Initial Study on the Effects of Transformer and Transmission Line Noise on People

Volume 1: Annoyance

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EPRI PERSPECTIVE

PROJECT DESCRIPTION

EPRI is undertaking an expanded interdivisional research program directed at the evaluation and mitigation of electric utility produced noise. That program will include a consideration of noise from power plants, substations, and transmission lines. Whereas other EPRI divisions will have lead responsibility for studies on noise reduction techniques, the Environmental Assessment Department will focus on noise impact on both occupational personnel and neighboring communities. The project described in this final report is EPRI's first attempt to evaluate the effects of transformer and transmission line noise. The report consists of three volumes, each describing a separate topic of the study.

PROJECT OBJECTIVE

The objective of this three-part study was to compare the annoyance value of transformer- and transmission-induced noise with other common sources of noise in the community as determined by a laboratory study performed in an anechoic chamber (Volume 1); a study of sleep disturbance carried out in the homes of volunteer families (Volume 2); and an attitudinal survey carried out among residents living adjacent to utility equipment (Volume 3).

PROJECT RESULTS

The study shows that transformer noise is about 10 decibels (dB) more acceptable than transmission line noise and thus casts some doubt on the general validity of the A-weighted sound level index (dBA) as a predictor of the relative annoyance of transformer noise as compared to transmission line corona noise. (A-weighted means that the decibel level is weighted to take account of the sensitivity of human response at different frequencies.)

This observation is consistent with basic psychoacoustic data showing that the A-weighting underestimates by about 10 dB the subjective annoyance of noise energy in the frequency region around 2500 Hz, the region in which the corona noise is relatively stronger than transformer noise. Thus these studies confirm what is known about noise assessment and the inadequacy of the dBA as a unit for the assessment of certain types of relative noise evaluation.

This report should be considered as preliminary and should be interpreted with caution. Only a single transmission line noise spectrum was used, and that may or may not be representative. Furthermore, there is considerable unexplained variability in the data collected from the study of annoyance judgments.

Nevertheless, the current findings do provide some useful estimates of approximate noise levels that are likely to awaken people. Such information needs to be included in design practices followed by electrical utilities.

Further EPRI work is anticipated evaluating these data and expansion of the community annoyance data base.

Leonard A. Sagan, Program Manager
Energy Analysis and Environment Division

EXECUTIVE SUMMARY

The research program "Human Response to Low Level Noise" (EPRI RP-852) included three separate studies: laboratory experimentation on annoyance, field research on sleep interference, and a social survey of community reaction. All three studies indicated that conventional (A-weighted) measures of the sound level of corona discharge noise of extra high voltage transmission lines underestimate the effects of such noise on people.

The laboratory study, reported in Volume 1, assessed the annoyance of corona discharge noise and transformer hum by means of an adaptive paired comparison procedure. The procedure permitted test subjects to vary the presentation level of a synthetic sound until it was equally as annoying as each of a series of other sounds. All of these comparisons were made under free field listening conditions (in an anechoic chamber). A laboratory computer controlled all aspects of signal generation, presentation to subjects, and recording of data thoughout the course of data collection. Thirty-two audiometrically screened people between the ages of 18 and 47 years were paid to participate in the experimentation.

Table I lists the sounds (and their levels) presented for annoyance judgments. Figure 1 shows the average relative levels at which the sounds were judged to be equally annoying. The conventional A-weighting network gave a good account of the relative annoyance of the transformer hum and most other sounds. The clear exception was corona discharge noise and other sounds with prominent high frequency used in this study, for which the A-weighted sound pressure level underestimated judged annoyance by about ten decibels. This underestimation of annoyance was attributed to

TABLE I

PEST - STIMULI PRESENTATION LEVEL

	Signal No.	Abbrev.	Type +	A-Level (dBA)*
			Variable	L_{eq}
Standard	1	ST	Simulated Transformer	
	2	2 kHz	2 kHz Octave Band	
			Fixed	
Comparison	3	SMT	20 MVA Transformer	50.0
	4	TTL	Test Transmission Line	45.2
	5	LGT	1050 MVA Transformer	50.0
	6	OTL	Operating Transmission Line	44.6
	7	NTL	Shaped Noise-Operating Transmission Line	45.0
	8	NT	Shaped Noise - 1050 MVA Transformer	49.8
	9	NST	Shaped Noise - Simulated Transformer	49.8
	10	TLH	Transmission Line - With Only Low Frequency Hum	37.9
	11	TLC	Transmission Line - With Only High Frequency Crackle	41.9
	12	RAN	Rain	40.1
	13	TRF	Traffic	45.2
	14	BAB	Multi-Talker - Babble	55.3
	15	TRC	Tractor	54.4
	16	LWN	Lawnmower	49.9
	17	DIS	Dishwasher	50.1
	18	AC	Air Conditioner	44.7
	19	NOY	Shaped Noise - Noy Curve	44.7
Background			PNC-20	31.2

+All stimuli except the 2 kHz octave band standard incorporate the house filter indoor spectrum.

*Level heard by subjects during test.

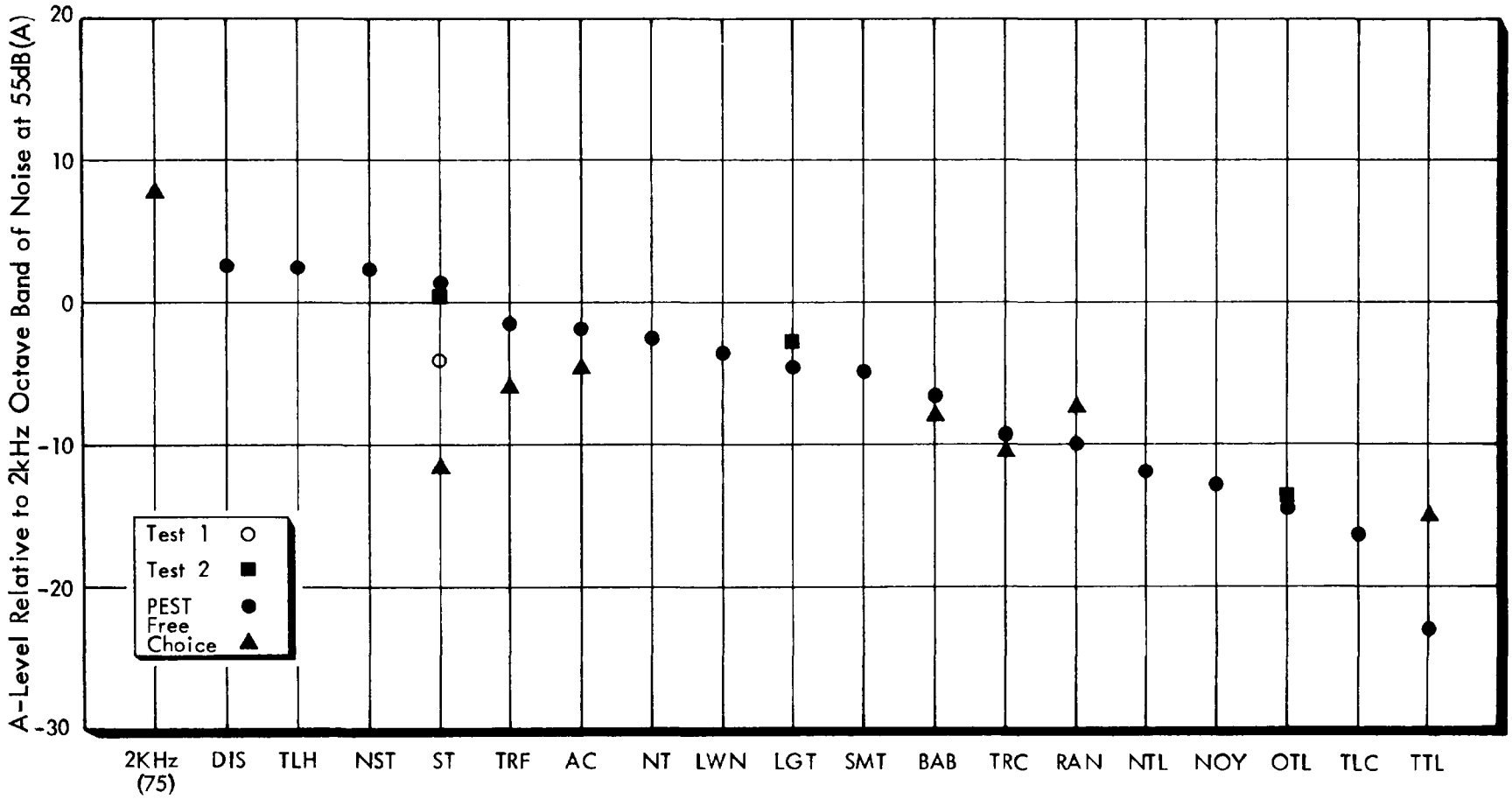


FIGURE 1. A-LEVEL OF TEST SIGNALS RELATIVE TO 2kHz NOISE FOR ALL TESTS AT EQUAL ANNOYANCE

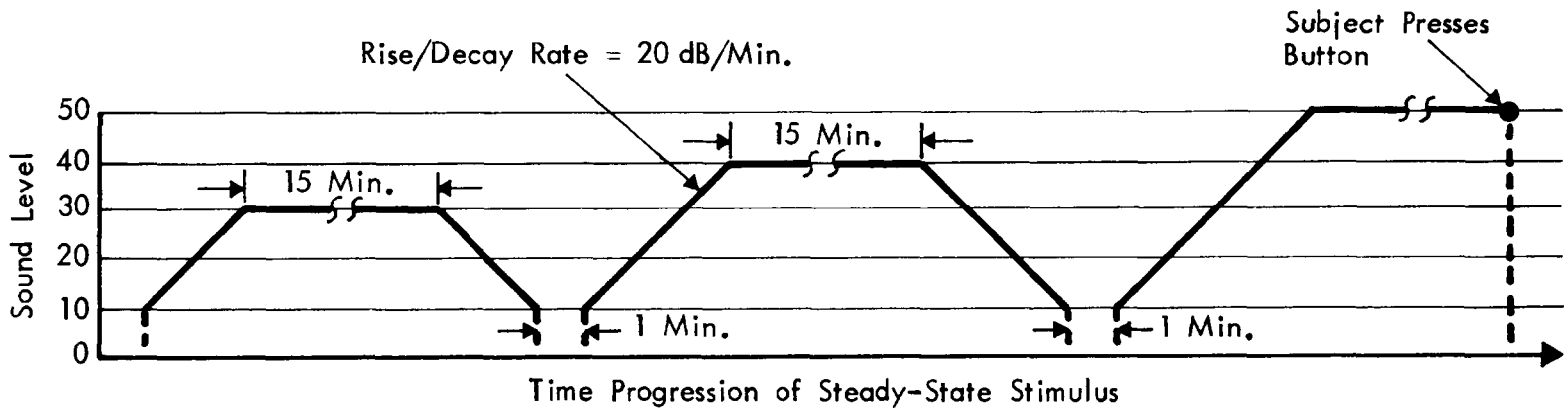
the high frequency content of corona discharge noise. Correction procedures for predicting the annoyance of sounds with appreciable high frequency energy content were suggested and evaluated.

Variability among subjects' annoyance judgments was found to be unexpectedly large. It was determined that the large individual differences were attributable to the low presentation levels of the sounds heard in the experiment.

The sleep study, reported in Volume 2, evaluated the ability of low-level sounds to awaken people. This study was conducted in the homes of fourteen test participants. These people's homes were connected by telephone lines to a laboratory computer that was able to produce several different sounds of varying time pattern (duration) and level throughout the night, and to record a simple measure of awakening - a button push. Test participants were instructed to push a button on their bedsteads upon awakening for any reason whatever during their three week participation in the study.

The computer could produce four different sounds in participants' bedrooms: corona discharge noise from a high voltage transmission line, hum from a simulated electrical transformer, air conditioner noise, and the sounds of distant traffic. The non-electrical noises were included to provide information on any potential differences in awakening rates of electrical and non-electrical noise sources.

All of these sounds were presented in two time patterns, seen in Figure 2: a "transient" shape, with rapid rise and decay times, and a "steady" shape. The two time patterns were included



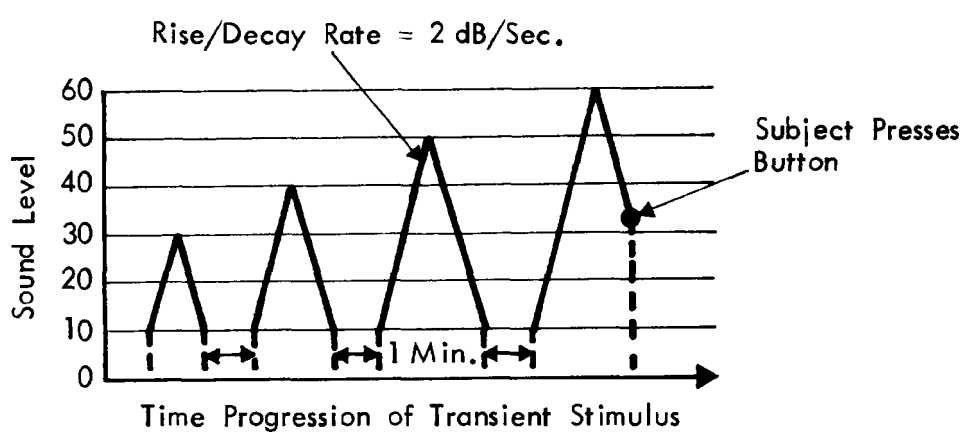


FIGURE 2. STIMULUS PRESENTATION PLAN FOR BEHAVIORAL AWAKENING STUDY

in the study to investigate whether the abruptness of onset or offset of noises affected awakening rates. Background noise measurements in participants' bedrooms were made during the course of the study to quantify the audibility of the computer-produced sounds.

No effort was made to obtain a statistically representative sample of the national population, nor is any claim made that inferences drawn from this experimentation may be freely generalized to wider populations or to other forms of noise exposure. Nonetheless, it is felt that the current findings do provide some useful estimates of approximate noise levels that are likely to awaken sufficient numbers of people to be of concern to electrical utilities.

Over three hundred participant-nights of data were collected, during which 482 awakenings were observed in response to about 2500 signal presentations. The basic relationships between probabilities of awakening and noise levels may be seen in Figure 3. The lines drawn through the data points are weighted least square fits, based on correlations that account for about 70% of the variance in the data. Note that these data are concentrated in the region of greatest practical interest - probabilities of awakenings lower than about 50%.

It can be seen from Figure 3 that transient sounds were *not* as effective in awakening people as longer duration sounds, since transient sounds 30 dB higher in level than long duration sounds were associated with similar probabilities of awakening.

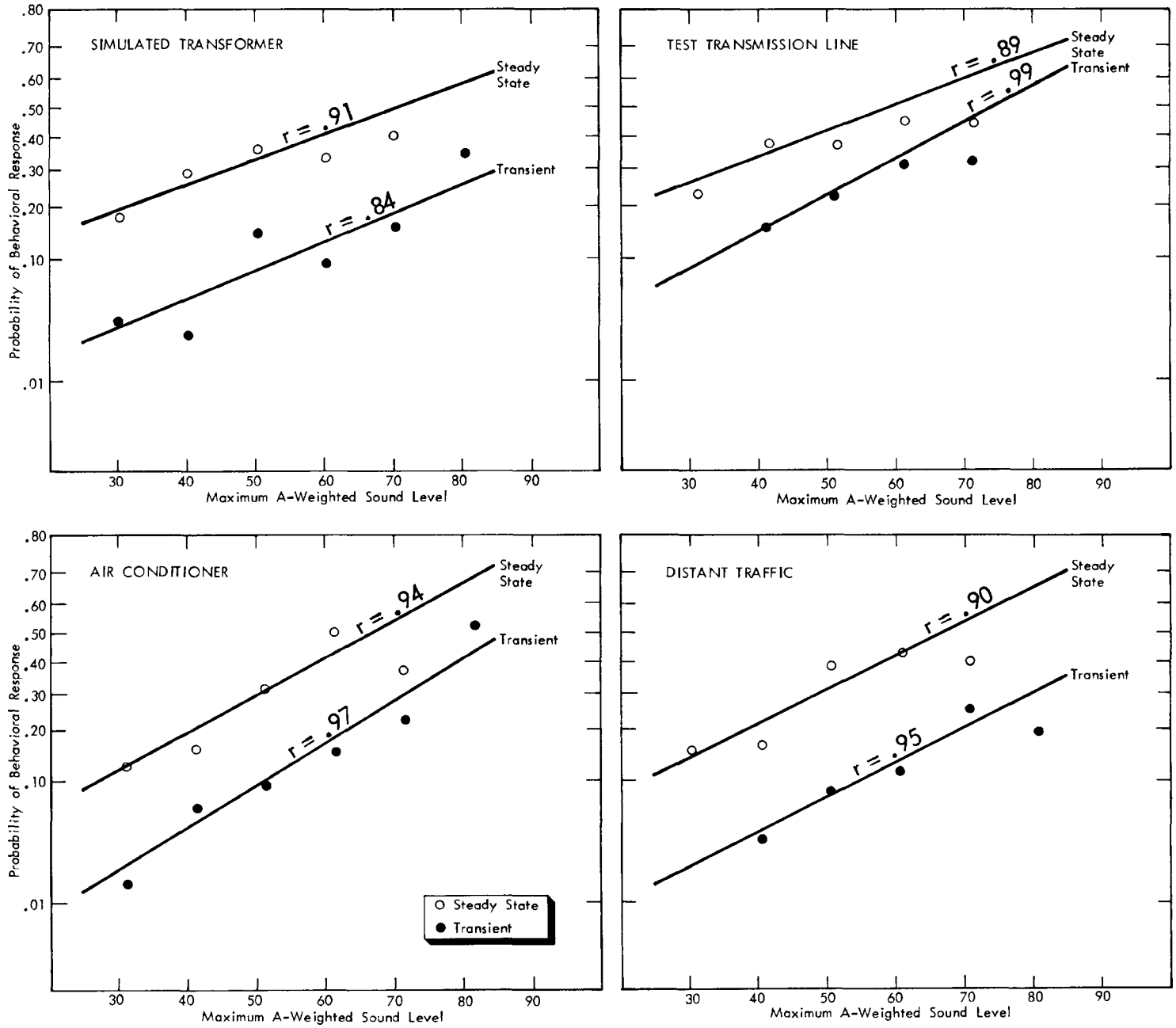


FIGURE 3. OBSERVED PSYCHOMETRIC FUNCTIONS SHOWING EFFECTS OF DIFFERING TEMPORAL PATTERNS

It was also observed that the sound of the power transmission line was more effective in awakening people than the other sounds used in the study. Exposure to the power line at levels about 10 to 15 dB(A) lower than the other sounds was associated with an equal probability of awakening. It is conjectured that this phenomenon may be related to the detectability rather than the absolute level of the transmission line noise.

