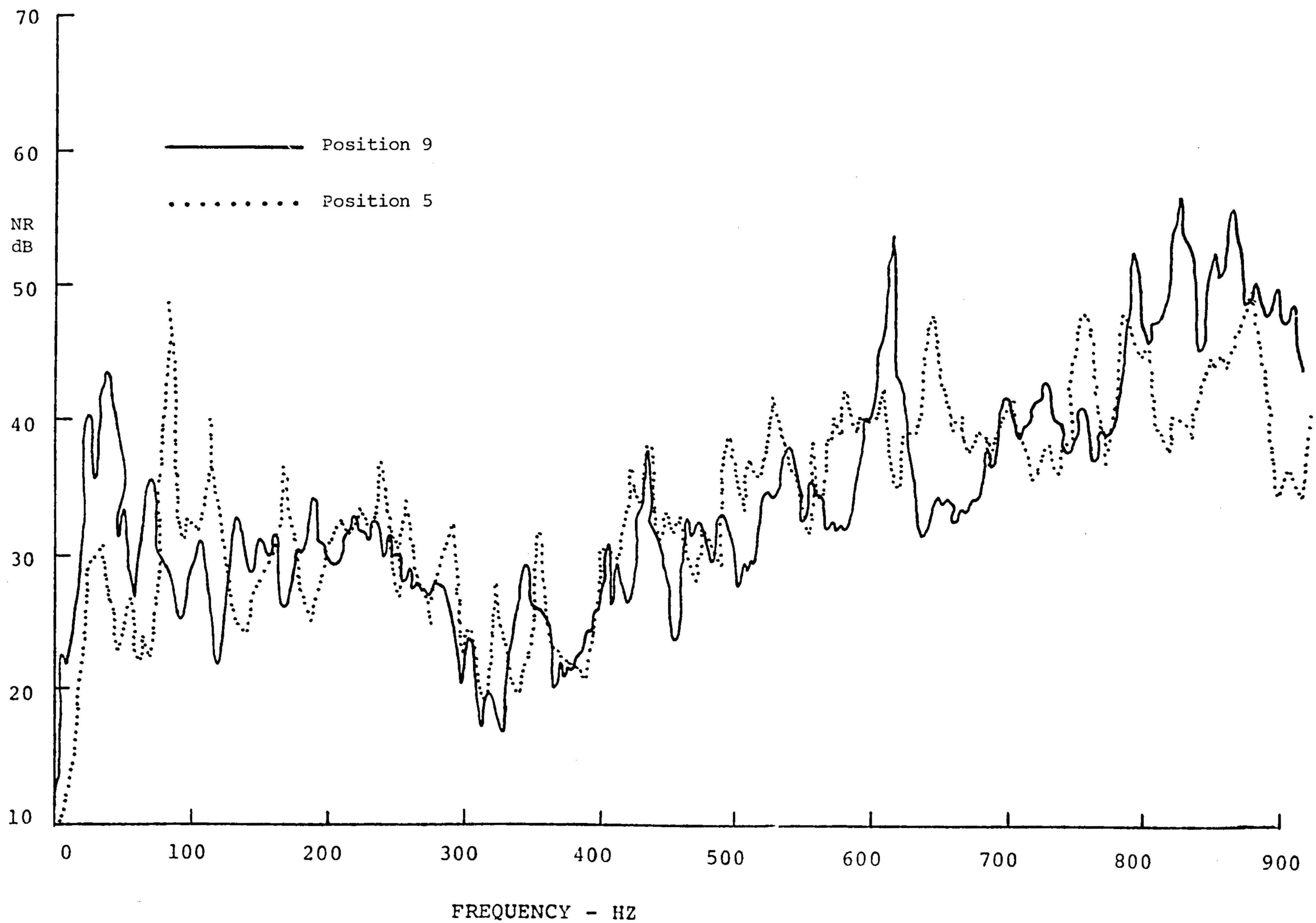


Fig. 43 Noise reduction of double wall window (7P) at positions 5 and 9.

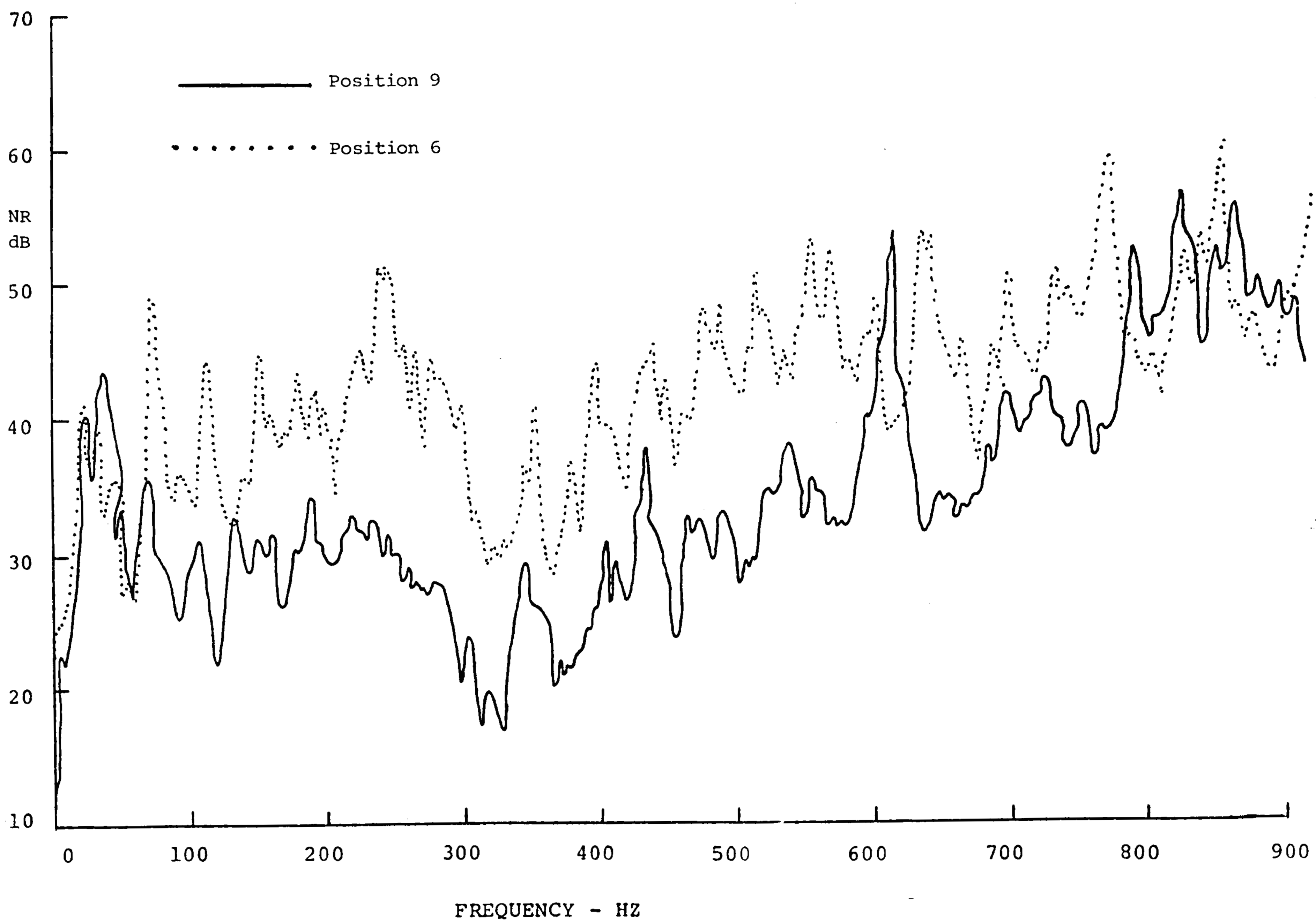


Fig. 44 Noise reduction of double wall window (7P) at positions 6 and 9.

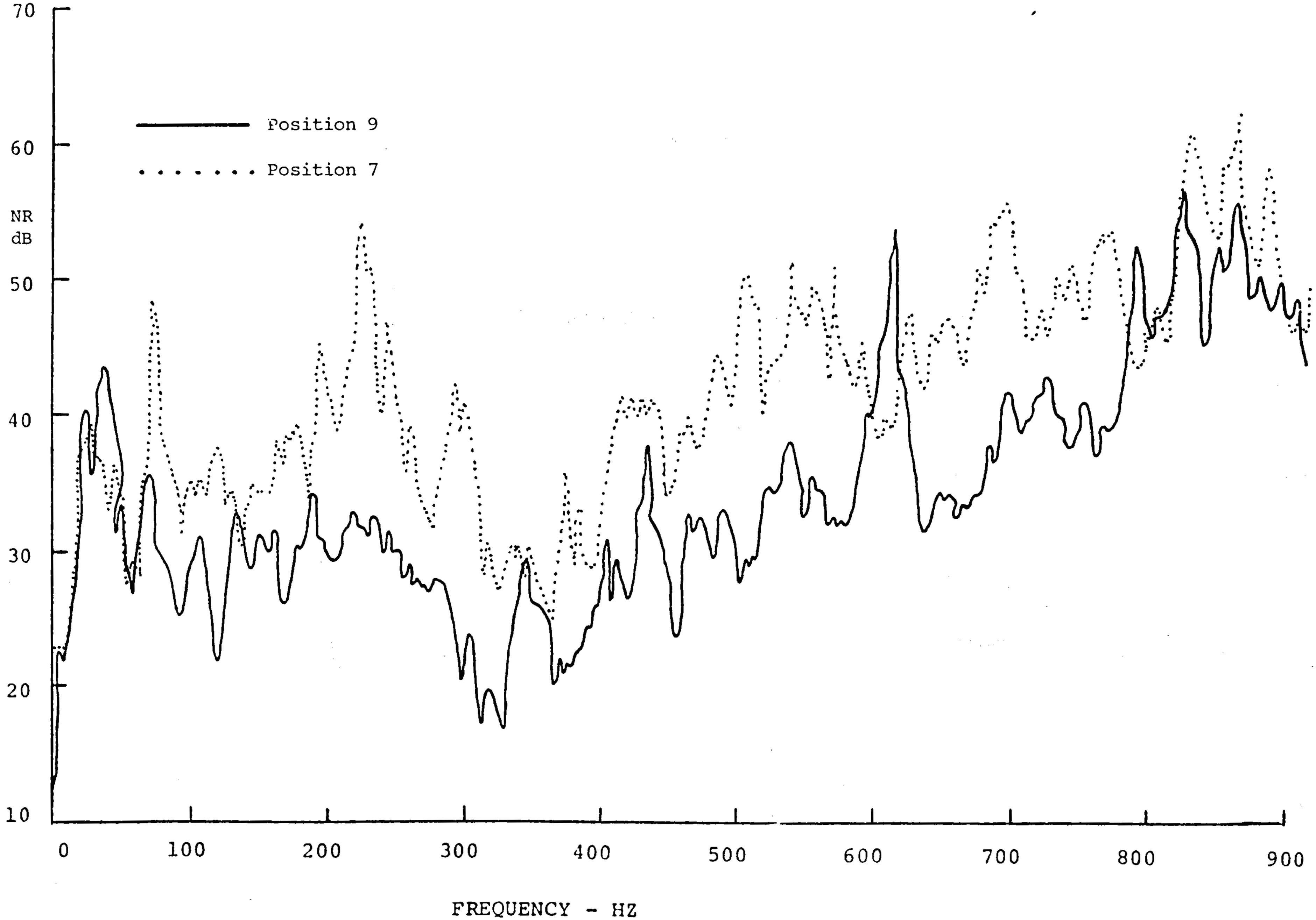


Fig. 45 Noise reduction of double wall window (7P) at positions 7 and 9.

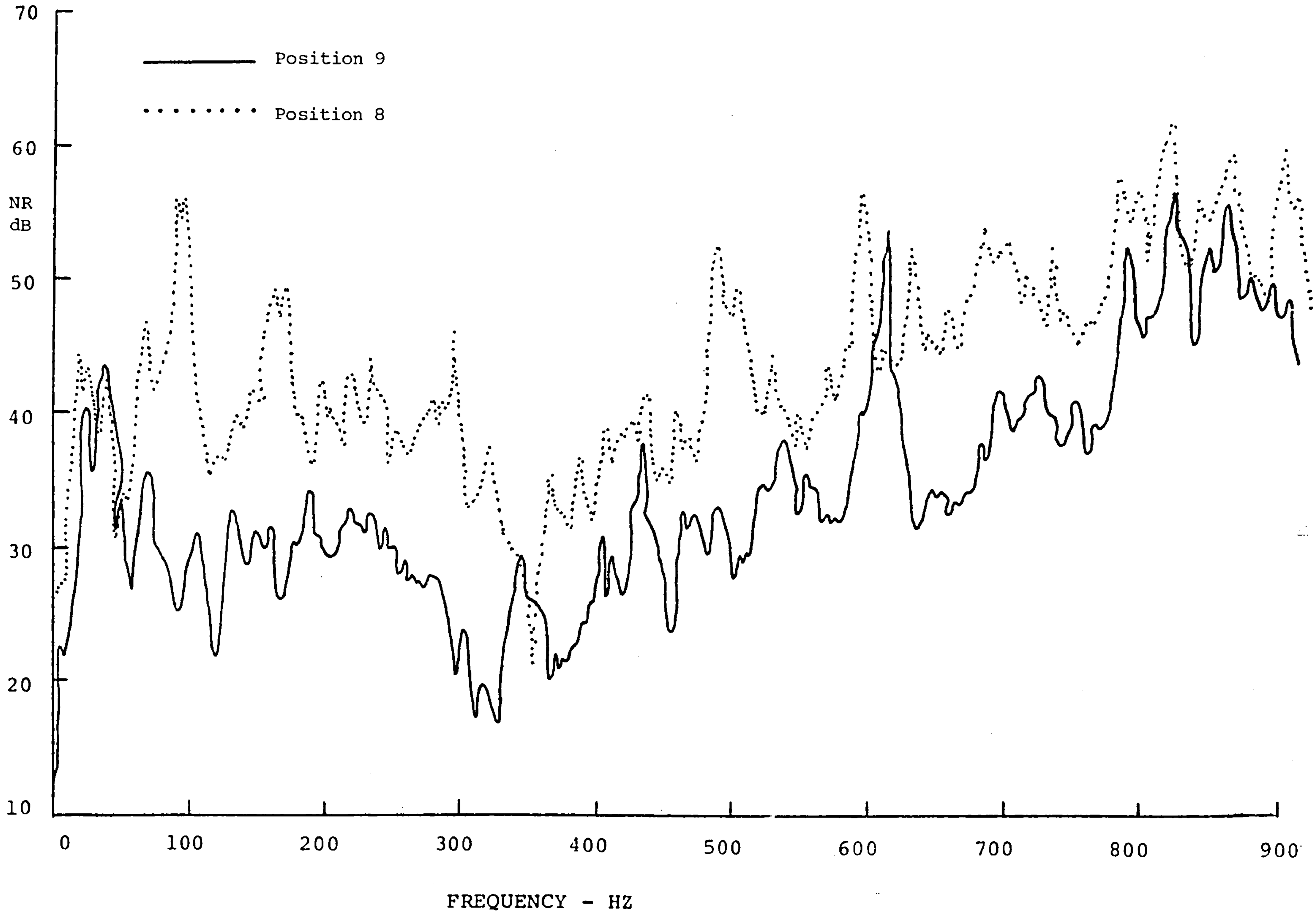


Fig. 46 Noise reduction of double wall window (7P) at positions 8 and 9.

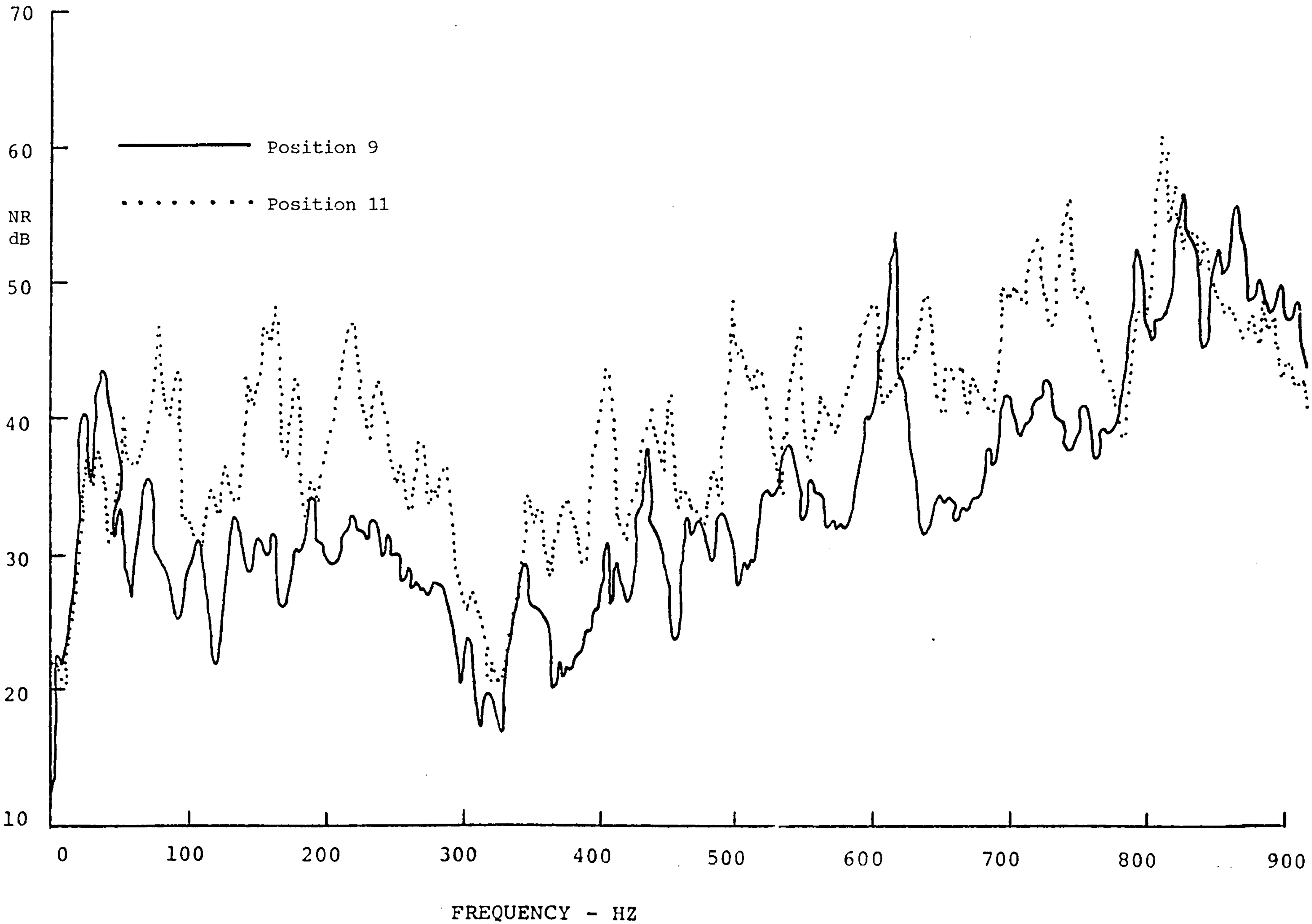


Fig. 47 Noise reduction of double wall window (7P) at positions 11 and 9.

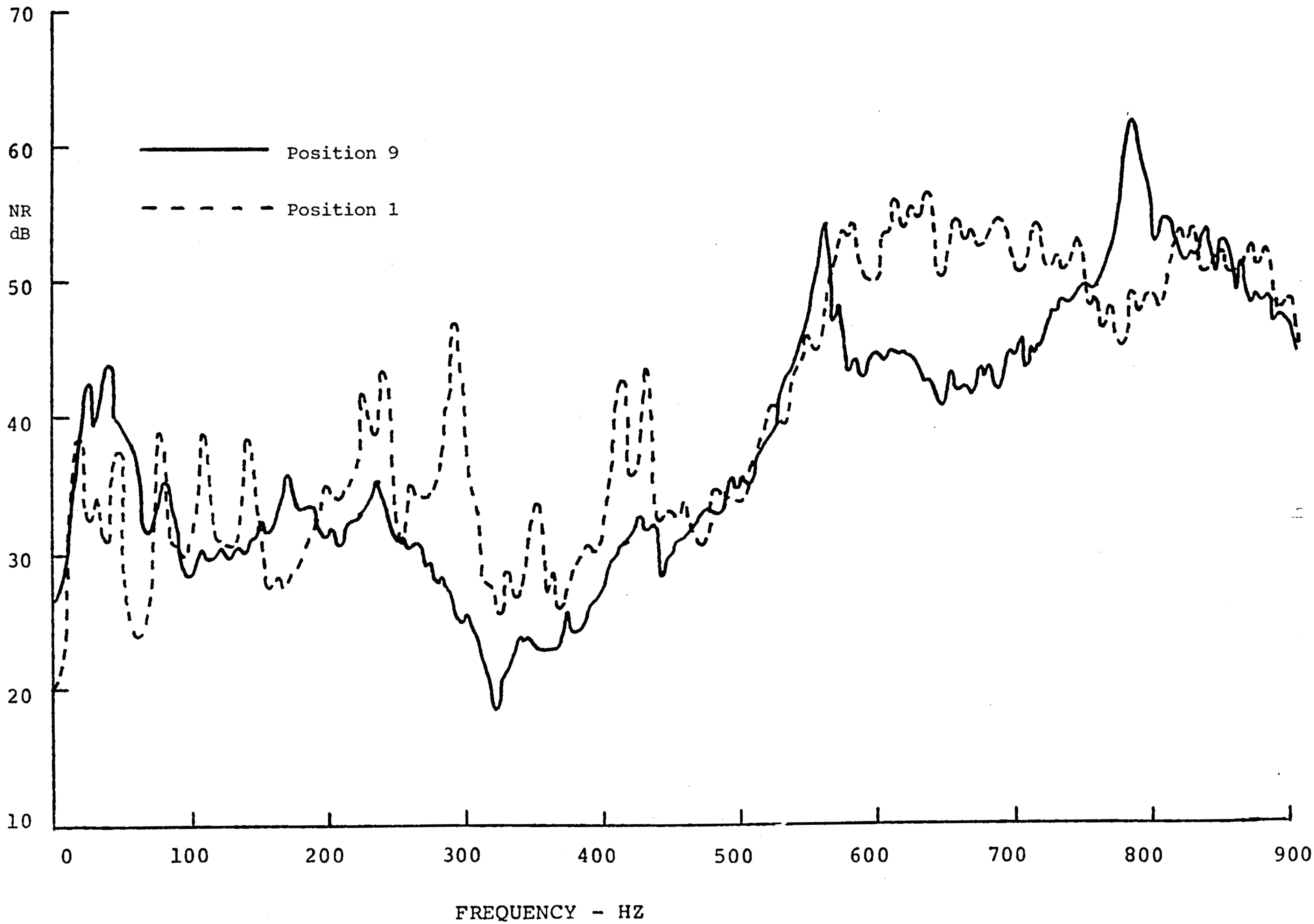


Fig. 48 Noise reduction of double wall window (7P) at positions 1 and 9 with three layers of blanket treatment

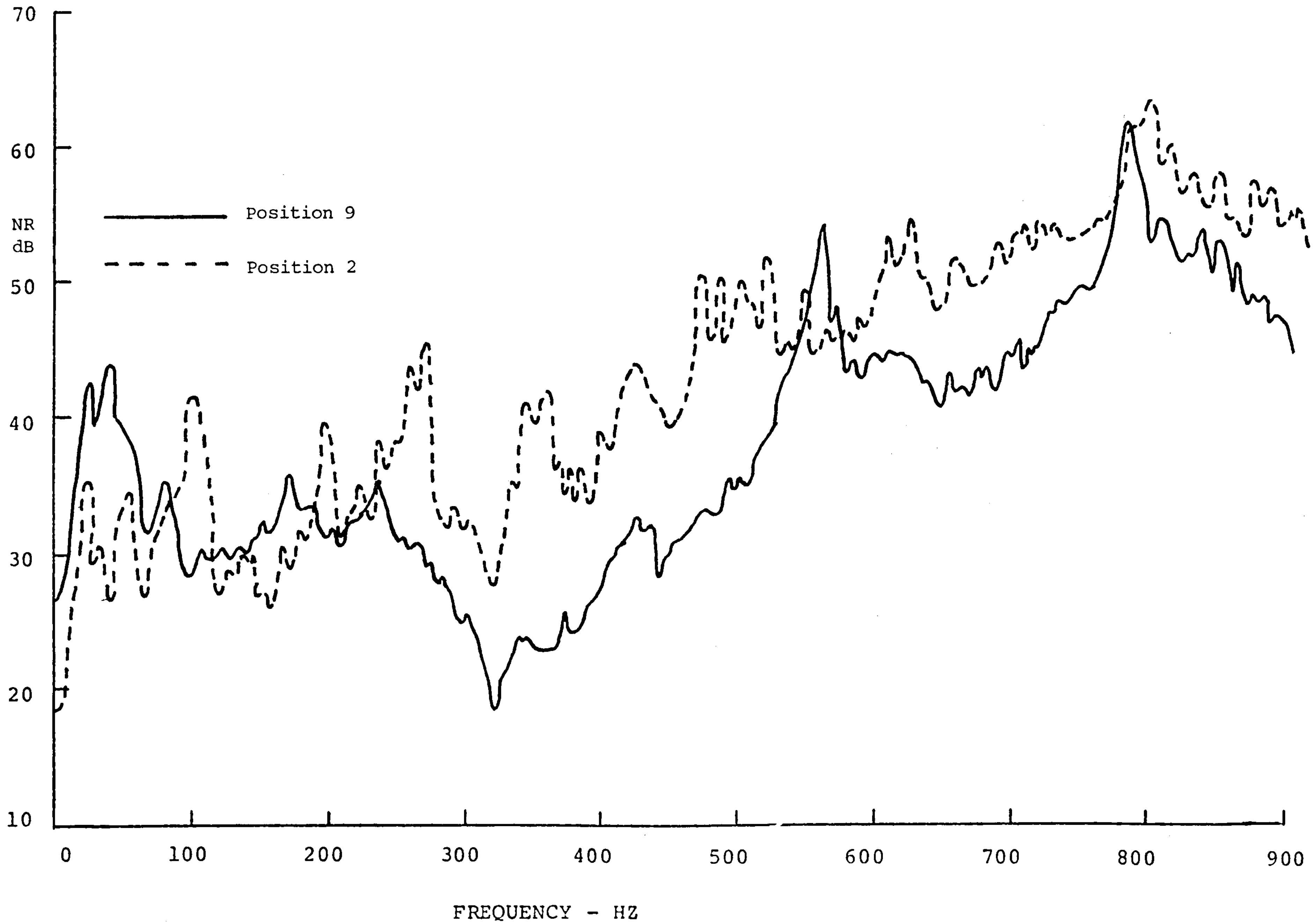


Fig. 49 Noise reduction of double wall window (7P) at positions 2 and 9 with three layers of blanket treatment

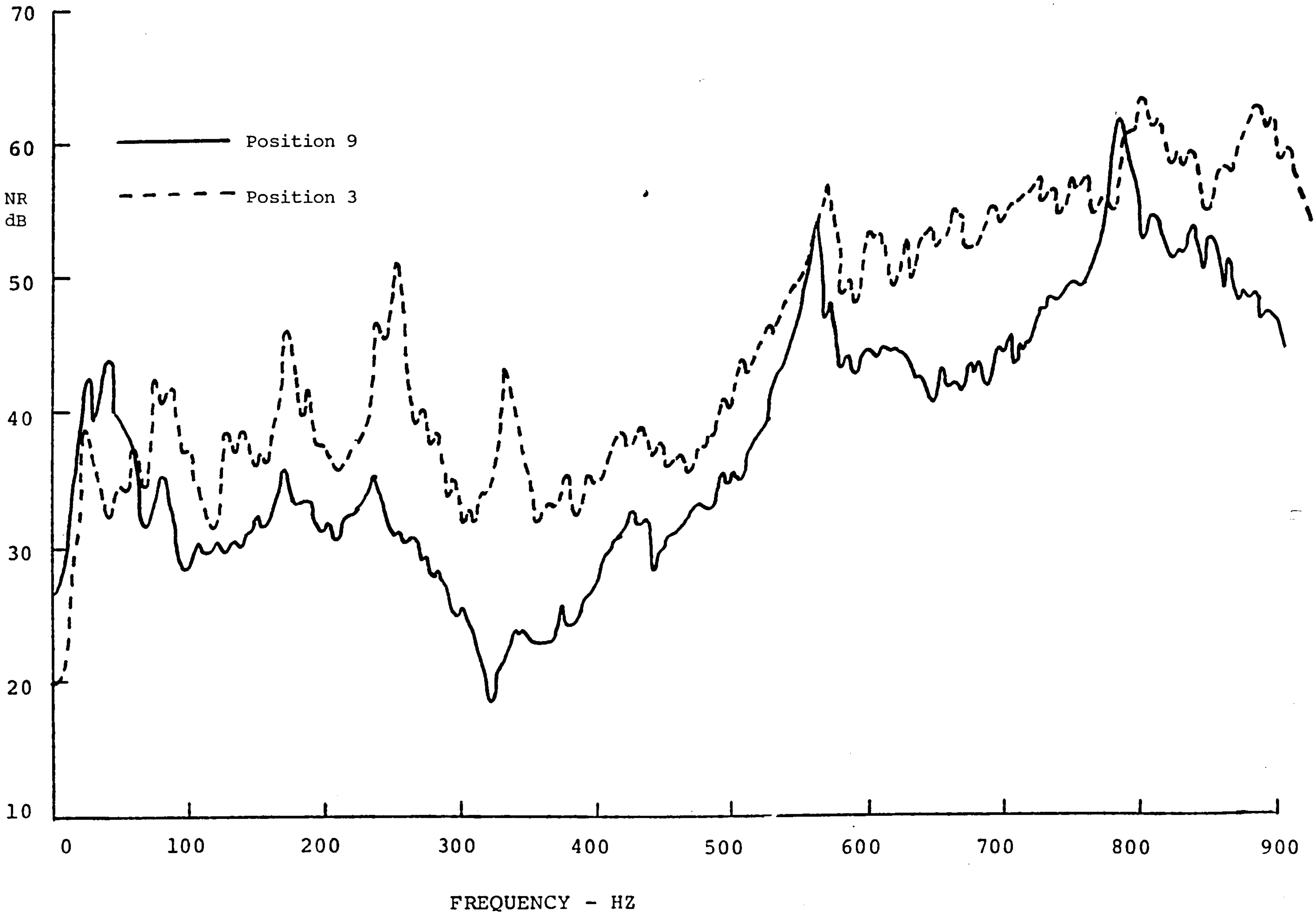


Fig. 50 Noise reduction of double wall window (7P) at positions 3 and 9 with three layers of blanket treatment.