The social survey, reported in Volume 3, was conducted to gauge community reaction to exposure to noise from actual high voltage transmission lines and transformer substations under routine operating conditions. About four hundred people residing at seventeen sites adjacent to power lines or transformer substations were interviewed to determine their opinions about exposure to electrical noise sources in an urban environment.

The survey presented a number of problems in sample selection and measurement of exposure, which were only partially resolved by a purposive sampling plan and considerable manipulation of noise measurements. Volume 3 contains lengthy discussion of analytic techniques used for estimating proportions of the national population exposed to varying levels of electrical noise, and for inferring levels of exposure to electrical noise sources in urban environments.

Interviews were conducted by structured questionnaires that sought information about long term (annual) rather than immediate opinions. The reactions of people exposed to power lines and transformer substation noise were generally quite mild. Very few people spontaneously mentioned electrical noise per se as a major community

problem; few had complained specifically about such noise; and few experienced speech or sleep interference, fear or startle from exposure to electrical noise sources.

Even though the absolute numbers of people who reported substantial annoyance due to noise exposure from electrical sources were small, it was observed that the prevalence of annoyance from urban noise exposure at sites adjacent to 500 KV and 230 KV power lines was greater than would be expected at urban sites not adjacent to power line rights of way. Thus, it might be reasonably anticipated that community reaction to electrical noise exposure might become more adverse if sizeable increases in exposure were to occur in the future.

ABSTRACT

The relative annoyance of transmission line and transformer noise was evaluated along with shaped noise and other environmental noises. Thirty-two test subjects made paired comparisons of the annoyance of 19 signals under free field listening conditions.

Transmission line noise and other signals with high frequency content were judged relatively more annoying than other low level sounds. Such signals would have to be 10 dB lower in level to be judged equally annoying to other low level environmental signals. It was not necessary, however, to adjust the physical levels of the transformer signals evaluated in this study to make them equally annoying to other low level signals.

PREFACE

The Electric Power Research Institute (EPRI) has sponsored a three-part study of the effects of electrical noise such as transformer and transmission (power line) noise on: (1) annoyance, (2) sleep interference, and (3) community reaction. Each part is reported in a separate volume.

The first study compared annoyance judgments in a laboratory setting of power lines, transformers, and other common low level sounds. The second study explored the effects of commonly occurring steady-state sounds (i.e., electrical noise samples, traffic, air conditioners) on sleep in test participants' homes. The last study used social survey techniques to assess community reaction to power line and transformer noise.

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SUMMARY

The following conclusions can be drawn from the relative annoyance judgments of this study using signals as they would be heard in peoples' homes. Note that no claim is made that the two transmission line recordings heard by test subjects are representative of all extra high voltage transmission lines.

1) Annoyance produced by exposure to transmission line noise is greater than that of other low level signals of similar A-level. Levels of transmission lines and other low level sounds with appreciable high frequency energy must be 10 dB lower in level to be judged equally annoying to other environmental sounds.

2) Annoyance produced by exposure to transformer noise is comparable to that of other environmental sounds of similar A-level. No pure tone correction appears to be necessary for the low level transformer noise evaluated in this study.

3) The following two noise correction procedures appeared to be more effective predictors of annoyance than A-weighted sound level for low level sounds:

a) The Theory of Signal Detectability (TSD); or
b) 10 dB corrected A-level for signals whose range in one-third octave band spectra is less than 25 dB from 50 Hz to 8000 Hz, or for spectra which exhibit a rise in level with increased frequency.

4) Variability of individual relative annoyance judgments of low level (45-55 dB(A)) signals is greater than variability in judgments of the annoyance of higher level signals.

I. INTRODUCTION

Audible noise from electrical power transformers and transmission lines has long been recognized as one of many community noise sources. Relative to other common noise sources, these electrical sources have been widely viewed as of minor significance. For a number of reasons, this situation has begun to change.

First, sufficient public attention has been directed to the major, high level sources (primarily aircraft and highway traffic) that alleviation of their effects may be foreseen in the near future. Second, evolving technology has made possible higher operating voltages for electrical power systems in recent years, setting a trend toward even higher voltages in the future. Noise levels at these operating levels are indisputably higher. Third, awareness of environmental matters has generally heightened for all forms of pollution in recent years, to the extent that community noise problems which received little attention in the past are causing greater concern.

Taken together, these trends suggest that noise from electrical sources may not long remain a minor problem. For example, extensive hearings in New York State on the construction of a 765 KV transmission line have concentrated on anticipated noise effects. In Oregon, there is considerable concern about whether major transformer installations will be able to meet new state noise regulations.

Since the bulk of current knowledge of the effects of noise on people is derived from studies of high level noise sources, much

of the current debate over electrical noise sources is of a frankly speculative nature. What is missing is a basic understanding of the effects of exposure to low level noise sources in general, and of noise from electrical sources in particular. This study was performed to gather empirical information on subjective comparisons of the annoyance of audible noise from transformers and transmission line noise with other environmental sounds.

II. BACKGROUND

A brief discussion of the nature of noise from electrical sources is provided as a preface to the study of effects of noise from electrical sources on people.

A. Source and Nature of Transformer Noise

Physical studies (White, 1974; Berger, 1968; Schultz, 1960) have proven that magnetostriction is responsible for the core vibrations in a transformer, and for its radiated noise. Magnetostrictive core excitation produces pure tone components of transformer noise at 120 Hz, 240 Hz, 360 Hz and subsequent harmonics of 60 Hz. The strength of these tonal components is such that they may dominate the ambient noise spectrum over a large part of the frequency range of general interest--particularly at mid-frequencies. A typical example is shown in Figure 1, which shows in a narrow band analysis the numerous harmonics measured in a community immediately adjoining a large transformer installation.

Noise level spectra for another transformer installation are presented in Figures 2 and 3 in terms of one-third octave and octave band sound pressure levels. These spectra were measured in a community 1000 feet from a large transformer bank. While evidence of a number of tonal components can be inferred from the one-third octave band data in Figure 2, the octave band data in Figure 3 suggest a tone (or narrow band noise) only in the 125 Hz octave band. In fact, just as in the case in Figure 1, narrow band frequency analysis would demonstrate the presence of many tonal components.

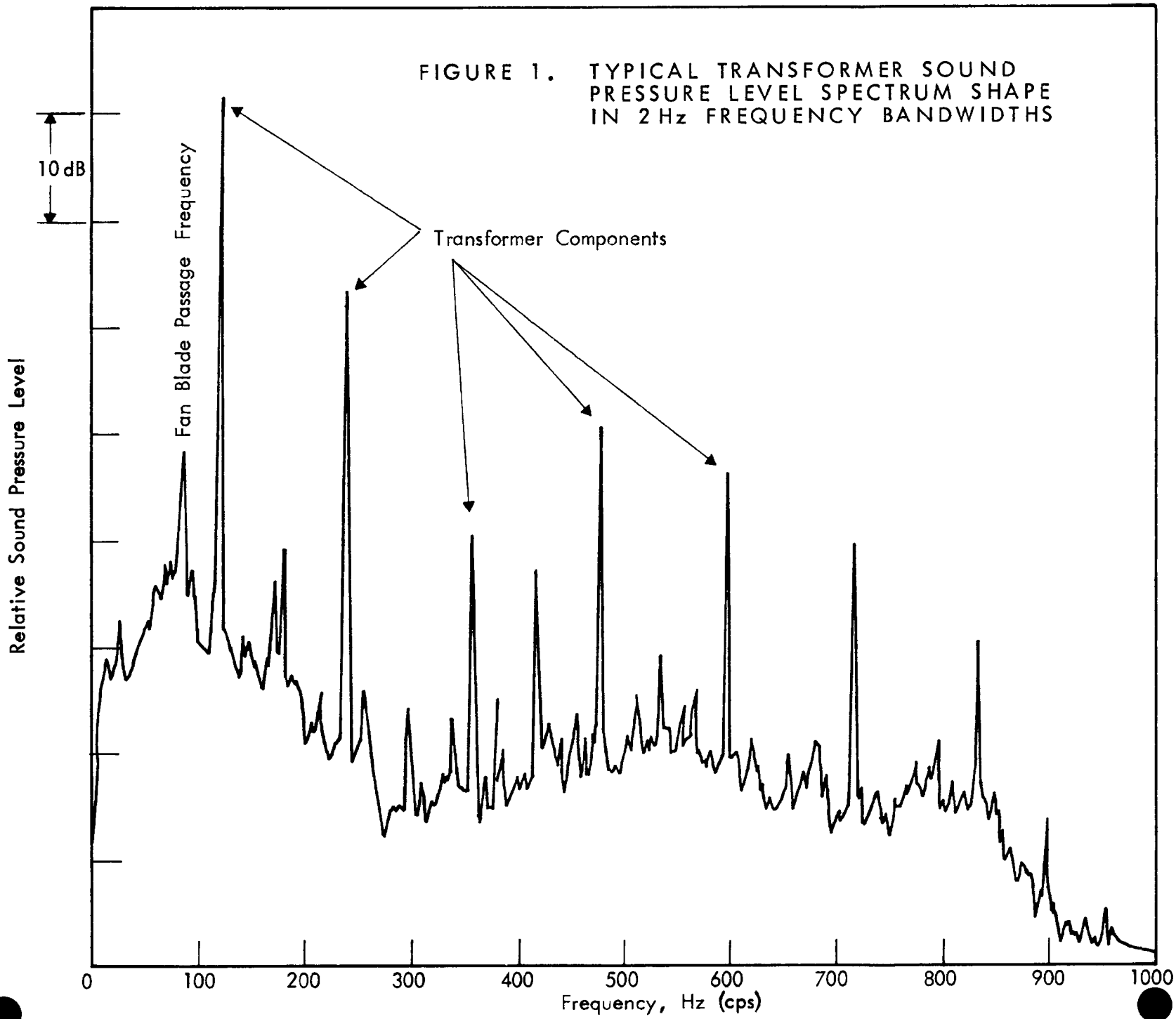

FIGURE 1. TYPICAL TRANSFORMER SOUND PRESSURE LEVEL SPECTRUM SHAPE IN 2 Hz FREQUENCY BANDWIDTHS

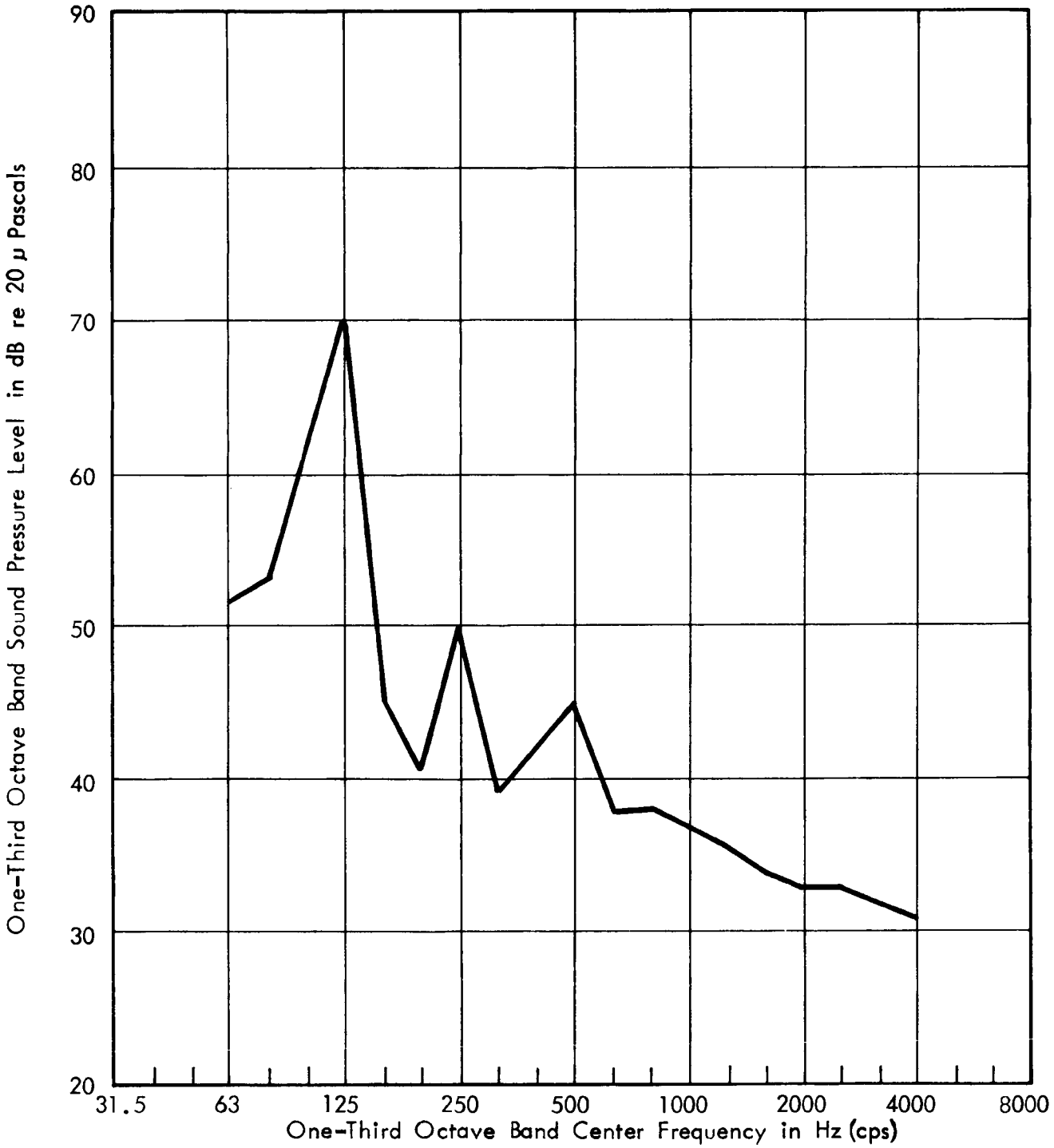

FIGURE 2. ONE-THIRD OCTAVE BAND ANALYSIS OF TRANSFORMER NOISE LEVELS AT A DISTANCE OF 1000 FEET FROM A BANK OF THREE, SINGLE PHASE UNITS RATED AT 900 MVA IN TOTAL

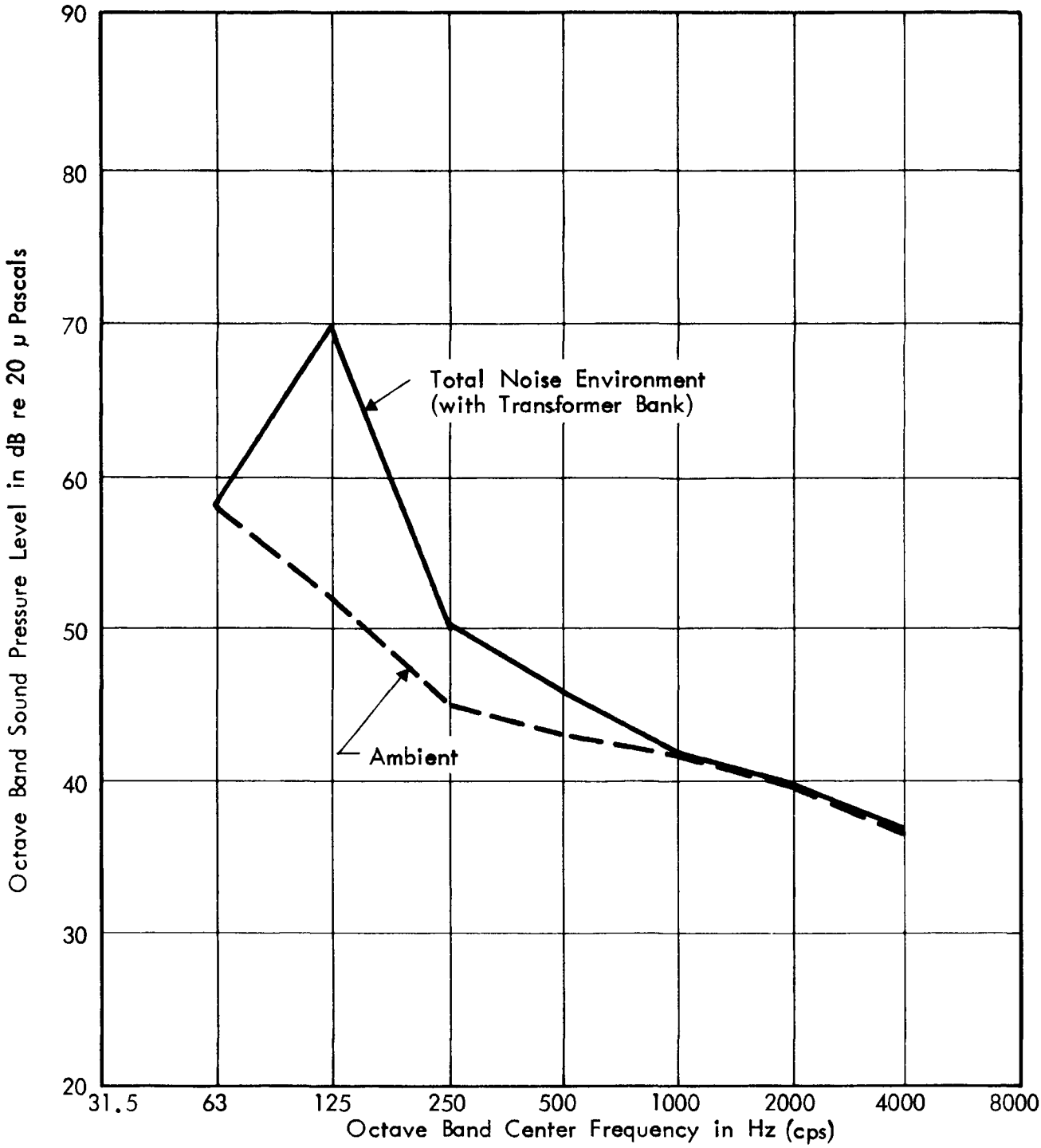

FIGURE 3. OCTAVE BAND ANALYSES OF TRANSFORMER NOISE LEVELS AT A DISTANCE OF 1000 FEET FROM A BANK OF THREE, SINGLE PHASE UNITS RATED AT 900 MVA IN TOTAL

Figure 3 shows that transformer noise exceeds the ambient noise levels significantly*. In the 125 Hz octave band in particular, the excess is 18 decibels. In terms of the A-scale sound levels, the excess is still 7 decibels.