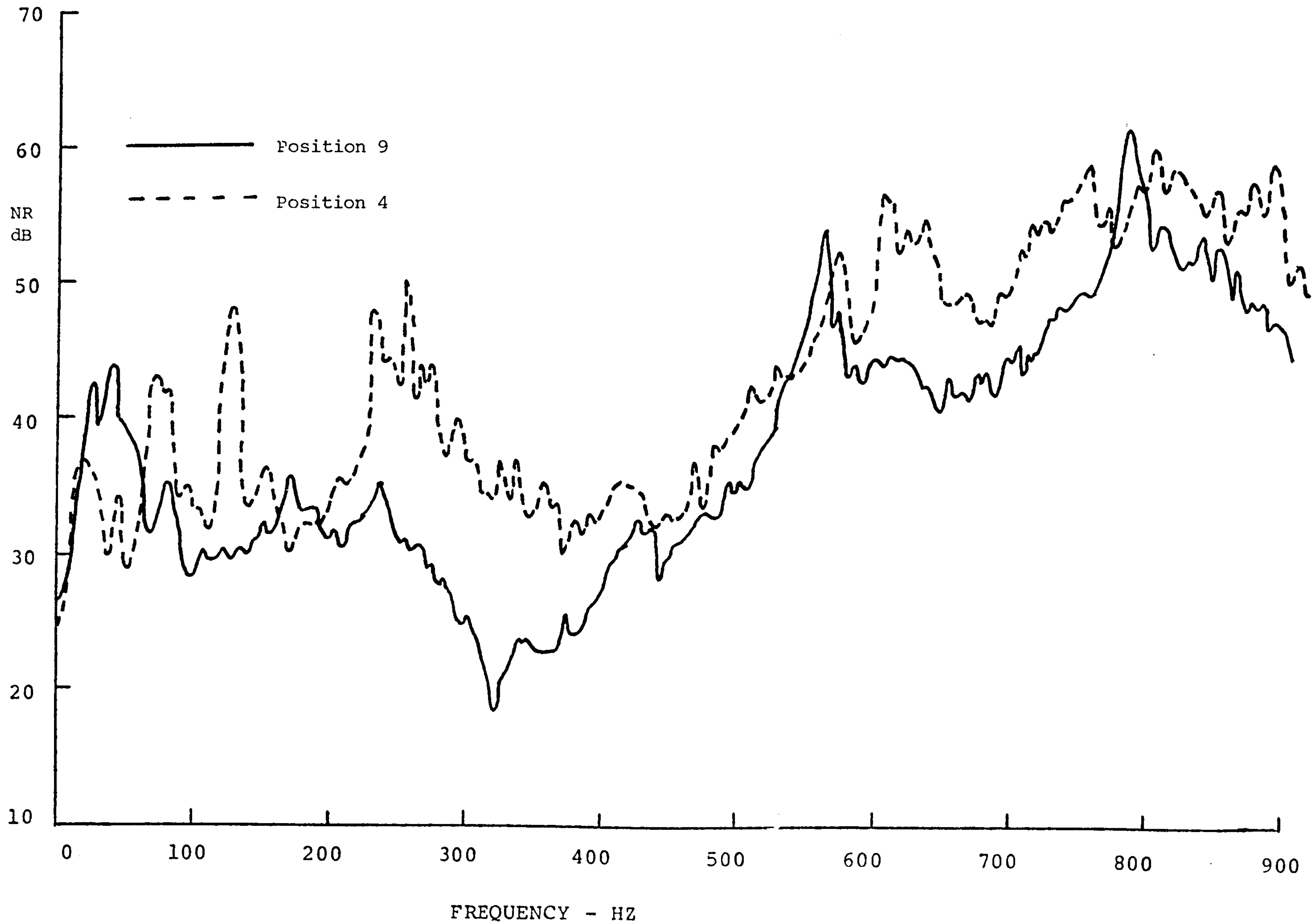


Fig. 51 Noise reduction of double wall window (7P) at positions 4 and 9 with three layers of ` blanket treatment

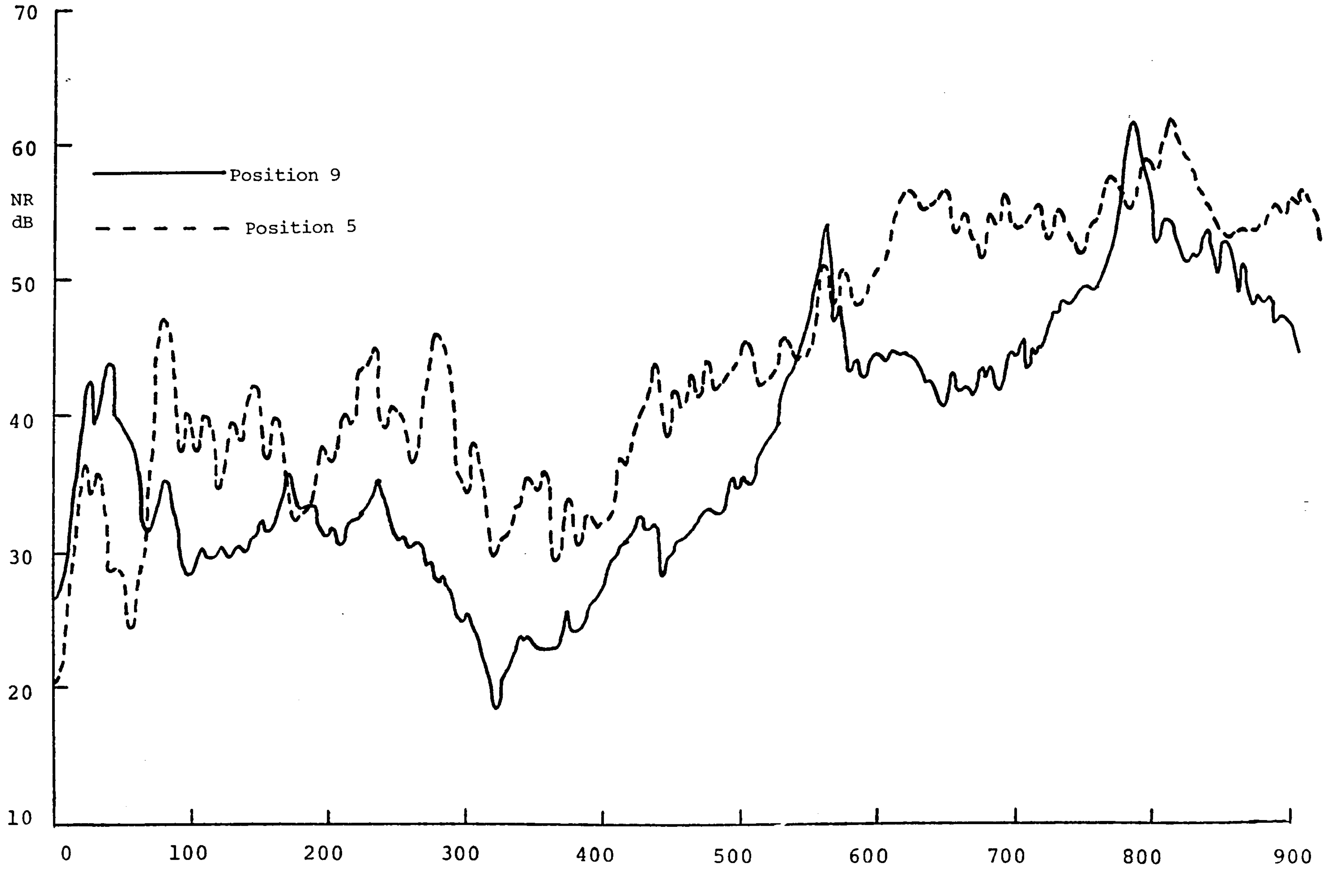


Fig. 52 Noise reduction of double wall window (7P) at positions 5 and 9 with three layers of blanket treatment

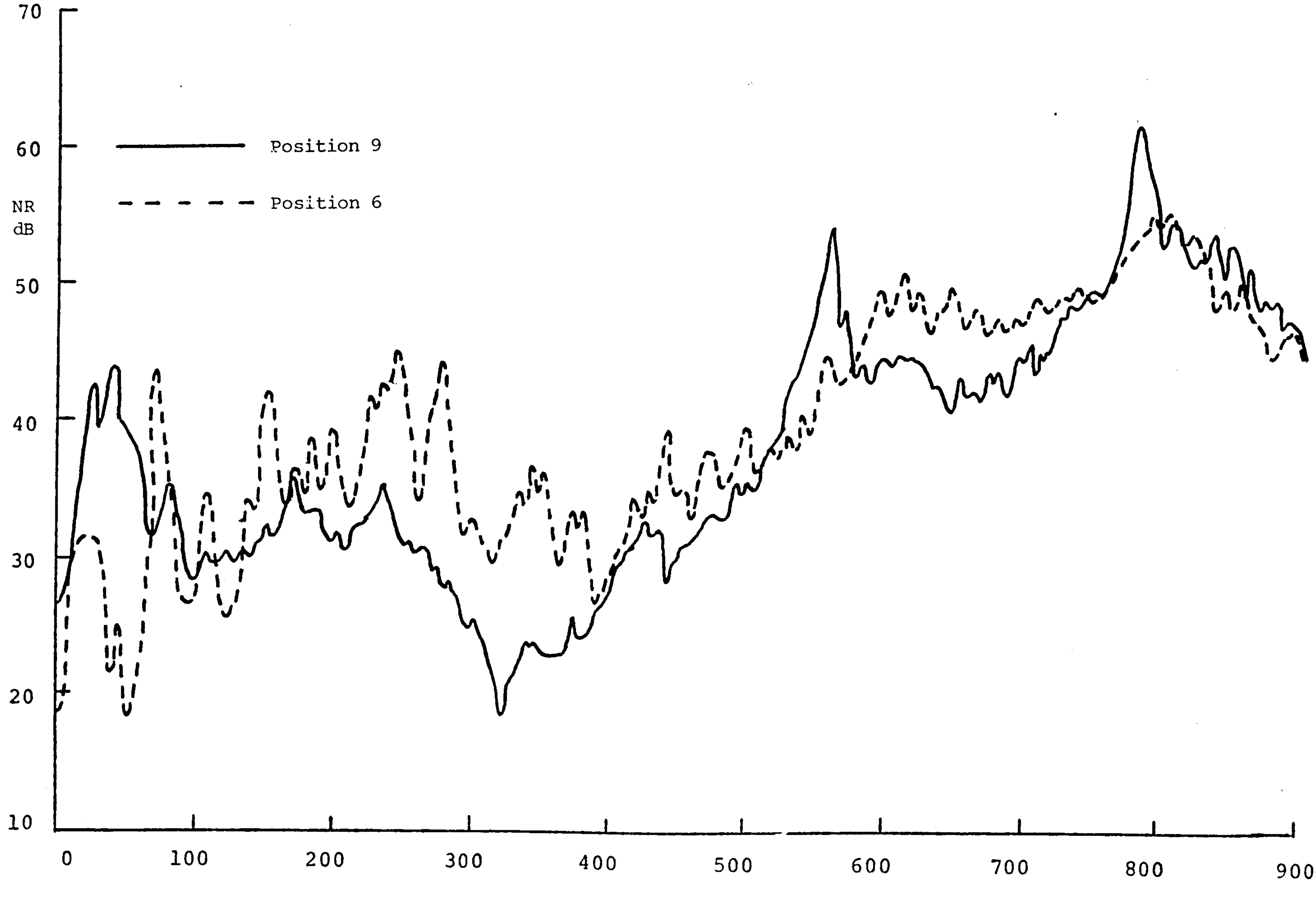


Fig. 53 Noise reduction of double wall window (7P) at positions 6 and 9 with three layers of blanket treatment.

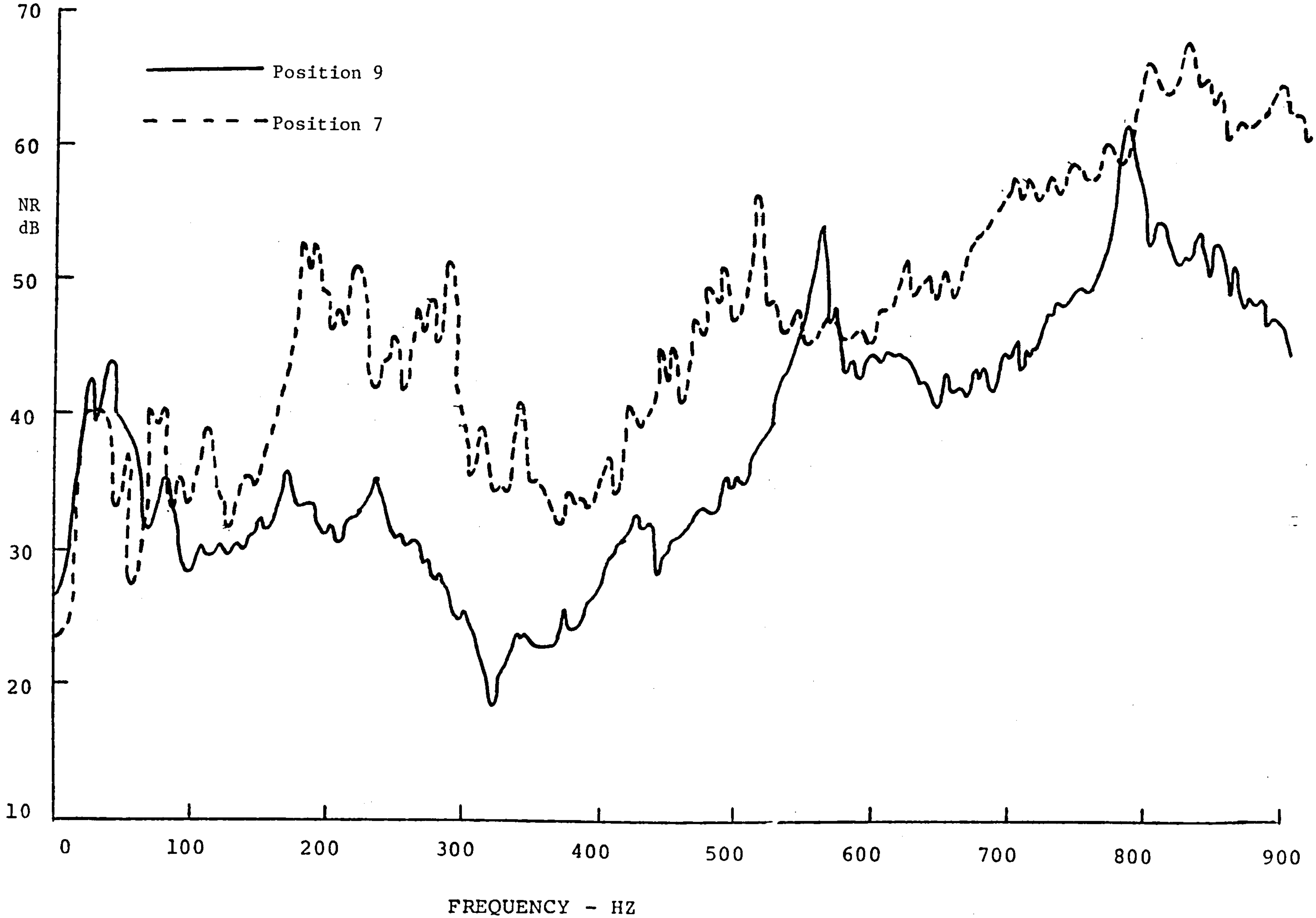


Fig. 54 Noise reduction of double wall window (7P) at positions 7 and 9 with three layers of . blanket treatment

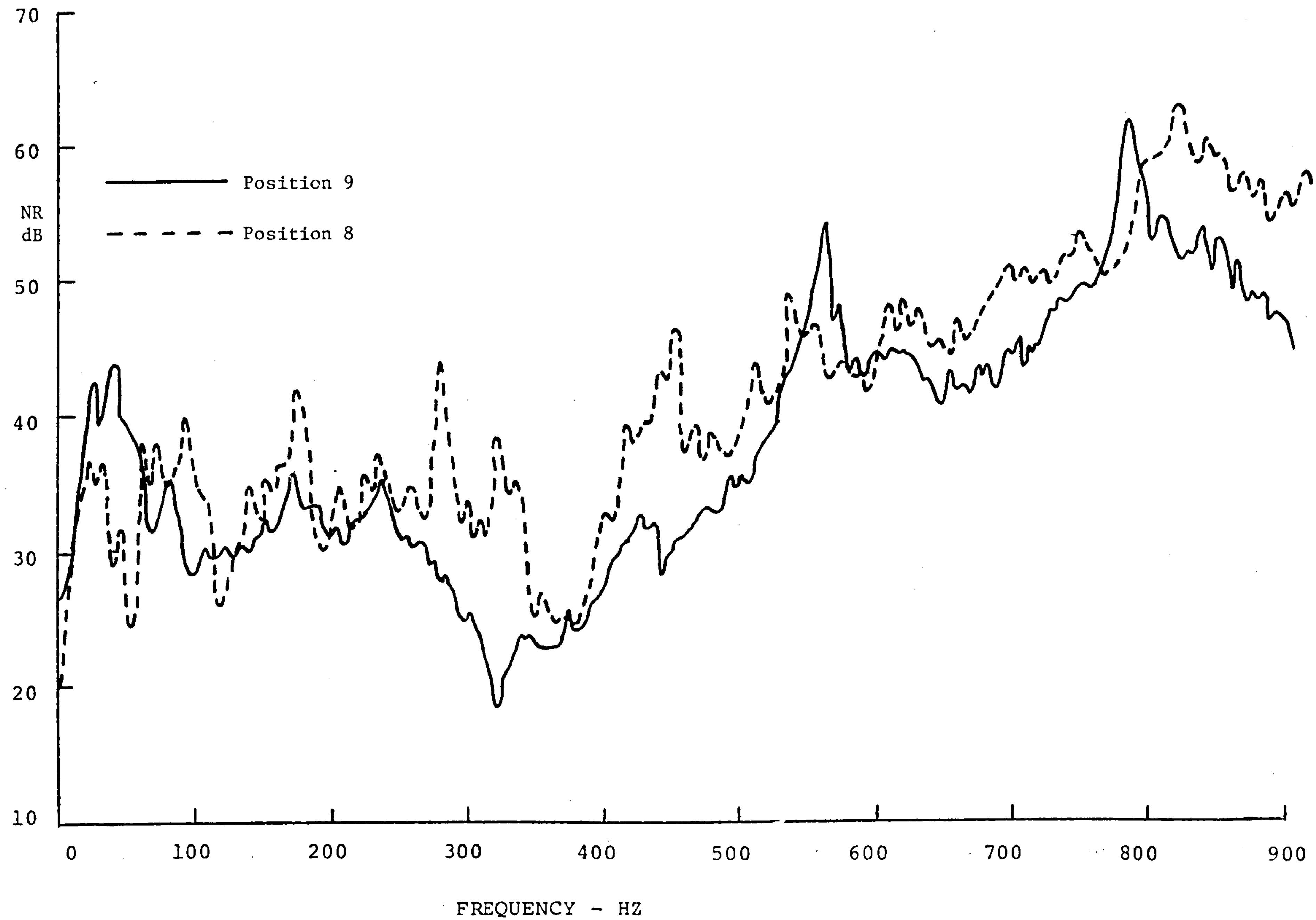


Fig. 55 Noise reduction of double wall window (7P) at positions 8 and 9 with three layers of blanket treatment

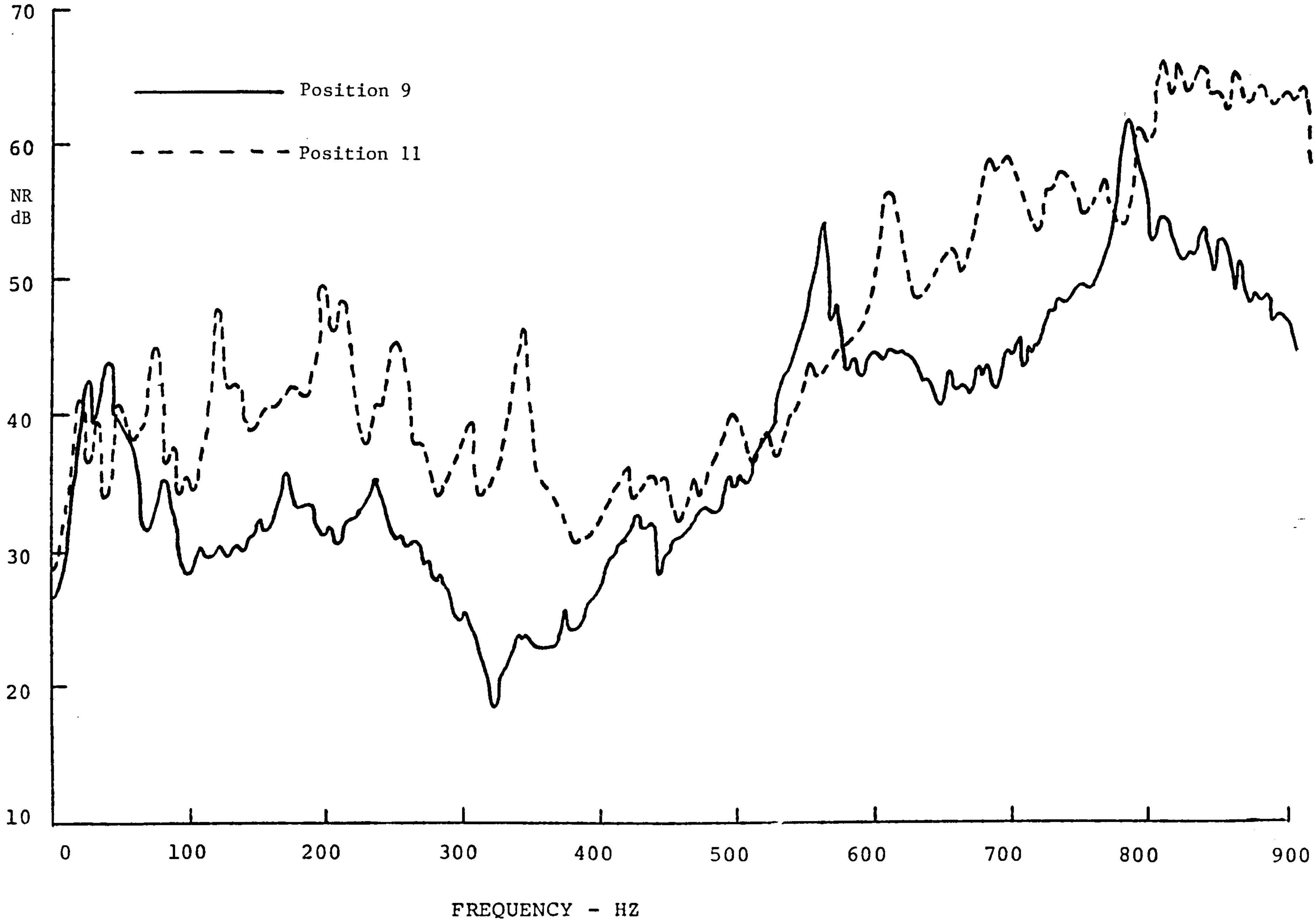


Fig. 56 Noise reduction of double wall window (7P) at positions 11 and 9 with three layers of blanket treatment

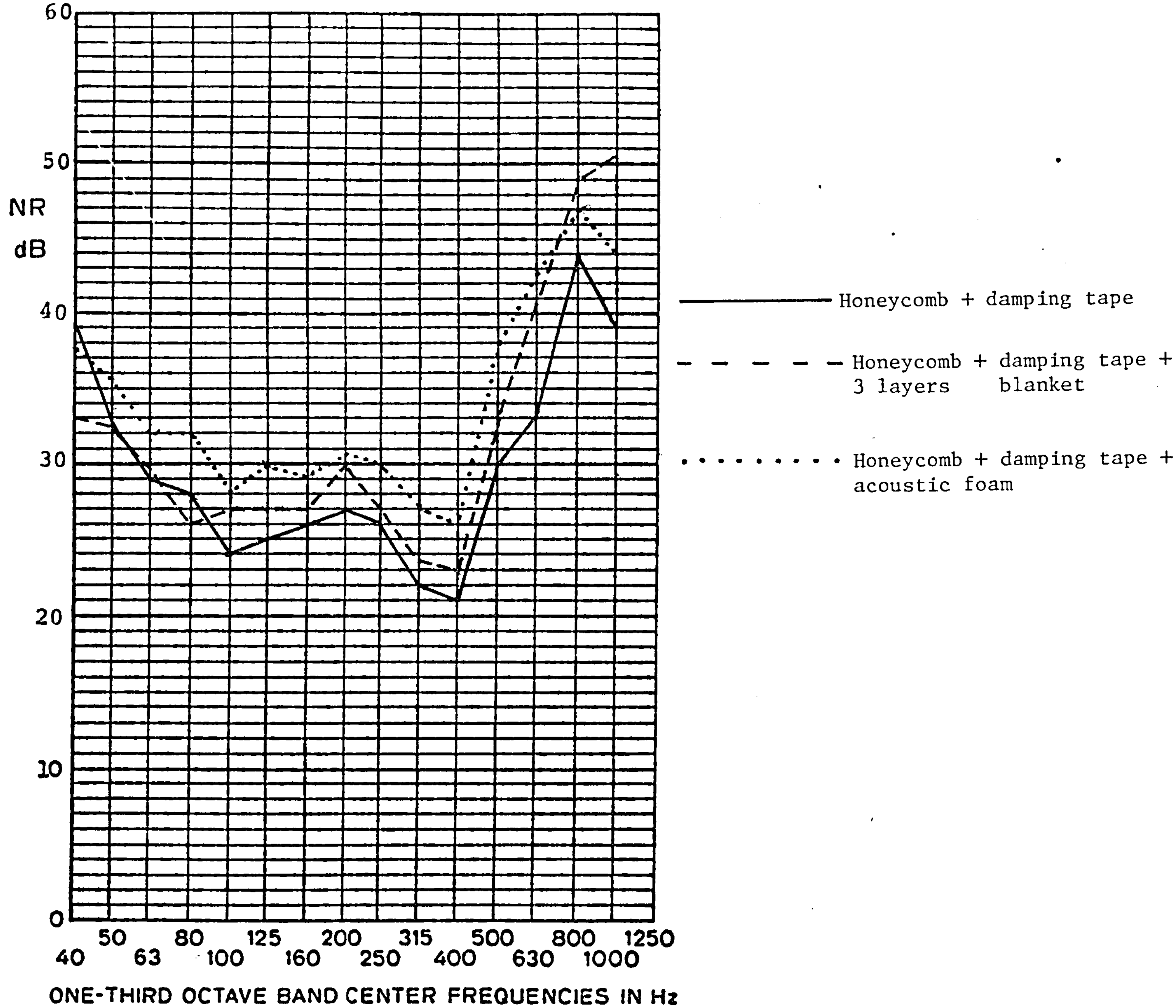


Fig. 57 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 9)

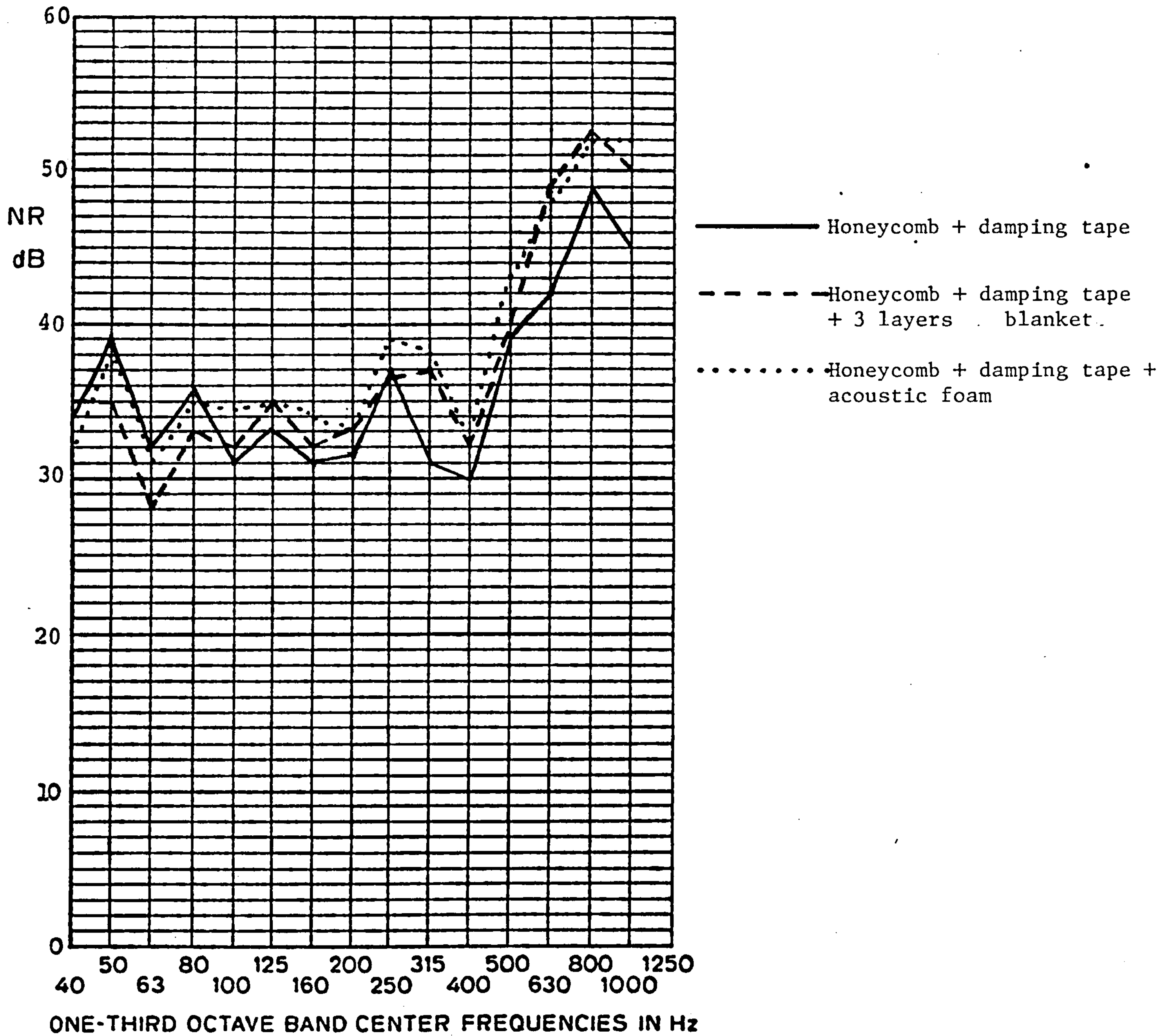


Fig. 58 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 1)

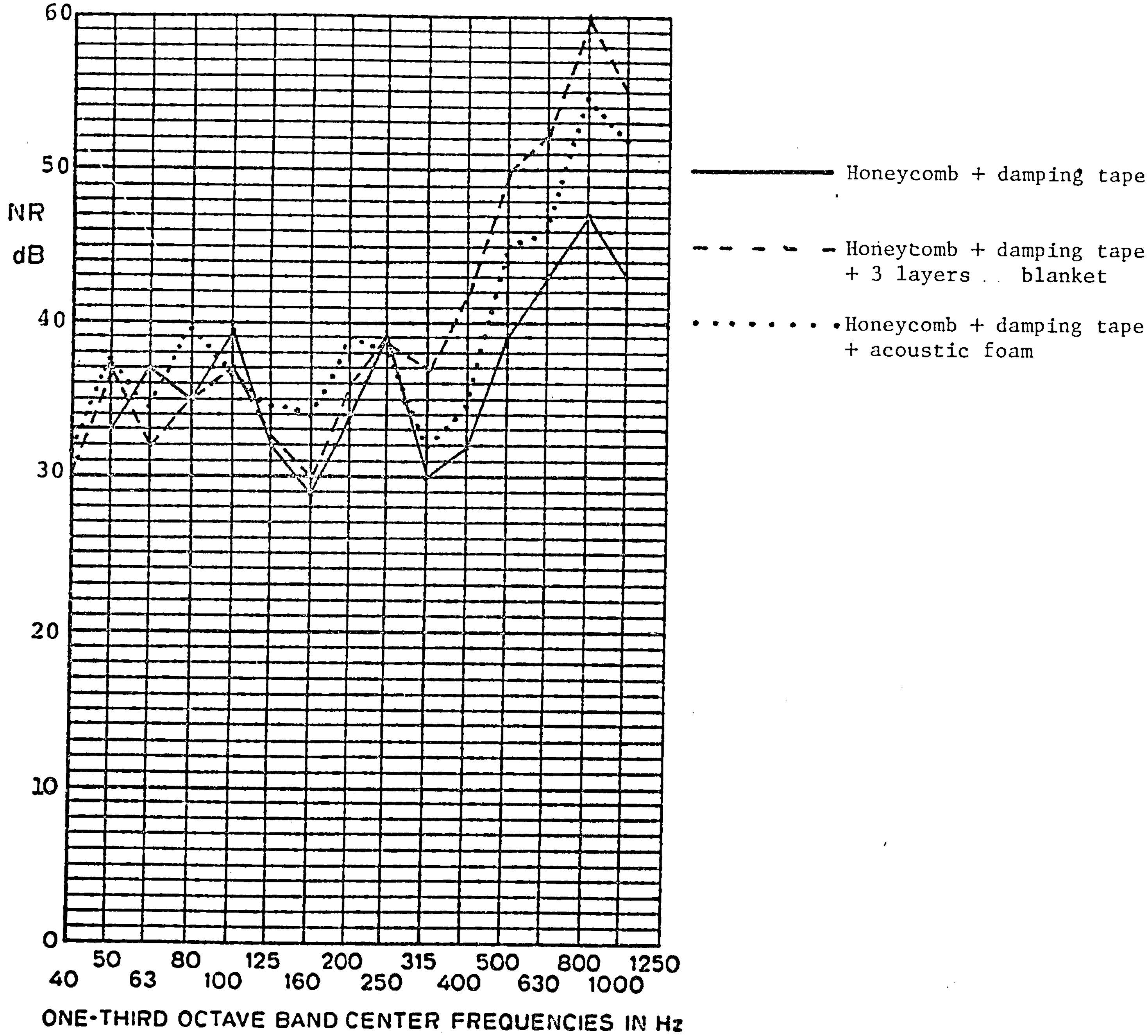


Fig. 59 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 2)

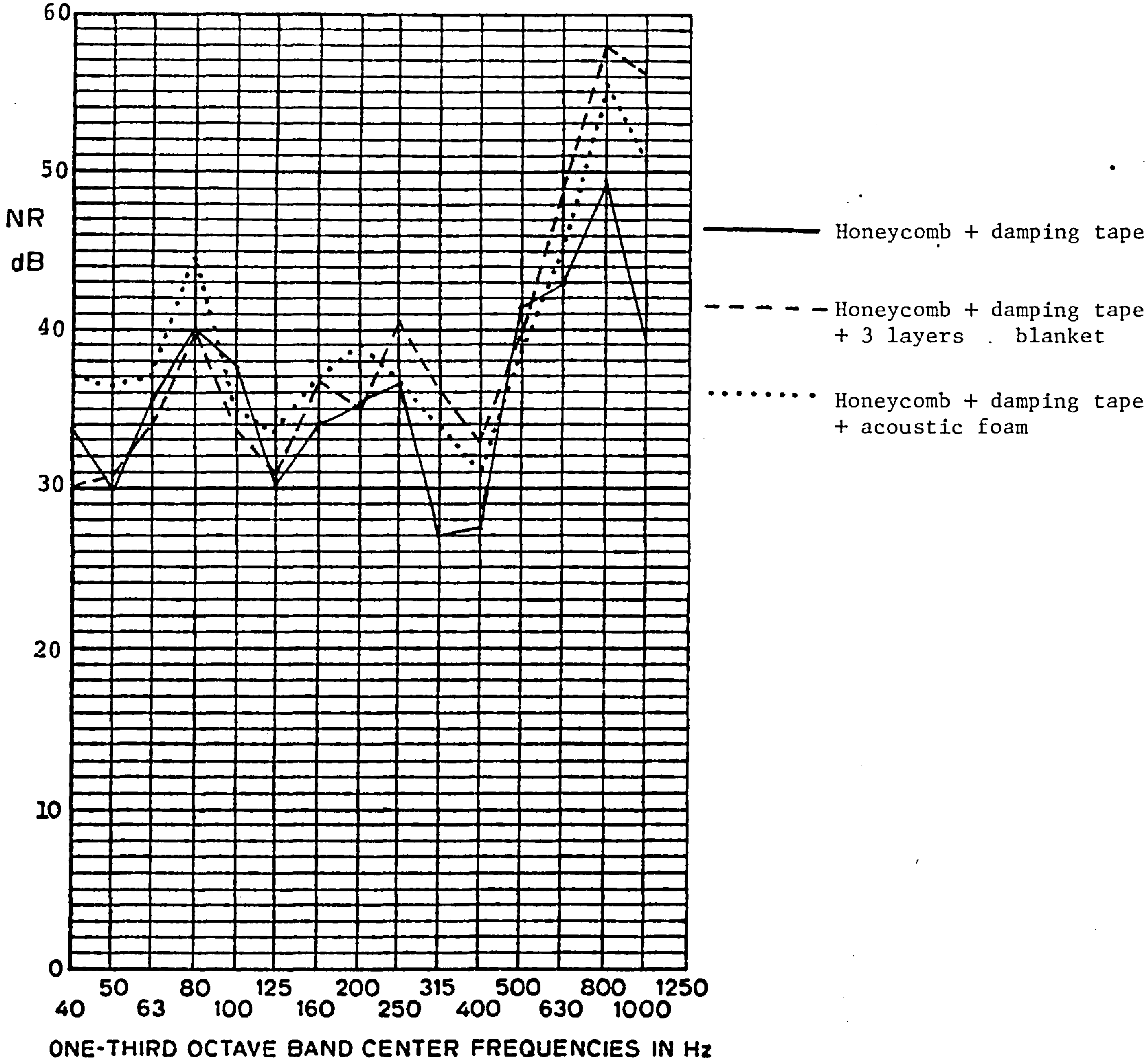


Fig. 60 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 3)

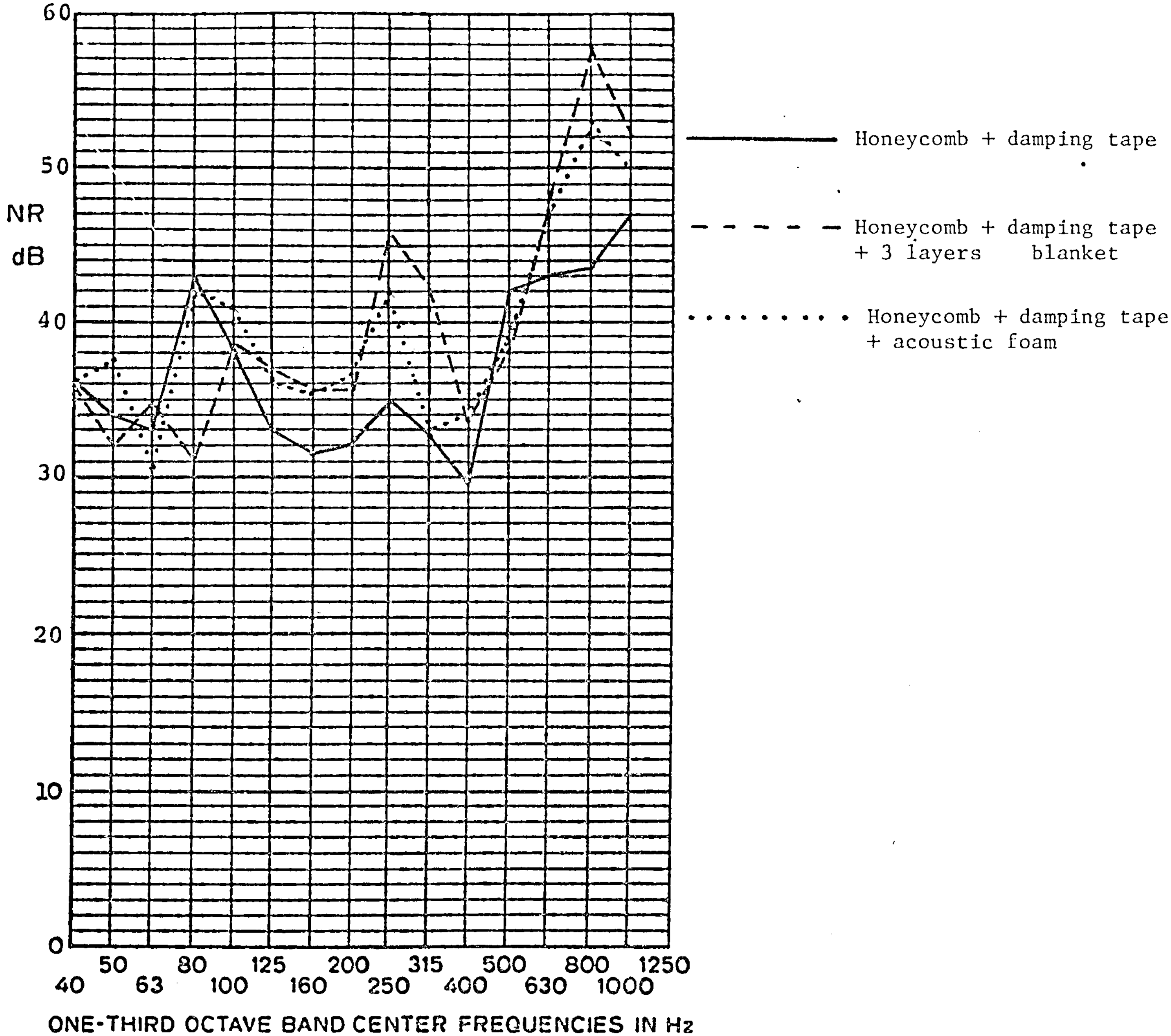


Fig. 61 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 4)

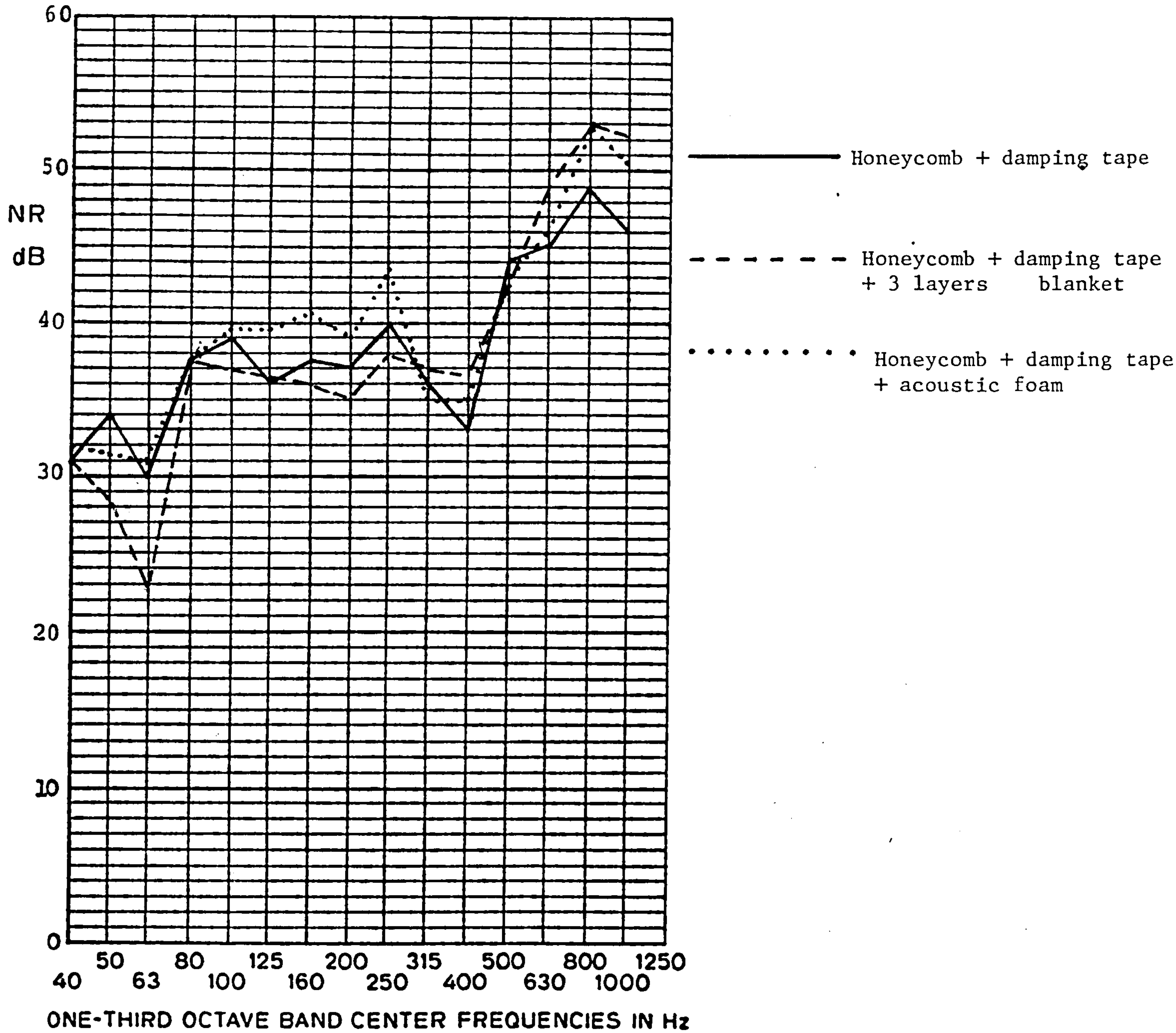


Fig. 62 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 5)

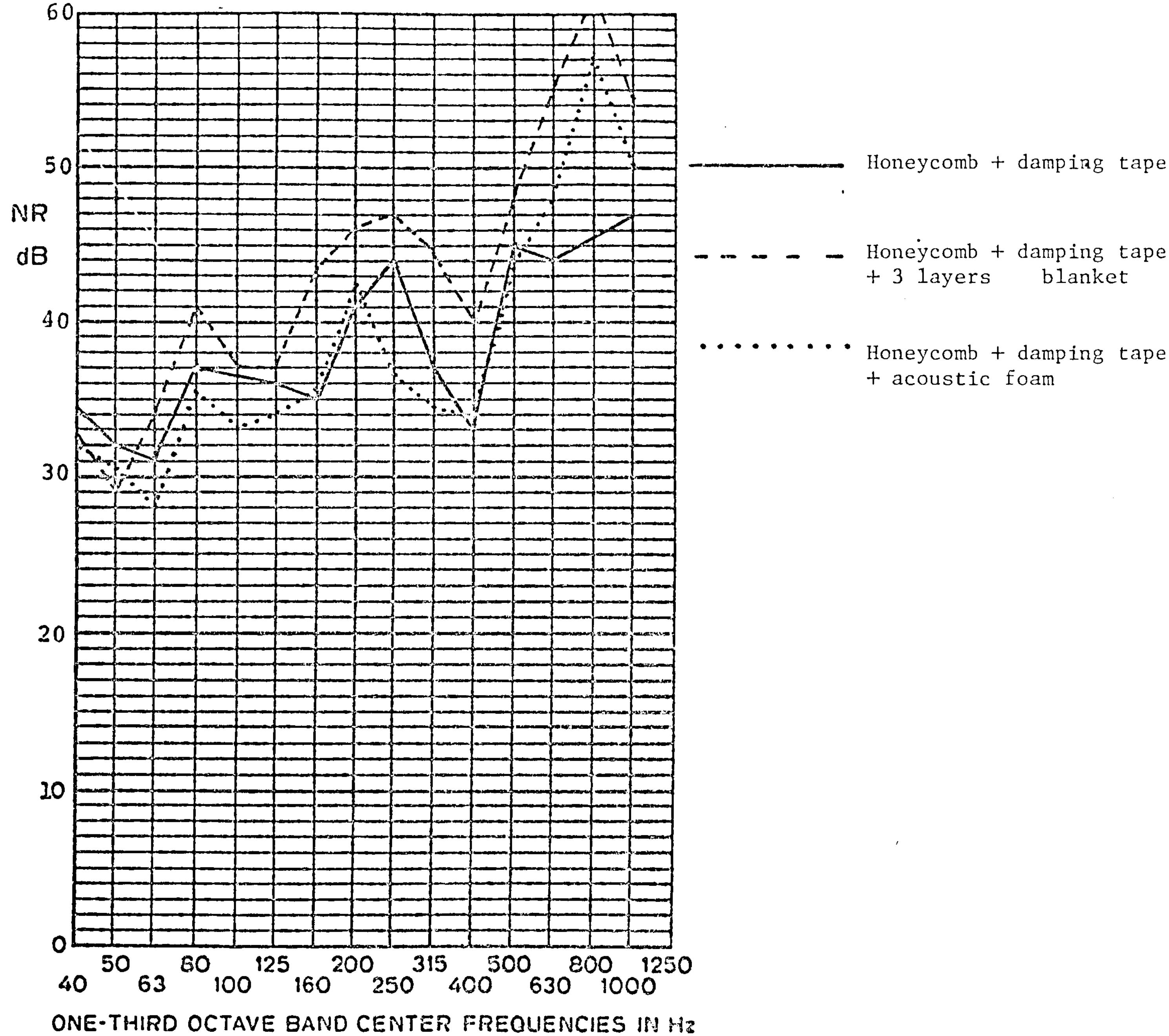


Fig. 63 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 6)

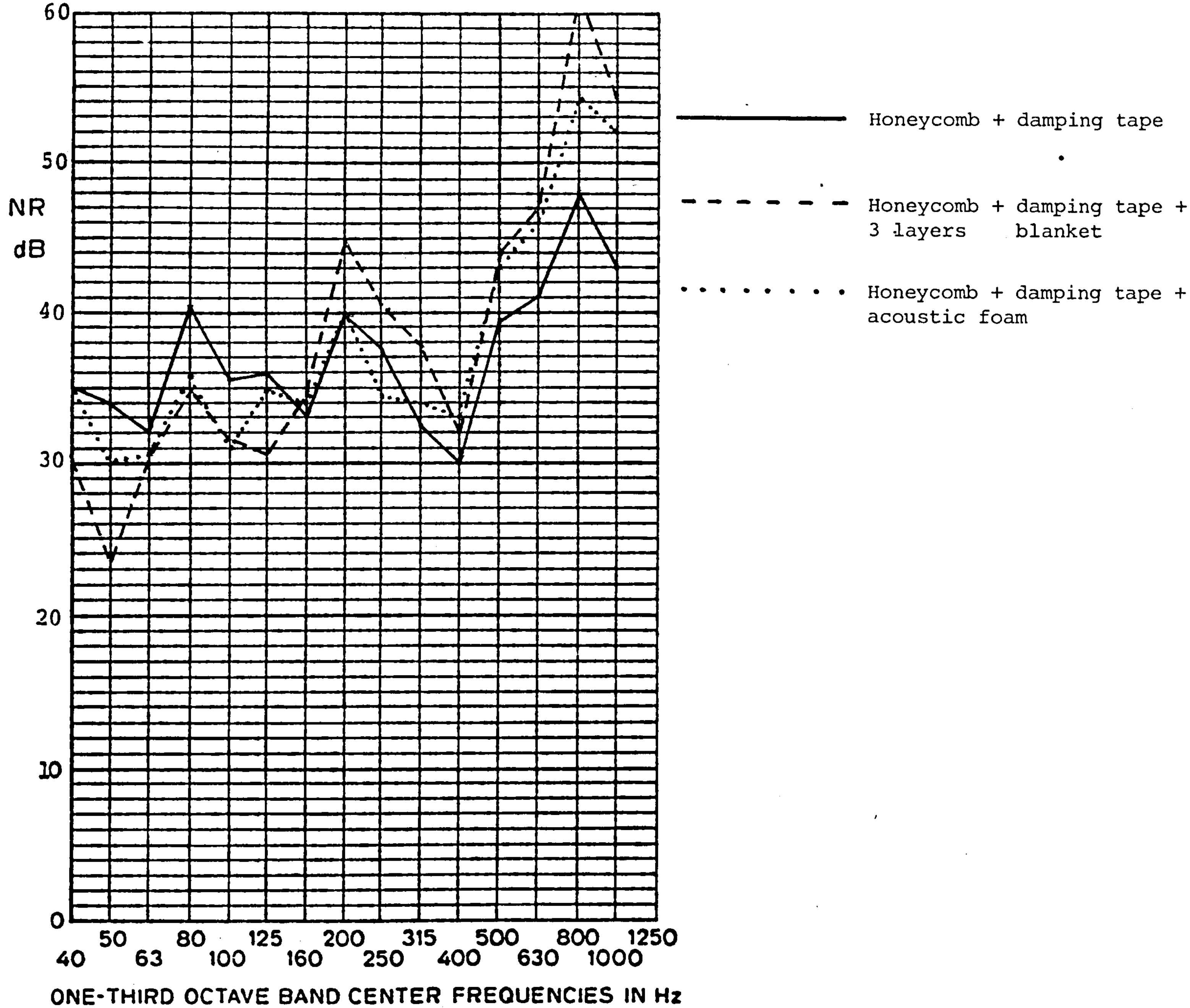


Fig. 64 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 7)

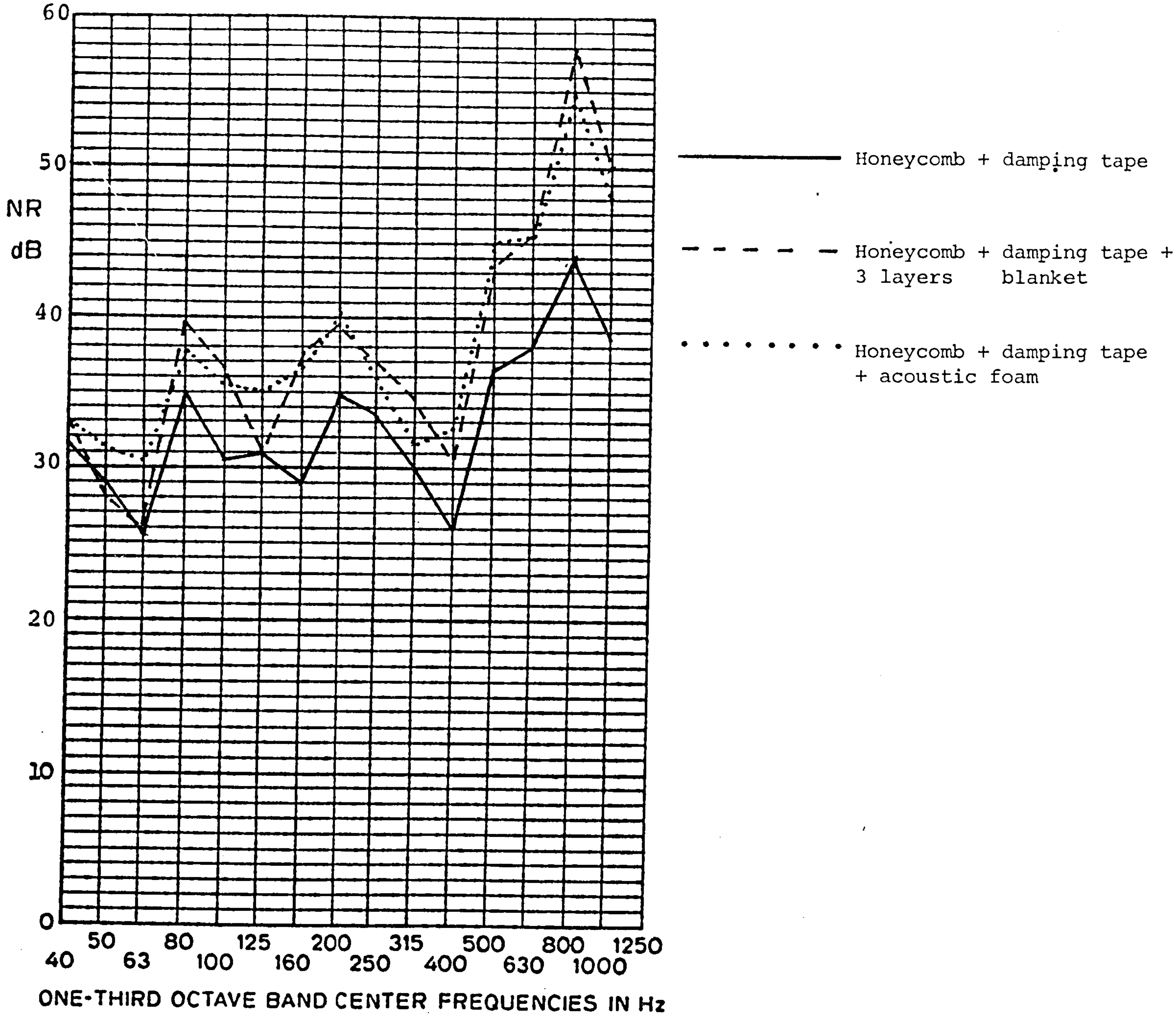


Fig. 65 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 8)

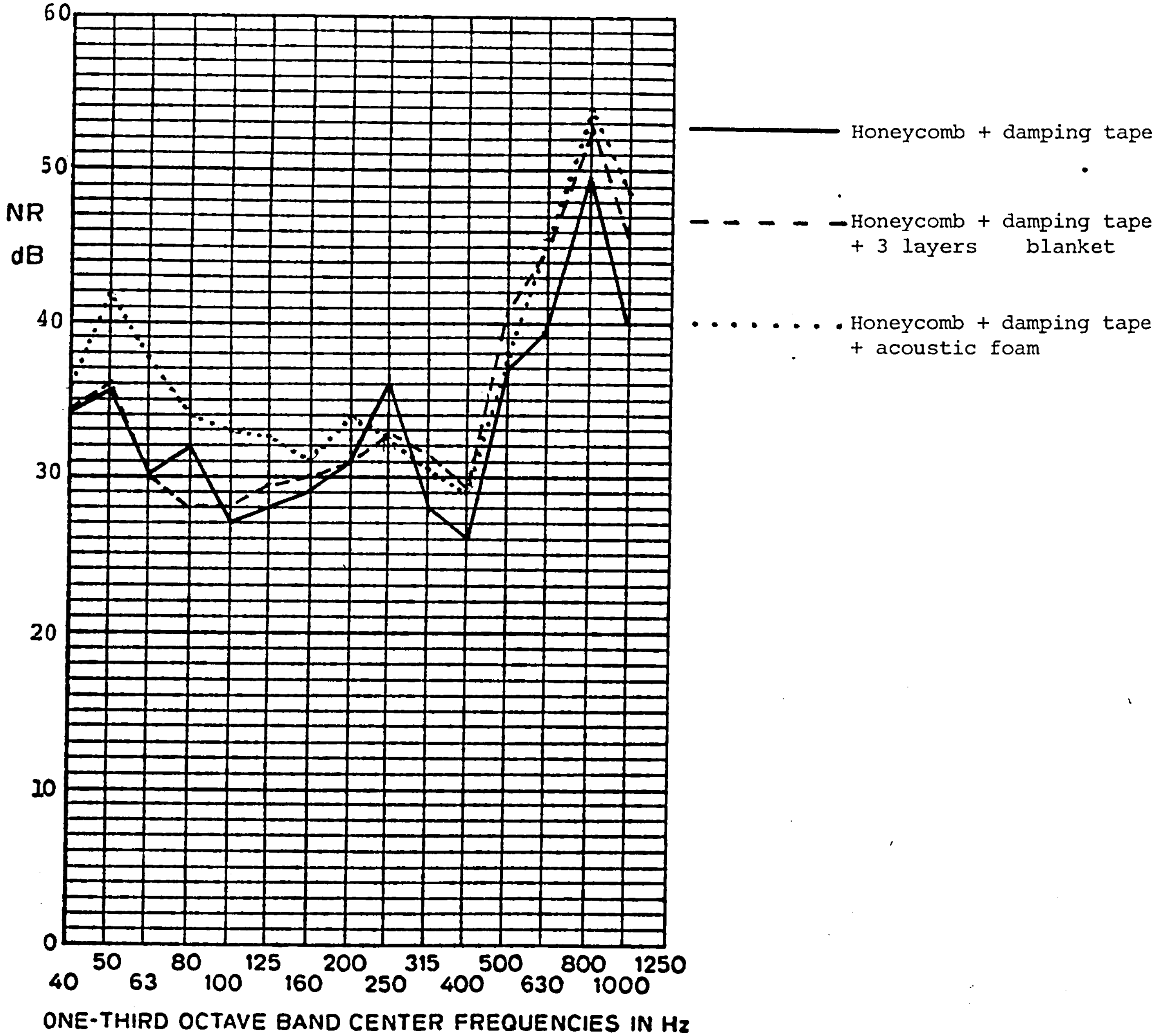


Fig. 66 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 10)

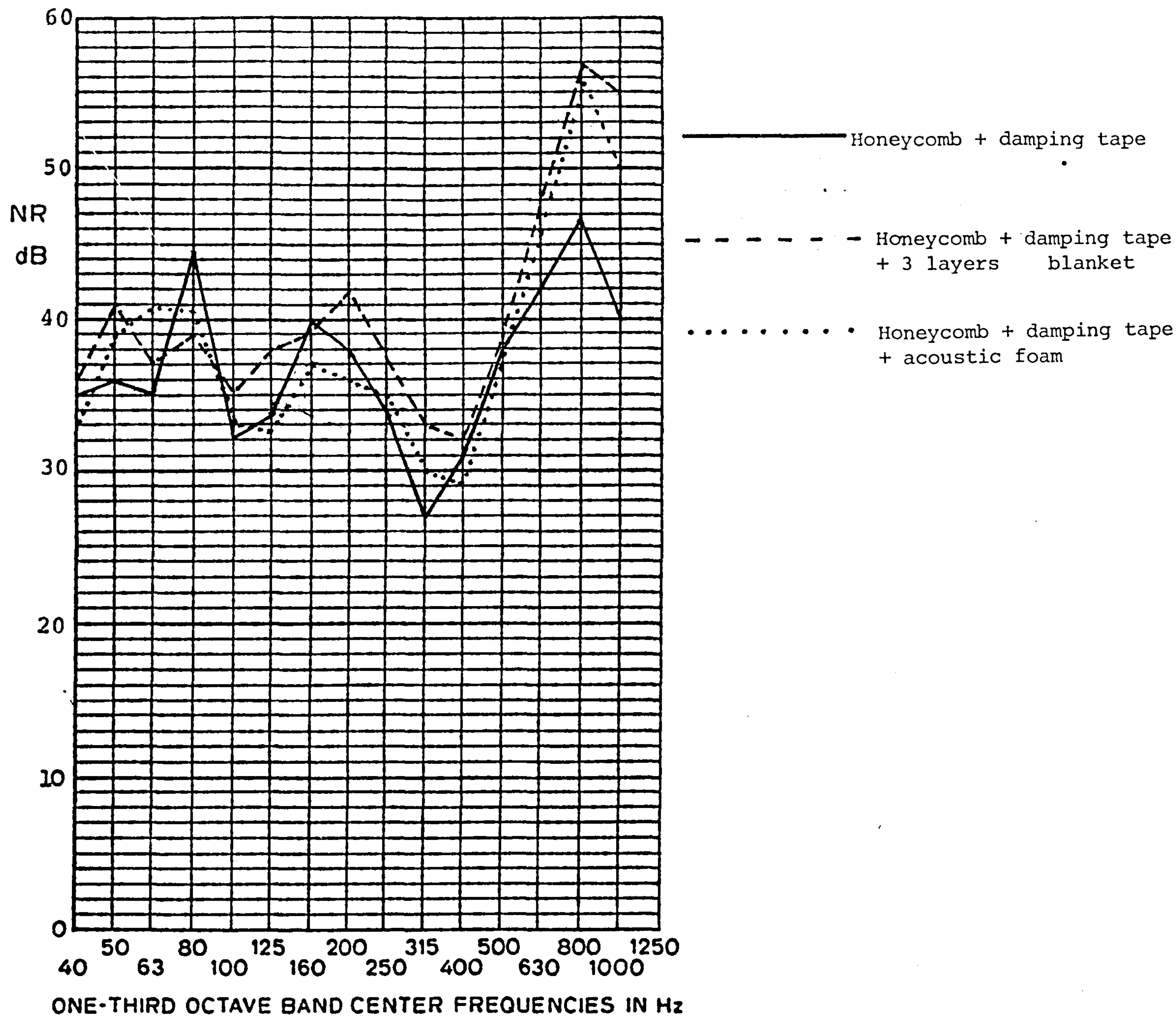


Fig. 67 Noise reduction of double wall window (7P) for different treatments of interior cabin (Position 11)

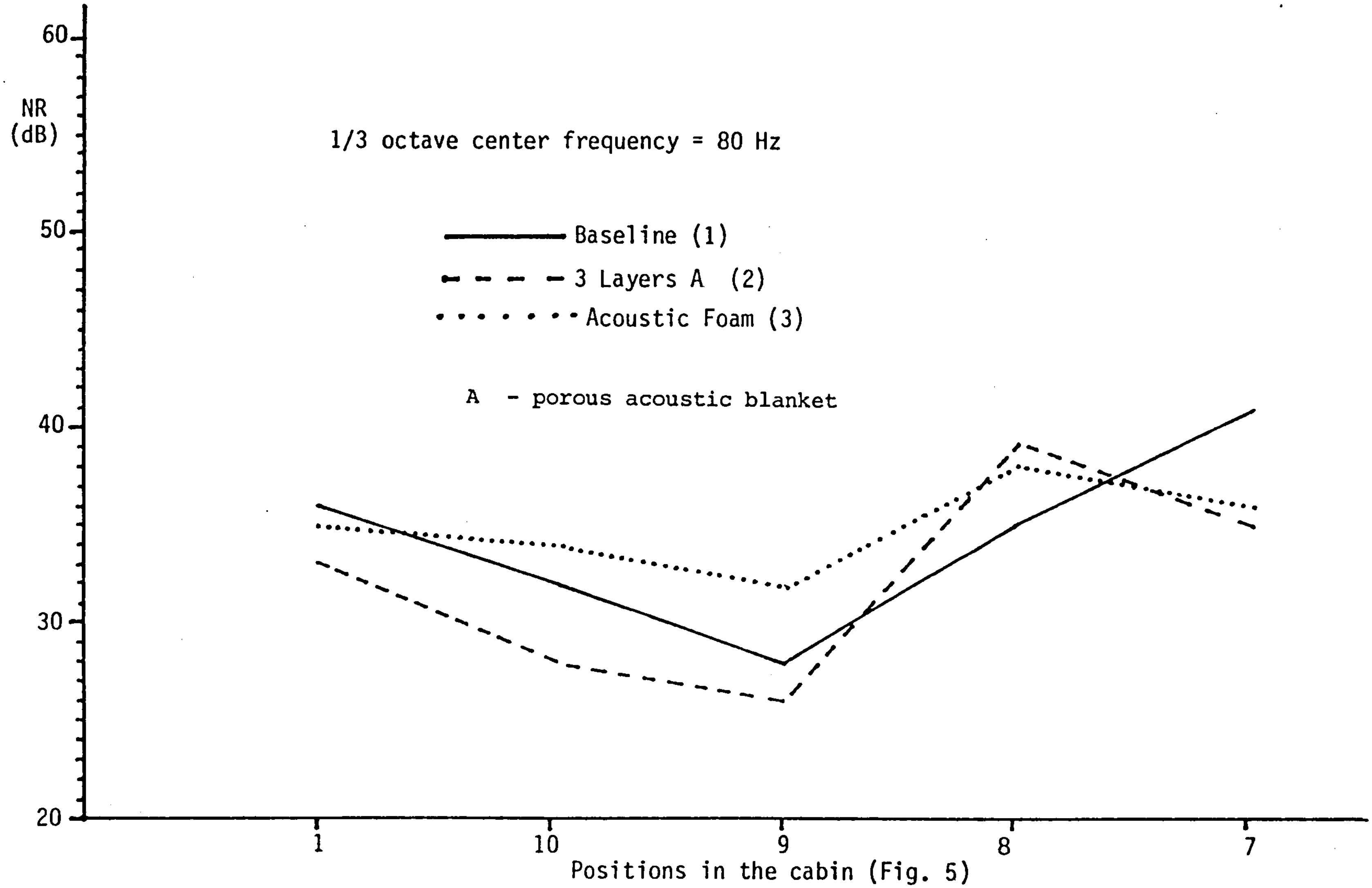


Fig. 68 Noise Reduction in the Cabin (Center Frequency = 80 Hz, Port)

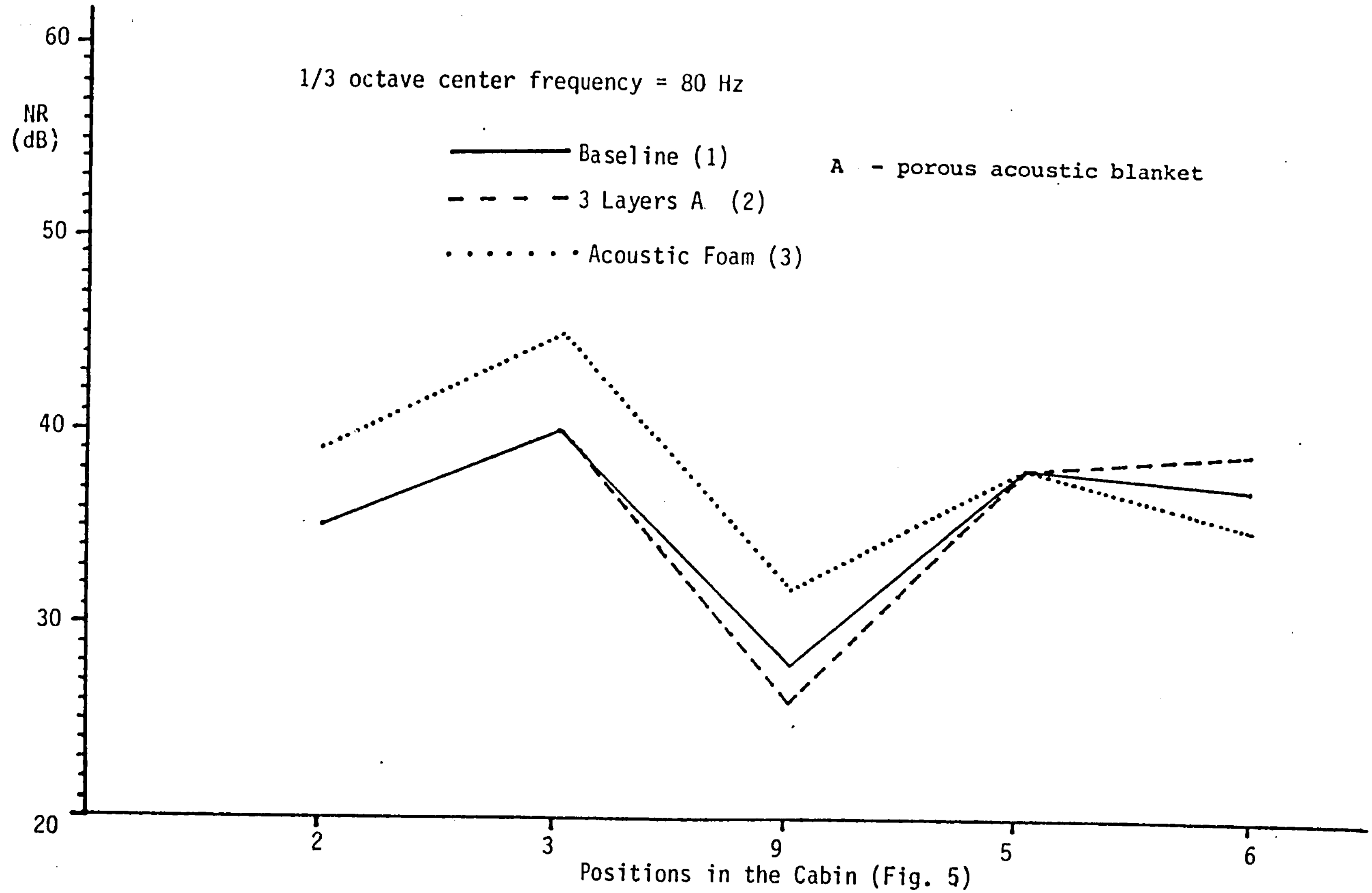


Fig. 69 Noise Reduction in the Cabin (Center Frequency = 80 Hz, Starboard)

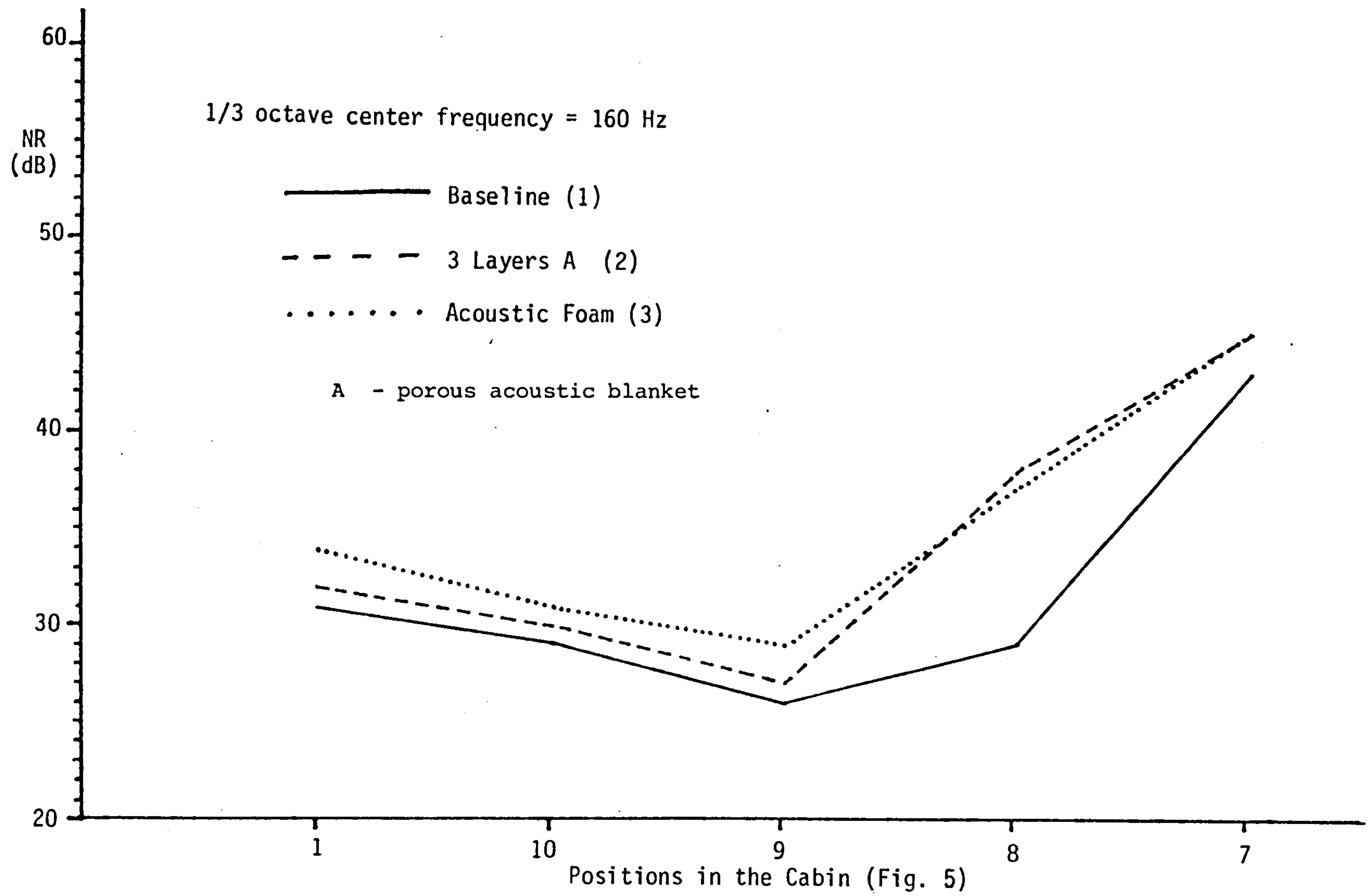


Fig. 70 Noise Reduction in the Cabin (Center Frequency = 160 Hz, Port)