This situation is merely one example of transformer noise intrusion into communities. Both more severe and less severe intrusions may be found since the relative strength of transformer harmonics can vary significantly with transformer size and distance. The potential for community complaint nonetheless exists wherever a transformer is audible. Extensive noise control engineering has been found necessary at some installations to abate community reaction to transformer noise.

B. Source and Nature of Transmission Line Noise

Transmission line noise has become a subject of study in recent years (EPRI, 1975). Audible noise from the lines has increased with increasing line voltage, thereby increasing the likelihood of community complaints. Weather plays an important role in the amount of noise produced by transmission lines: Figure 4 shows the influence of humidity on radiated noise. As the relative humidity (R.H.) increased at a site, the noise levels increased too, from 44 dB(A) at about 80% R.H. to 51 dB(A) at effectively 100% R.H. The broadband characteristic of corona noise and a large proportion of high frequency energy is evident from this figure. Not shown are the occasional pure tone component at 120 Hz and higher order harmonics of the 120 Hz tone, a consequence in part of conditions at the time of measurement.

*Tonal components produced by the transformer were removed from the spectrum to obtain the background level unaffected by the transformer.

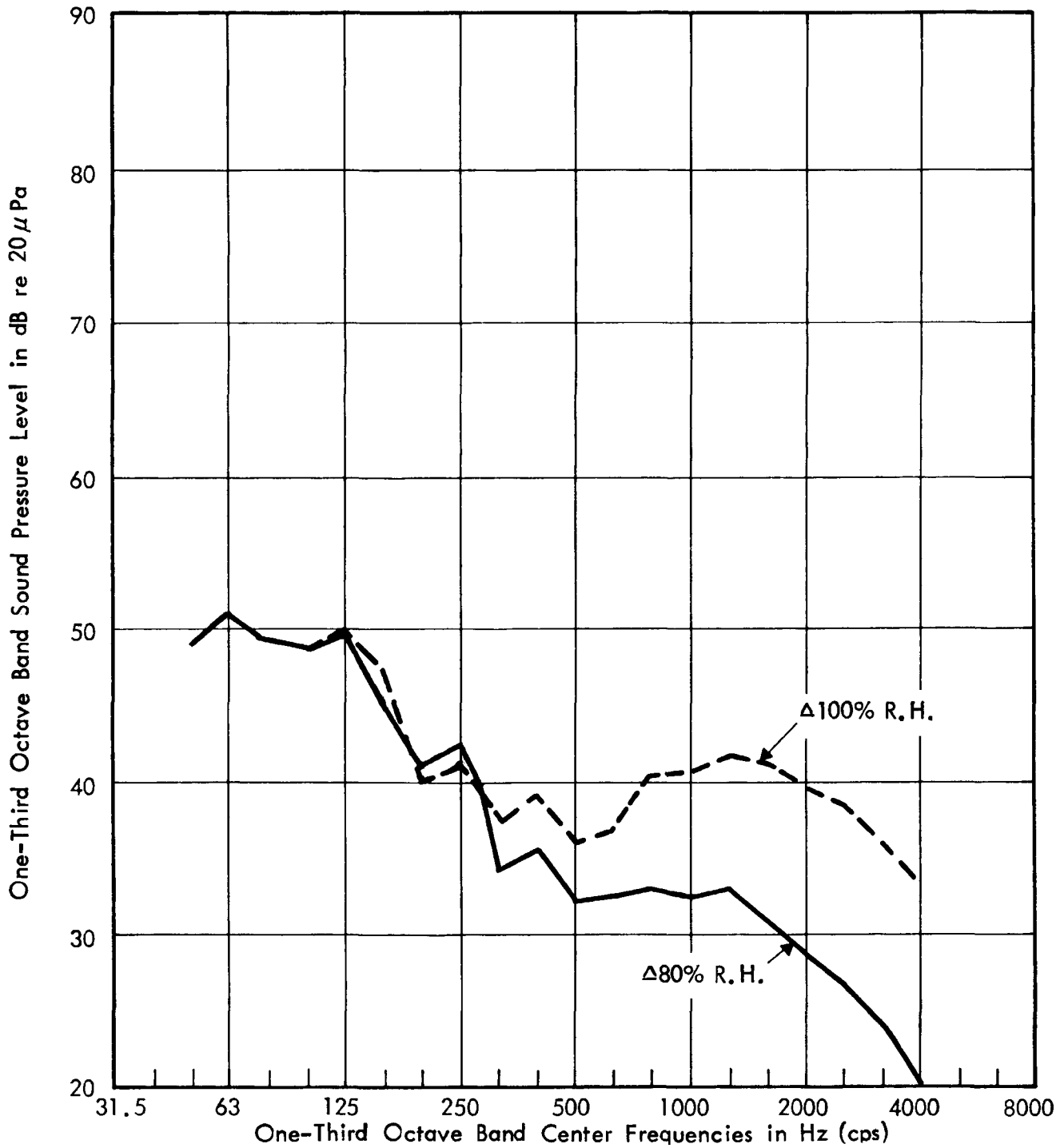

FIGURE 4. EFFECT OF RELATIVE HUMIDITY ON CORONA NOISE. 500 KV LINE AT 250 FEET

C. The Annoyance of Electrical Noise

Little research has been conducted on the relative annoyance of either transformer noise or transmission line noise in the laboratory. Wells (1974) reported that the best rating measure of power line noise was B-weighted sound pressure level. However there was not a large difference between all of the measures used in this test since standard deviations ranged from 0.8 to 1.2 dB for 25 different types of noise when they were all judged to be equally annoying. Wells concluded as a possible compromise that B-weighted sound pressure level be used to estimate community reaction even though A-weighted sound pressure level may be specified in noise ordinances.

Other work is in progress (Forman, 1977; Molino, 1977) to further investigate the annoyance of high voltage power line noise. However no conclusive results are available at this time.

Transformer noise is presently rated by using A-weighted sound pressure level. One method developed by Stevens et al. (1955) to predict the community response to all noises including transformer noise, accounted for the pure tone character of this noise by adding 5 dB to the measured A-level. Five dB was chosen since it represented one "scale point" on the complaint curve, an amount judged as compensation for the tonal effect. Another method that is suggested to avoid community complaints about transformer noise requires that the A-weighted sound pressure level of the transformer be 0-5 dB lower than the background noise in the community (White and McNally, 1974). However this approach to evaluating community response has not been fully validated at this time.

In summary, there is a paucity of information which relates directly to the relative annoyance of low level electrical noises. The study described in this report provides comparisons of transformers and audible transmission line noise with other noises normally found in the environment.

III. METHOD

Nineteen signals which represent both naturally occurring environmental noises and sounds associated with outdoor electrical noise sources were compared using an adaptive paired comparison procedure (Parameter Estimation by Sequential Testing (PEST)). The procedure, test signals, and equipment are described below.

A. Procedure

The PEST procedure is essentially an adaptive computer controlled paired comparison test. Neither the sequence nor level of the signals is fixed in advance, but is determined by the subject's prior responses. A more complete discussion of this procedure is given in Appendix A.

PEST is an efficient method of determining the points of subjective equality among the annoyance values of a large number of noise signals. A point of subjective equality is defined, in this case, as a physical level at which a comparison signal is judged equally annoying to a standard signal. On a typical trial, the computer presents two noise signals: a comparison signal, invariant in level, and a standard signal, the level of which would be adjusted by computer in accordance with the responses of the test subject. The order of administration of trials, randomization of test conditions, selection of comparison signals, adjustment of levels, recording of results, and so forth, is under direct control of the computer. The efficiency of this method of data collection permits testing of a large number of noise signals in a short period of time.

Each subject was tested individually in an anechoic chamber. Appendix B contains instructions to the subjects. They were trained in the testing procedure by judging the annoyance of a signal compared to itself. A subject was considered trained when the difference in level for a signal compared with itself was not greater than 1 dB. The subjects were given a brief rest prior to commencement of the main test, and once during the test. During the primary study, which lasted approximately 2 hours, the subjects were asked to compare the annoyance of 34 pairs of sounds.

B. Test Signals

The signals tested in this study were categorized as three types: (1) outdoor electrical sounds, (2) naturally occurring sounds, and (3) shaped noise. A complete list of the signals is shown in Table I and the one-third octave band spectra are given in Appendix C. The outdoor environmental sounds, whether electrical or otherwise, were first recorded outdoors near their noise source. They were reproduced during the test through a filter (Figure 5) designed to simulate an indoor listening environment (SAE, 1971). Results from preliminary tests (see Appendix D) indicated that a comparison of the chosen signals to one or two "standard" sounds would provide the necessary information to rank all signals in terms of annoyance. The first standard, a simulated transformer, was a phase-locked, harmonically related series of tones at 120, 240, 360, and 480 Hz. The second standard, a 2 kHz octave band of noise, was shaped pink noise from a noise generator. The 2 kHz standard was used rather than the more conventional 1 kHz noise since it was not as masked by the

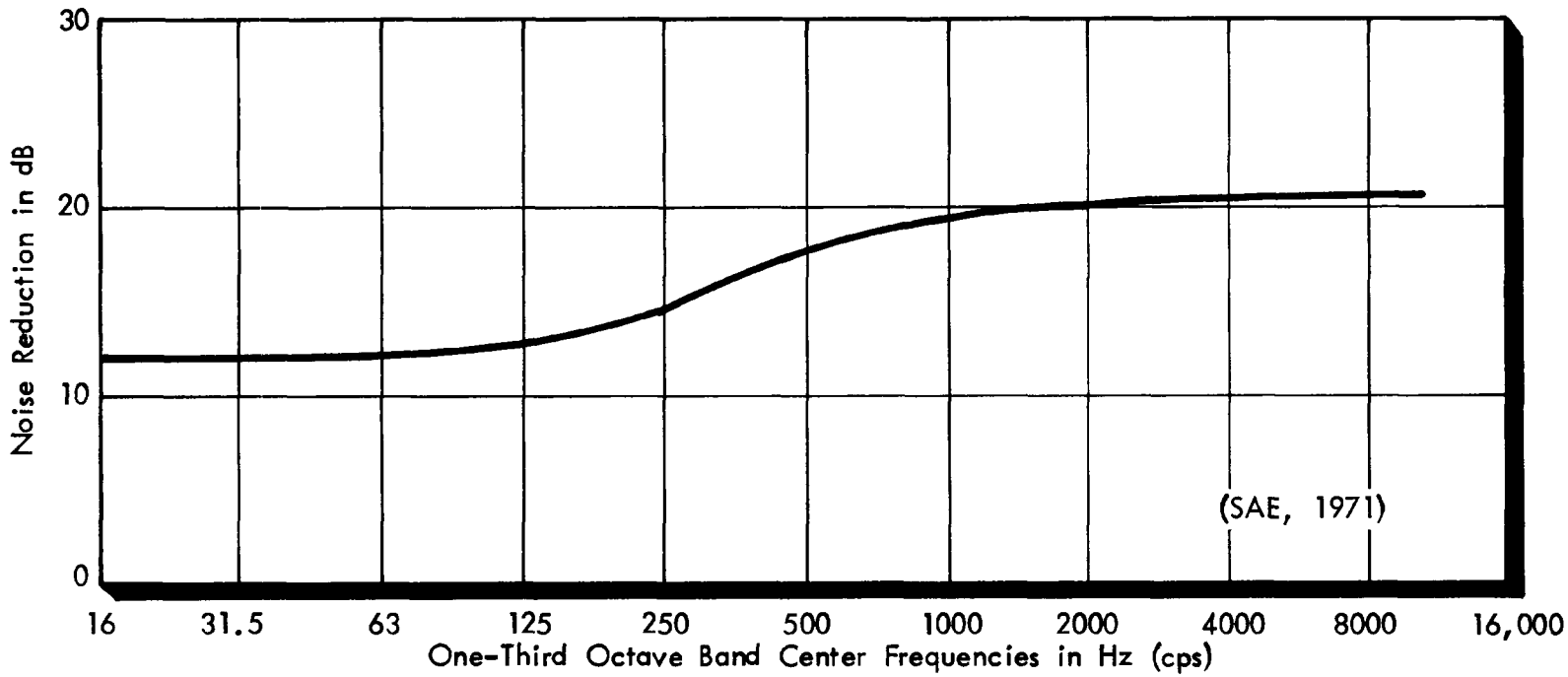

FIGURE 5. HOUSE FILTER NOISE REDUCTION

TABLE I

PEST - SIGNAL PRESENTATION LEVEL

	Signal No.	Abbrev.	Type +	A-Level (dBA)*
			Variable	L_{eq}
Standard	1	ST	Simulated Transformer	
	2	2 kHz	2 kHz Octave Band	
			Fixed	
Comparison	3	SMT	20 MVA Transformer	50.0
	4	TTL	Test Transmission Line	45.2
	5	LGT	1050 MVA Transformer	50.0
	6	OTL	Operating Transmission Line	44.6
	7	NTL	Shaped Noise-Operating Transmission Line	45.0
	8	NT	Shaped Noise - 1050 MVA Transformer	49.8
	9	NST	Shaped Noise - Simulated Transformer	49.8
	10	TLH	Transmission Line - With Only Low Frequency Hum	37.9
	11	TLC	Transmission Line - With Only High Frequency Crackle	41.9
	12	RAN	Rain	40.1
	13	TRF	Traffic	45.2
	14	BAB	Multi-Talker - Babble	55.3
	15	TRC	Tractor	54.4
	16	LWN	Lawnmower	49.9
	17	DIS	Dishwasher	50.1
	18	AC	Air Conditioner	44.7
	19	NOY	Shaped Noise - Noy Curve	44.7
Background			PNC-20	31.2

+All stimuli except the 2 kHz octave band standard incorporate the house filter indoor spectrum.

*Level heard by subjects during test.

background noise at low levels. Both standards were chosen as examples of artificial and electrical noise. All the signals were four seconds in length as determined by a pilot test (see Appendix D) and were heard in the presence of PNC-20 background (Figure 6) noise, similar in character to the ambient found in homes. The spectral shape is taken from noise criteria curves suggested by Beranek (1971).

C. Subjects

Thirty-two subjects ranging in age from 18 to 47 years participated in this study. The average age was 25 years. There were 16 female subjects and 16 male subjects. All subjects were audiometrically screened to within 20 dB of normal hearing as defined in ISO recommended standards (1964).

D. Equipment

The equipment used for data acquisition is illustrated in the block diagram shown in Figure 7. The computer automatically controlled the presentation of the two independent standards and the pre-recorded comparison signals. Presentation levels of the signals were regulated by a voltage-controlled amplifier.