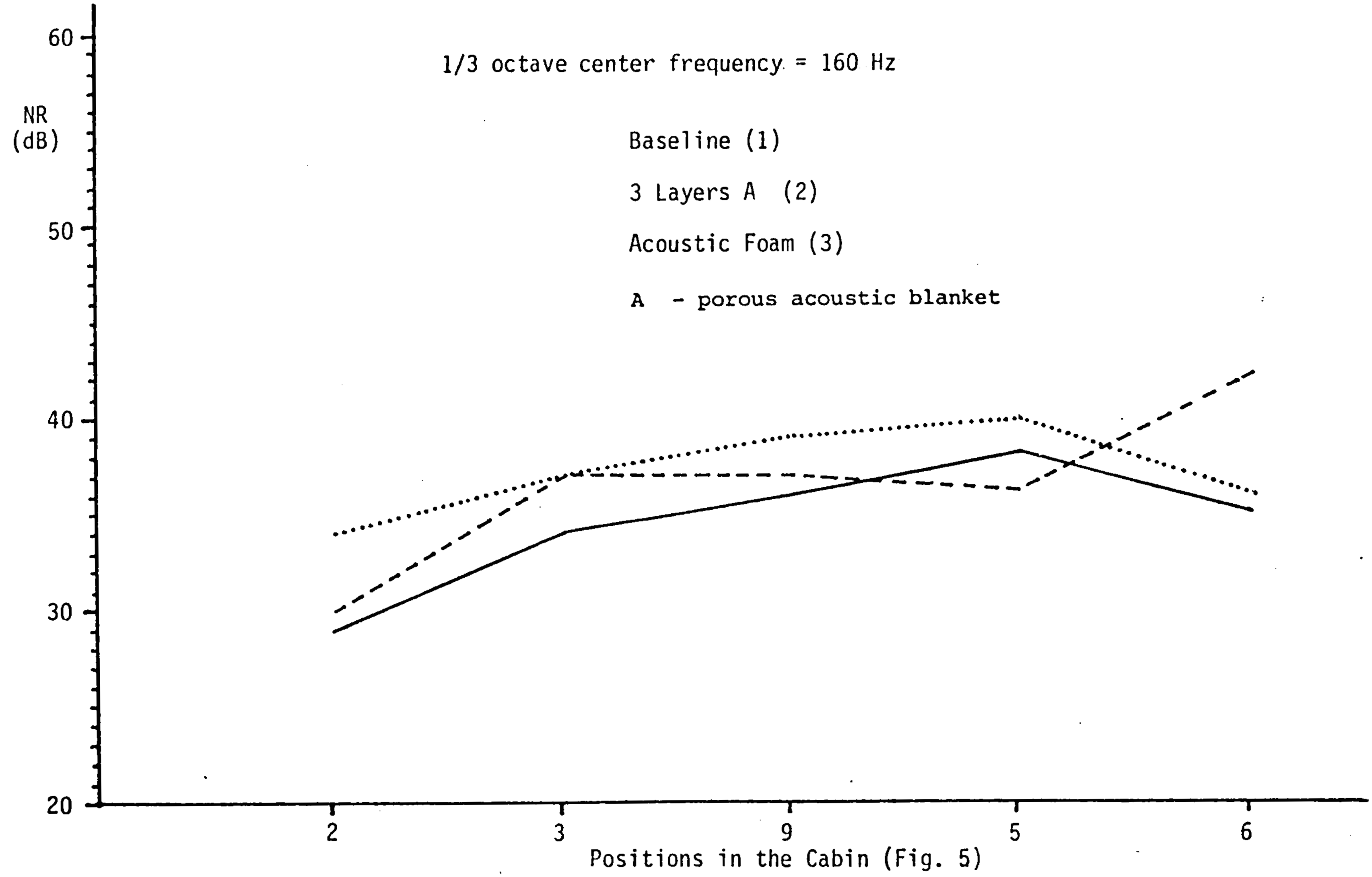


Fig. 71 Noise Reduction in the Cabin (Center Frequency = 160 Hz, Starboard)

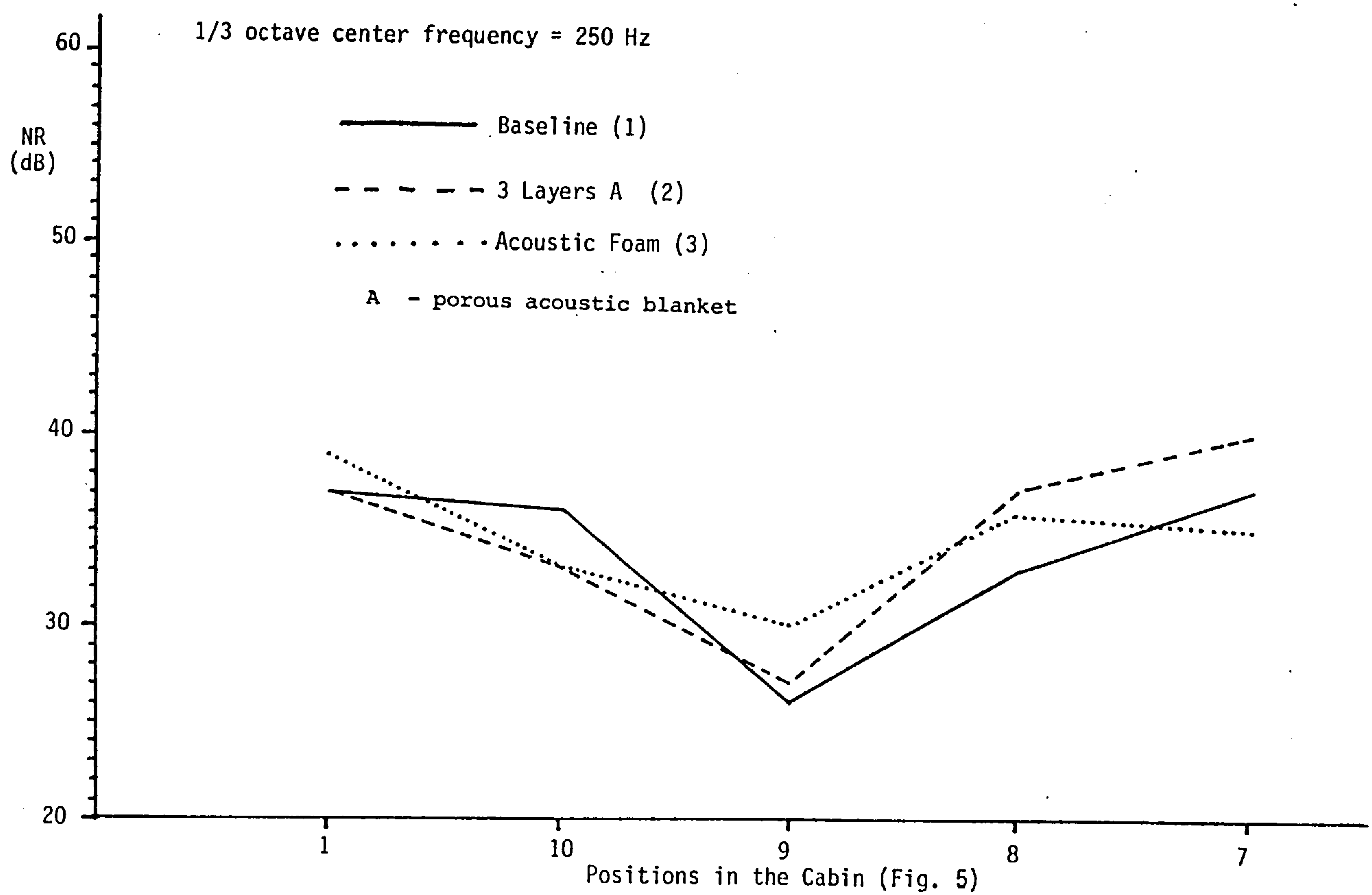


Fig. 72 Noise Reduction in the Cabin (Center Frequency = 250 Hz, Port)

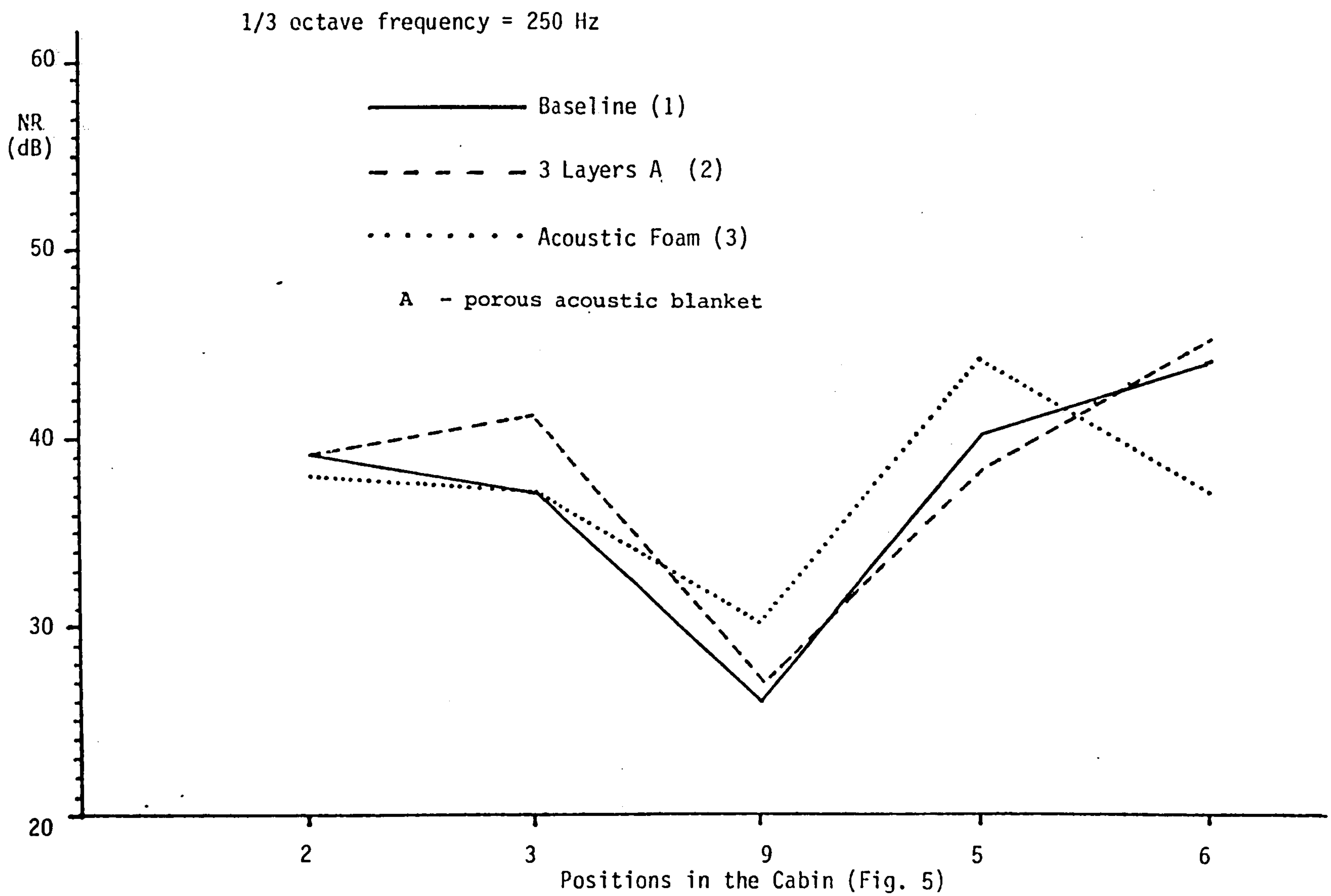


Fig. 73 Noise Reduction in the Cabin (Center Frequency = 250 Hz, Starboard)

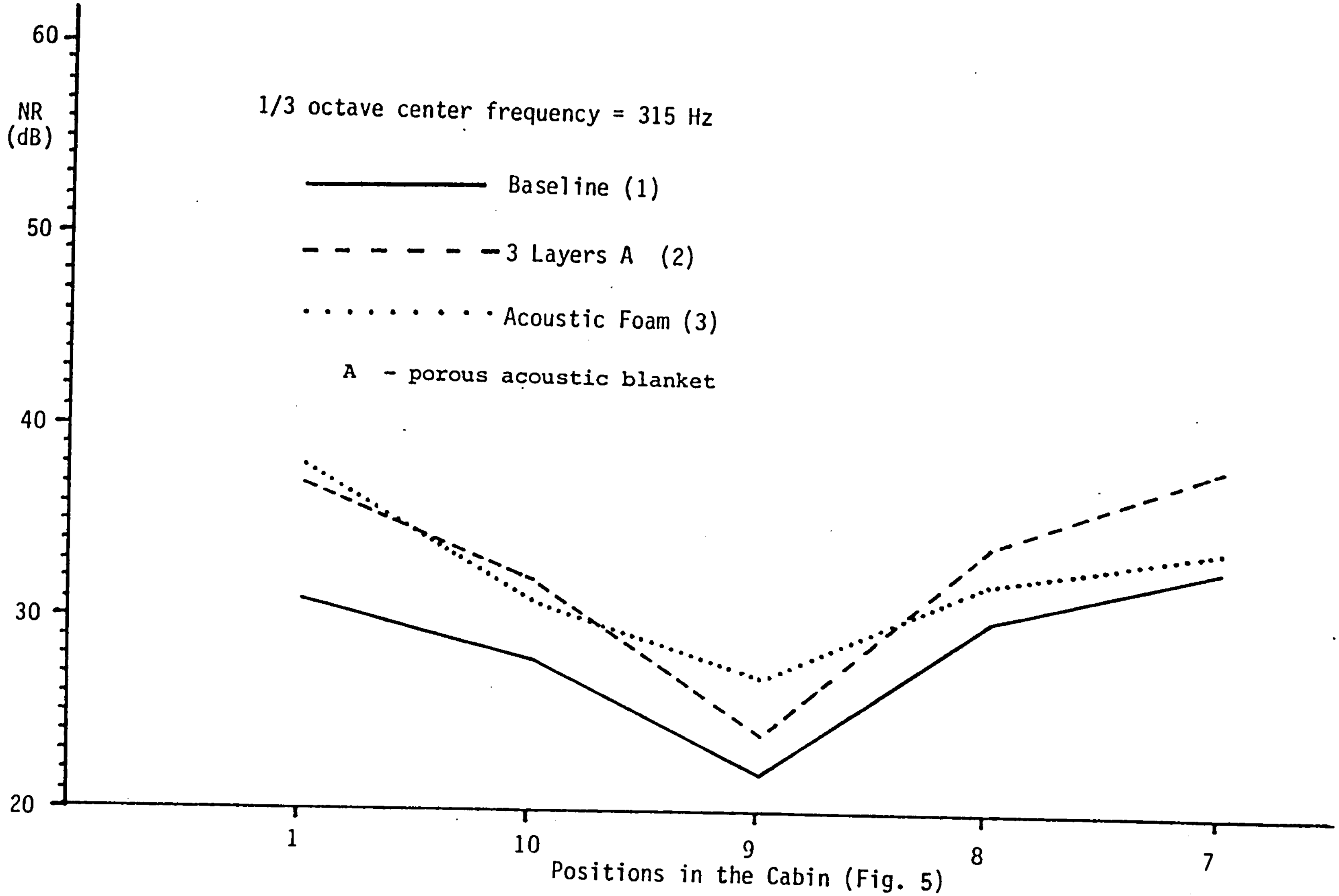


Fig. 74 Noise Reduction in the Cabin (Center Frequency = 315 Hz, Port)

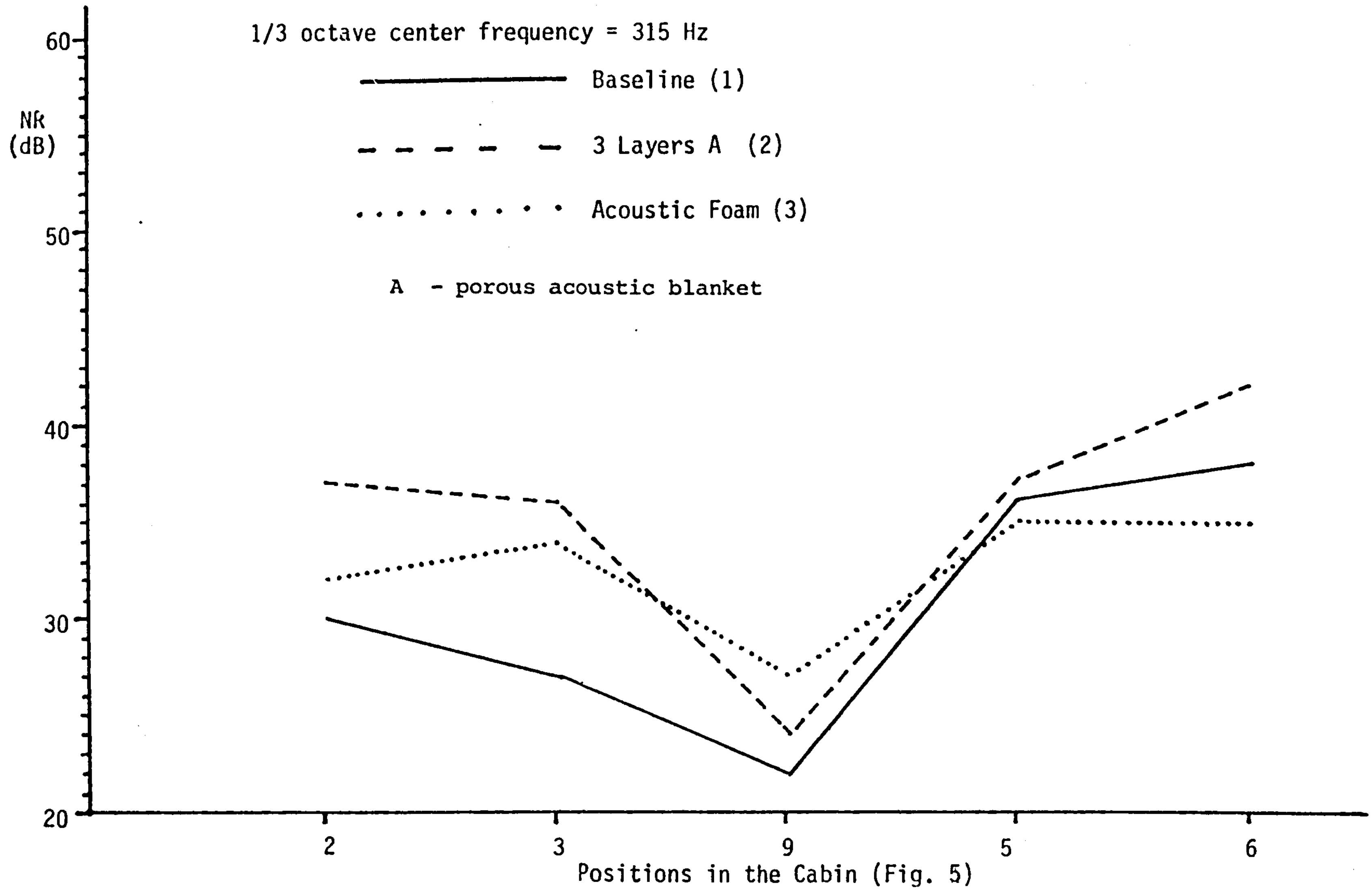


Fig. 75 Noise Reduction in the Cabin (Center Frequency = 315 Hz, Starboard)

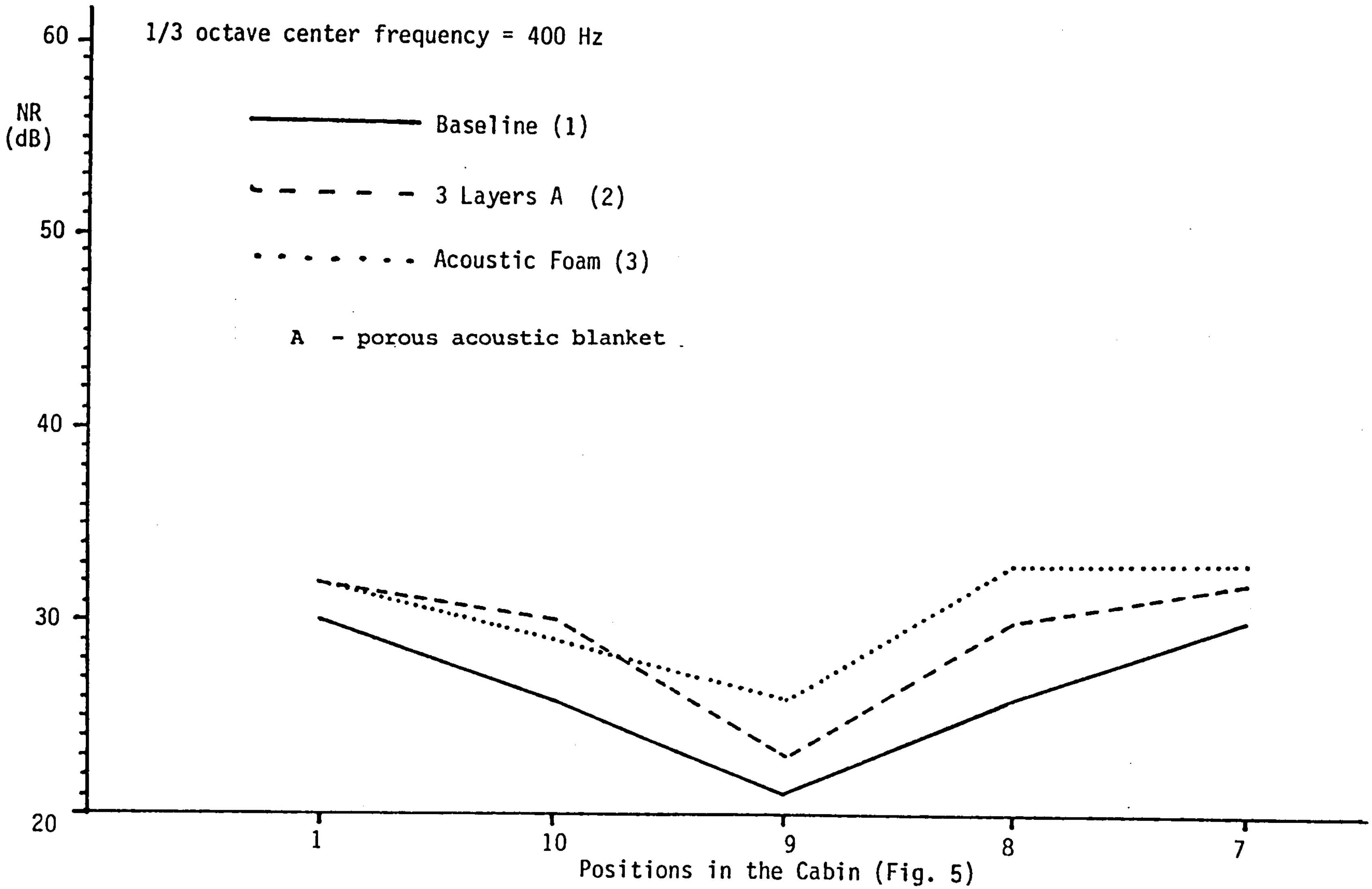


Fig. 76 Noise Reduction in the Cabin (Center Frequency = 400 Hz, Port)

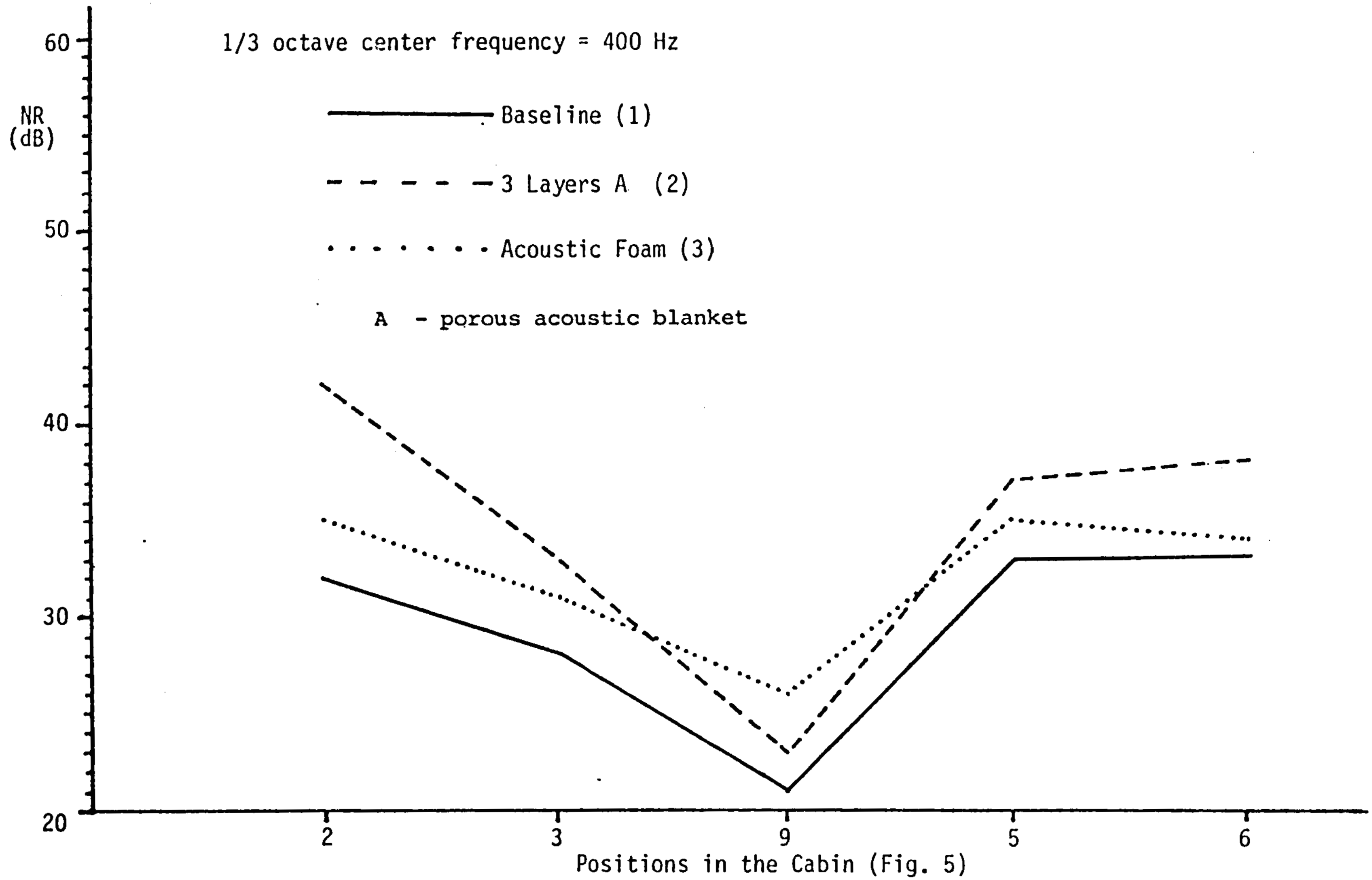


Fig. 77 Noise Reduction in the Cabin (Center Frequency = 400 Hz, Starboard)

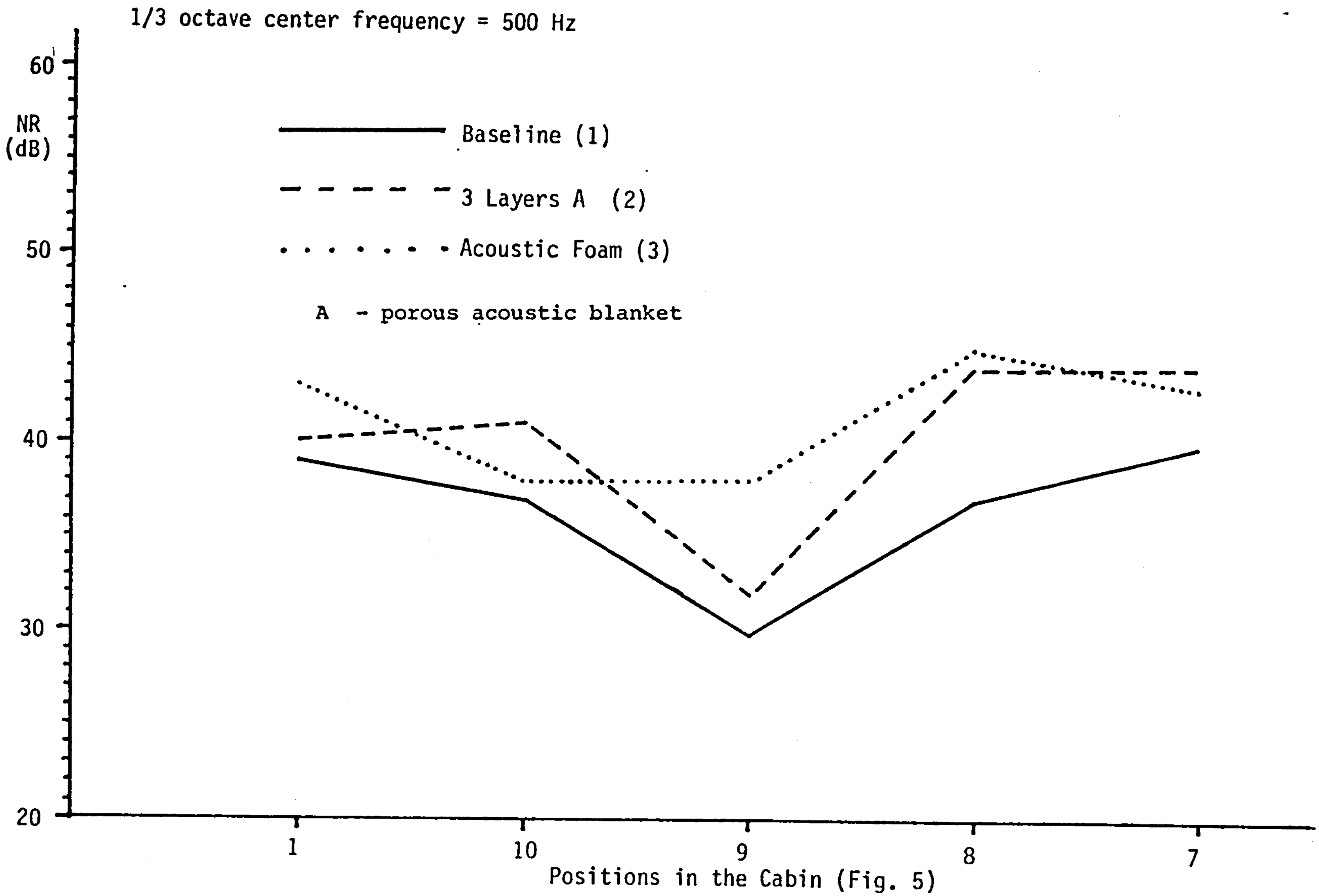


Fig. 78 Noise Reduction in the Cabin (Center Frequency = 500 Hz, Port)

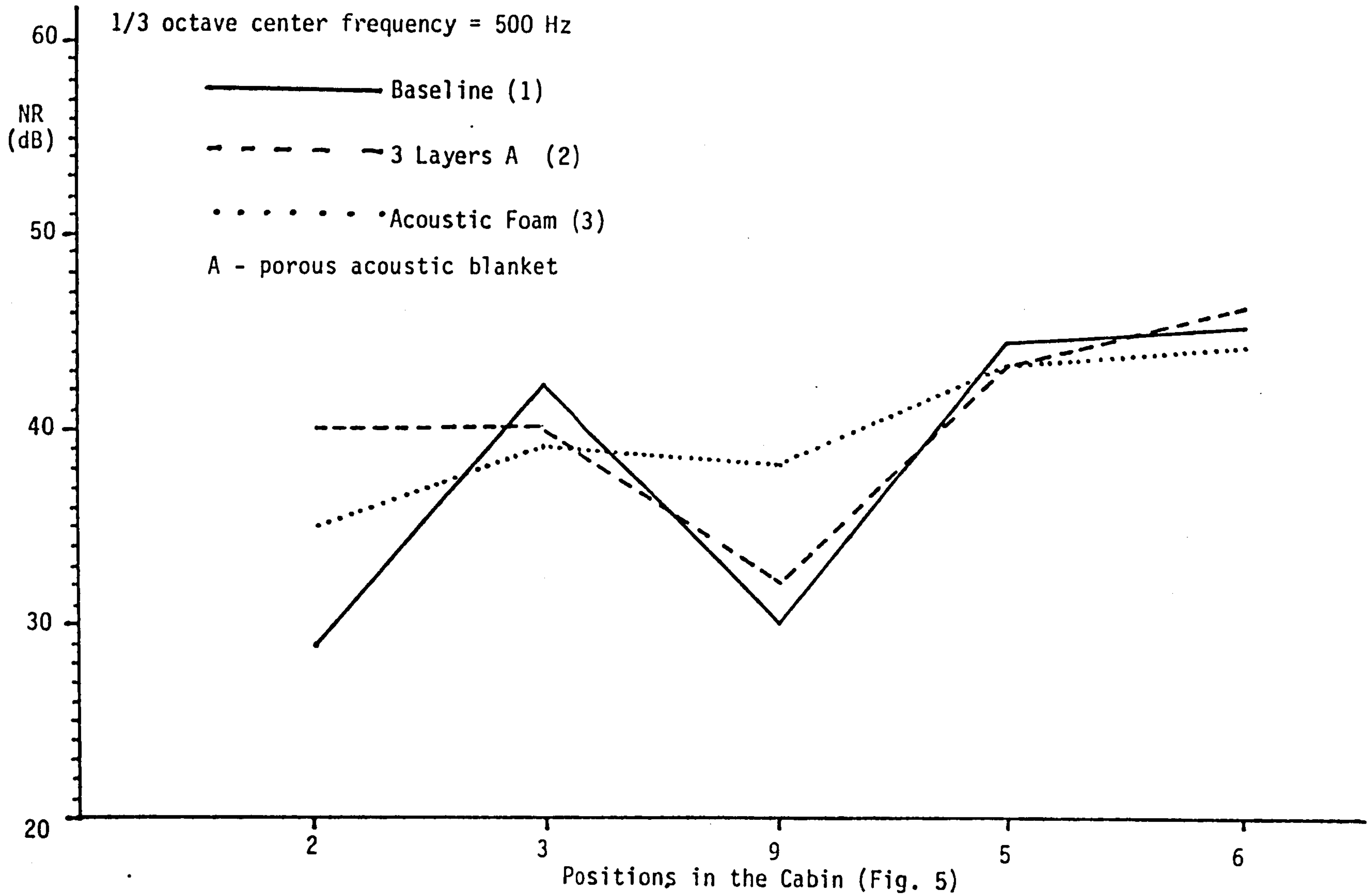


Fig. 79 Noise Reduction in the Cabin (Center Frequency 500 Hz Starboard)

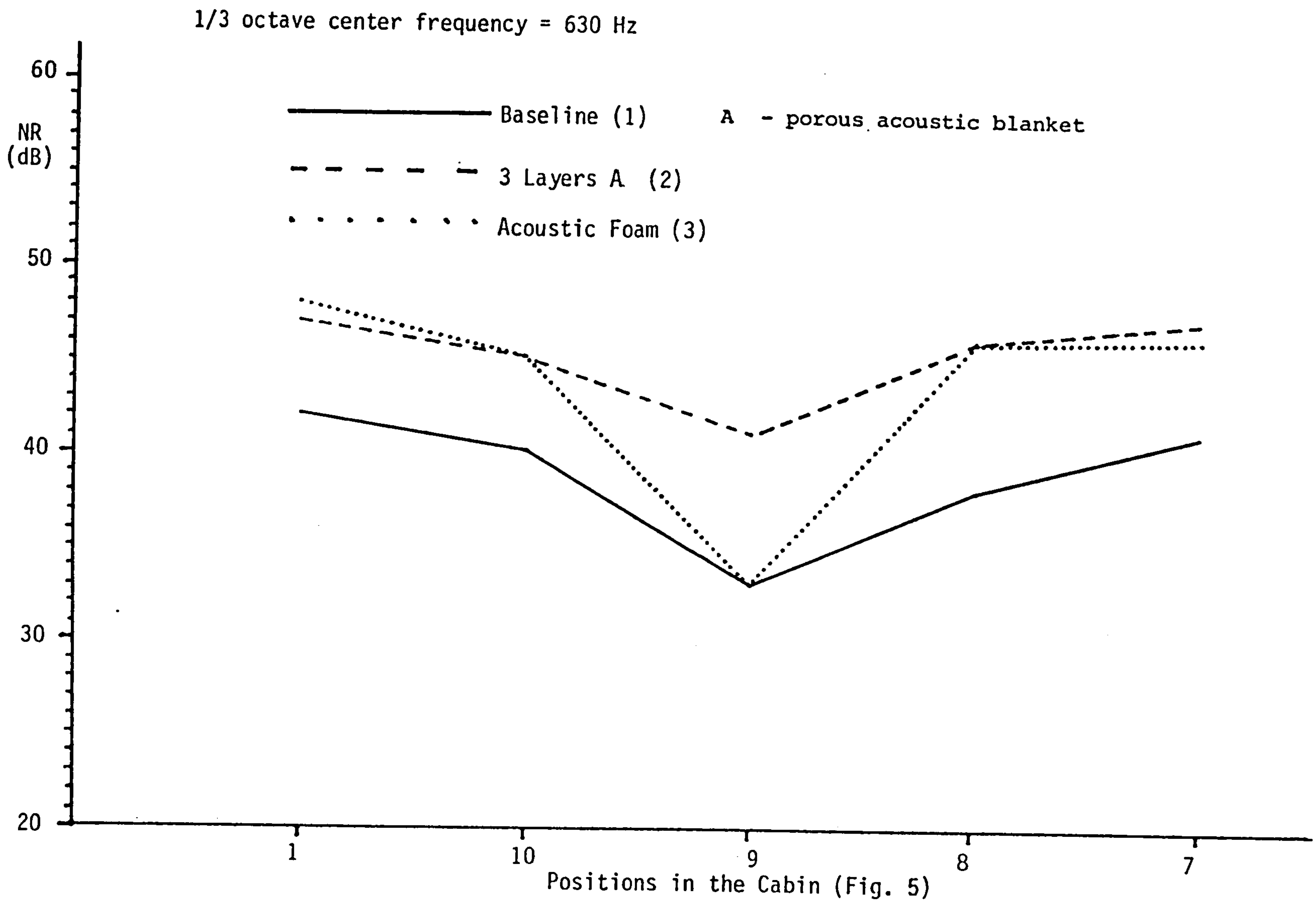


Fig. 80 Noise Reduction in the Cabin (Center Frequency = 630 Hz, Port)

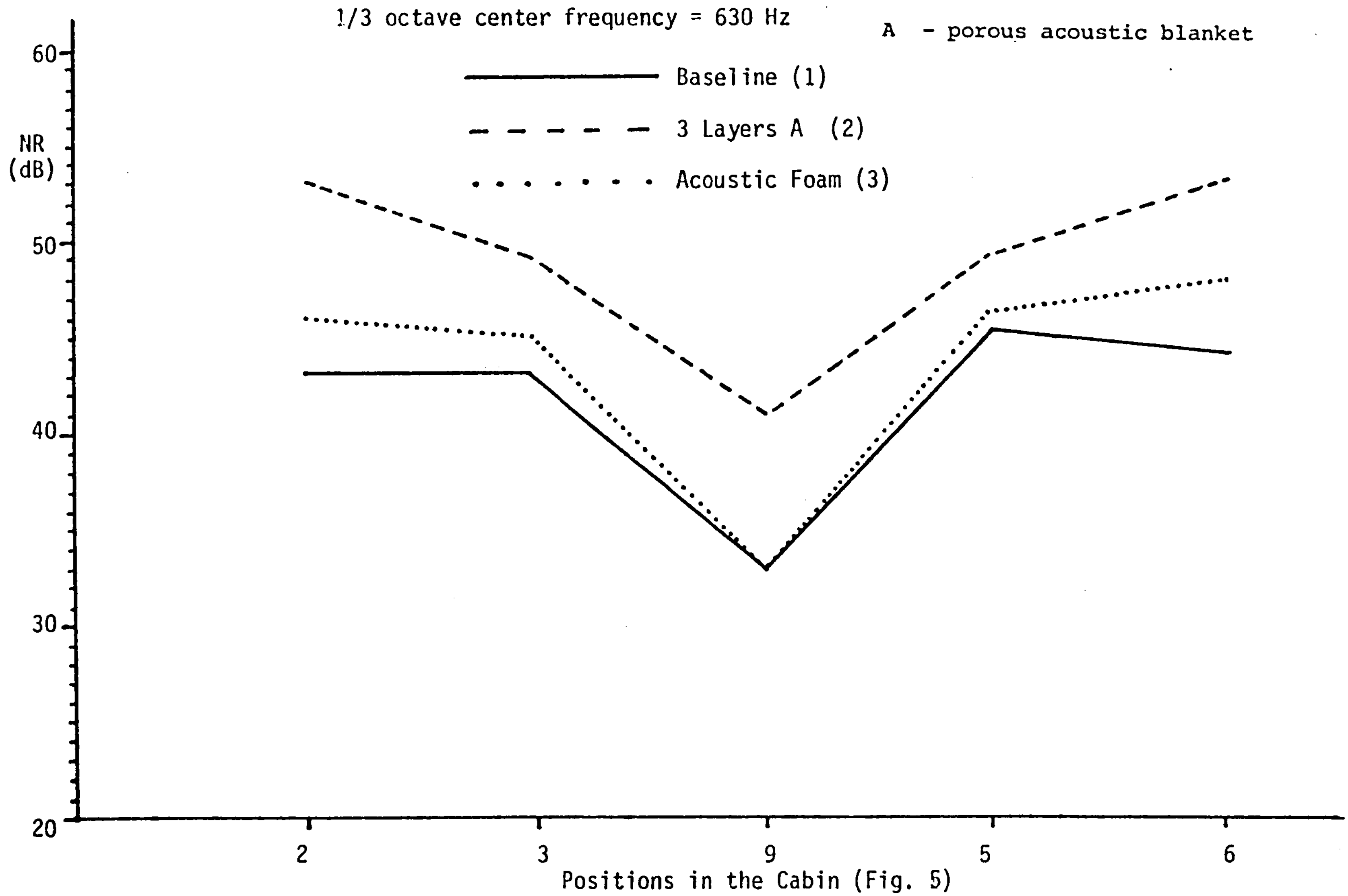


Fig. 81 Noise Reduction in the Cabin (Center Frequency = 630 Hz, Starboard)

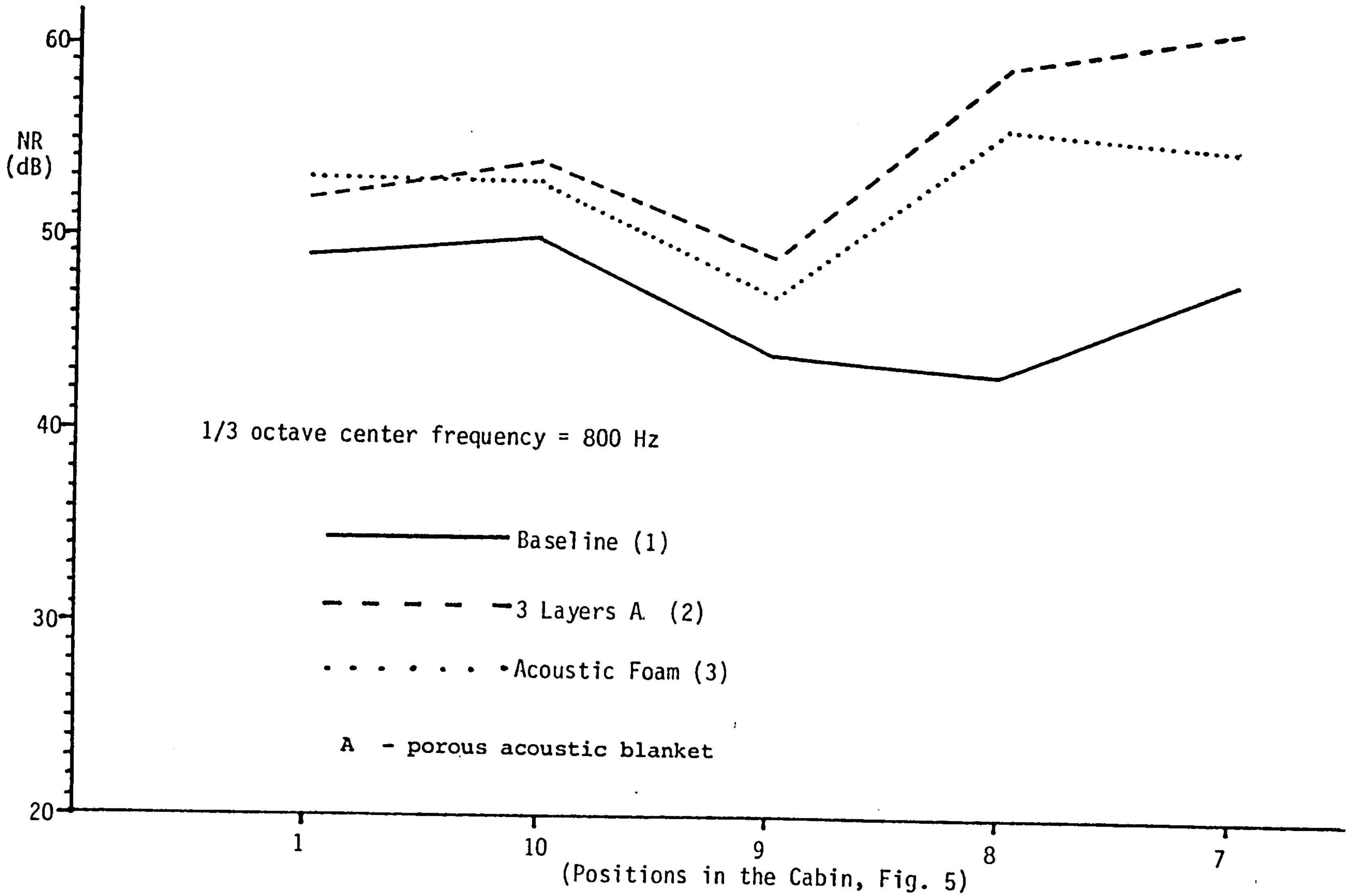


Fig. 82 Noise Reduction in the Cabin (Center Frequency = 800 Hz, Port)

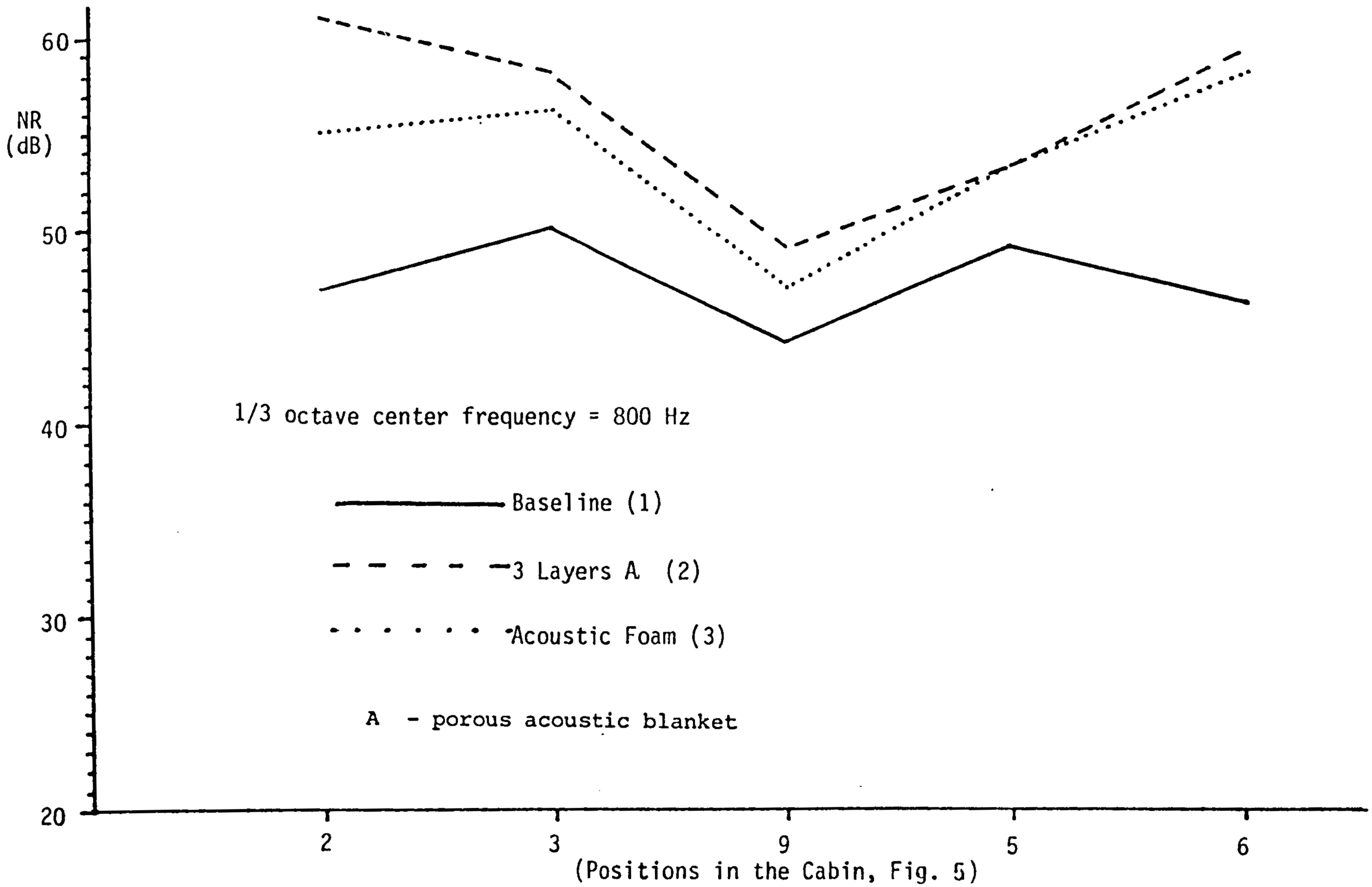


Fig. 83 Noise Reduction in the Cabin (Center Frequency = 800 Hz, Starboard)

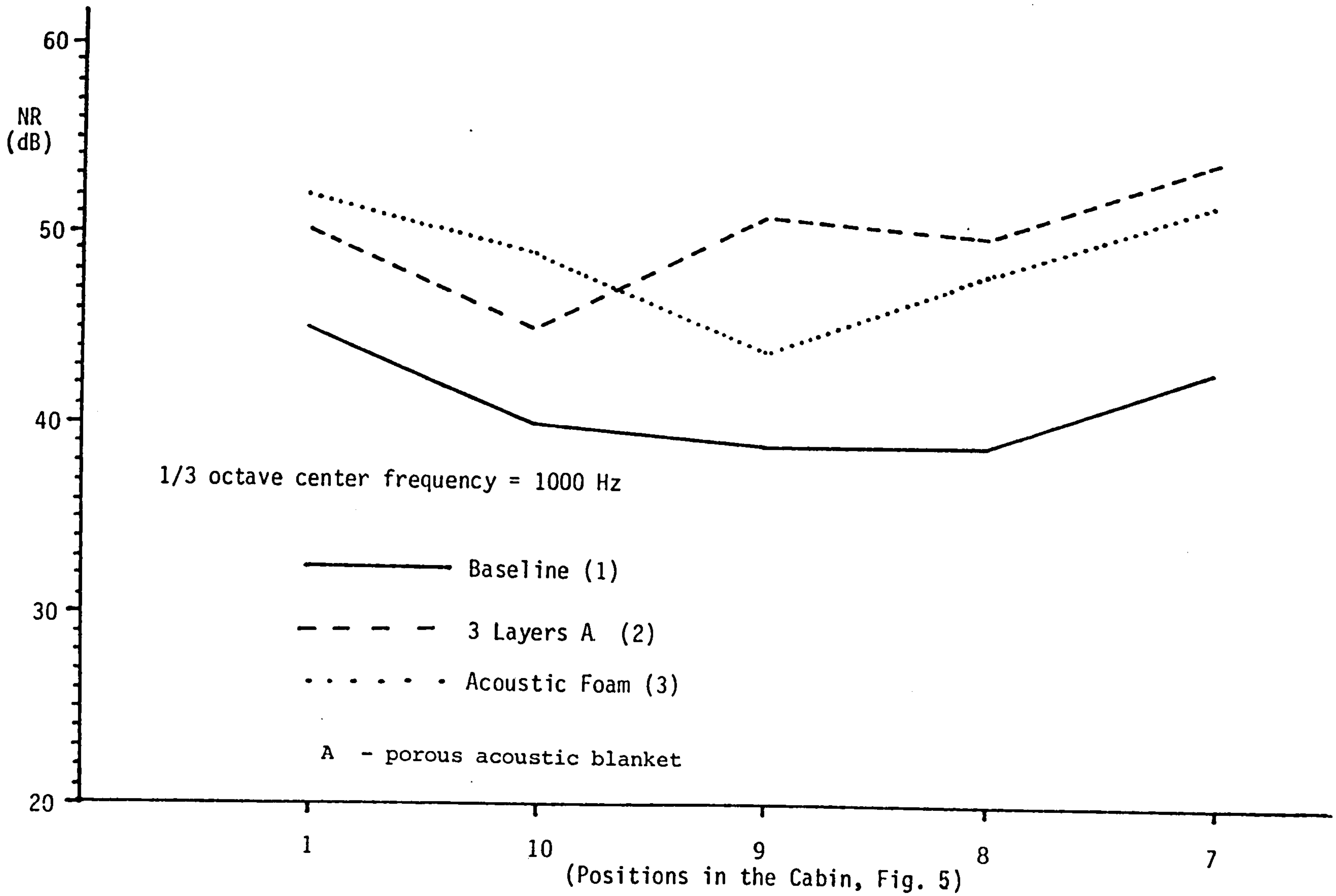


Fig. 84 Noise Reduction in the Cabin (Center Frequency = 1000 Hz, Port)

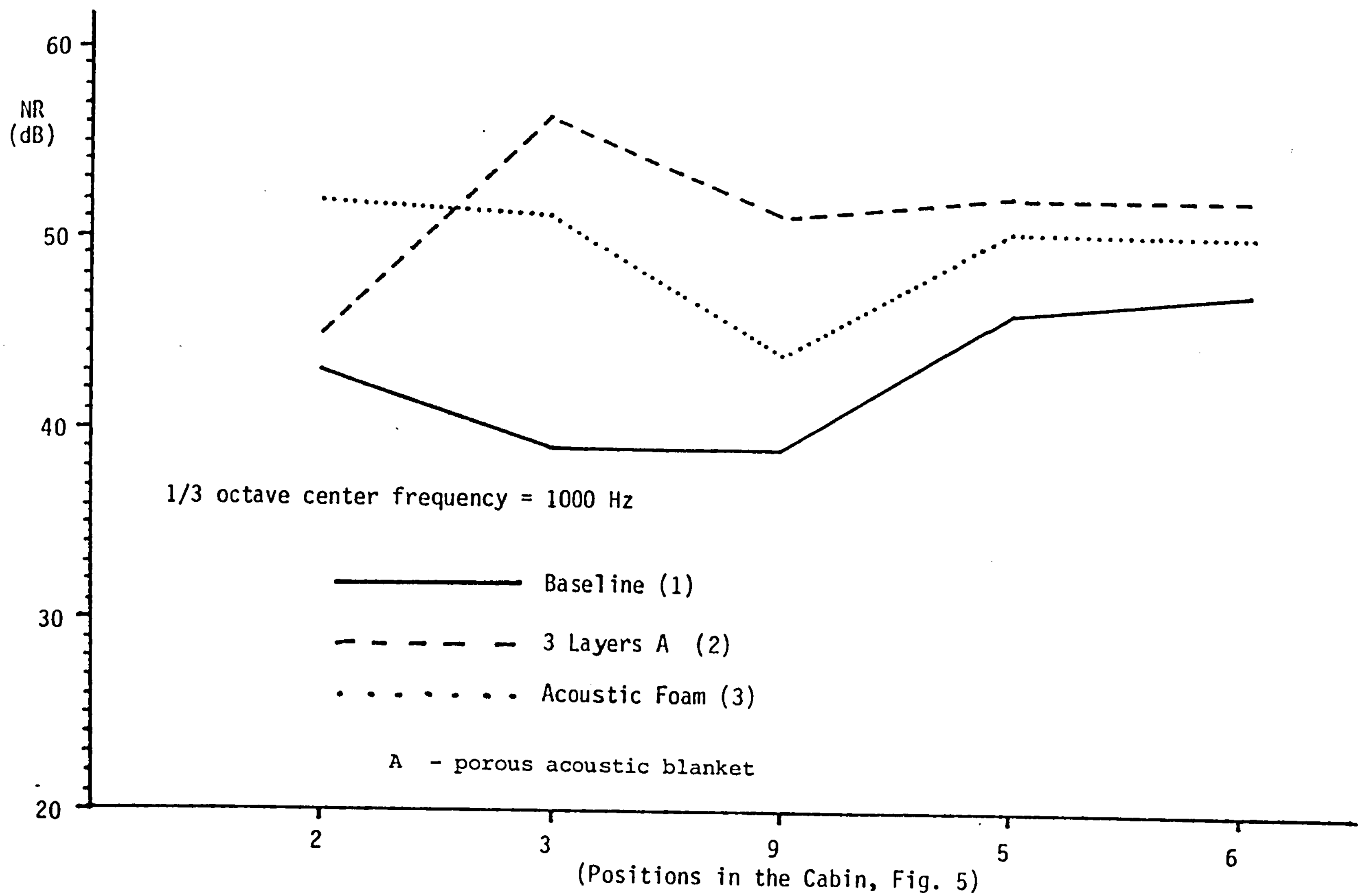


Fig. 85 Noise Reduction in the Cabin (Center Frequency = 1000 Hz, Starboard)

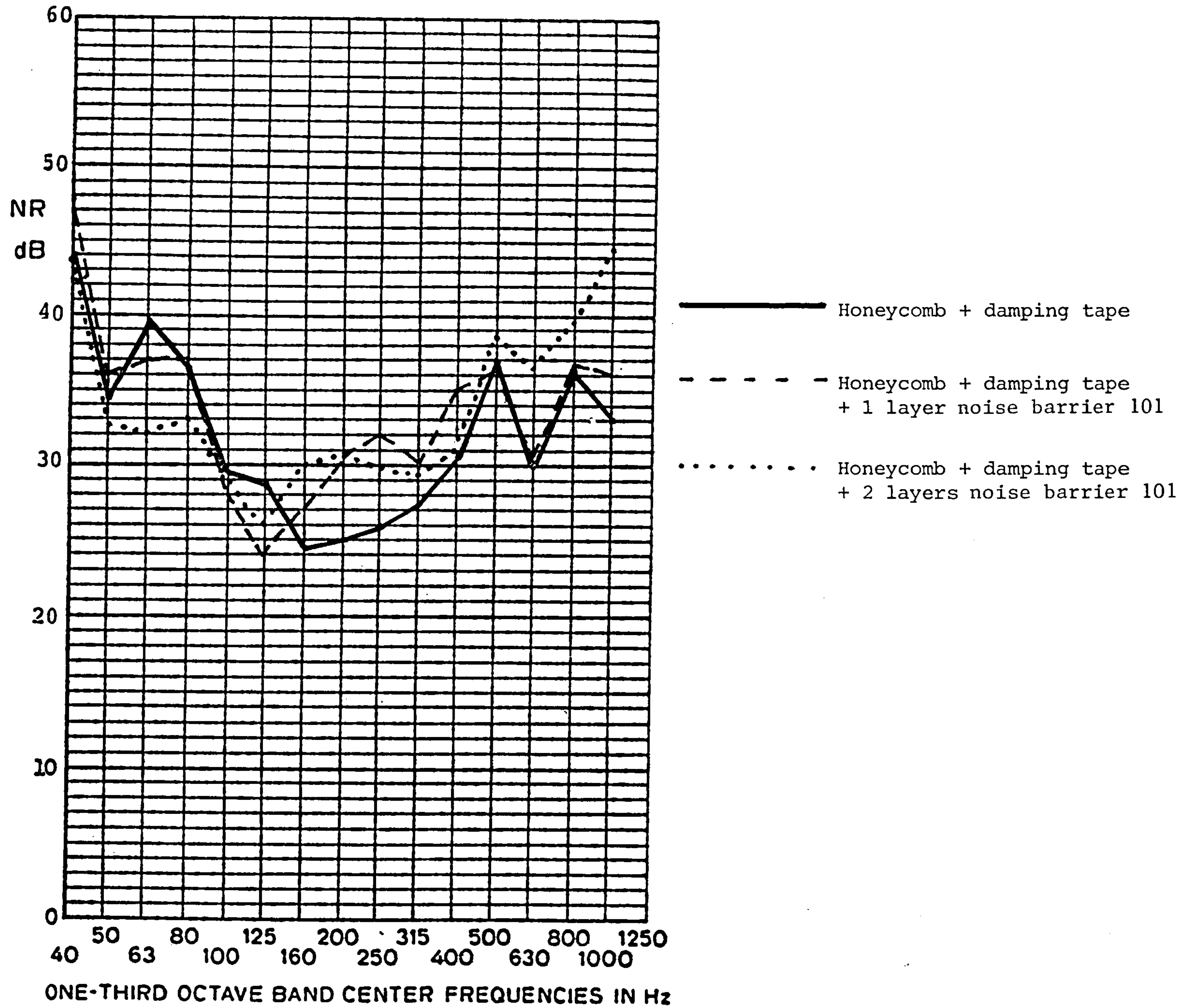


Fig. 86 Noise reduction for panel 4S with mass add-on treatments (position 11)