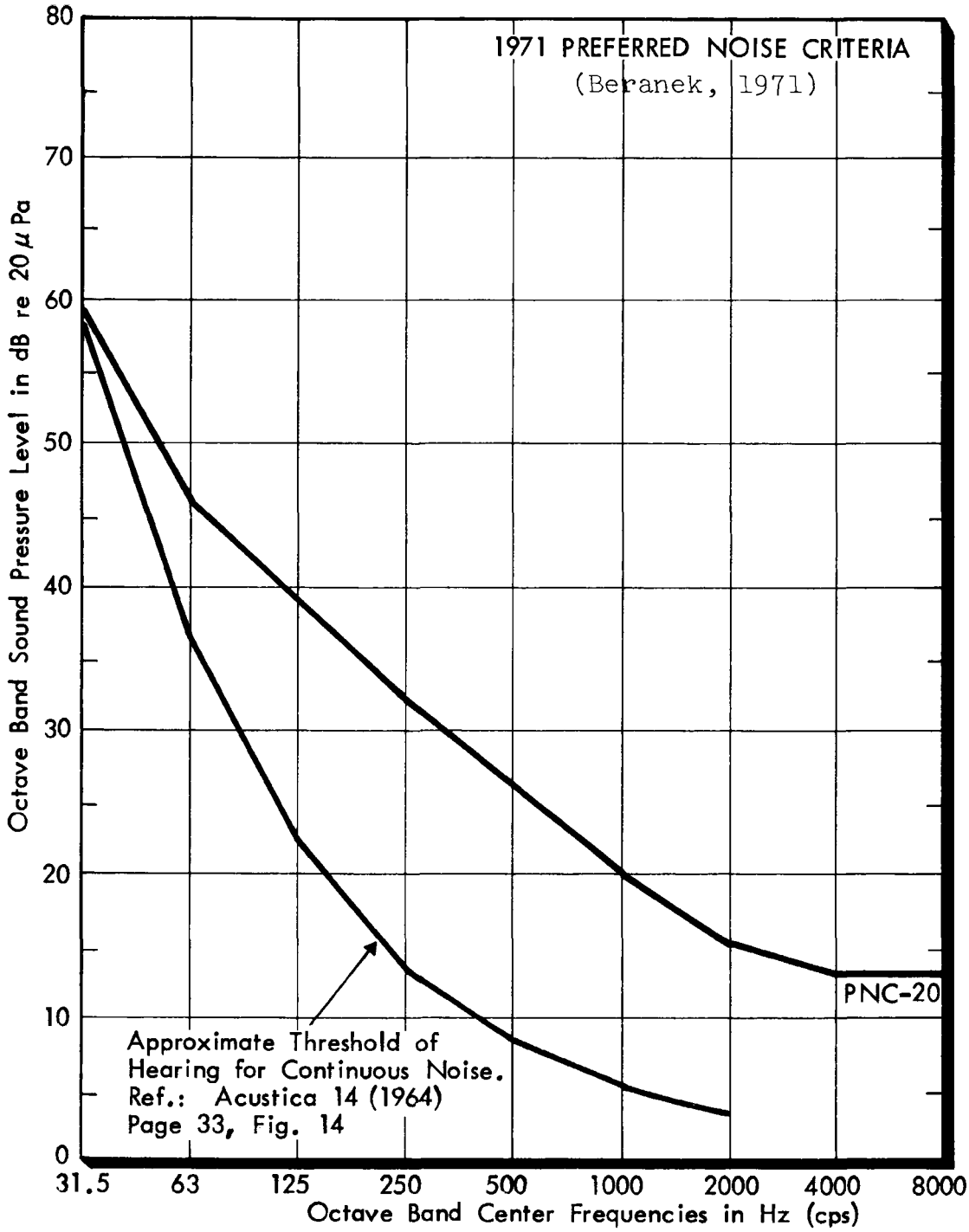

FIGURE 6. BACKGROUND NOISE FOR PEST

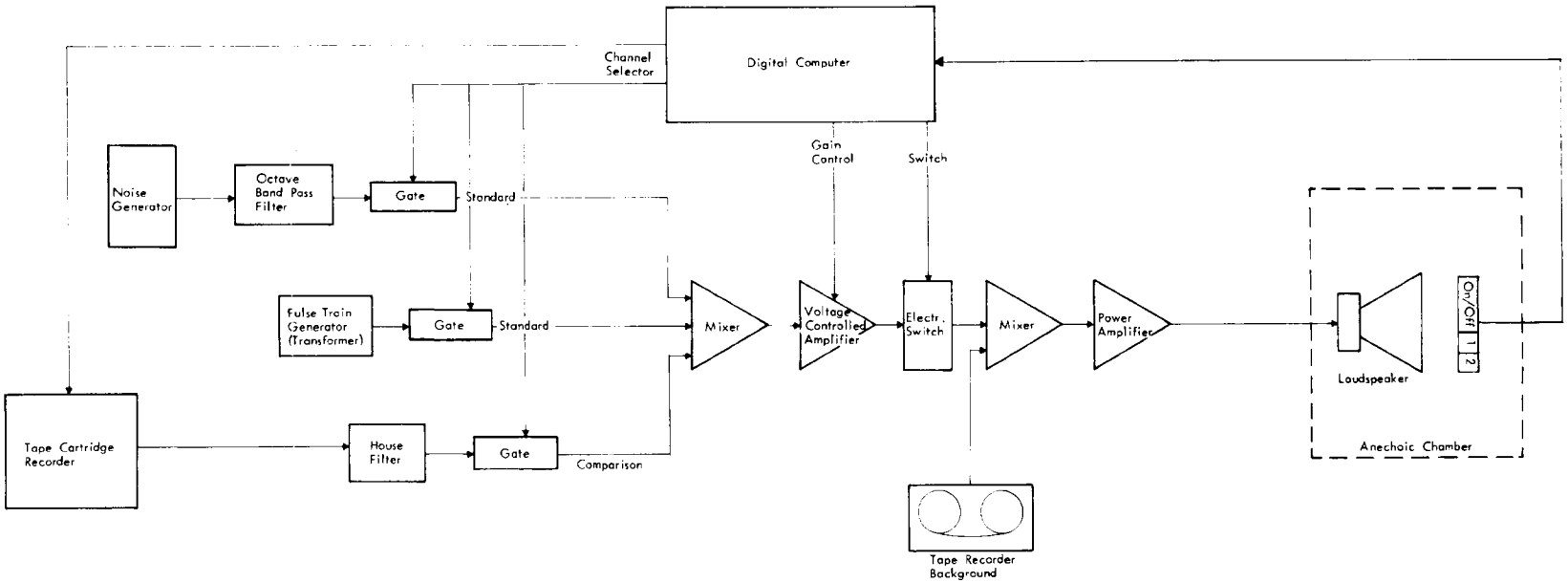

FIGURE 7. BLOCK DIAGRAM OF DATA AQUISITION EQUIPMENT FOR PEST STUDY

IV. RESULTS

Annoyance judgments are summarized in terms of the relative difference between the variable-level standard and the invariant comparison signals. The annoyance of two standard signals (the simulated transformer and the 2 kHz octave band of noise) was compared with the annoyance of 17 comparison signals for a total of 34 paired comparisons. The difference, in A-weighted sound level, between the level of judged annoyance for the standard signal and the fixed presentation level of the comparison signal for each subject is shown in Figures 8 and 9.

The great range in annoyance judgments for each signal is evident in Figures 8 and 9. The average standard deviation across subjects for signals compared to the simulated transformer was 10.8 dB. For the signals compared to the 2 kHz octave band of noise, the same figure was 12.8 dB. More than one-half of the standard deviations ranged from 10-20 dB, a much larger range than is normally observed in other annoyance judgment tests. Signal #4 (test transmission line) had the smallest standard deviations (5.6 and 6.3 dB) and predictably the smallest range across subjects (23 to 28 dB) when judged against the simulated transformer and the 2 kHz octave band of noise.

The mean difference across subjects for each signal was also calculated. The signals in Figures 8 and 9 were plotted according to the rank order of the mean differences. A Spearman correlation coefficient was computed for the rank order of annoyance judgments for the two standard signals to examine their degree of similarity. The obtained value of Spearman's ratio was 0.9. This high

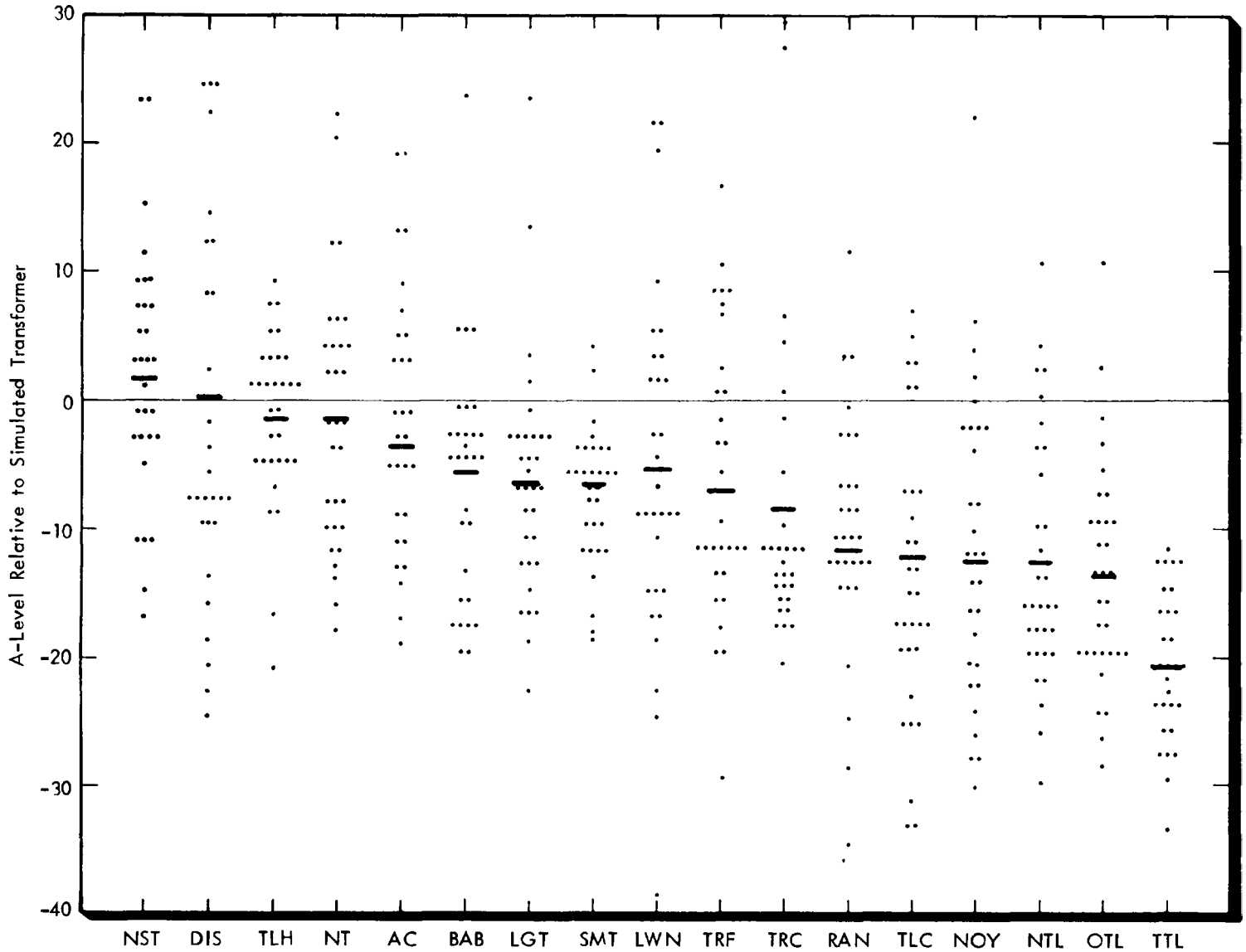

FIGURE 8. A-LEVEL OF TEST SIGNALS RELATIVE TO SIMULATED TRANSFORMER AT EQUAL ANNOYANCE FOR INDIVIDUAL RESPONSES (PEST)

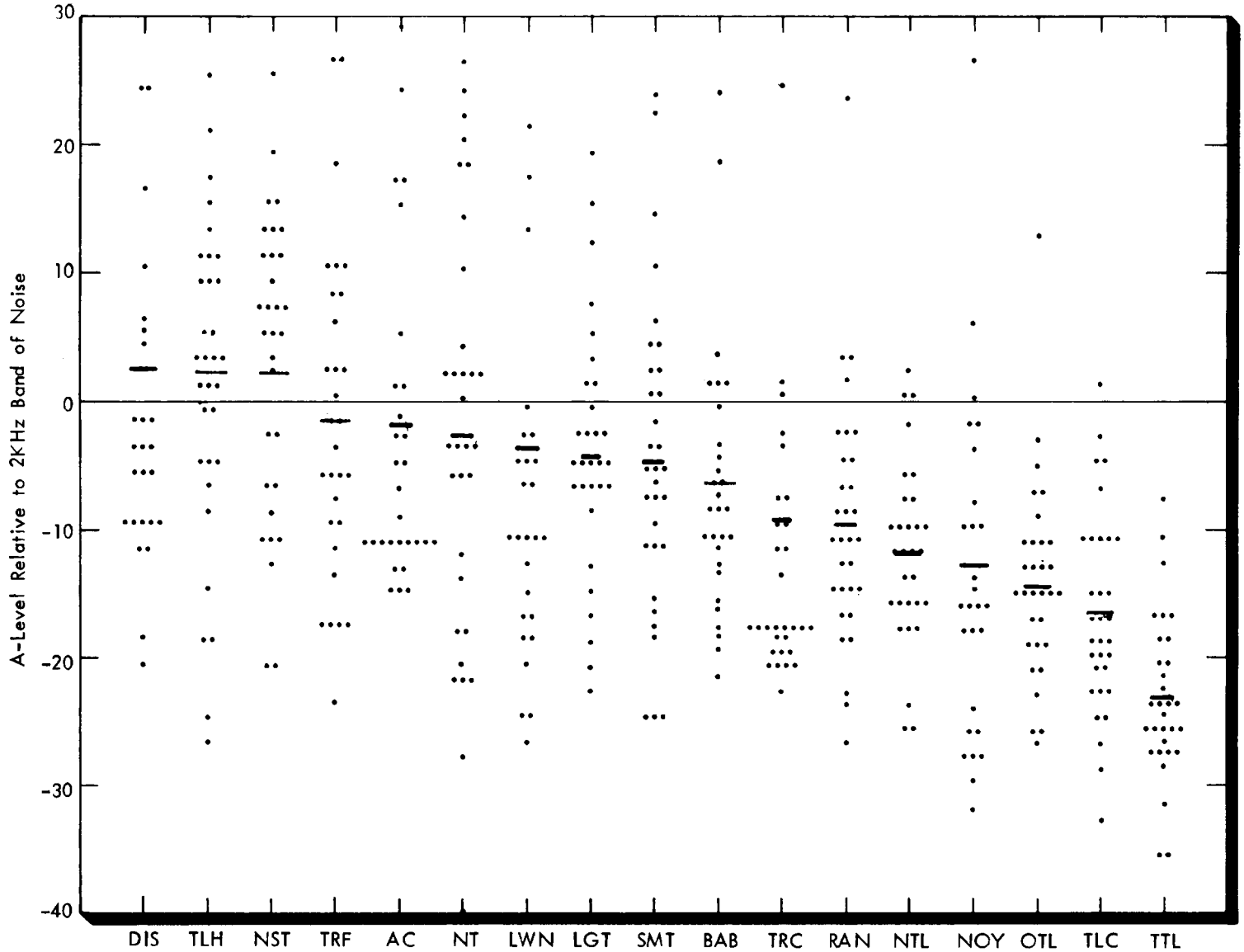

FIGURE 9. A-LEVEL OF TEST SIGNALS RELATIVE TO 2KHz OCTAVE BAND OF NOISE AT EQUAL ANNOYANCE FOR INDIVIDUAL RESPONSES (PEST)

correlation supports pilot observations (Appendix D) that the rank order for the 17 signals would not be affected by the choice of the standard signal.

The similarity between the two standards was further substantiated by the high product-moment correlation ($r = .96$) between the mean differences of the annoyance judgments. A least-squares regression line is plotted in Figure 10 along with the standard error of the mean for each signal. The standard error of the mean for the signals ranges between 1 and 3.4 dB.

Seven noise measurement scales were tested for their ability to predict the observed annoyance judgments. Figure 11 shows the effect of overall sound levels (OASPL), B-weighted sound level, A-weighted sound leve, D-weighted sound level, Loudness Level, Perceived Noise Level (PNL), and Tone Corrected Perceived Noise Level (PNLT) as applied to each signal.

The best predictor of annoyance is the noise measurement procedure which yields the smallest standard deviation. A visual comparison of the results in Figure 11 indicates that PNL (standard 1: σ=5.0 dB and standard 2: σ=6.5 dB) and Loudness Level (standard 1: σ=5.3 dB and standard 2: σ=6.5 dB) are the most effective estimators of annoyance among the traditional noise scales. Overall sound level and B-level were poor predictors of annoyance because they did not reduce the standard deviation of judgments. A-level and D-level had comparable standard deviations for both the standards (ranging from 5.9 dB to 7.4 dB). The tone correction added to perceived noise level for PNLT did not appreciably improve the measure's ability to predict annoyance.