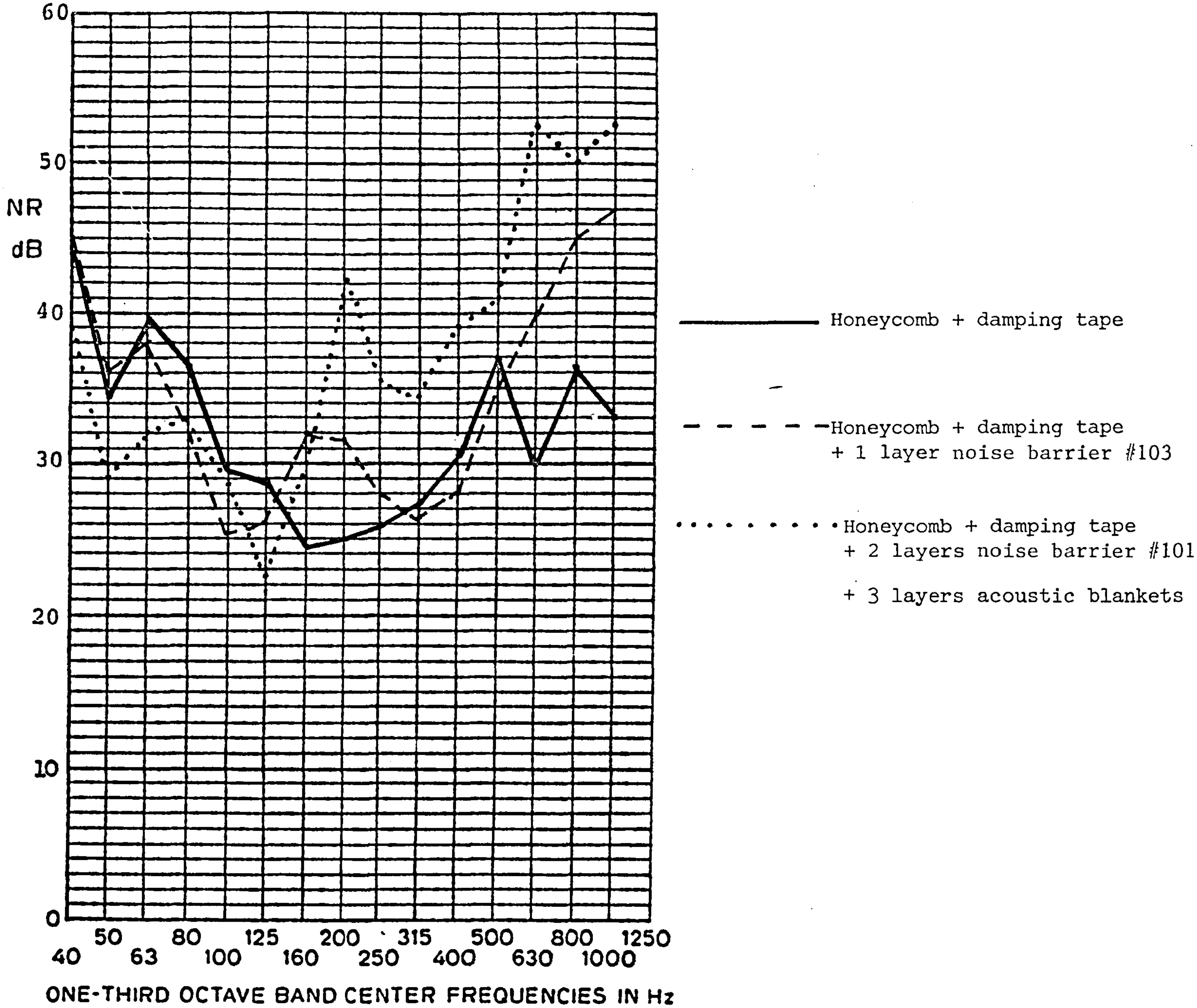


Fig. 87 Noise reduction for panel 4S with mass and porous blanket treatments

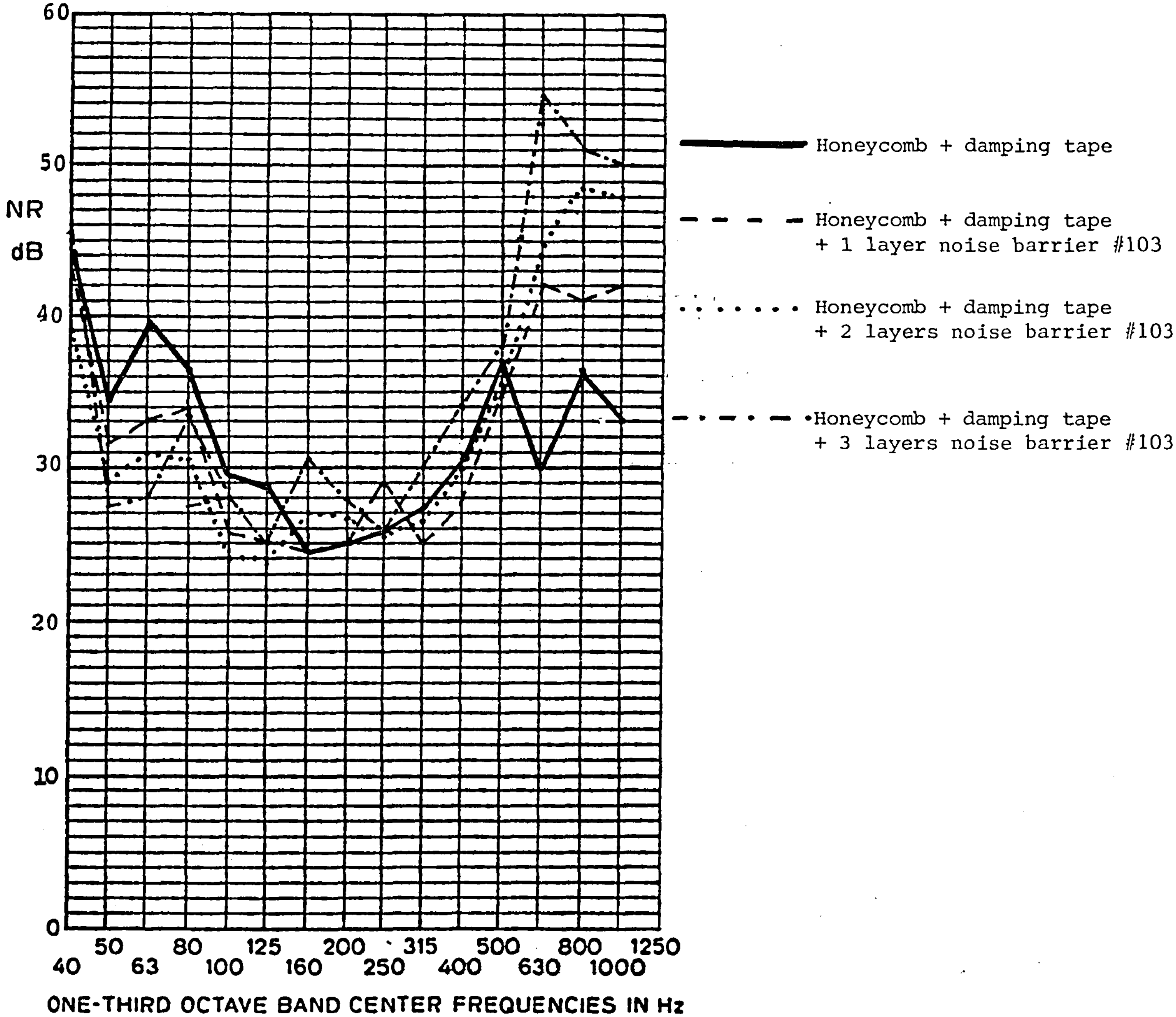


Fig. 88 Noise reduction for panel 4S with noise barrier #103 treatments

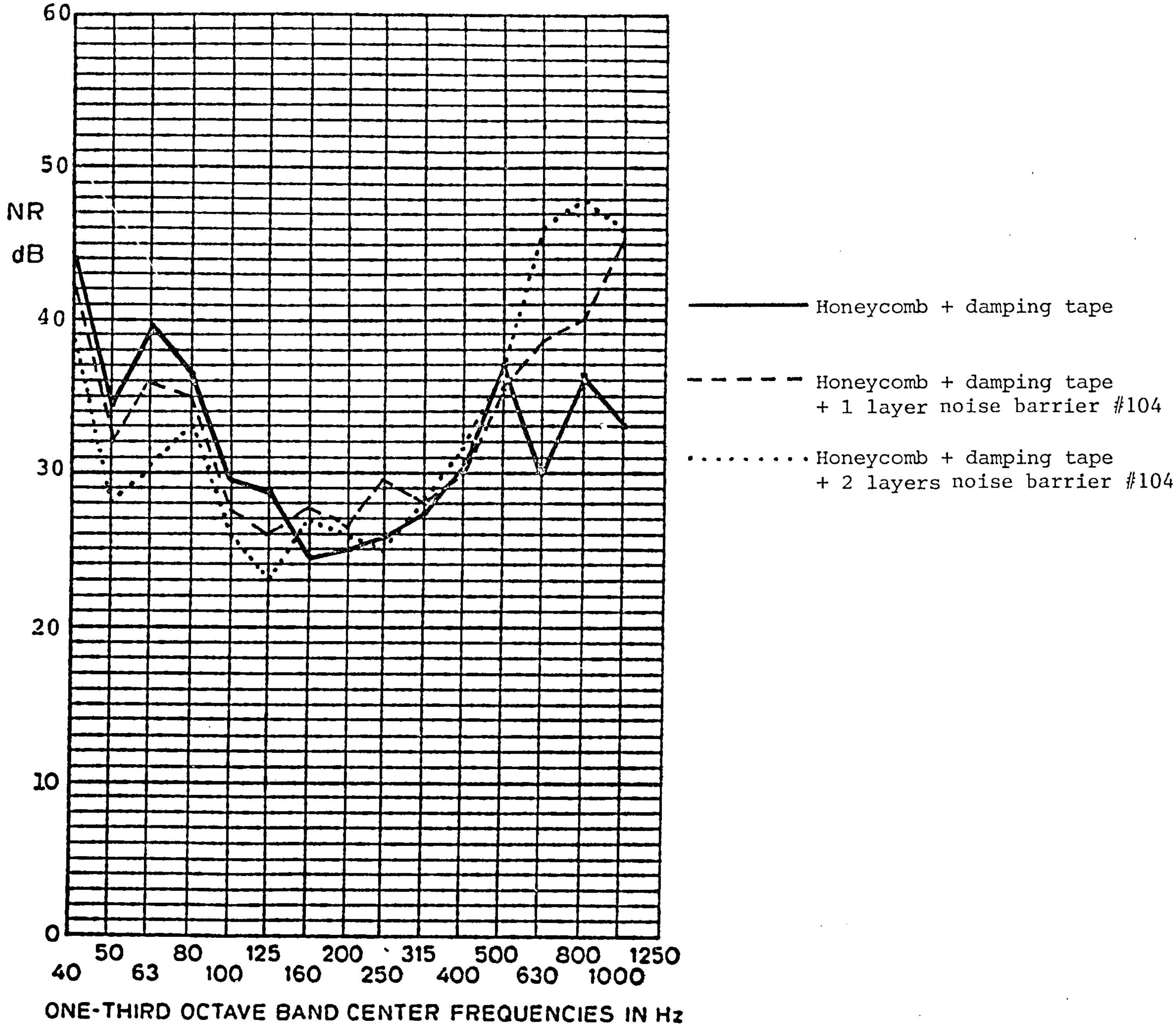


Fig. 89 Noise reduction for panel 4S with noise barrier #104 treatments

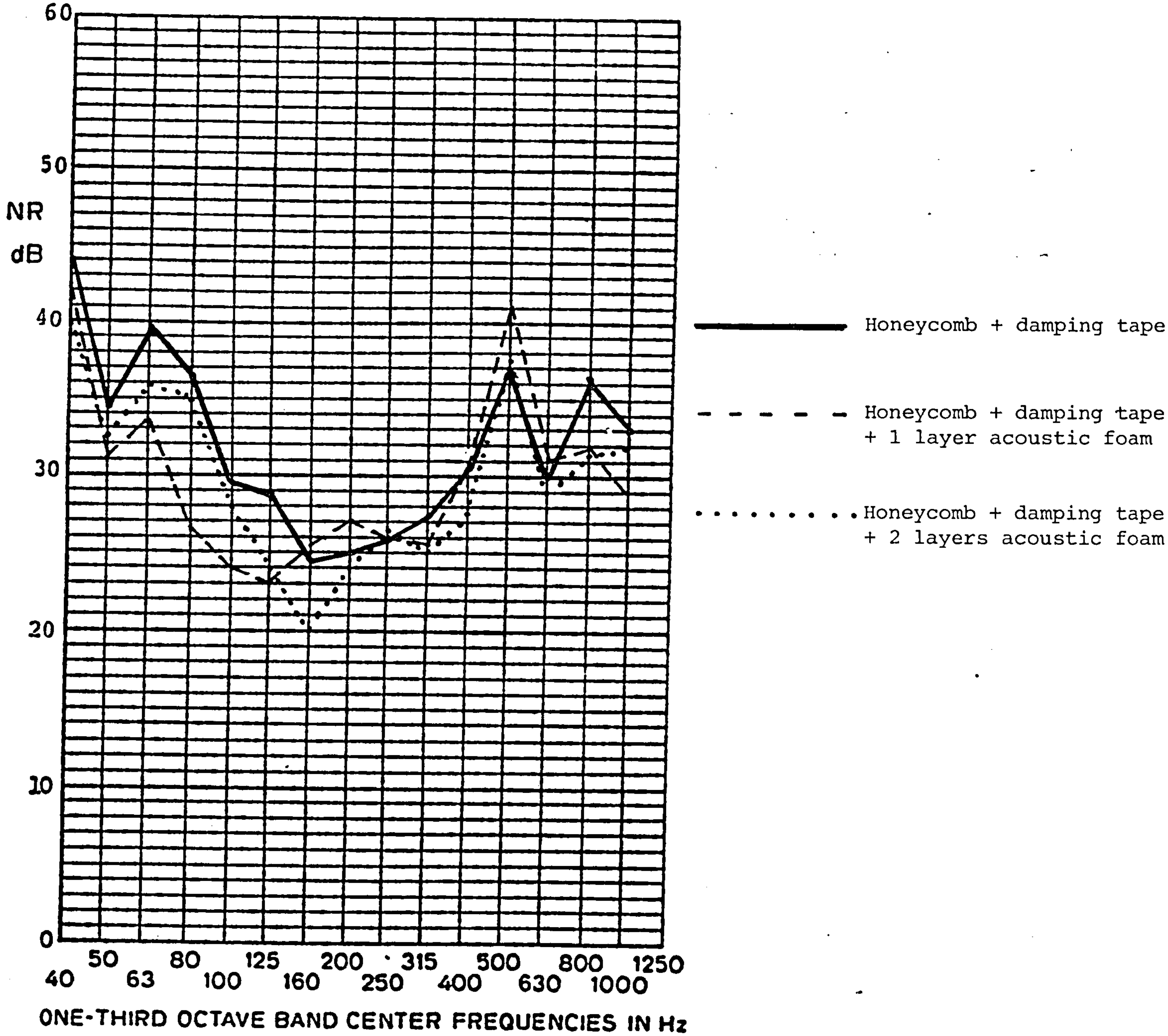


Fig. 90 Noise reduction for panel 4S with one and two layers of acoustic foam treatment

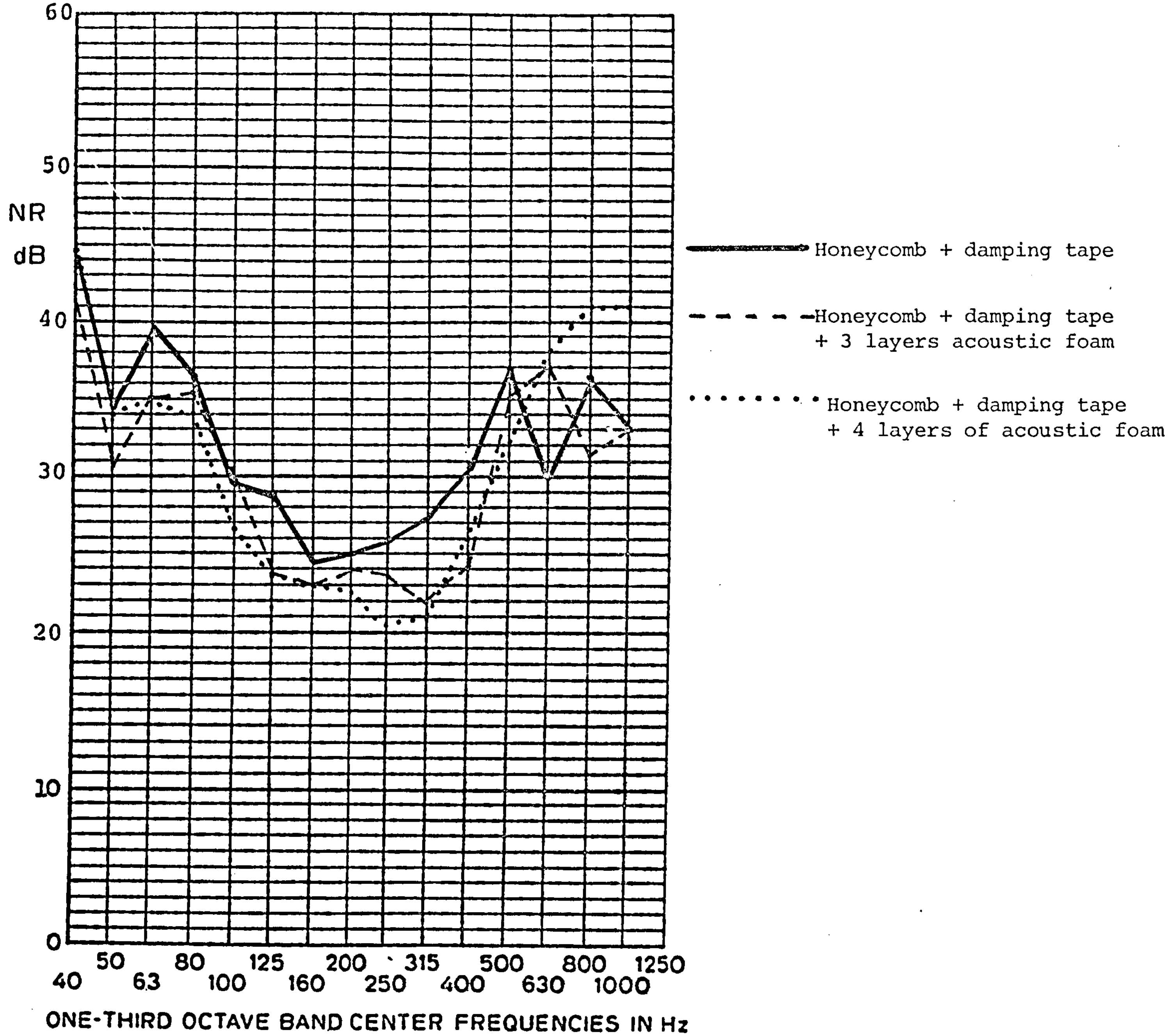


Fig. 91 Noise reduction for panel 4S with three and four layers of acoustic foam treatment

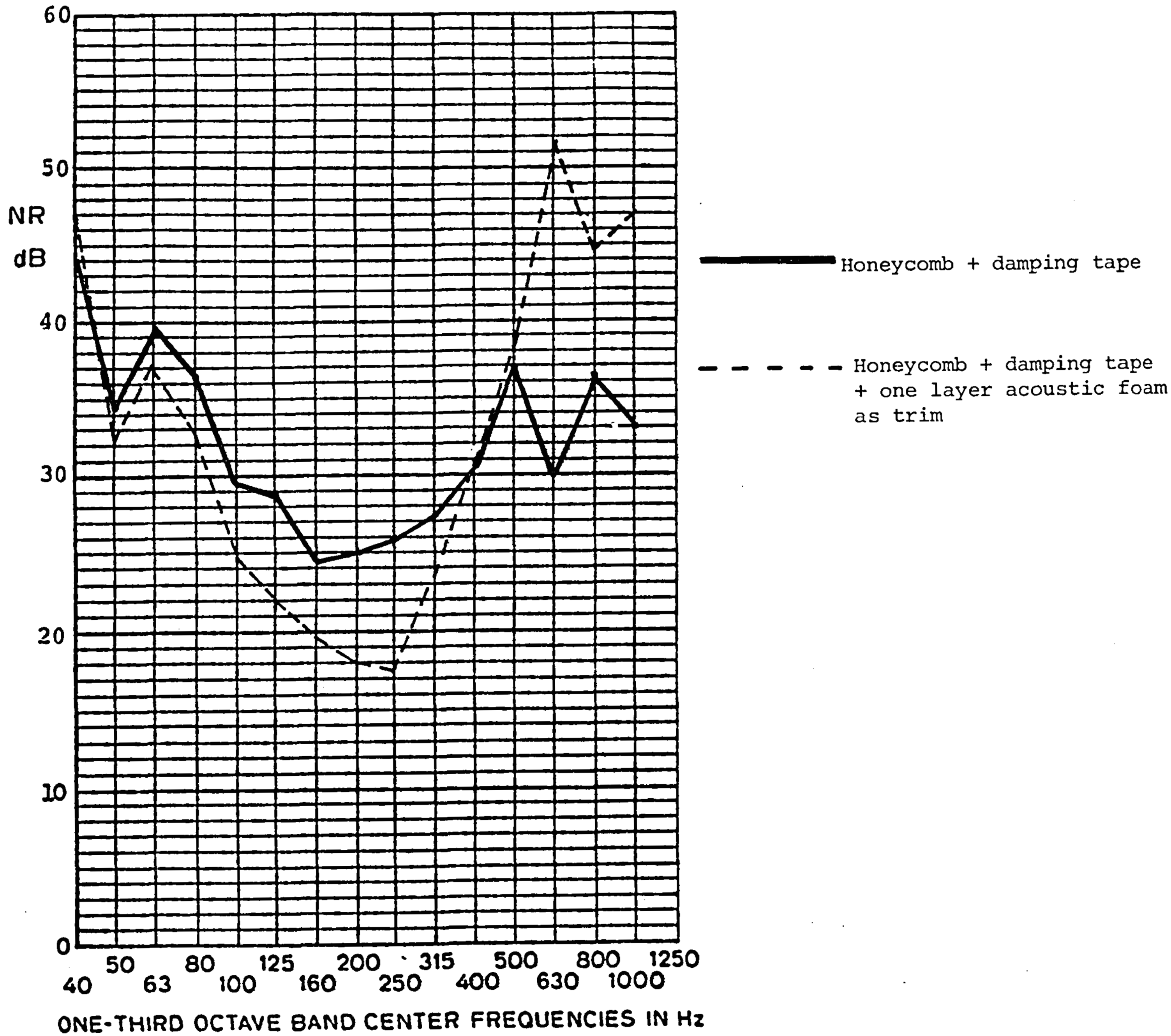


Fig. 92 Noise reduction for panel 4 S with acoustic foam used as trim

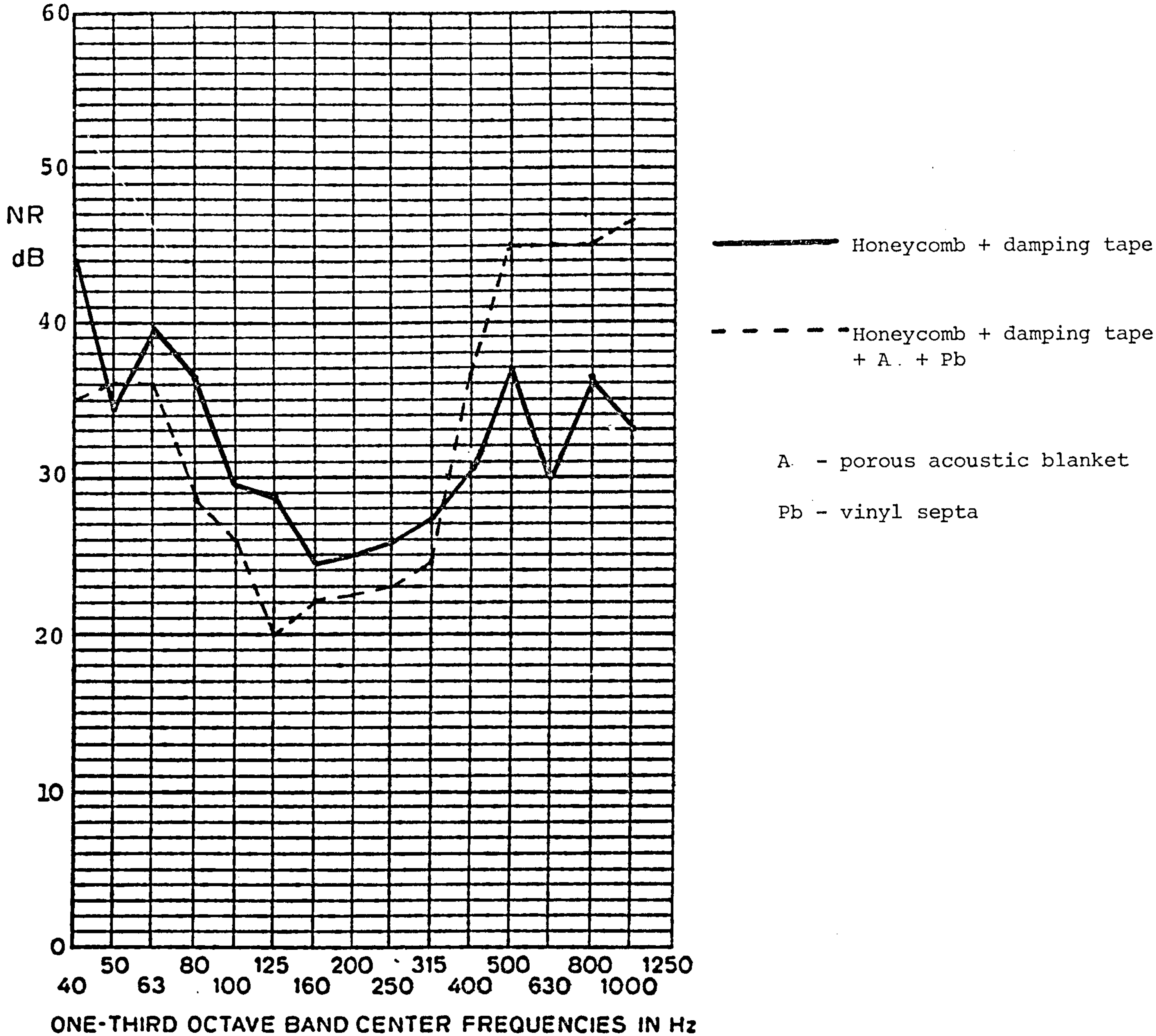


Fig. 93 Noise reduction for panel 4S with one layer porous blanket and one layer vinyl septa

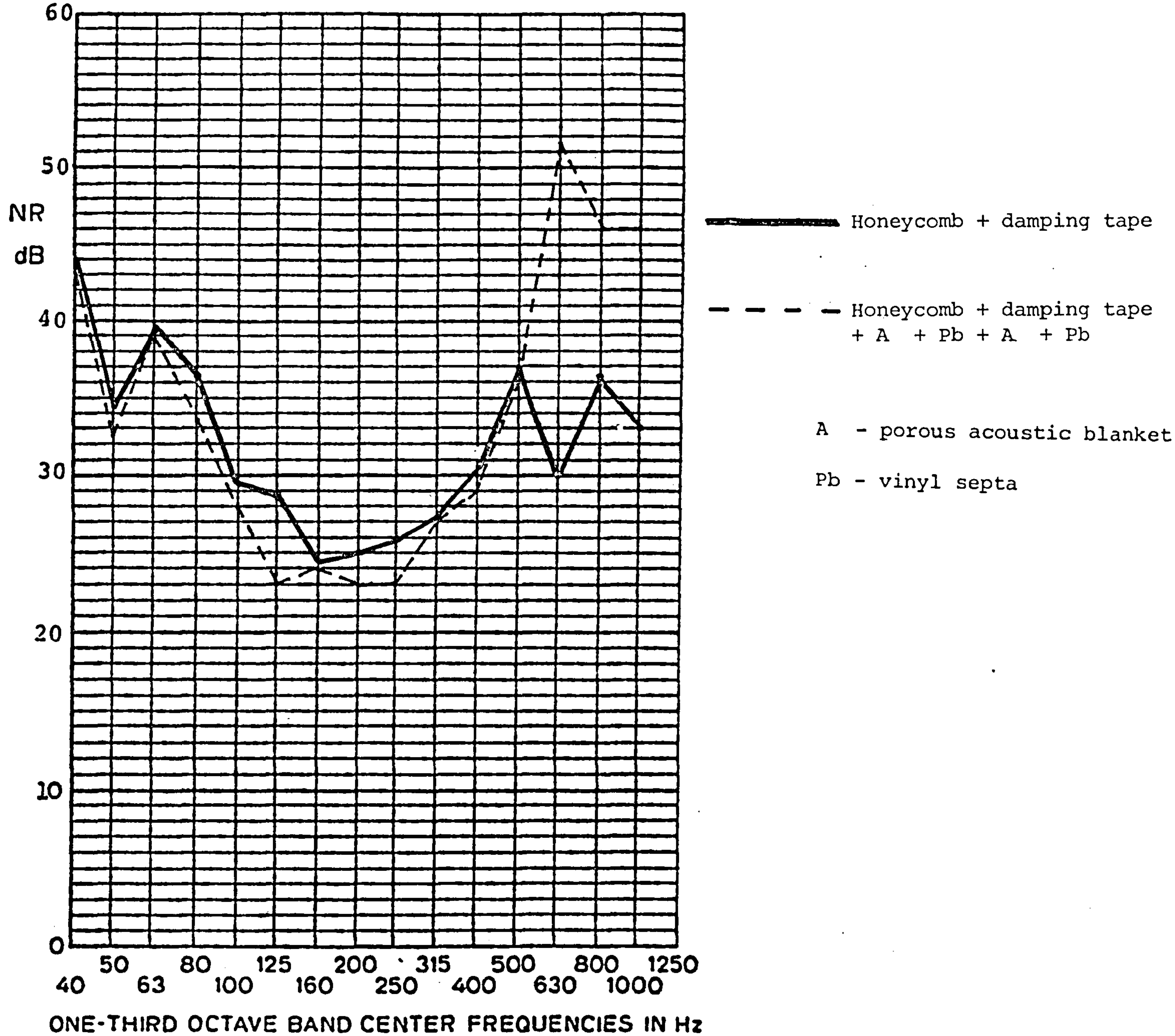


Fig. 94 Noise reduction for panel 4S with two layers of porous blankets and two layers of vinyl septa

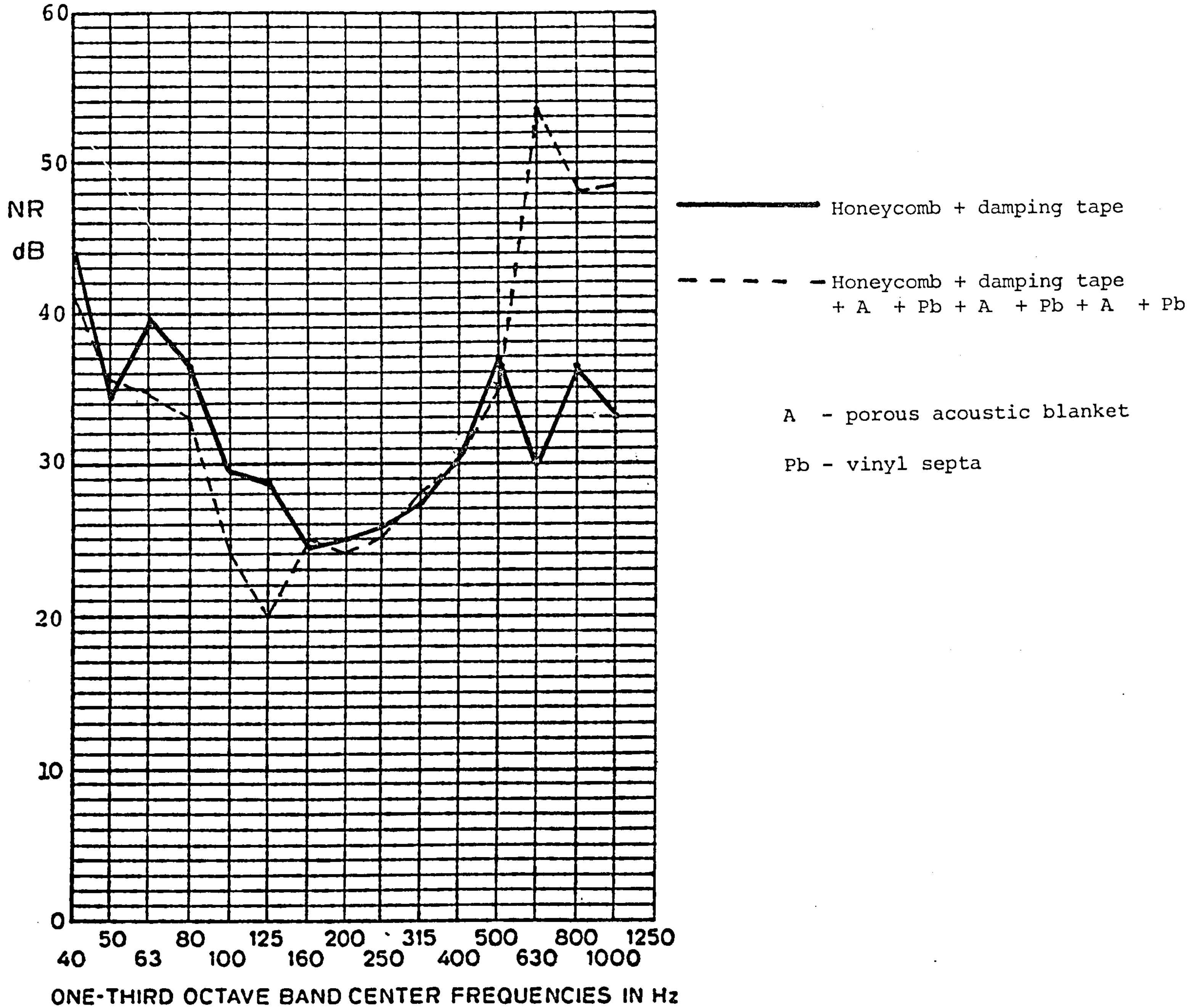


Fig. 95 Noise reduction for panel 4S with three layers of porous blankets and three layers of vinyl septa

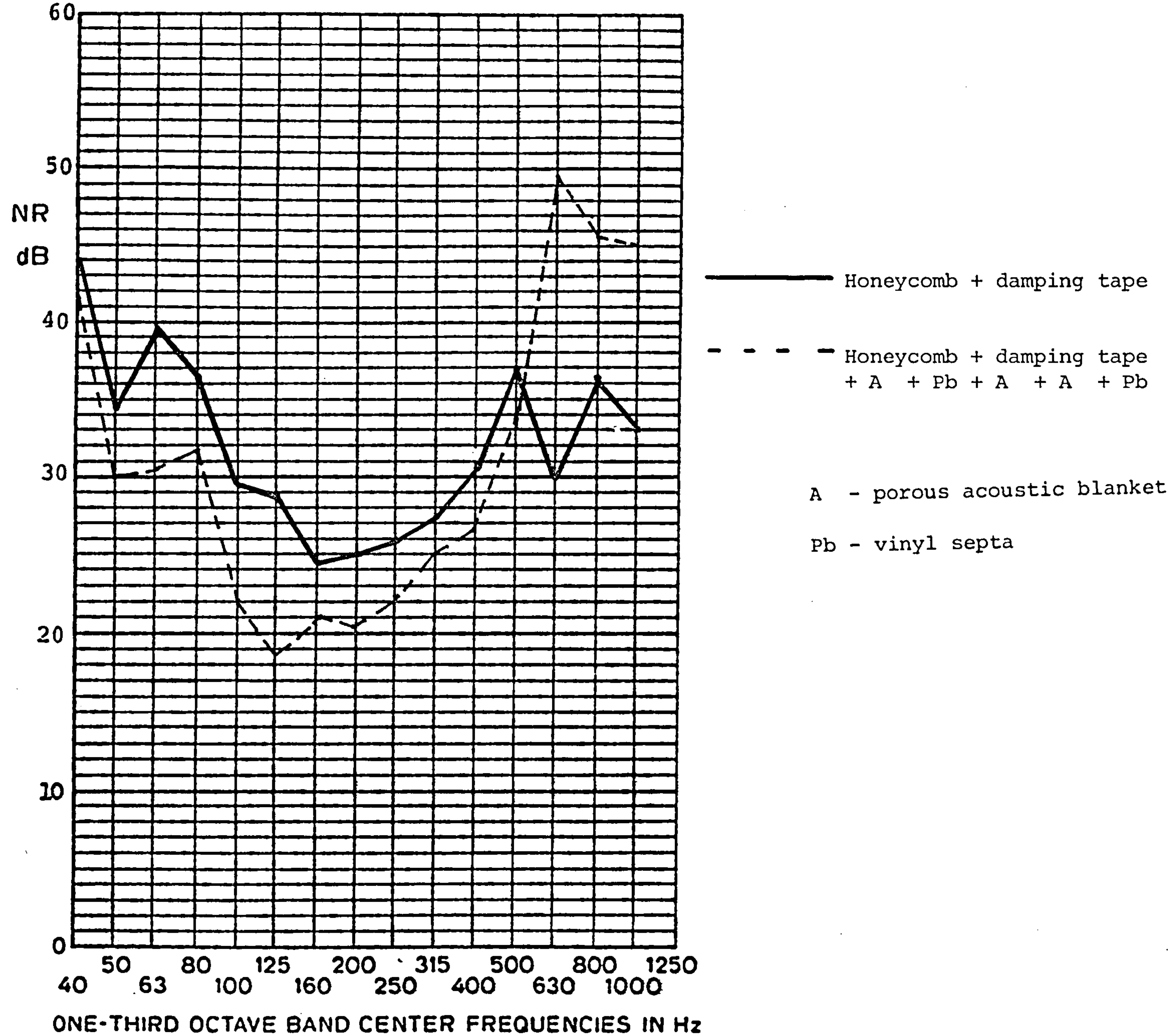


Fig. 96 Noise reduction for panel 4S with three layers of porous blankets and two layers of vinyl septa