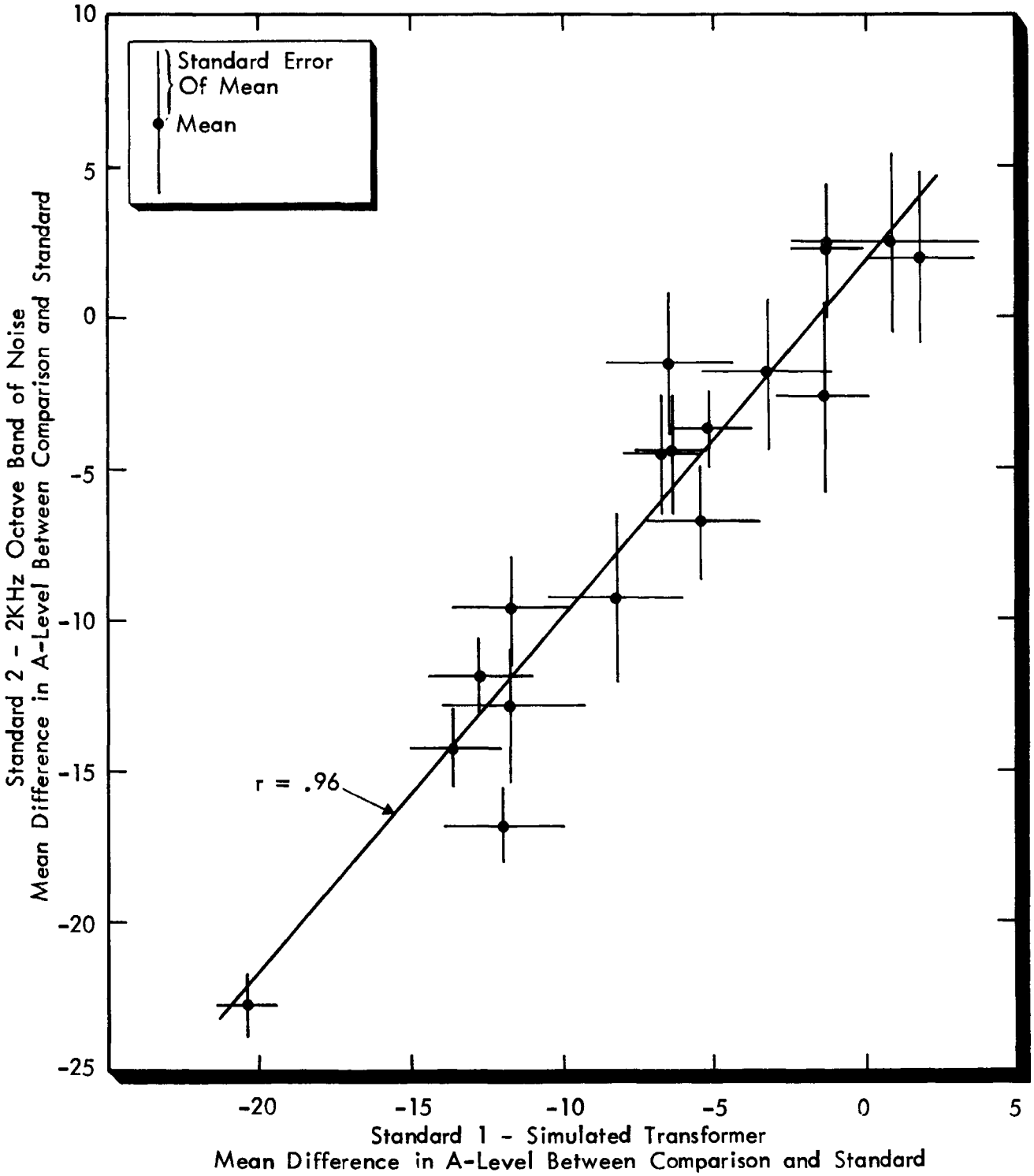

FIGURE 10. COMPARISON BETWEEN THE STANDARDS FOR PEST STUDY

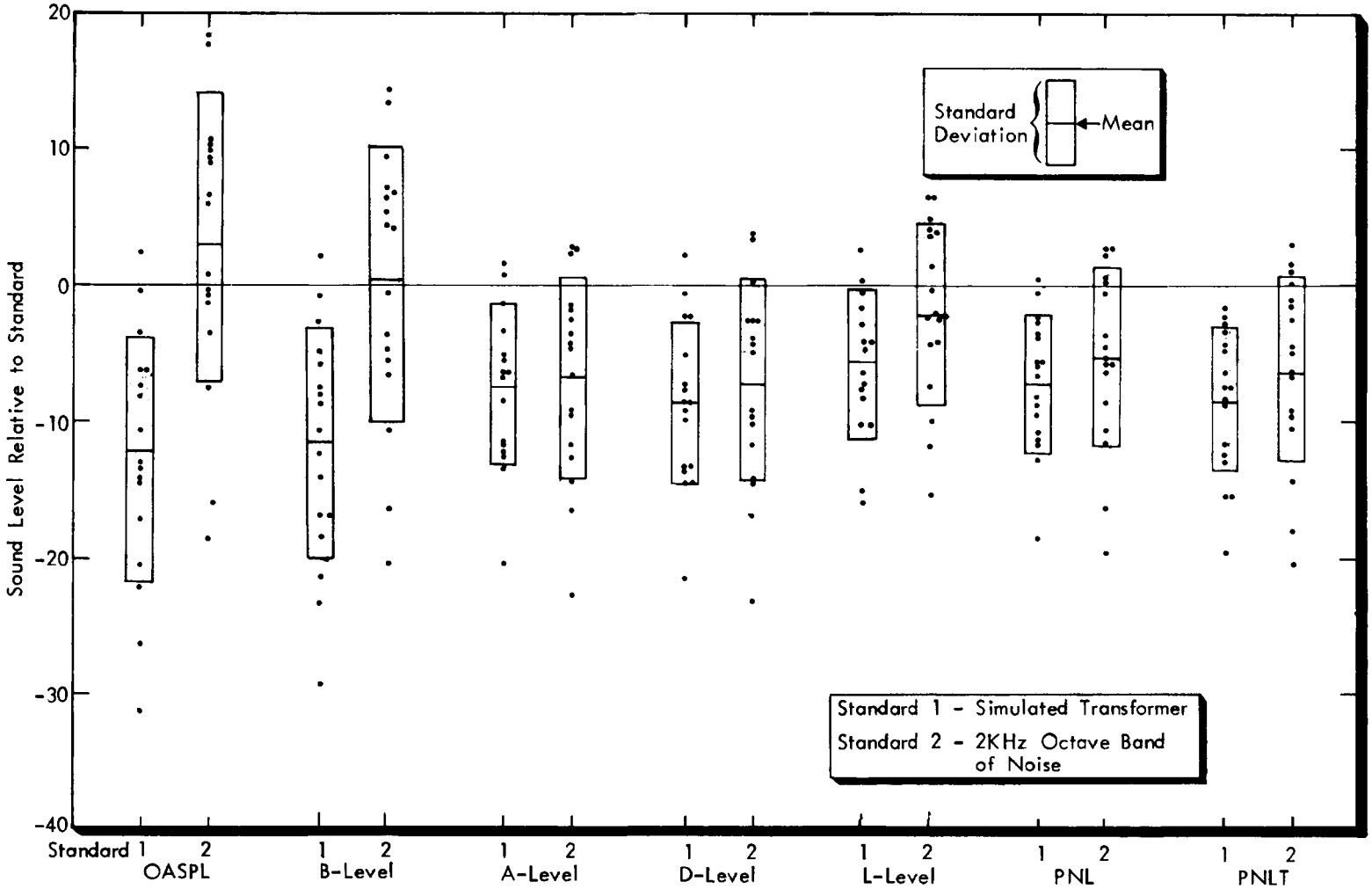

FIGURE 11. RESULTS OF PEST JUDGMENT TESTS FOR VARIOUS NOISE MEASURES

V. DISCUSSION

Subjective judgments of annoyance in this test were much more variable than expected. Typical standard deviations obtained for annoyance judgments of aircraft flyovers are about 6 dB. Comparable standard deviations for the low level noises judged in the present experiment were about twice as large. The relationships of level and frequency characteristics of the fixed signals to variability are examined below.

The primary concern of this study was to determine the annoyance of sounds usually heard at low levels in the everyday environment. Consequently, presentation levels of the fixed comparison signals in the study were much lower than those generally used in other paired comparison annoyance studies. The average presentation level of signals in this experimentation was 47 dB(A), with a range in presentation levels of only 17.4 dB. However, the subjects' annoyance judgments of the two variable level signals relative to the 17 comparison signals averaged 54 dB and yield a range approximately twice as large at 33 dB. Thus the subjects, on the average, adjusted the variable signals 7 dB higher than the comparison signals.

The relationship between the adjusted level at the point of subjective equality and the standard deviation among subjects for the signals is shown in Figure 12. The regression line of this data, with a correlation coefficient of $r = .32$, indicates that the variability among subjective judgments decreases as the level necessary to achieve point of subjective equality increases. The other regression line in this figure reflects results from a similar study (Fidell et al., 1977) in which the adjusted level ranged from 35 to 85 dB(A). Both studies suggest that for higher

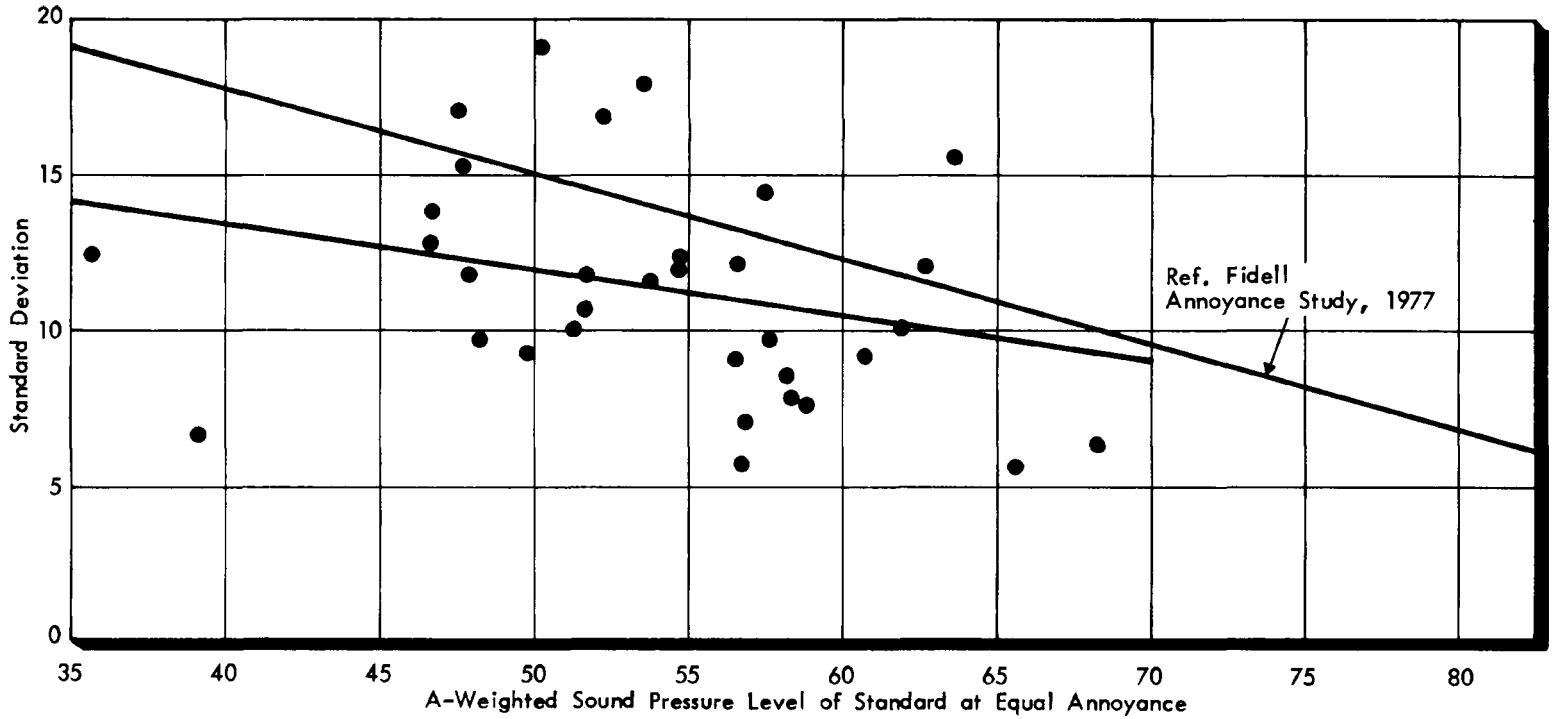

FIGURE 12. RELATIONSHIP BETWEEN ABSOLUTE LEVEL OF SIGNAL AND STANDARD DEVIATION OF ANNOYANCE JUDGMENTS

judged levels, the standard deviations decrease. This same trend is noted in other studies conducted at low levels (Green et al., 1977).

This finding directly relates to the assessment of community response to such low level noise sources as transformers and transmission lines. Greater variation in opinion about the annoyance of low level noises may be expected than about the annoyance of higher level sounds. This may also be due in part to the fact that higher level sounds cause a definite speech interference which is very annoying, whereas low level sounds do not create speech interference (Pearsons et al., 1977).

Spectral characteristics of the signals also influence the annoyance judgments. Figures 13 through 15 show the range of spectra for the 17 signals divided into three categories. The signals were assigned to the high, middle, or low category depending upon the respective A-level calculated for equal annoyance relative to a common standard presented at 55 dB(A). Visual inspection indicates that Figure 13 contains the spectra for the signals with predominantly low frequency content such as the air conditioner, or the transformer with low frequency hum. Figure 14 contains mainly low frequency energy as well as some high frequency energy. Figure 15 contains signals which have the greatest amount of energy at the high frequencies, e.g., transmission lines.

The averaged standard deviation across subjects for the signals in each of these figures was lower for the signals with greater high frequency content (Figure 15). Thus, the average standard deviation for the signals in Figure 13 was 13.8 dB(A); for Figure 14 it was 11.7 dB(A); and for Figure 15 it was 10.4 dB(A). This

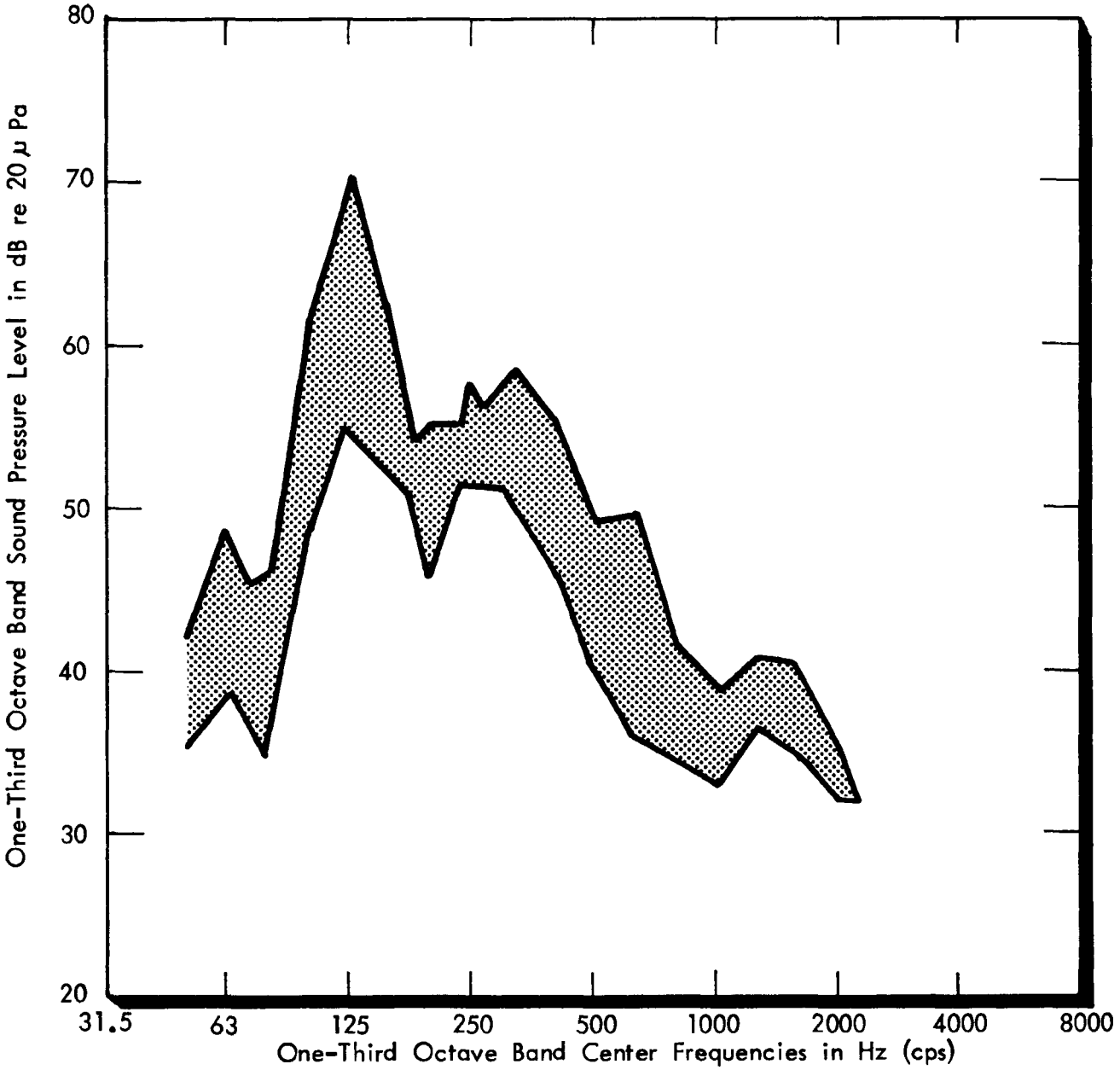

FIGURE 13. RANGE OF SPECTRA OF FIVE EQUALLY ANNOYING SIGNALS (HIGHEST RELATIVE A-LEVEL) (SIGNALS: 8, 9, 10, 17, 18)

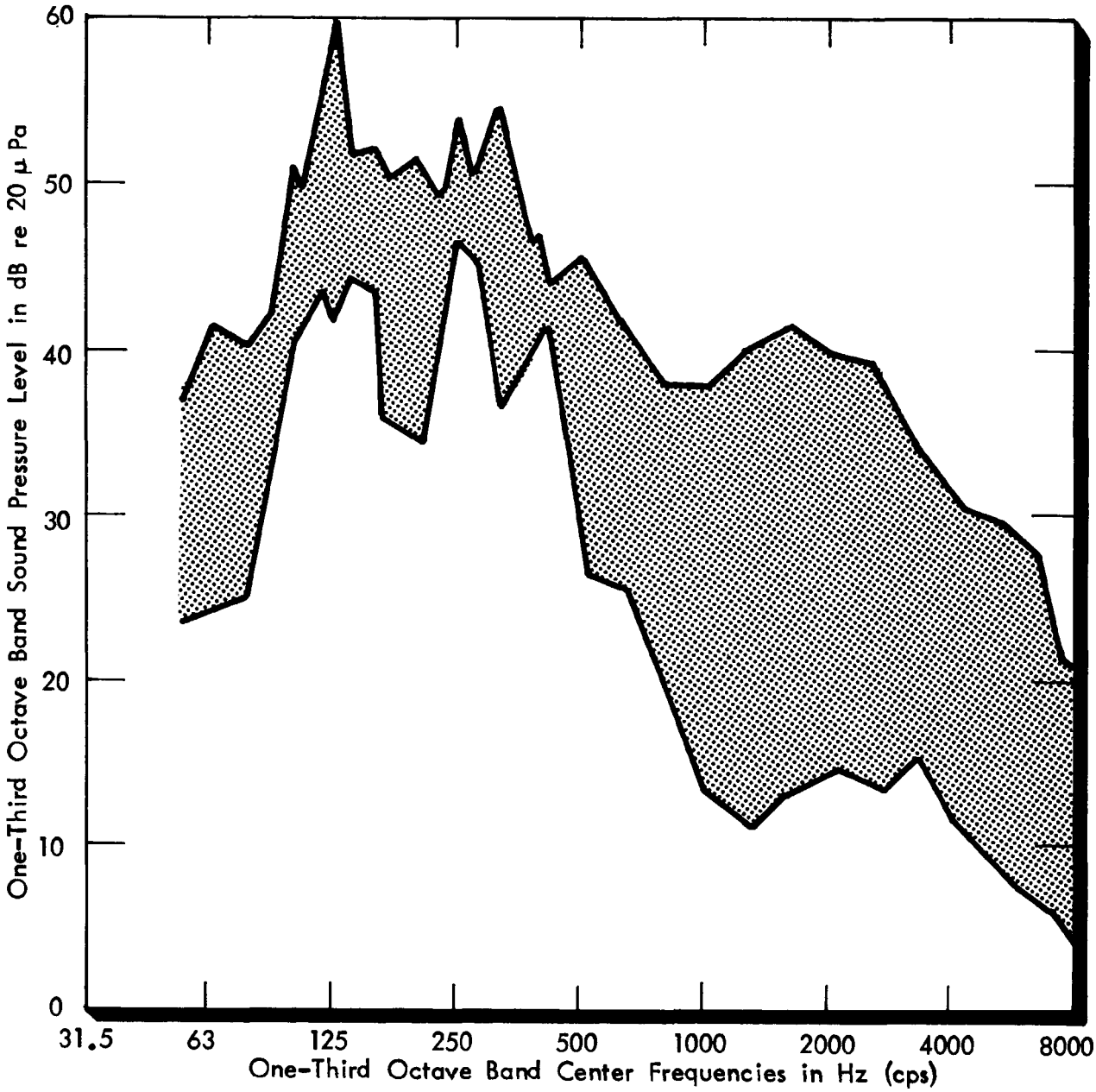

FIGURE 14. RANGE OF SPECTRA OF FIVE EQUALLY ANNOYING SIGNALS (MIDDLE RELATIVE A-LEVEL)
(SIGNALS: 3, 5, 13, 14, 16)