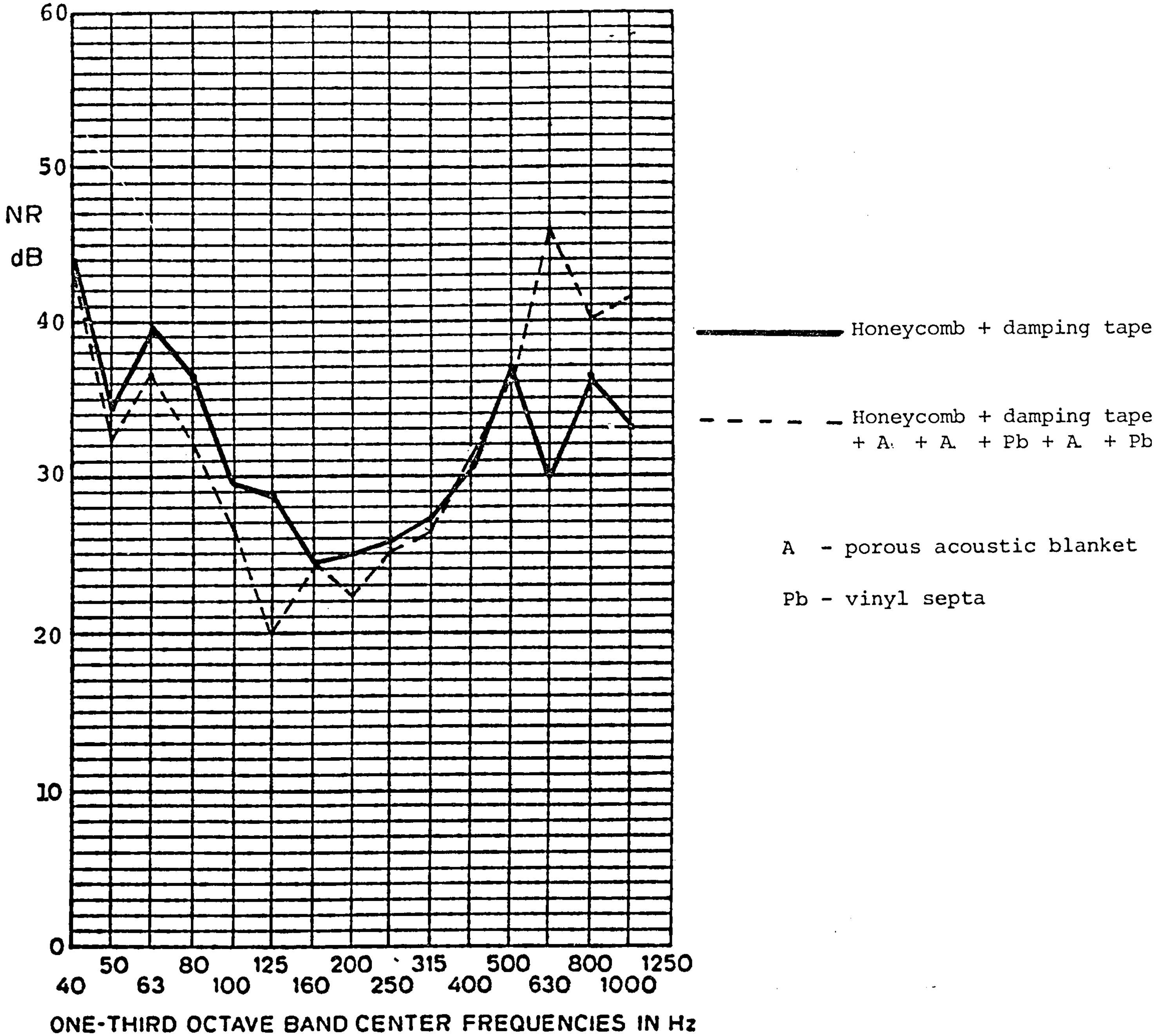


Fig. 97 Noise reduction for panel 4S with multi-layered treatment

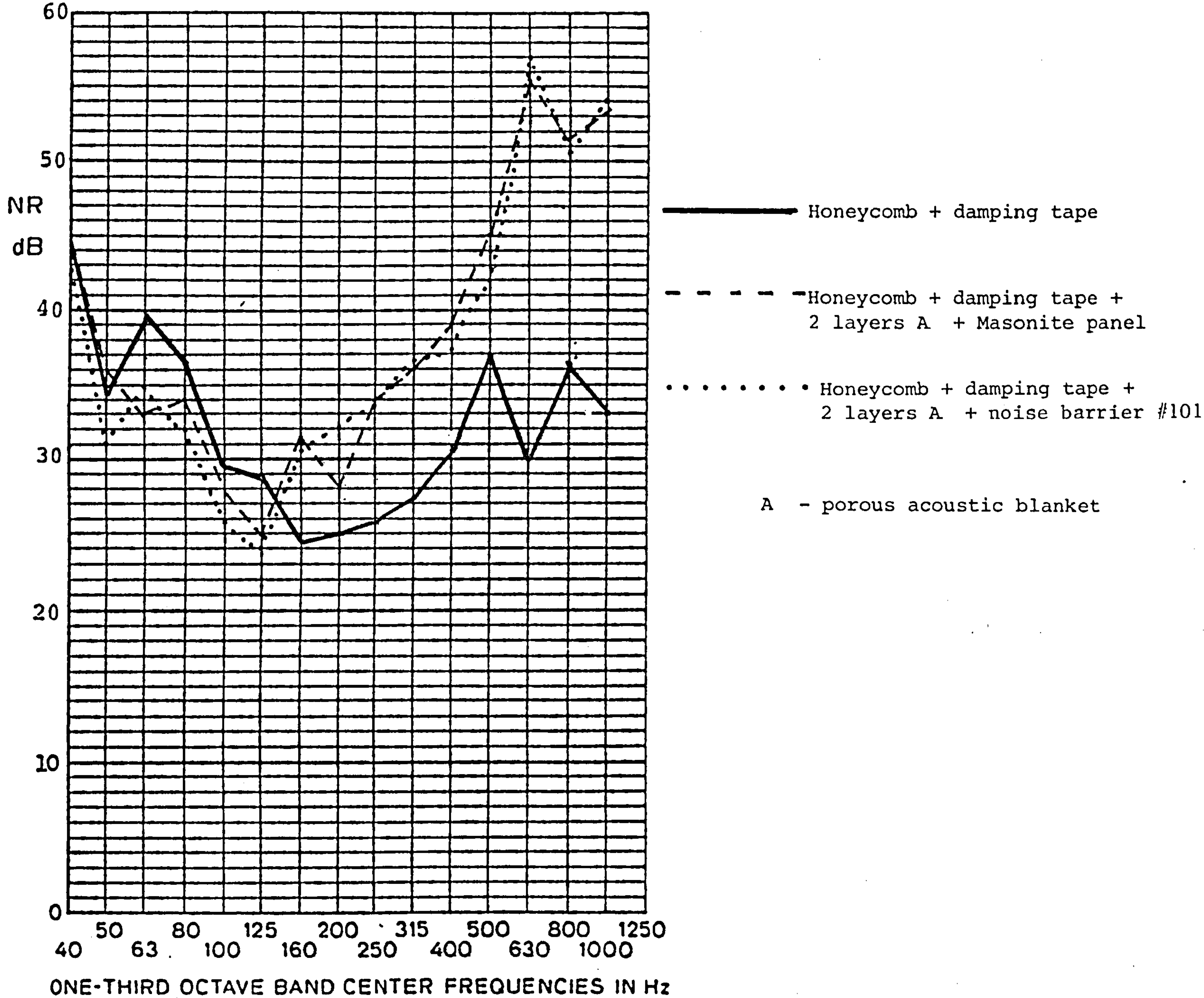


Fig. 98 Noise reduction with a heavy trim

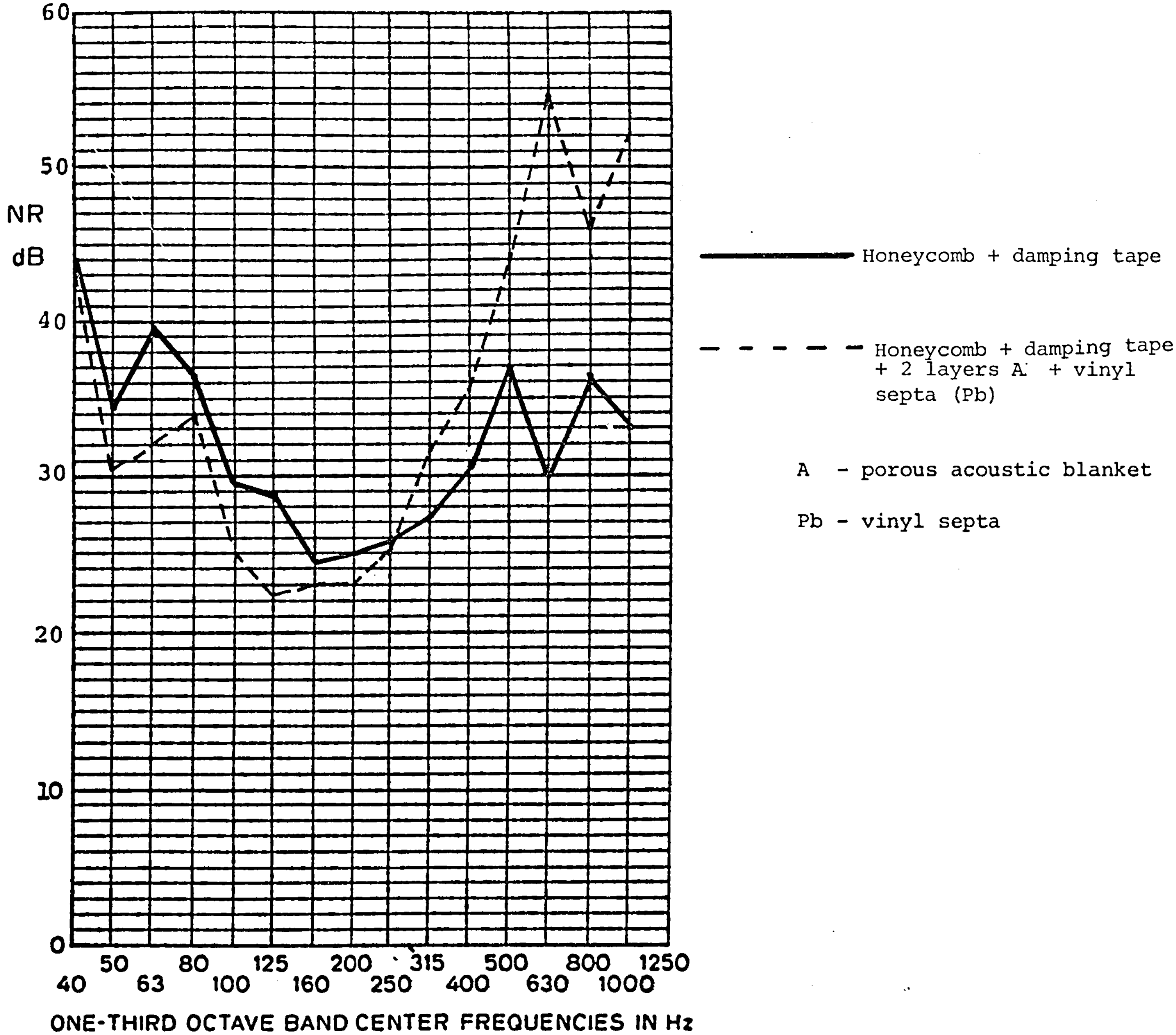


Fig. 99 Noise reduction with a light trim

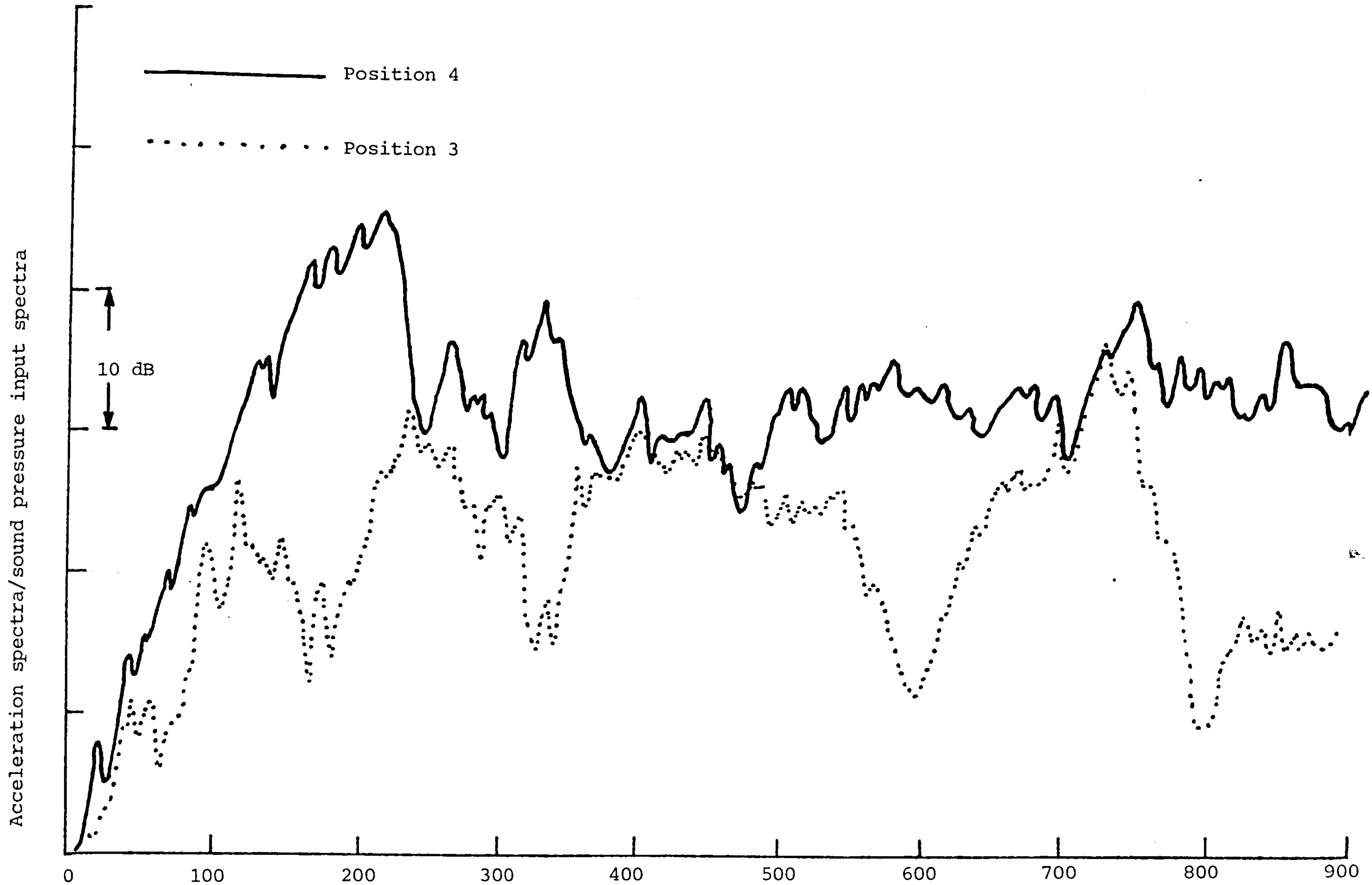


Fig. 100 Relative acceleration levels for positions 3 and 4

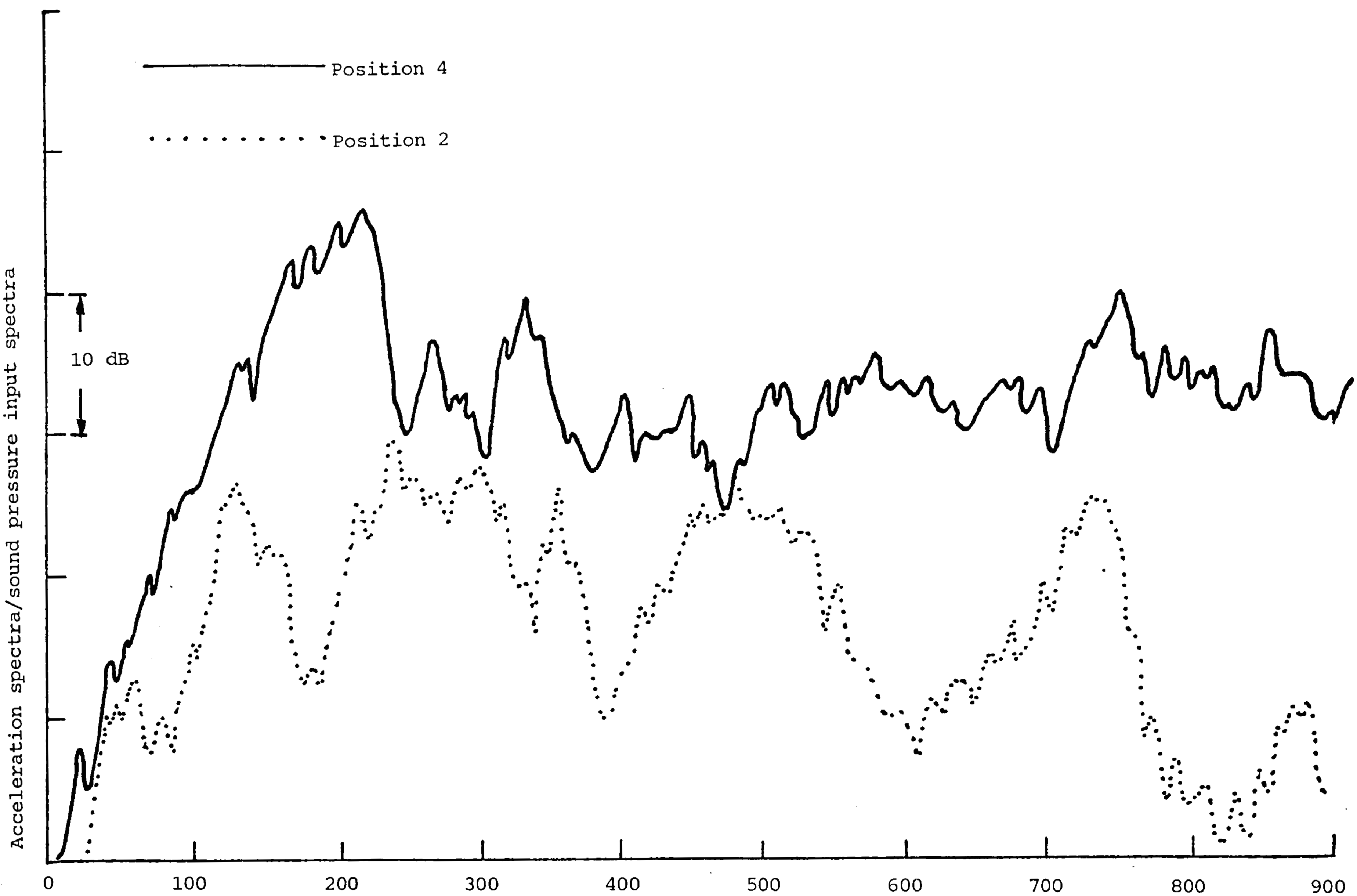


Fig. 101 Relative acceleration levels for positions 2 and 4

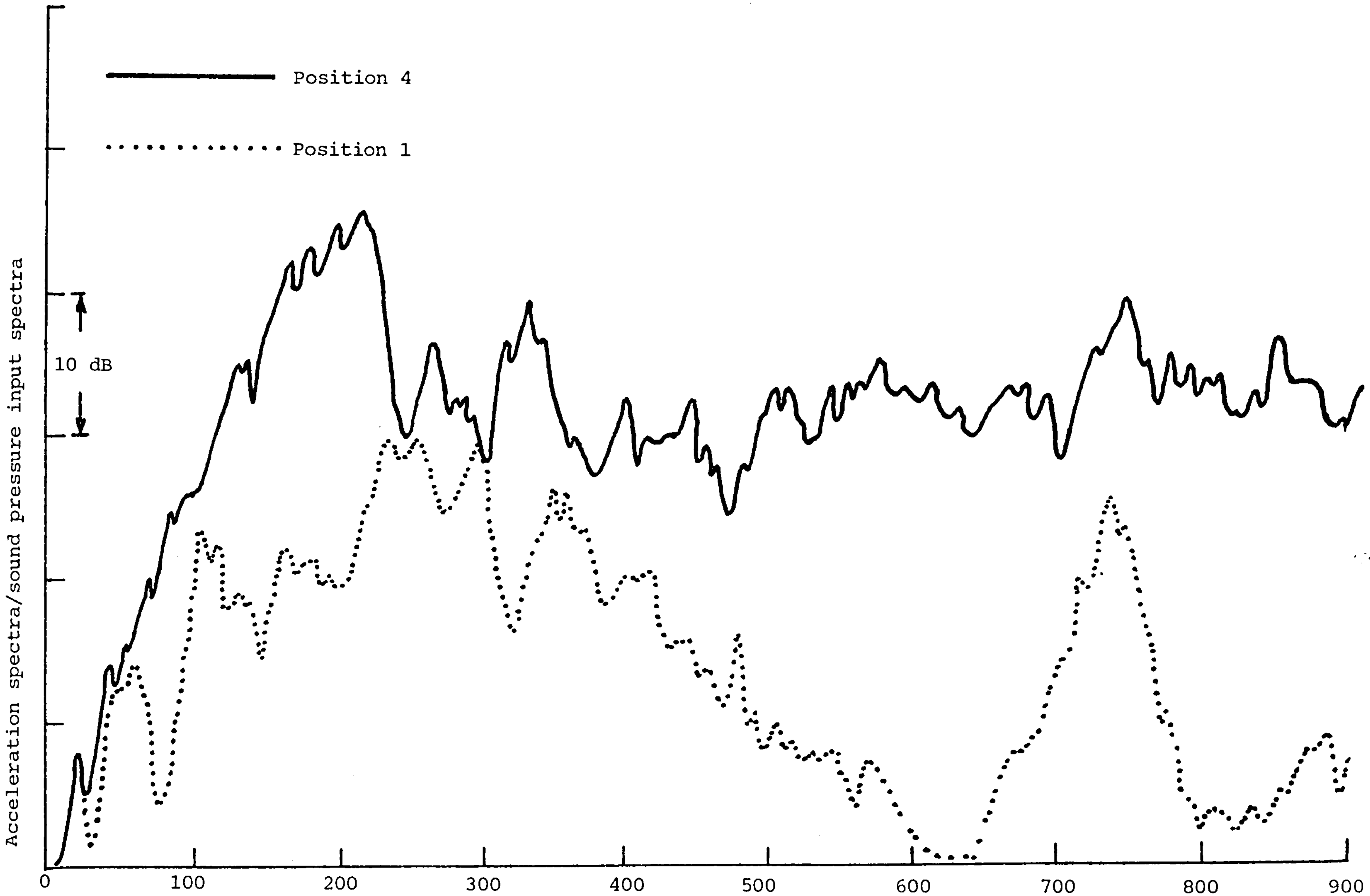


Fig. 102 Relative acceleration levels for positions 1 and 4

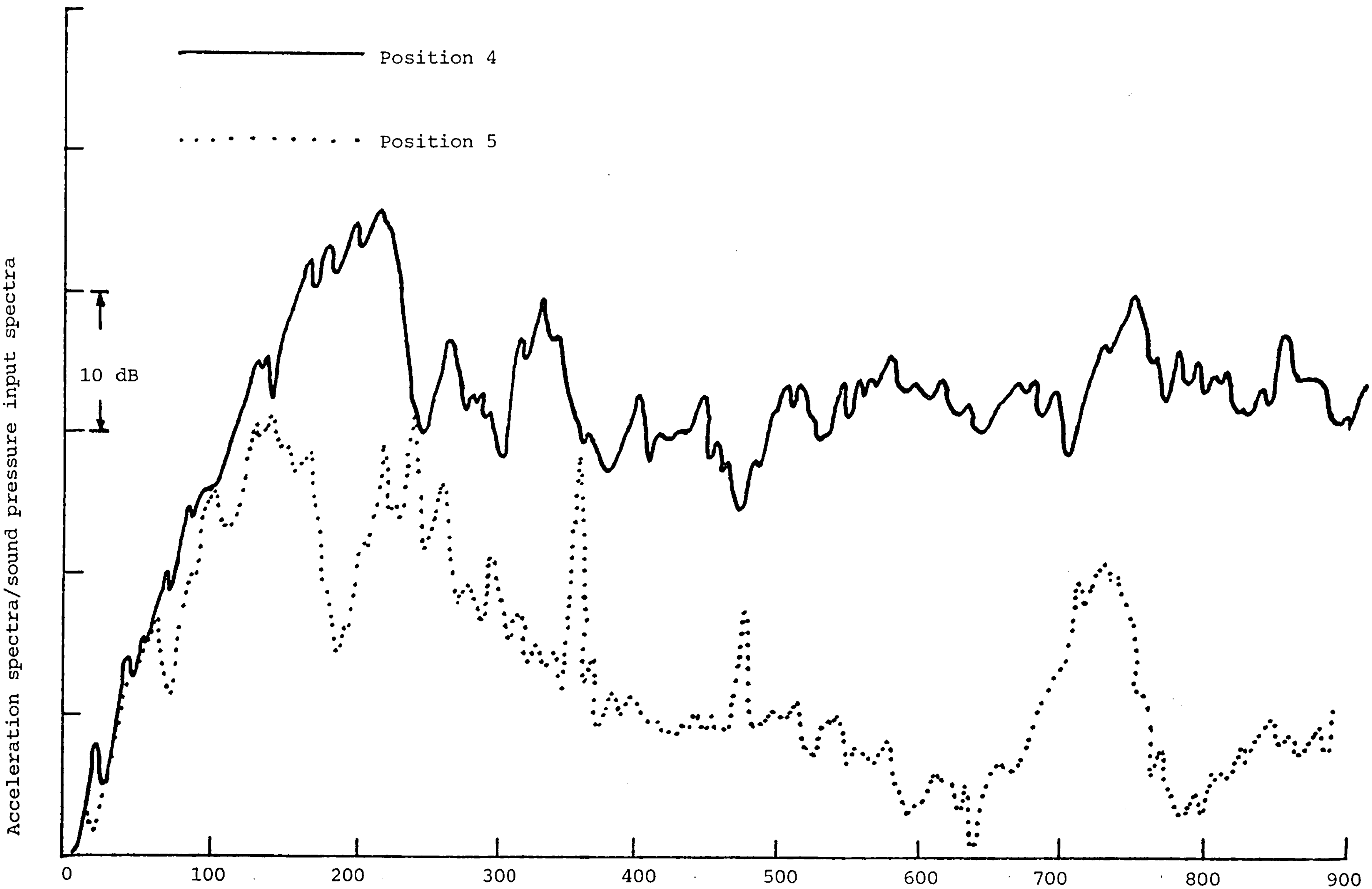


Fig. 103 Relative acceleration levels for positions 5 and 4

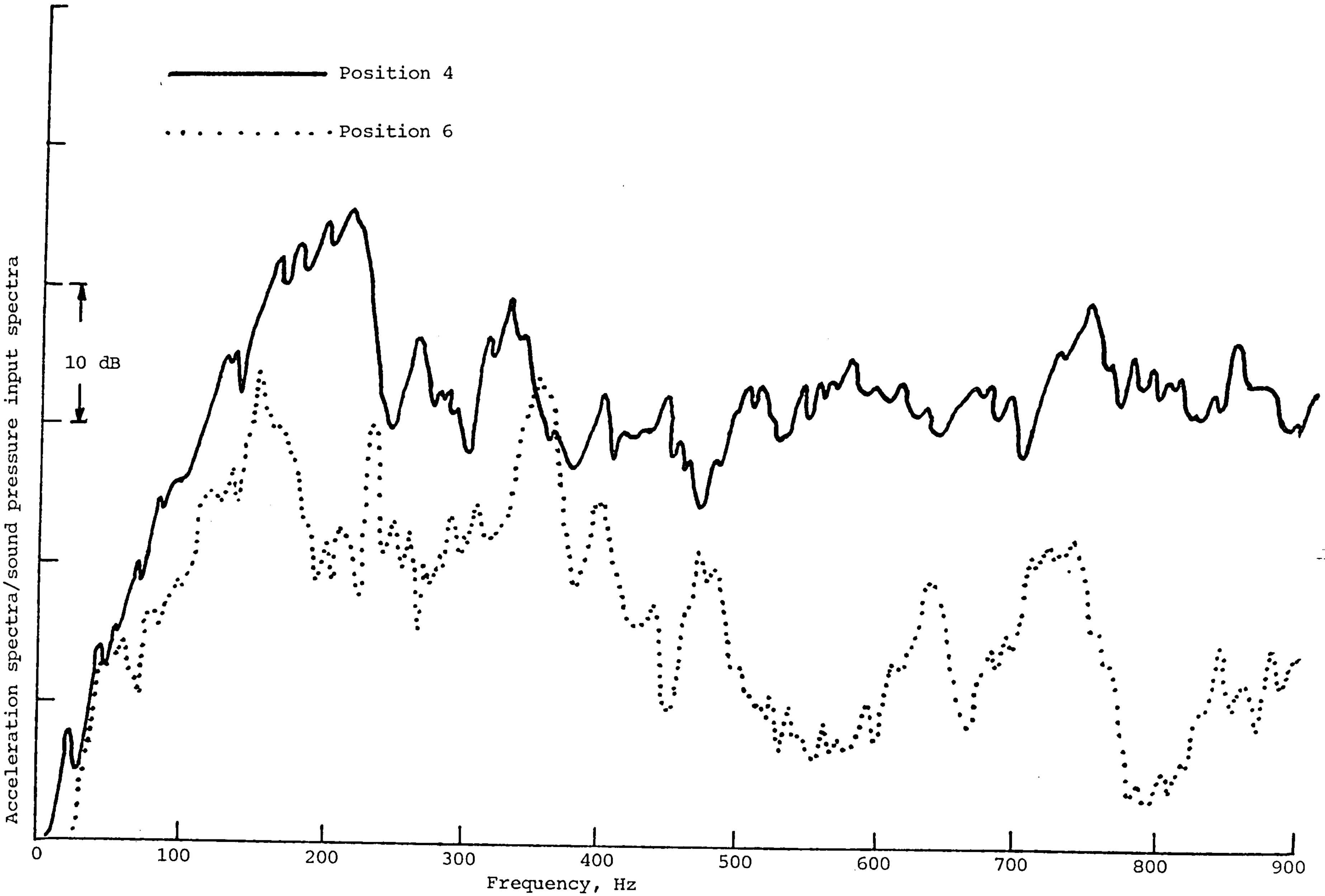


Fig. 104 Relative acceleration levels for position 6 and 4

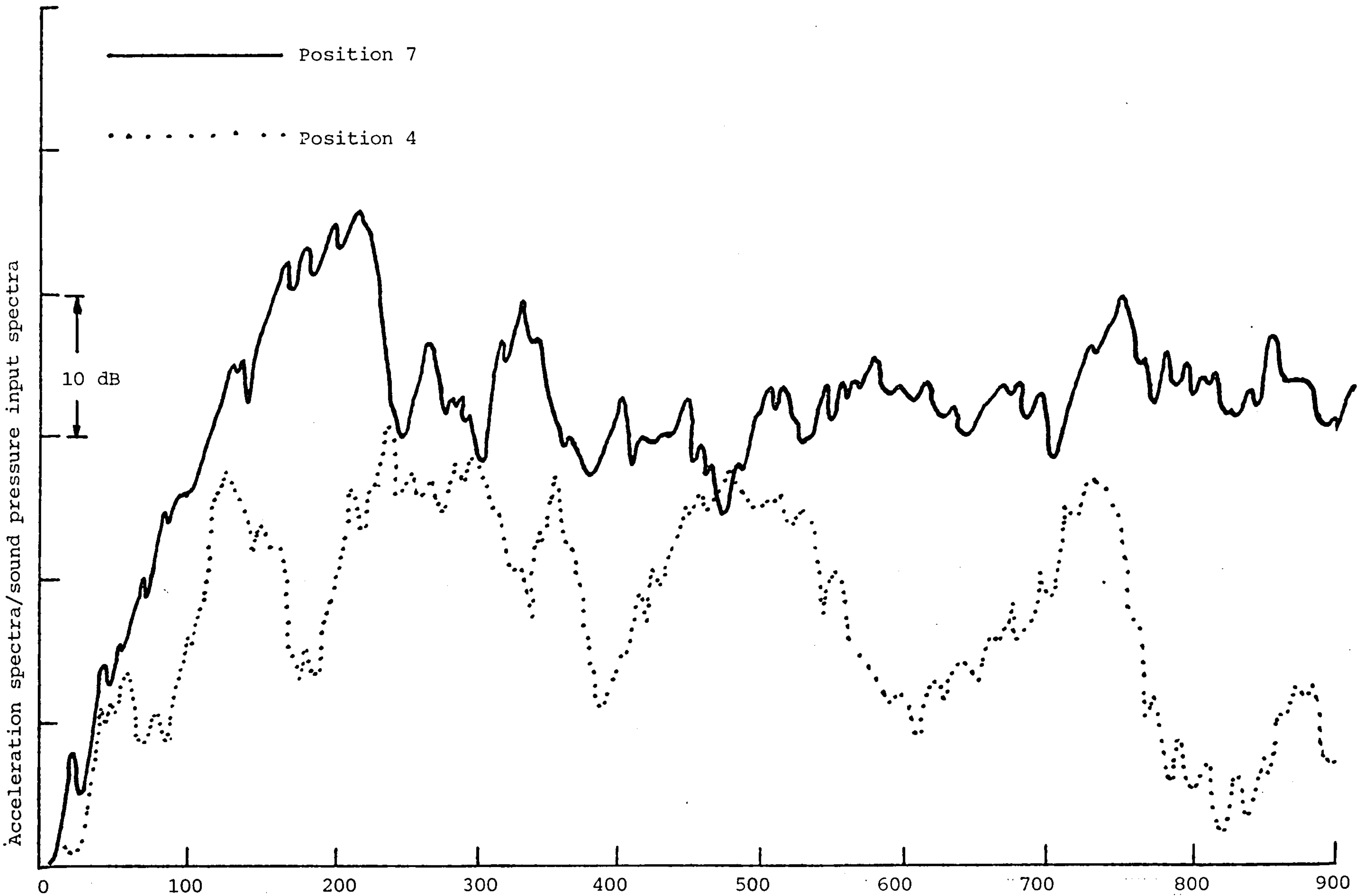


Fig. 105 Relative acceleration levels for positions 7 and 4

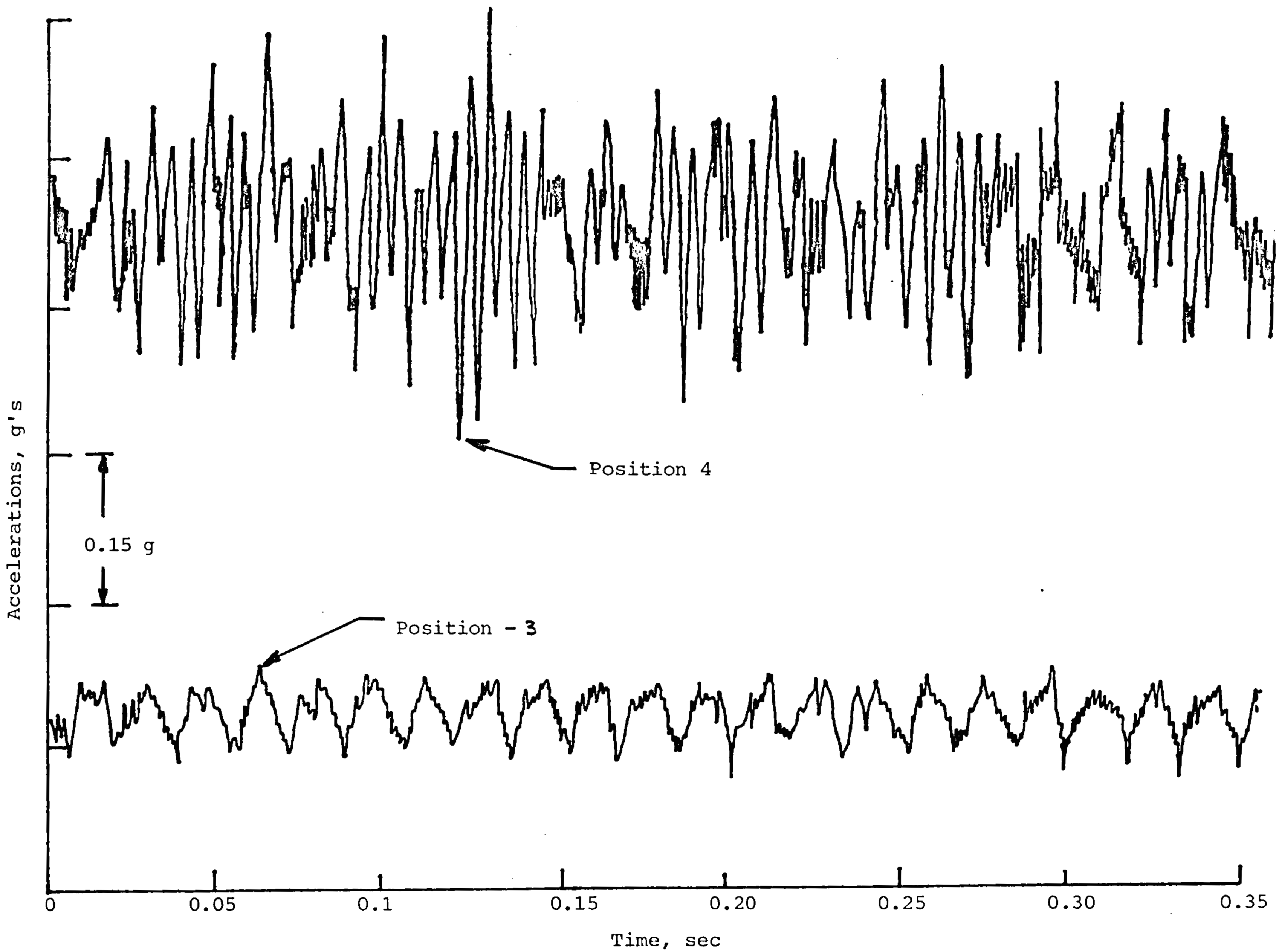


Fig. 106 Time history of acceleration of positions 4 and 3

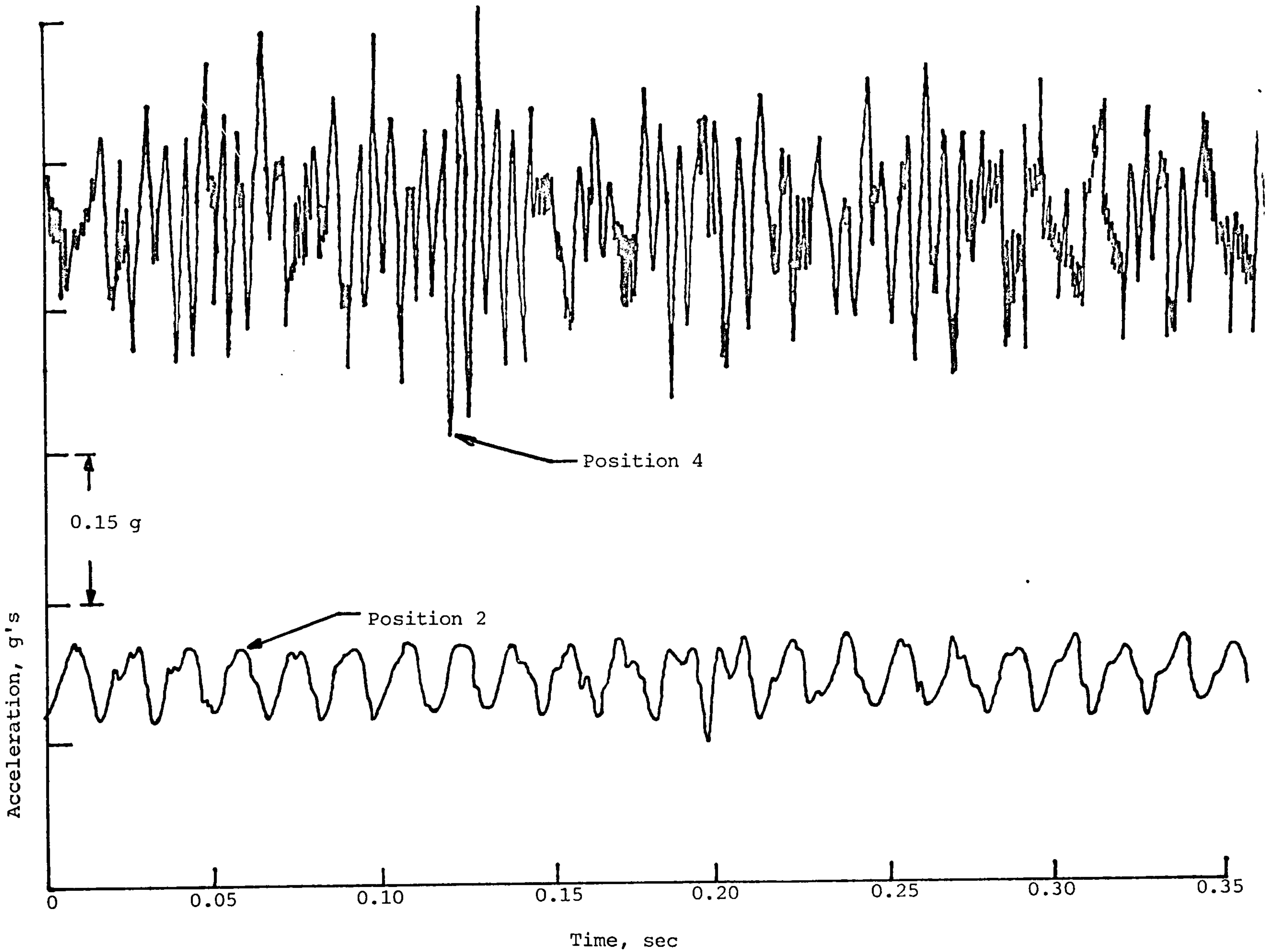


Fig. 107 Time history of acceleration of positions 4 and 2

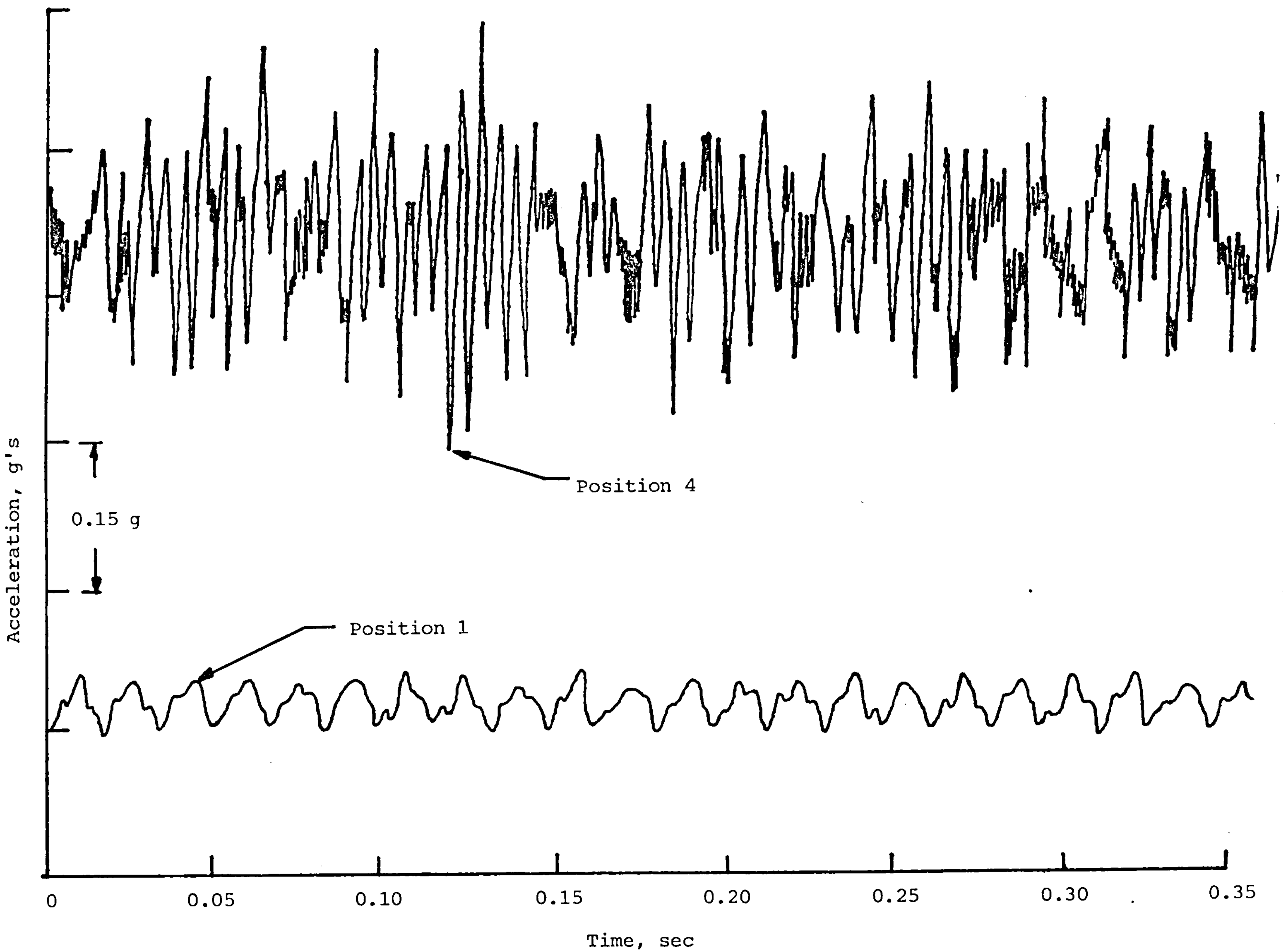


Fig. 108 Time history of acceleration at positions 4 and 1

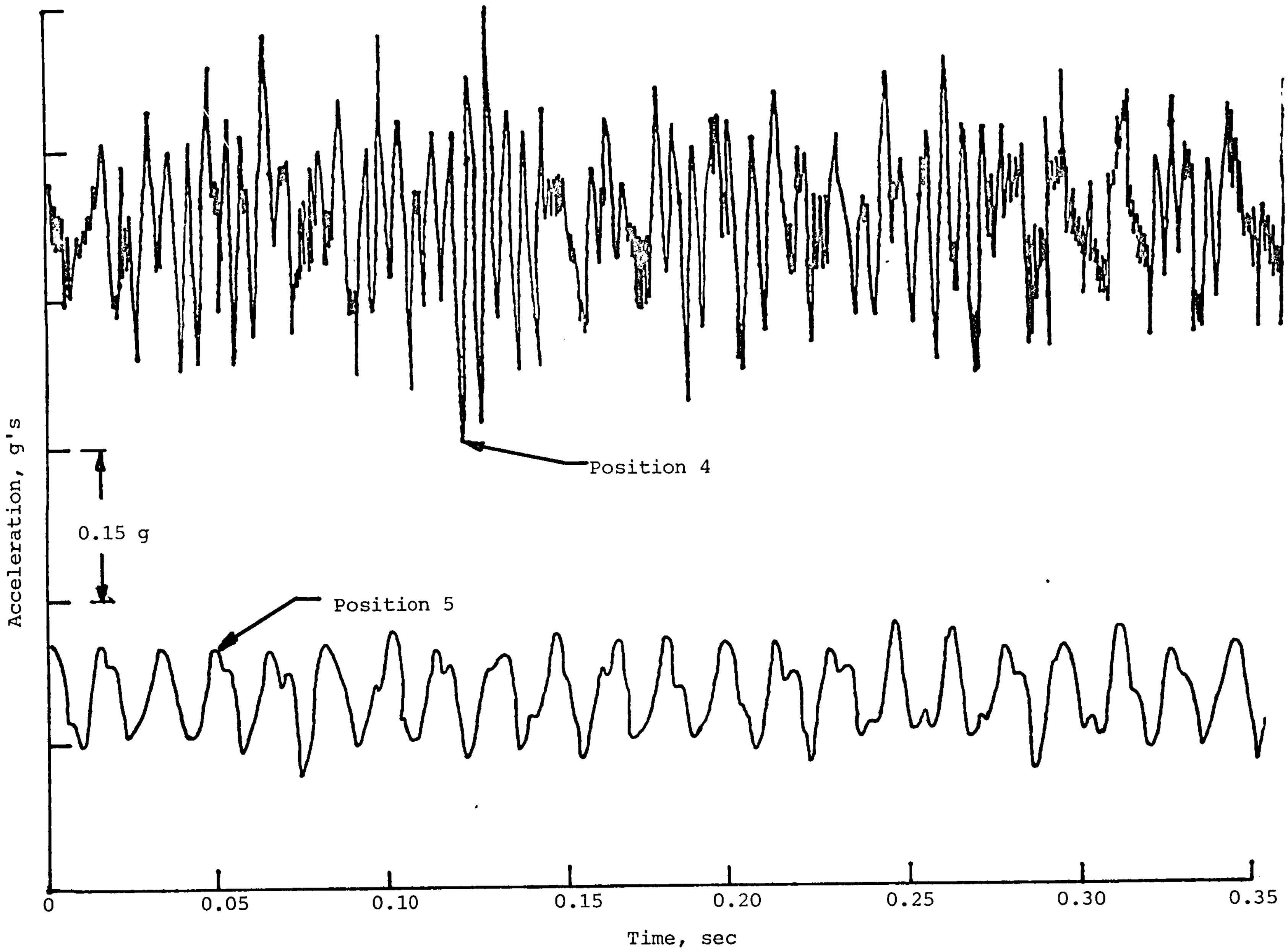


Fig. 109 Time histories of acceleration at positions 5 and 4

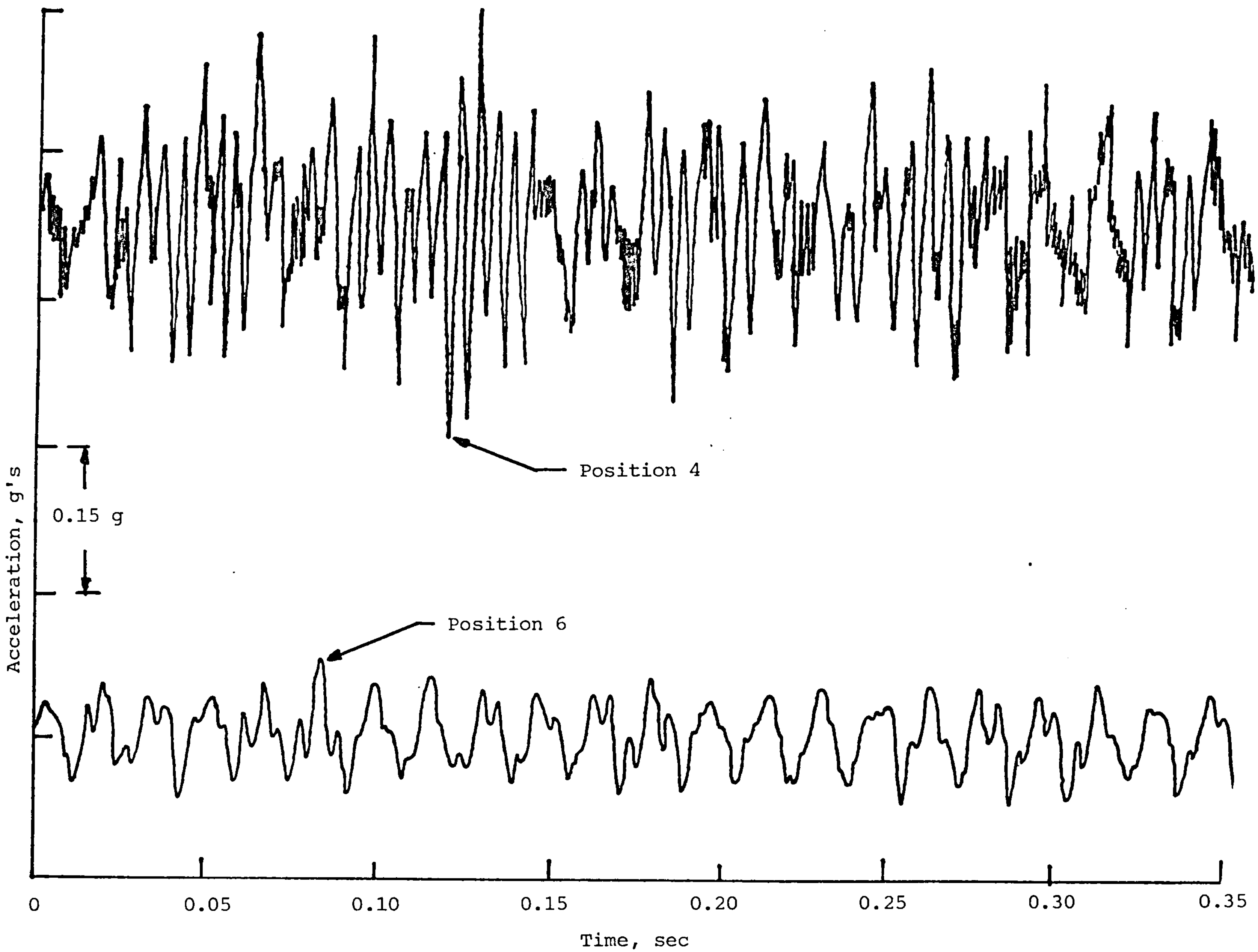


Fig. 110 Time history of accelerations at positions 4 and 6

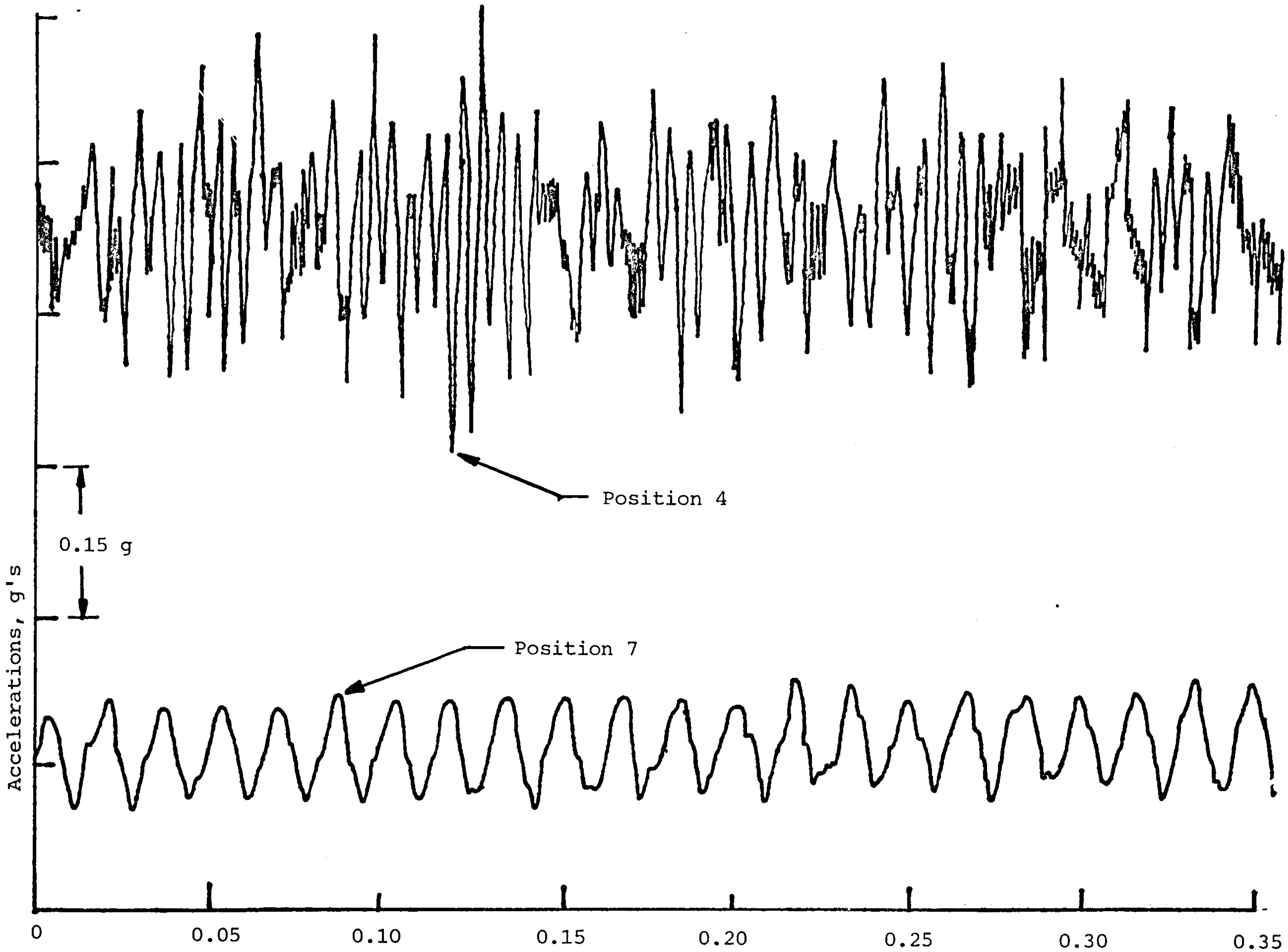


Fig. 111 Time history of acceleration at positions 4 and 7

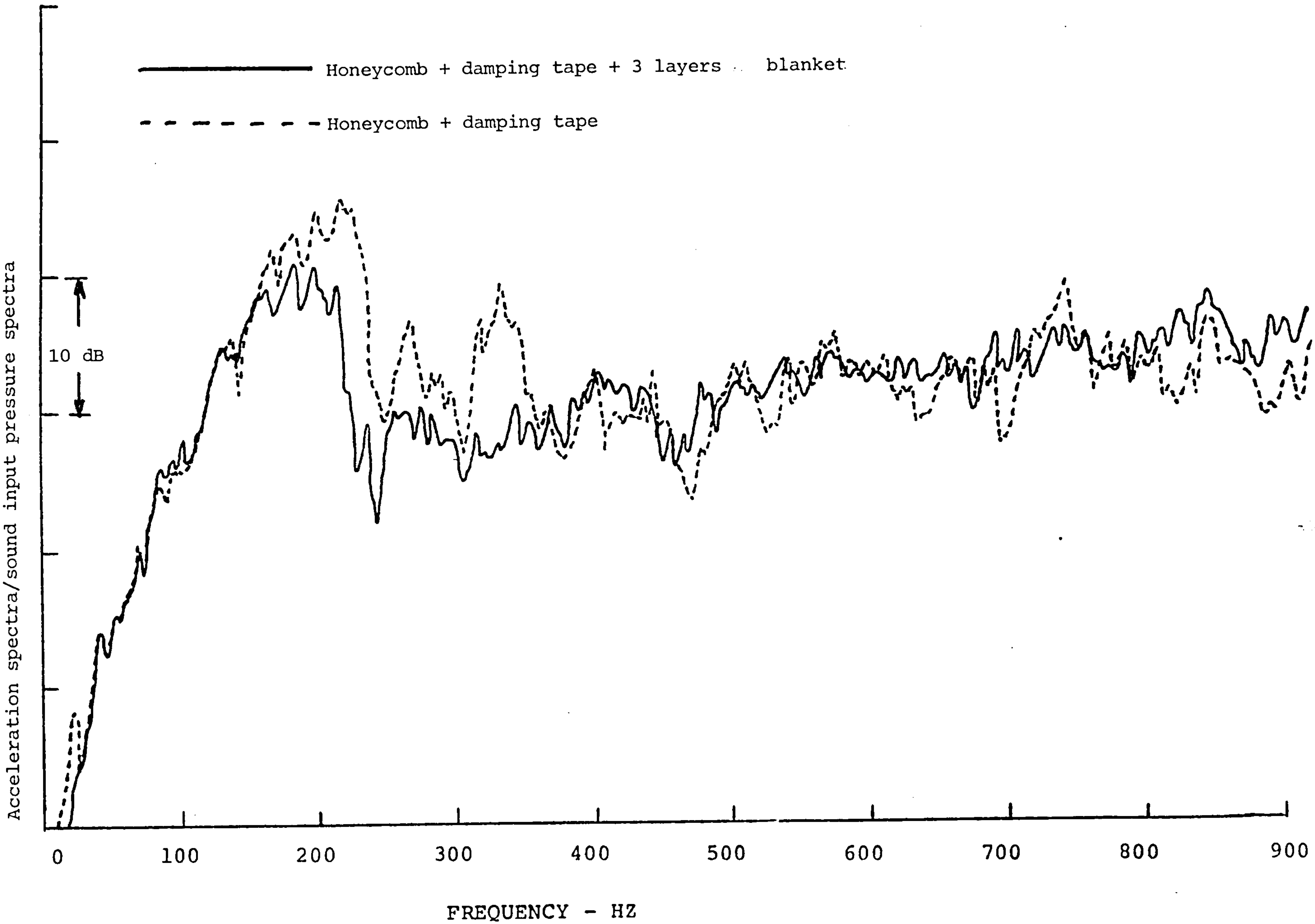


Fig. 112 Relative acceleration levels for panel 4S with different add-on treatments

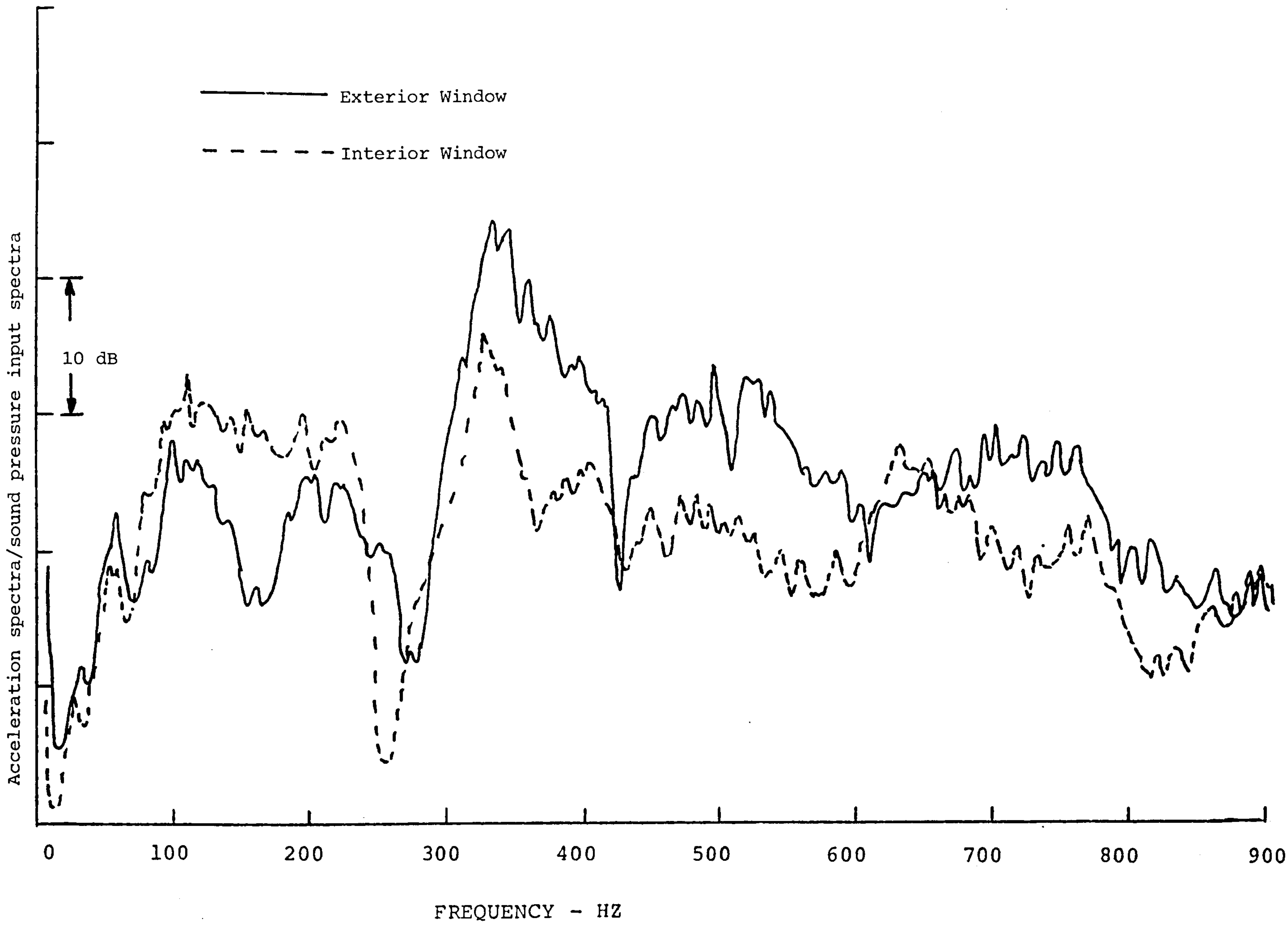


Fig. 113 Response of the double wall aircraft window (7P)

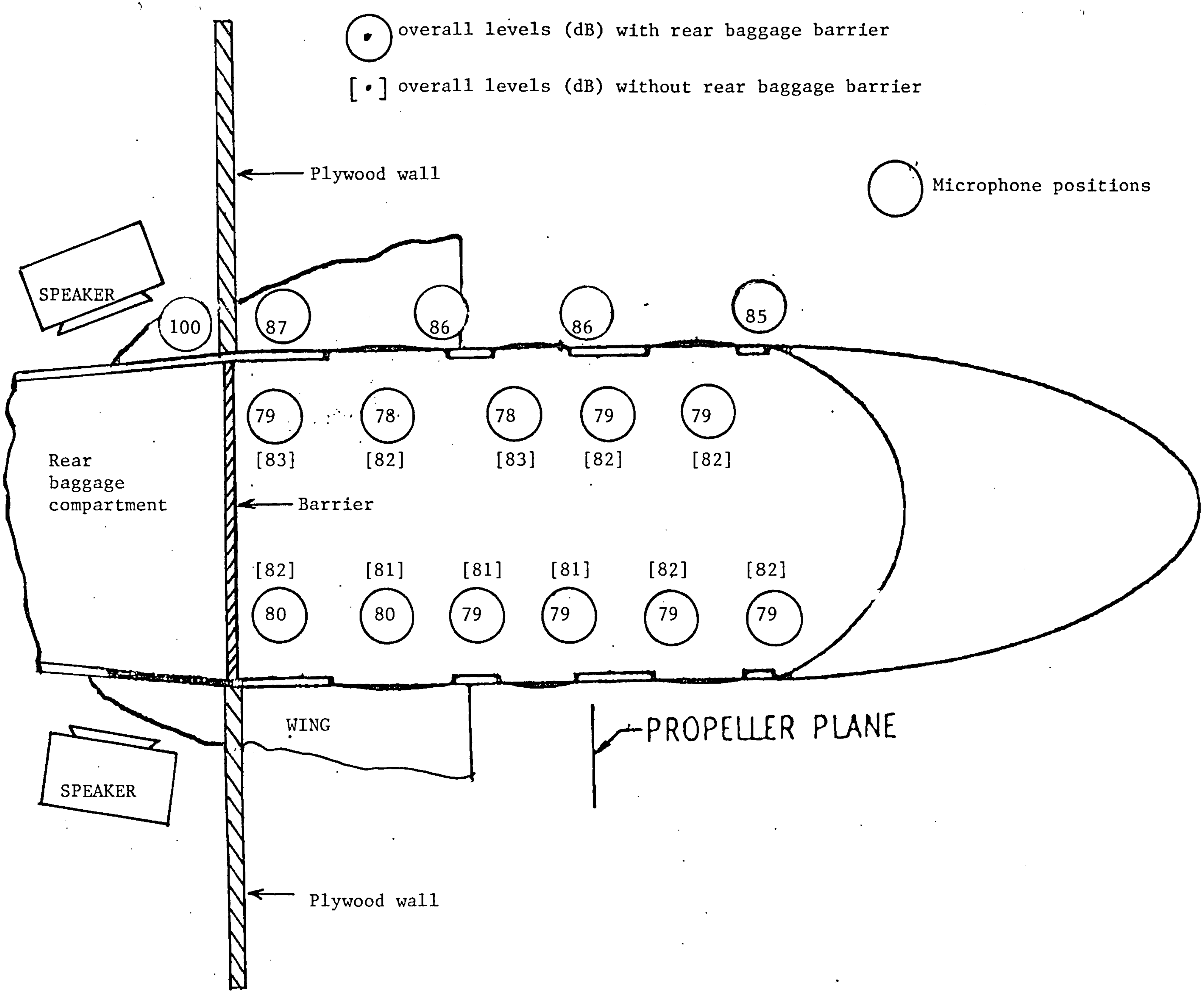
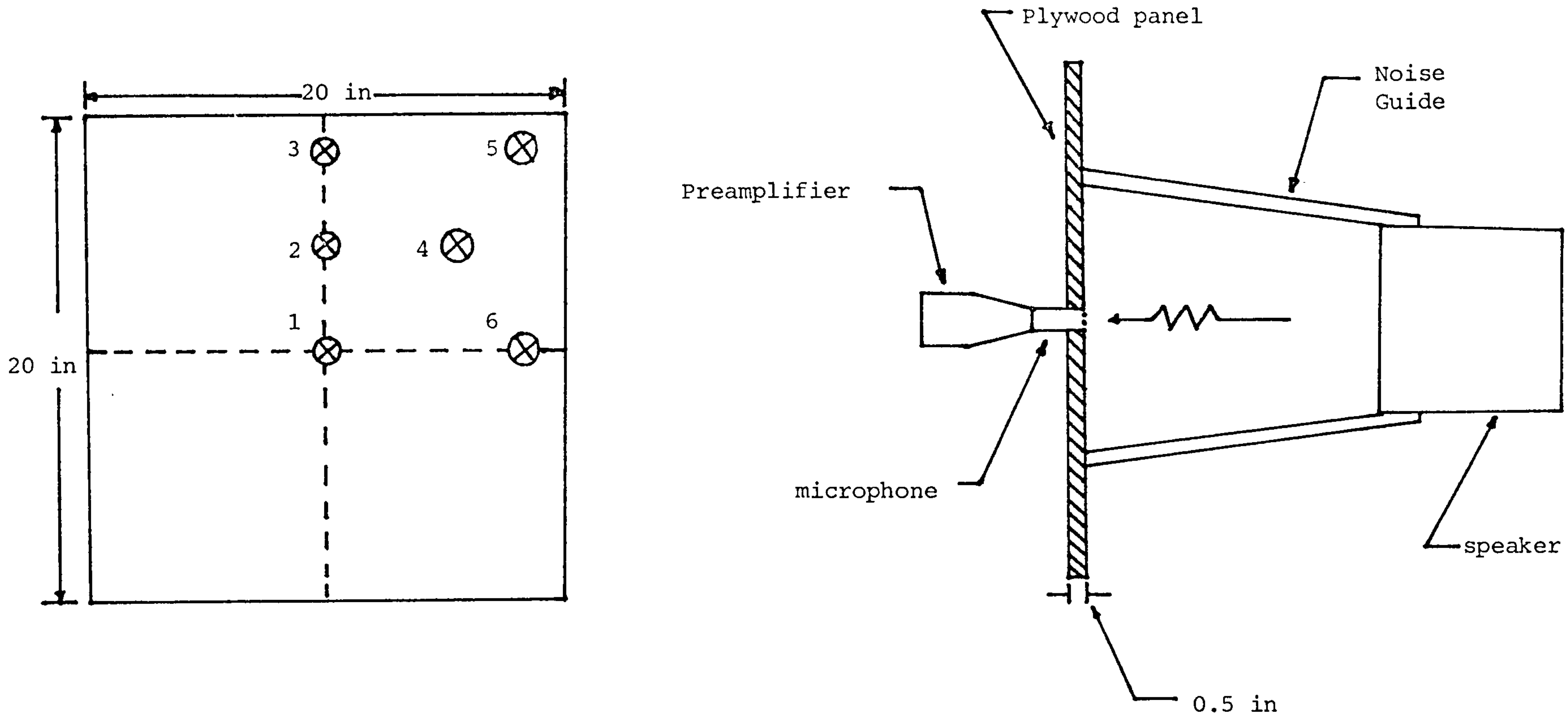


Fig. 114 Effect on interior noise of a barrier installed between the cabin and the rear baggage compartment



Microphone Location ⊗	Noise Level (dB)
1	125.1
2	124.4
3	124.8
4	124.3
5	124.8
6	124.9

Fig. 115 Noise generated by the acoustic guide on a flat surface

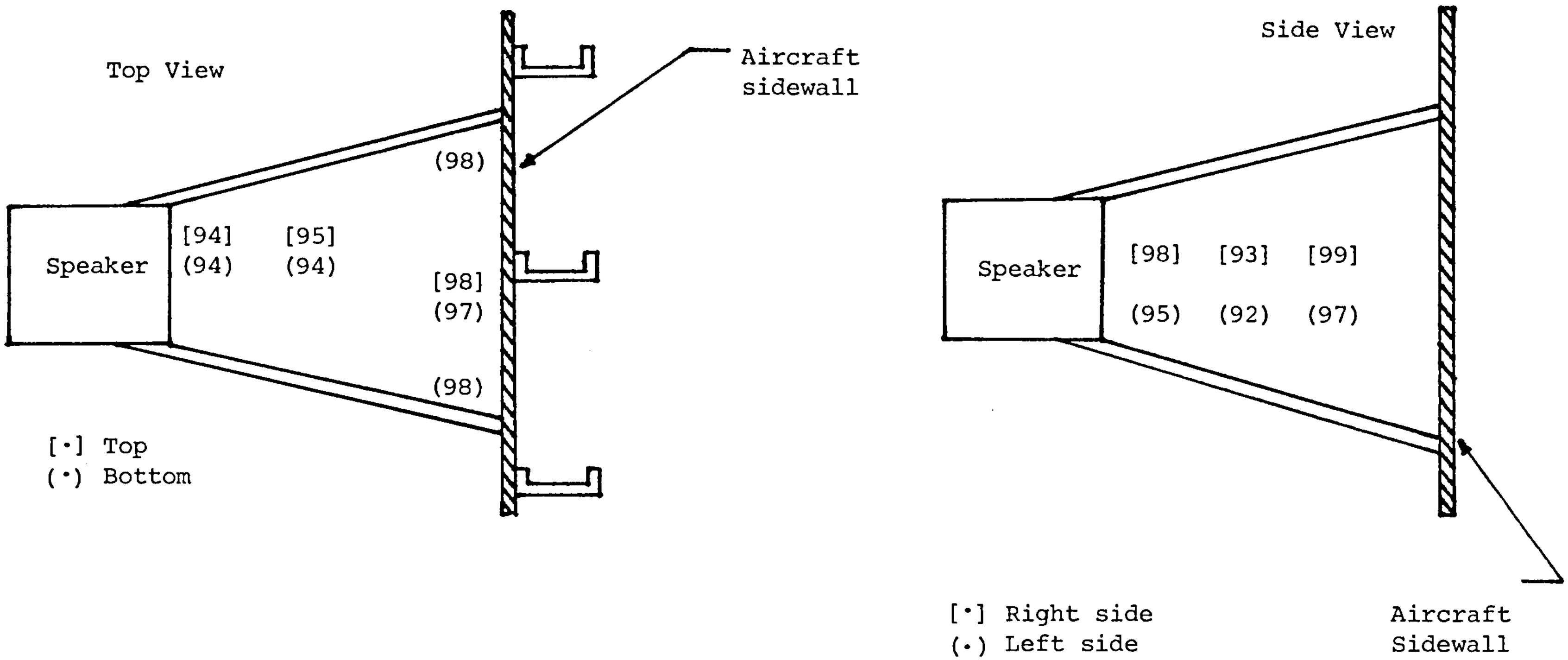


Fig. 116 Noise distribution on the exterior surface of the acoustic guide

APPENDIX A
List of Symbols

E_1, E_2 = elastic moduli of the aircraft skin panel and face plate of honeycomb

h_c = thickness of honeycomb core

h_p = thickness of aircraft skin panel

p_i = incident sound pressure

p_r = reflected sound pressure

p_t = transmitted sound pressure

R = flow resistivity coefficient