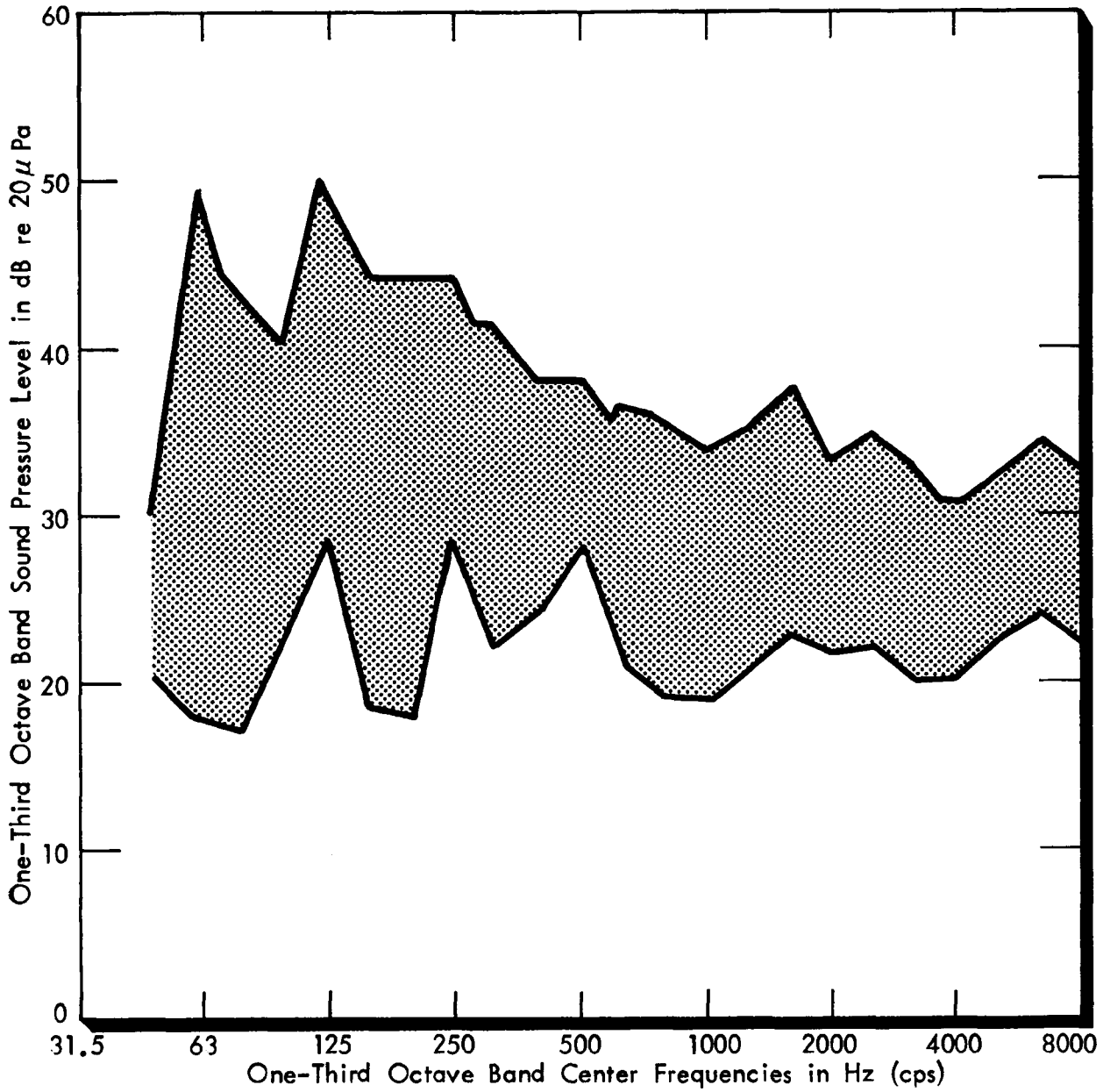

FIGURE 15. RANGE OF SPECTRA OF SEVEN EQUALLY ANNOYING SIGNALS (LOWEST RELATIVE A-LEVEL)
(SIGNALS: 4, 6, 7, 11, 12, 15, 19)

indicates less disagreement among subjects when making annoyance judgments about signals with high frequency content.

The spectral effect on mean annoyance suggested in Figures 13-15 is depicted in Figure 16. Figure 16 contains a plot of the mean annoyance results for the signals with high frequency content (Figure 15) and for the other signals (Figures 13 and 14). The subjects judged the signals with predominantly high frequency characteristics as more annoying with an average mean annoyance of -13.5 dB. This result may be contrasted with the -2.7 dB average mean annoyance for the other signals. The approximate 10 dB difference between the two groups indicates that in order for people to judge noise from a transmission line and from a transformer as equally annoying, the level of the transmission line noise (with its high frequency energy content) must be 10 dB lower than the transformer noise.

The results previously presented suggested none of the traditional noise measurement procedures were effective in reducing the large variability among the signals (Figure 12). Thus they were not adequate predictors of annoyance for these signals. Undoubtedly, the high frequency content of some of these signals contributed to this large standard deviation.

An attempt was made to develop a post hoc correction to account for the 10 dB difference in mean annoyance between the high frequency content signals and the other signals. Note that the signals in Figure 15, which have been categorized as high frequency spectra, have relatively flat spectra. A detailed examination of each spectrum in this class reveals that each of

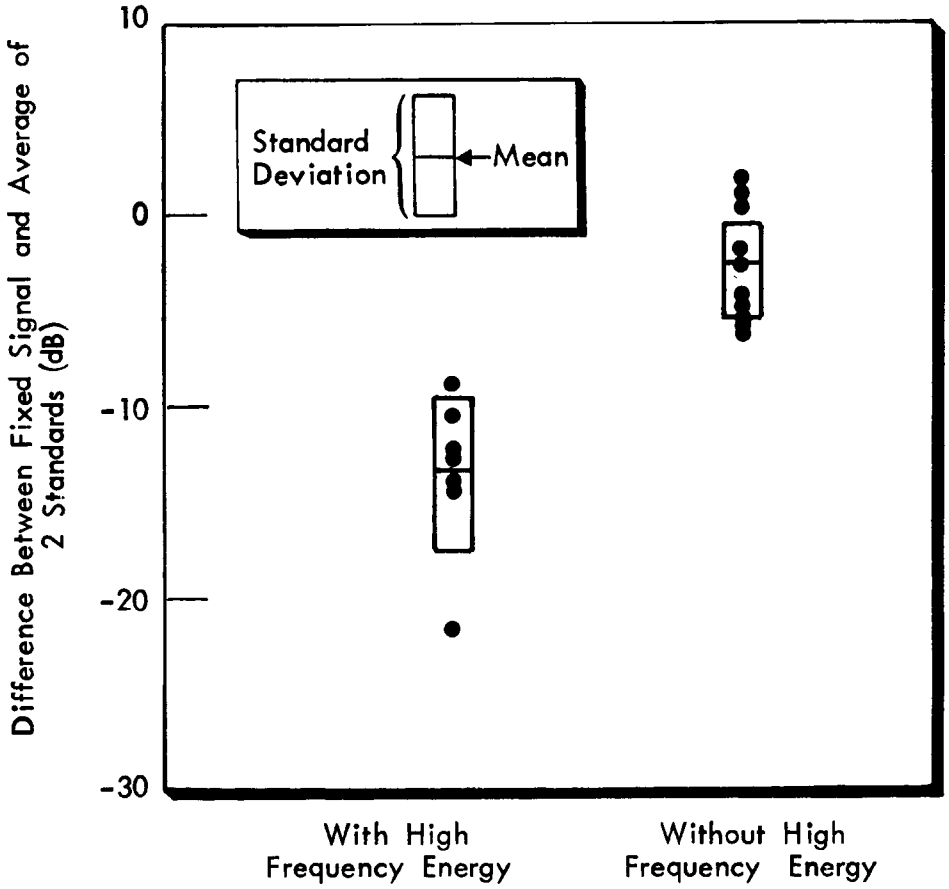

FIGURE 16. COMPARISON OF ANNOYANCE JUDGMENTS FOR SIGNALS WITH AND WITHOUT HIGH FREQUENCY ENERGY

the one-third octave band spectra either: (1) rises with frequency, or (2) is "flat" or "falling" with frequency but lies within a 25 dB range from 50 Hz to 8000 Hz. In an effort to reduce the variability among signals, a 10 dB correction was applied to these high frequency signals. This correction represents the average difference between the two energy groups as illustrated in Figure 16.

Another measure that may be applied to predict the annoyance of the signals in this study is the Theory of Signal Detectability (TSD). This approach has been employed in another recent study conducted at BBN (Fidell et al., 1977). The detectability measure uses the following formula:

$$d' = \eta (W)^{1/2} \; S/N$$

where d' is the detectability index, η is an efficiency term (a constant for any given situation), W is the one-third octave bandwidth centered at the signal frequency, and S/N is the signal-to-noise ratio (ratio of powers) measured in the same one-third octave band.

This formula may be converted to a logarithmic function to compare the results with the other measures used in this study. The formula for the detection level is as follows:

$$d'_{max} = 10 \log d'.$$

Thus the detection level for each signal (i.e., the ratio between the signal level and the background noise at a given frequency and corrected by the bandwidth according to the above formula)

may be determined and compared with the detection level of the 2 kHz or transformer standard signals.

Figure 17 contains the results of the study analyzed in terms of A-level, d'_{max}, and the 10 dB corrected A-level. The standard deviations for the 10 dB corrected A-level was 3.6 dB and for the d'_{max} it was 3.4 dB, thus making them more effective predictors of annoyance than the A-level method with a standard deviation of 6.5 dB.

A post study called the adaptive free choice test (Appendix E) was conducted after the paired comparison study. The free choice test was conducted in an effort to determine the effects of experimental methodology on subjective responses. Eight of the same signals used in the paired comparison test were also included in the free choice study.

Figure 18 summarizes all of the data collected for the two pilot studies (Appendix D), the paired comparison annoyance test and the adaptive free choice test. These data are plotted relative to the 2 kHz standard as if it had been presented at a fixed level of 55 dB(A). The mean annoyance results for the signals judged in all of the tests were approximately the same. The high variability among subjects in judging the annoyance of the signals was also similar for the adaptive free choice method. However, it is premature to conclude that the free choice testing technique is an adequate replacement for the more conventional paired comparison method used in PEST without extensive research.

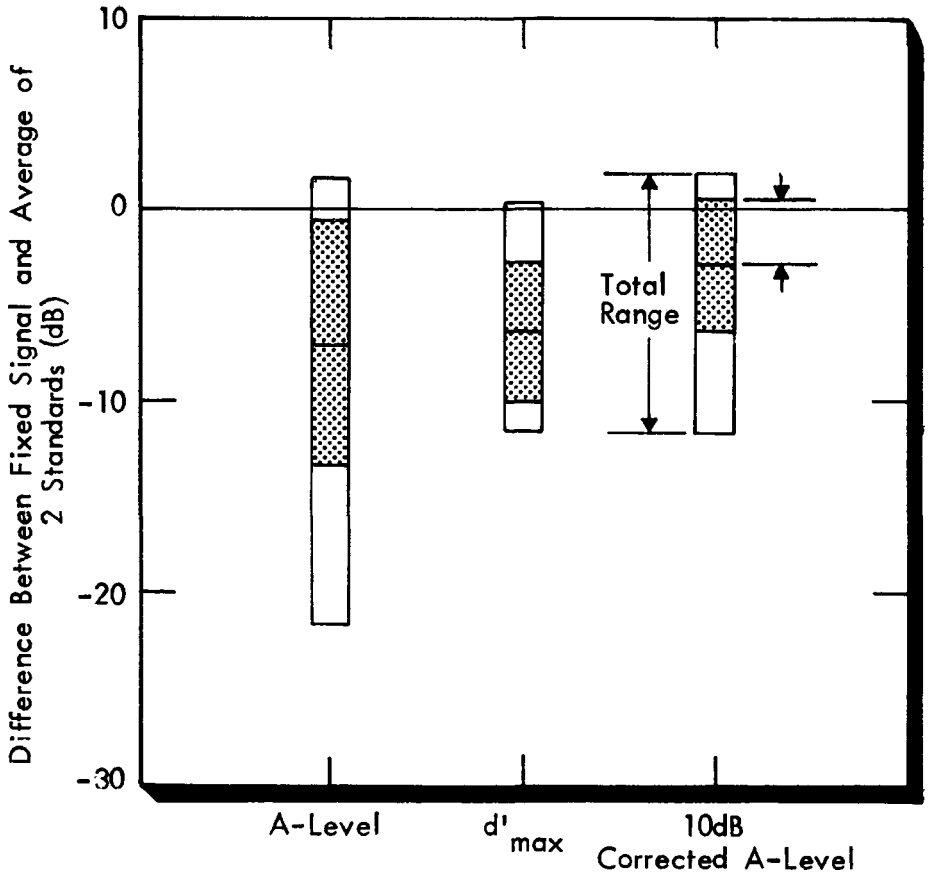

FIGURE 17. RANGE OF MEAN LEVELS AT JUDGED EQUAL ANNOYANCE (PEST)

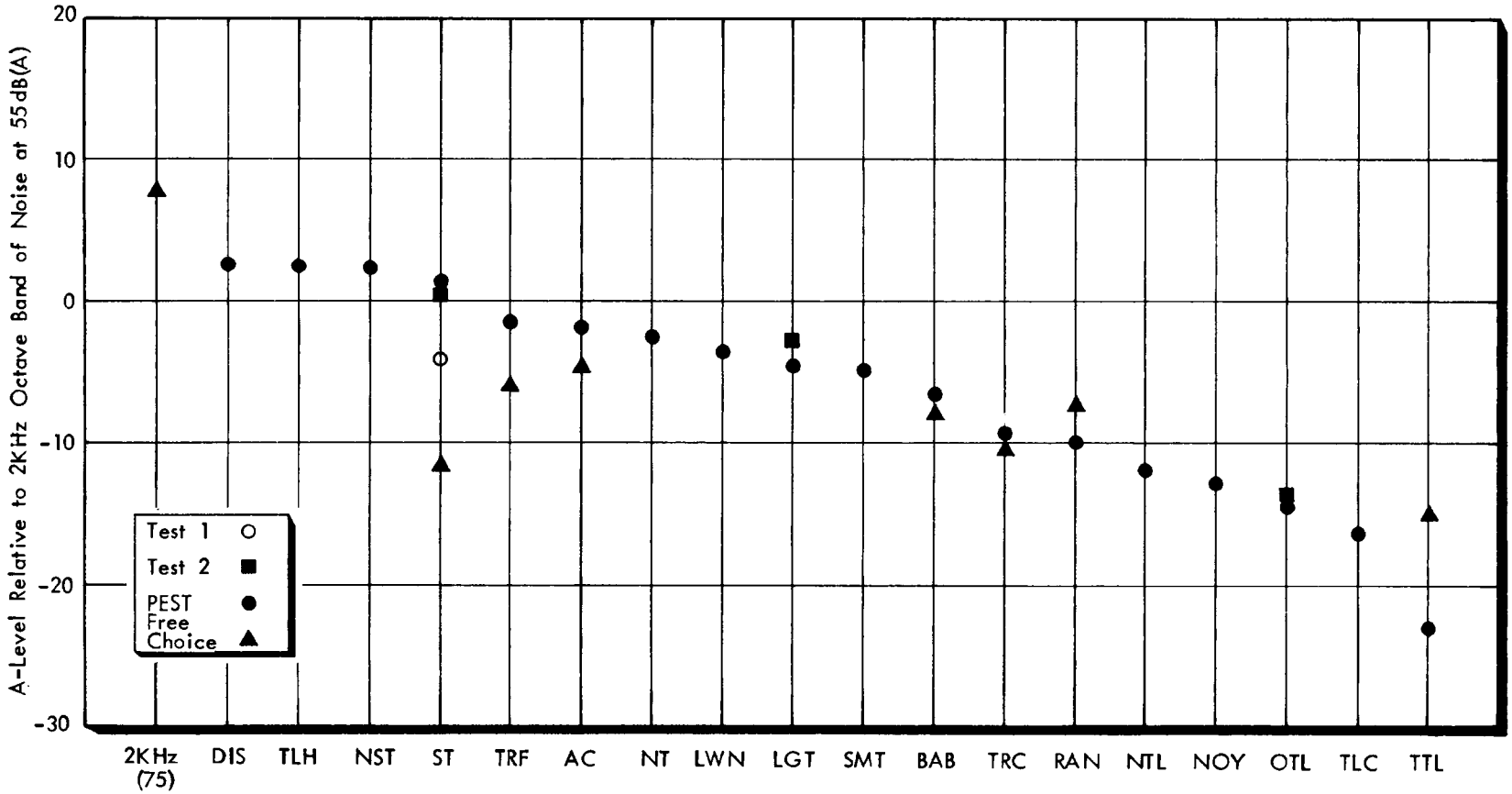

FIGURE 18. A-LEVEL OF TEST SIGNALS RELATIVE TO 2KHz NOISE FOR ALL TESTS AT EQUAL ANNOYANCE

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APPENDIX A

PEST PROCEDURE

PEST PROCEDURE EMPLOYED FOR SUBJECTIVE JUDGMENT TESTS

Parameter Estimation by Sequential Testing (PEST) is a computer-based adaptive psychophysical procedure that administers an iterative form of the standard paired comparison task to human observers. PEST is called an adaptive procedure because the sequence of signals heard by an observer is not fixed in advance, but rather is determined by his ongoing responses. PEST thus preserves many of the advantages of the paired comparison method while gaining the speed and convenience of an adjustment method.

BBN's implementation of the PEST is based on an interactive teletype conversation between the experimenter and the computer-based system. The system acquires information needed for conduct of an experiment by inquiring of the experimenter the values of a series of parameters which determine the course of the PEST procedure. Initially, the computer requests identification of the observer, the signals employed, and the experimental session. The next questions posed by the computer concern the relative levels at which signals are presented to the observer on subsequent trials.

The experimenter may then specify a standard operating procedure consisting of predetermined values of a dozen parameters such as the intersignal interval, intertrial interval, initial step size, maximum step size, degree of confidence in the observer's responses, anticipated direction of first step, and region of interest of the psychometric function.

A final question serves to delay onset of a trial series until the experimenter and observer are ready to proceed. Upon receiving an affirmative response to the question "READY?", the computer

types a data heading and awaits final confirmation in the form of "START" switch depression by an observer in an adjacent anechoic chamber.

The trial procedure is a two-interval forced choice, in which one signal (the comparison) is invariant over trials, while the other signal (the standard) may change in level. Approximately one second after START switch closure, the computer presents a pair of signals and waits for the observer to decide on his preference for the signal of the first or second interval. Upon receipt of the observer's response, the computer calculates the level at which the comparison signal will be presented on the next trial. After another pause of approximately one second, the computer initiates the next trial by presenting a modified signal pair.

PEST determines the increment in comparison signal level as follows (Taylor, 1967):

1. On every reversal of step direction, halve the step size.

2. The second step in a given direction, if called for, is the same size as the first.

3. Whether a third successive step in a given direction is the same as or double the second depends on the sequence of steps leading to the most recent reversal. If the step immediately preceding that reversal resulted from a doubling, then the third step is not doubled; while if the step leading to the most recent reversal was not the result of a doubling, then this third step is double the second.

4. The fourth and subsequent steps in a given direction are each double their predecessor (except that large steps may be disturbing to a human observer and an upper limit on permissible step size of 16 dB is maintained).

The system provides information about the progress of each run in the form of "UP" and "DOWN" lights (signifying the direction of change of comparison signal level on the current trial), and also in two digital counters which cumulate numbers of trials and of decision reversals.

A run, composed of a variable number of trials, is terminated when the system determines that sufficient information has been collected. The general stopping criterion for a run is satisfied when the anticipated step size is 1 dB. When a run terminates, the computer prints the number of the run, the level of the comparison signal on the last trial of the run, the number of trials in the run, and the mean response latency. The program is usually set to determine the point of subjective equality or the level at which observers judged the standard and comparison signals equally noisy.

APPENDIX B

INSTRUCTIONS

INSTRUCTIONS FOR PEST

During this experiment, you will hear a series of pairs of sounds. Your job will always be the same: to decide which sound of a pair is more annoying. The computer that presents the pairs of sounds to you will vary their length and loudness from time to time, based on which sounds you decide are more annoying.

In order for the computer to keep track of your decisions about which sound of a pair is more annoying, you will have to follow a certain trial procedure. A trial will start when the button marked "1" on your response box lights up. As long as Button 1 is lighted, you will be hearing the first sound of a pair. A short while after the light in Button 1 goes out, Button 2 will light up. As long as Button 2 is lighted, you will be hearing the second sound of a pair. As soon as the light in Button 2 goes out, you must press either Button 1 or Button 2 to indicate which sound you felt was more annoying. A short while later, the next trial will start.

The pairs of sounds you will hear will not be presented in any systematic pattern, but will be randomized by the computer. Since there is no "right" or "wrong" answer for a pair of sounds, and since there is no pattern to the order in which you will hear pairs of sounds, no "plan" or "scheme" can be used to help you make up your mind which sound of a pair is more annoying. All we ever want to know is which sound in the pair you have just heard is more annoying to you.