S_a = spectral density of accelerations

S_i = spectral density of noise pressure inside the acoustic guide

t_1, t_2 = thicknesses of honeycomb panel face plates

θ_1 = angle of incident pressure to normal

θ_2, θ_4, θ_6, θ_8, θ_{10} = angles of transmitted pressure to normal

ν = Poisson's ratio

μ_1 = surface density of aircraft sidewall

μ_3, μ_5, μ_7 = surface densities of septa barriers

μ_9 = surface density of trim

ω = circular frequency

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15. Supplementary Notes

Langley technical monitor: Dr. J.S. Mixson

16. Abstract An experimental study was conducted to determine the noise transmission into a cabin of a twin engine light aircraft. These experiments were carried out under laboratory conditions for diffuse and localized noise inputs. The effect on noise transmission due to add-on treatments was studied. These treatments include honeycomb panels, constrained layer damping tapes, nonload carrying mass, porous acoustic blankets, acoustic foams, noise barriers, multilayered septum, and trim panels. In addition, noise transmission through single pane and double pane aircraft windows was measured for several different acoustic interiors.

Results indicate that stiffening skin panels with honeycomb would provide on the average 3-7 dB insertion loss over the most of selected frequency range 0-1000 Hz. Addition of damping tape on top of the honeycomb treatment increases insertion loss by 2-3dB. Porous acoustic blankets show no attenuation of transmitted noise for frequencies below 300 Hz. Insertion of impervious vinyl septa between the layers of porous acoustic blankets do not provide additional noise reduction for frequencies up to about 500 Hz. Similar behavior was observed for noise barriers composed of urethane elastomer, decoupler foam and acoustic foam. A treatment composed from several layers of acoustic foams does not increase noise attenuation for the entire frequency range of 0-1000 Hz. A limp trim panel with 1 lb/ft^2 surface density could provide insertion losses from 3-20 dB for frequencies 160-1000 Hz. However, negative values of insertion loss were measured at the double wall resonance frequency of 125 Hz. An acoustic treatment composed of honeycomb panels, constrained layer damping tape, 2-3 inches of porous acoustic blankets, and limp-trim which is isolated from the vibrations of the main fuselage structure seems to provide the best option for noise control in this aircraft.

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