APPENDIX C

SPECTRA AT THE PRESENTATION LEVEL OF THE SIGNALS

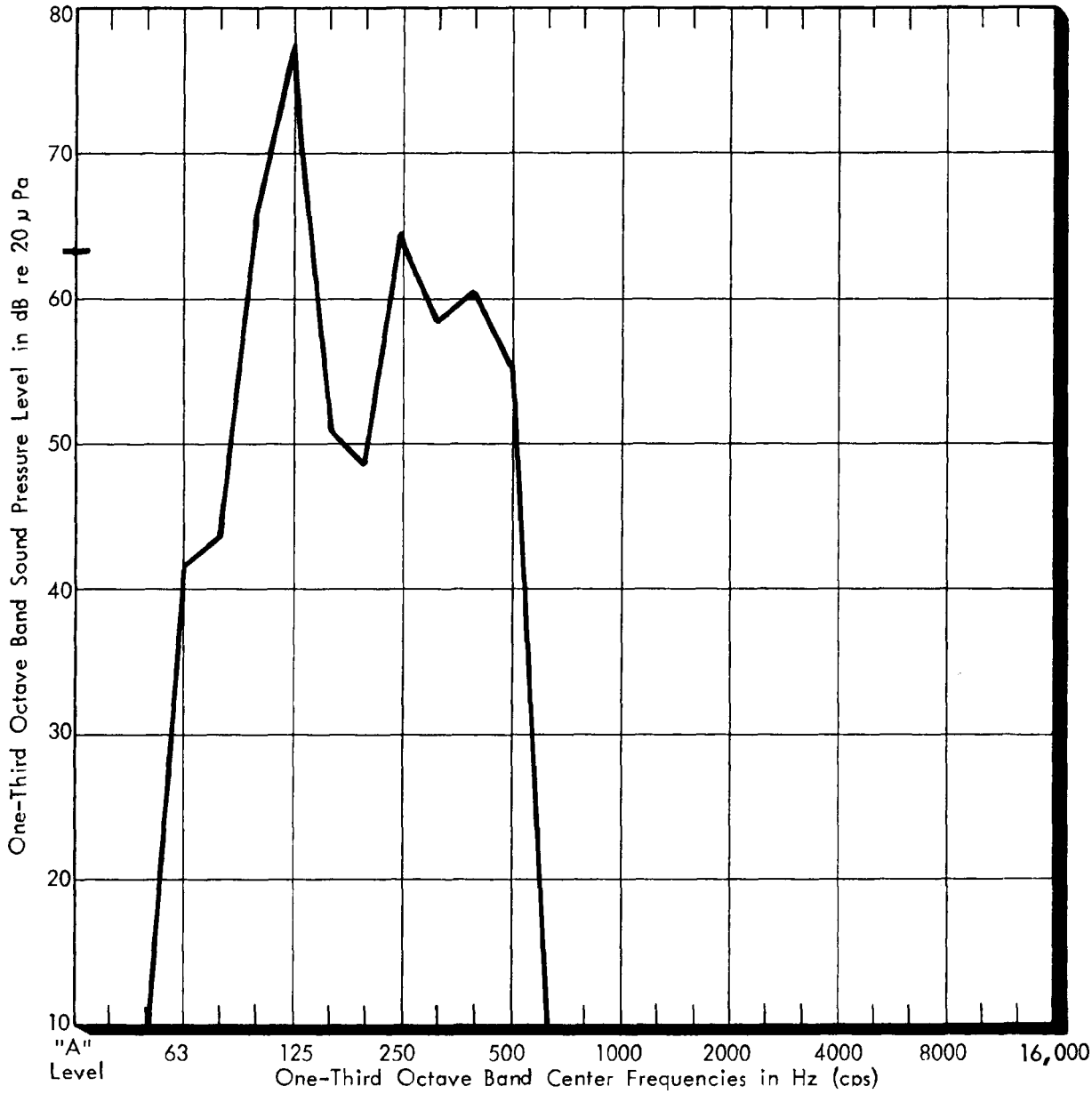

FIGURE C-1. STANDARD STIMULUS 1 - SIMULATED TRANSFORMER

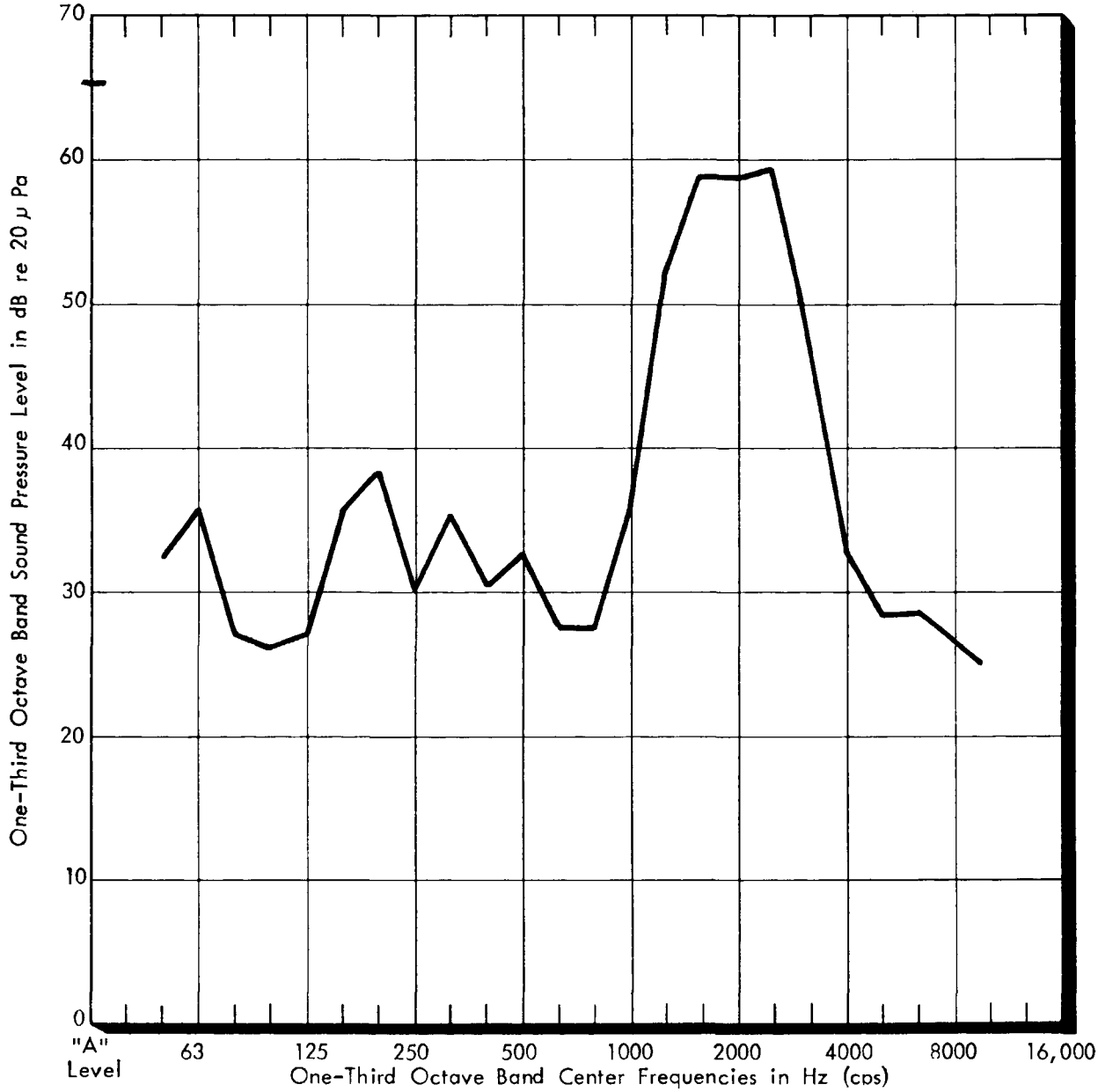

FIGURE C-2. STANDARD STIMULUS 2 - 2KHZ OCTAVE BAND OF NOISE

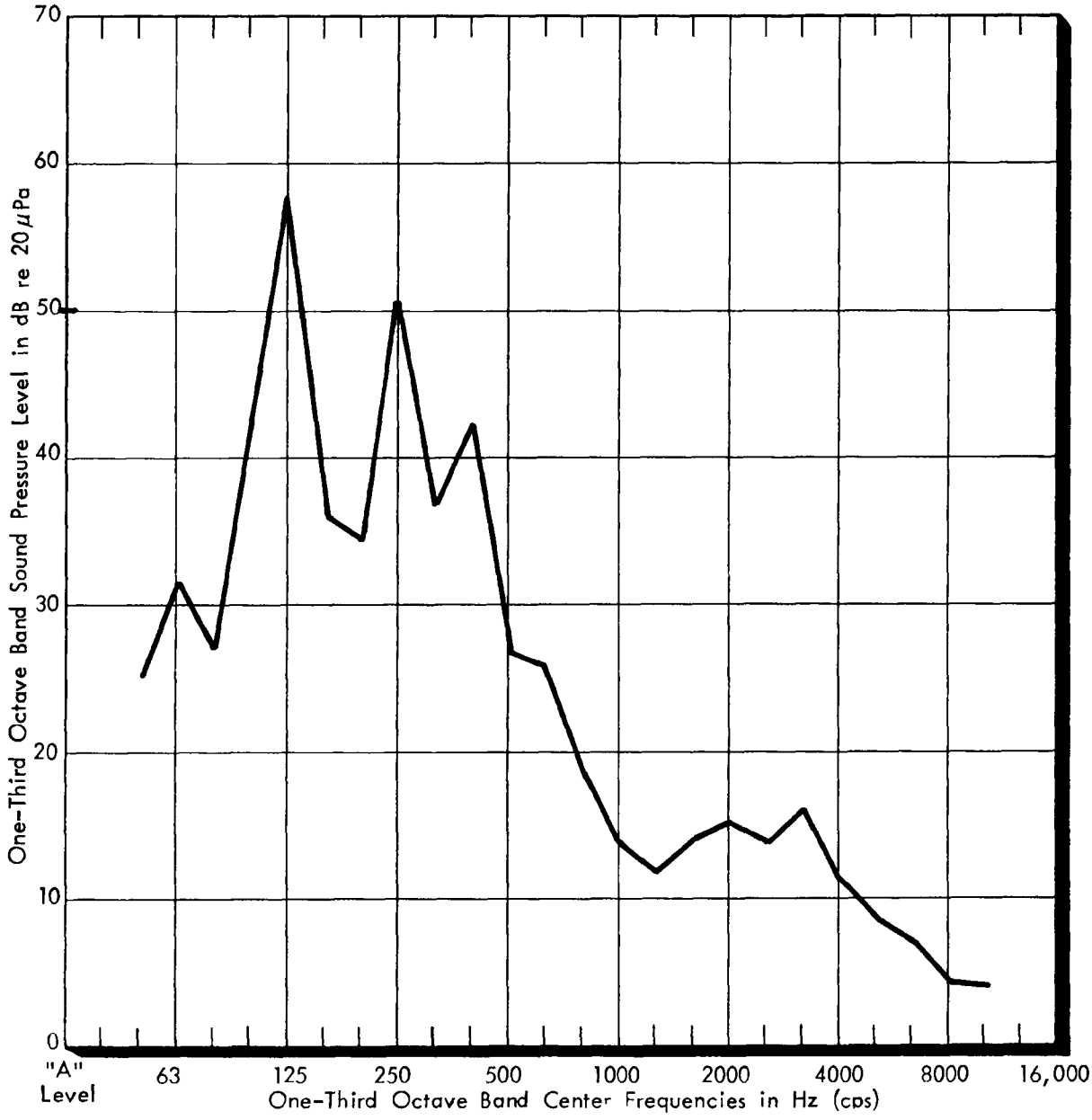

FIGURE C-3. STIMULUS 3 - 20 MVA TRANSFORMER

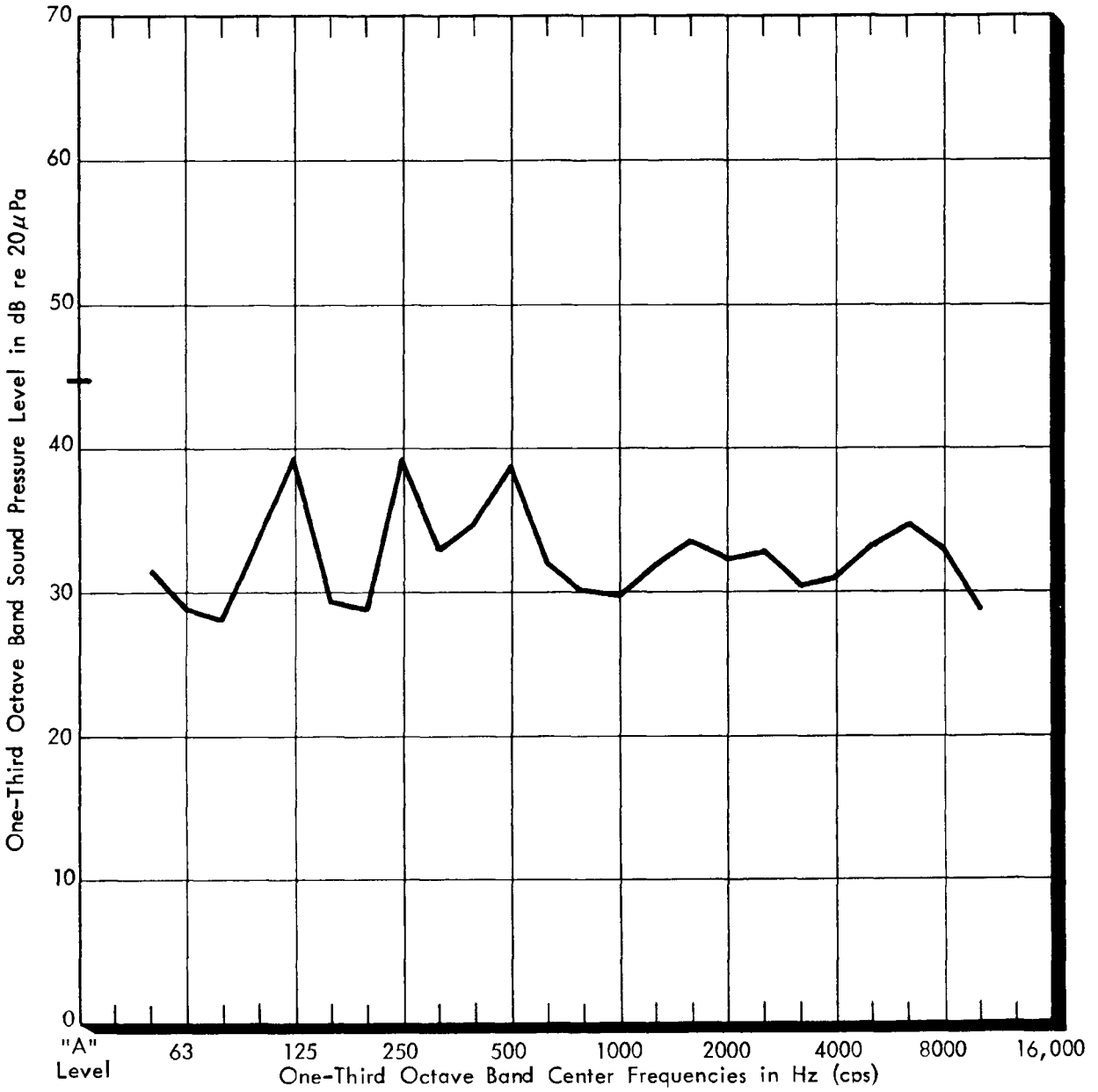

FIGURE C-4. STIMULUS 4 - TEST TRANSMISSION LINE

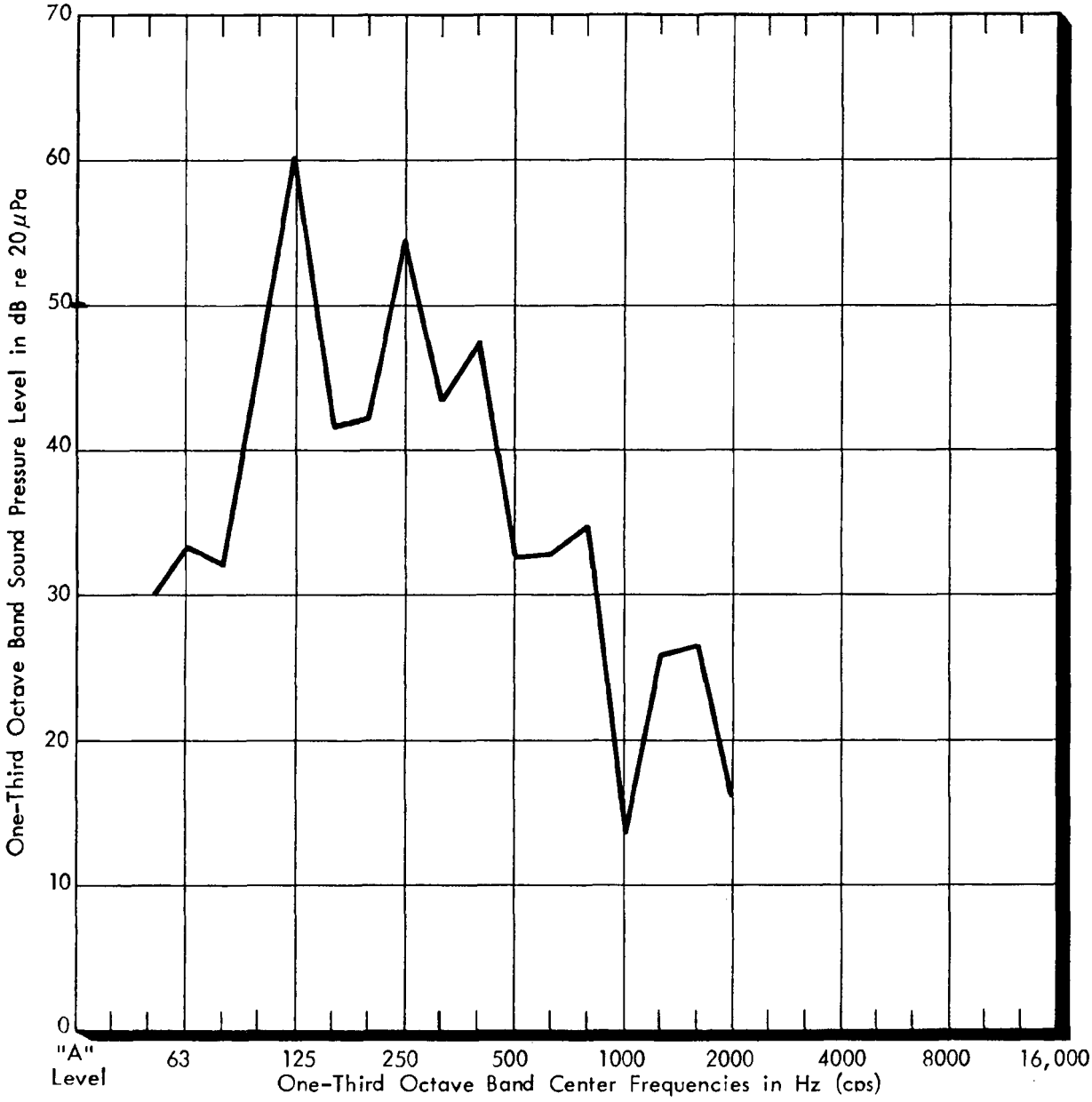

FIGURE C-5. STIMULUS 5 - 1050 MVA TRANSFORMER

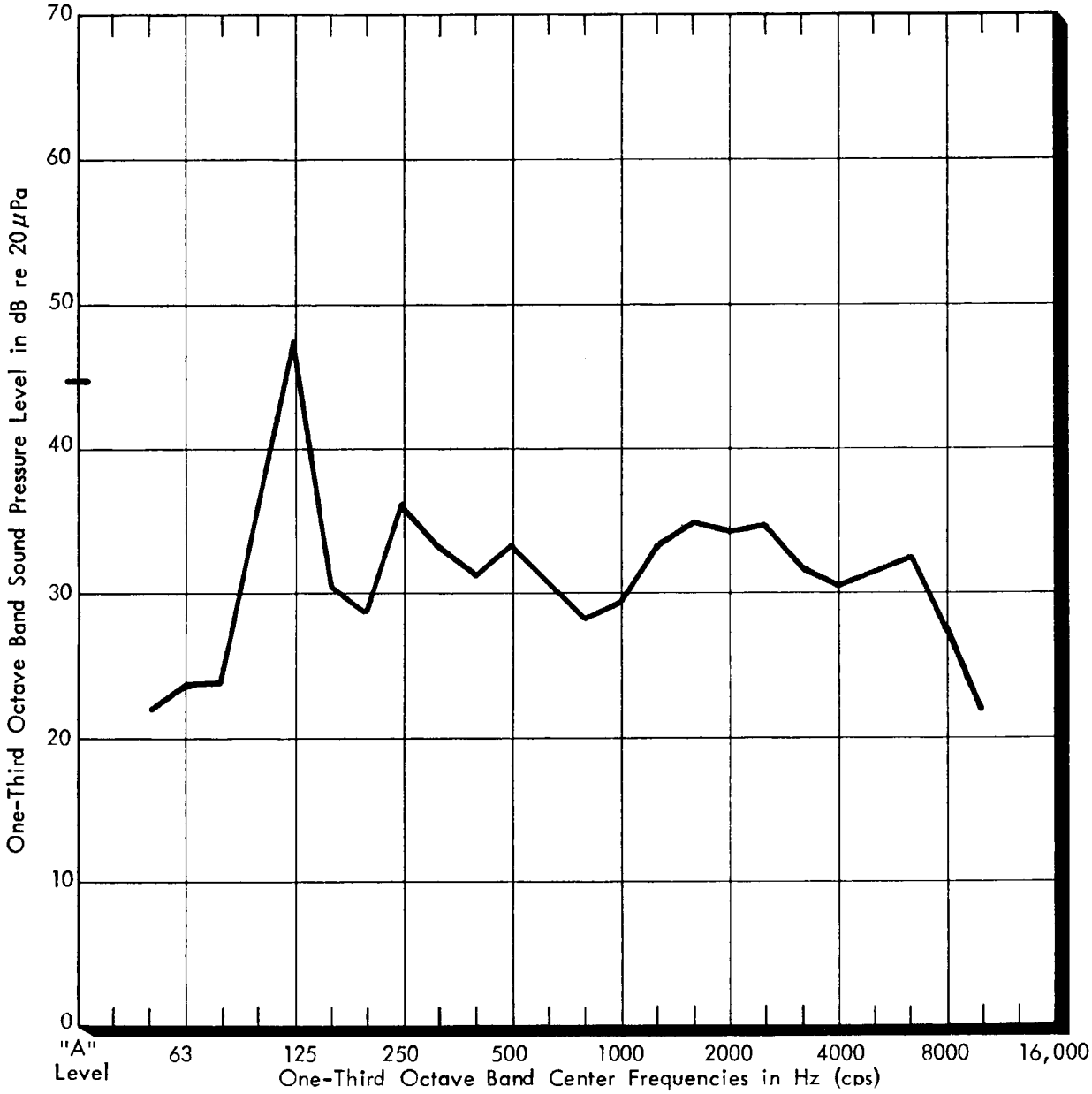

FIGURE C-6. STIMULUS 6 - OPERATING TRANSMISSION LINE

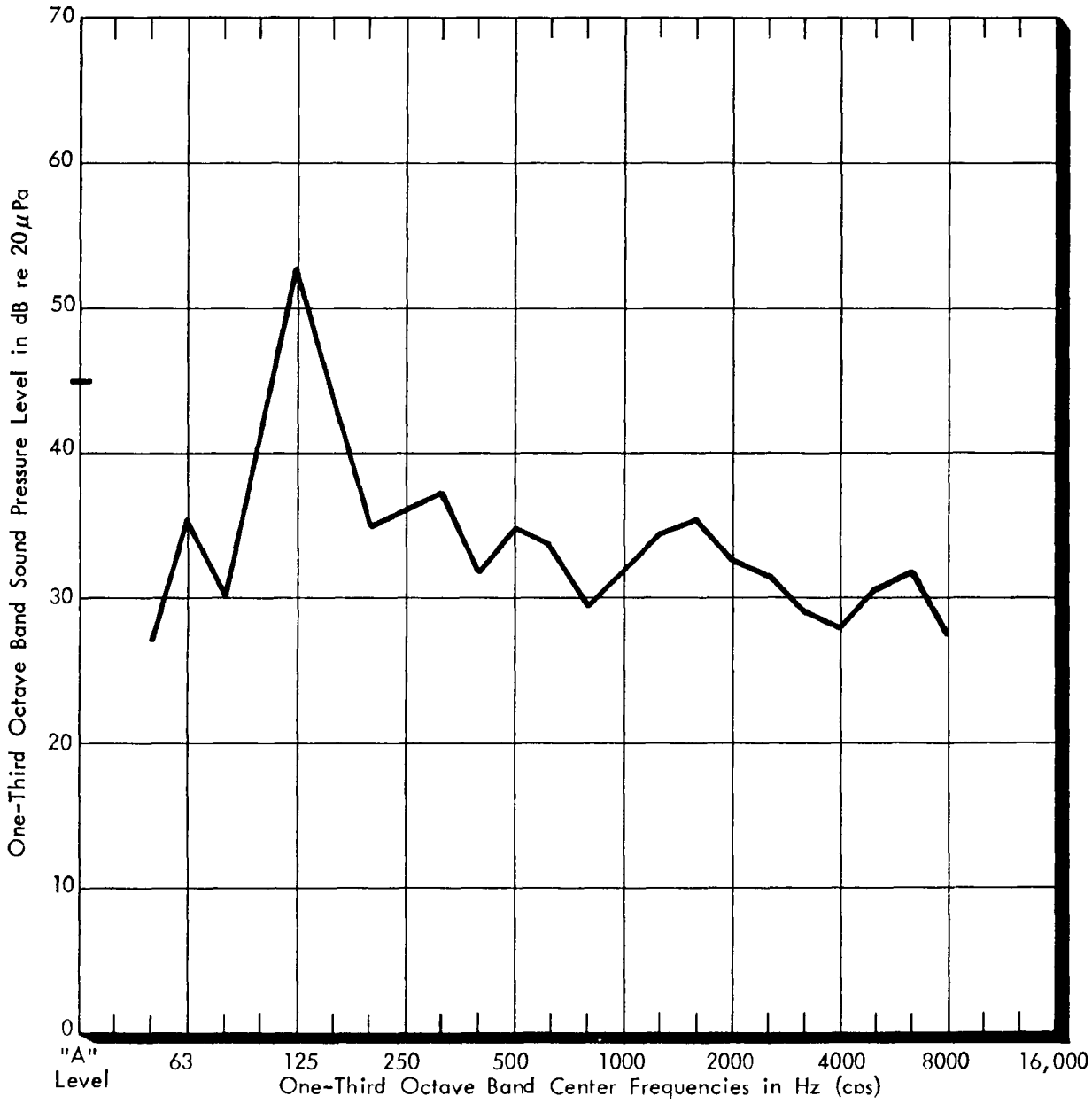

FIGURE C-7. STIMULUS 7 - SHAPED NOISE - OPERATING TRANSMISSION LINE

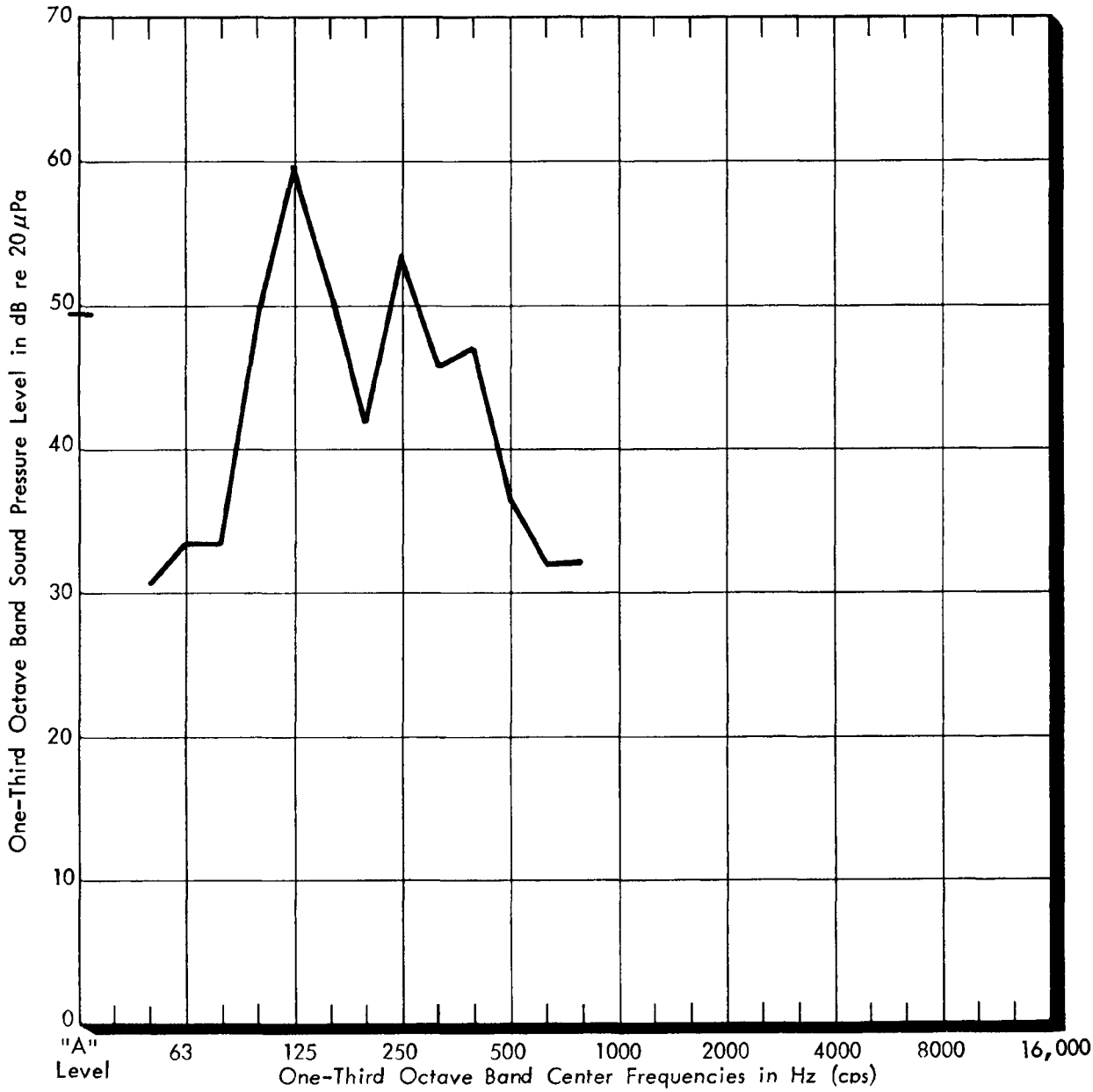

FIGURE C-8. STIMULUS 8 - SHAPED NOISE - 1050 MVA TRANSFORMER

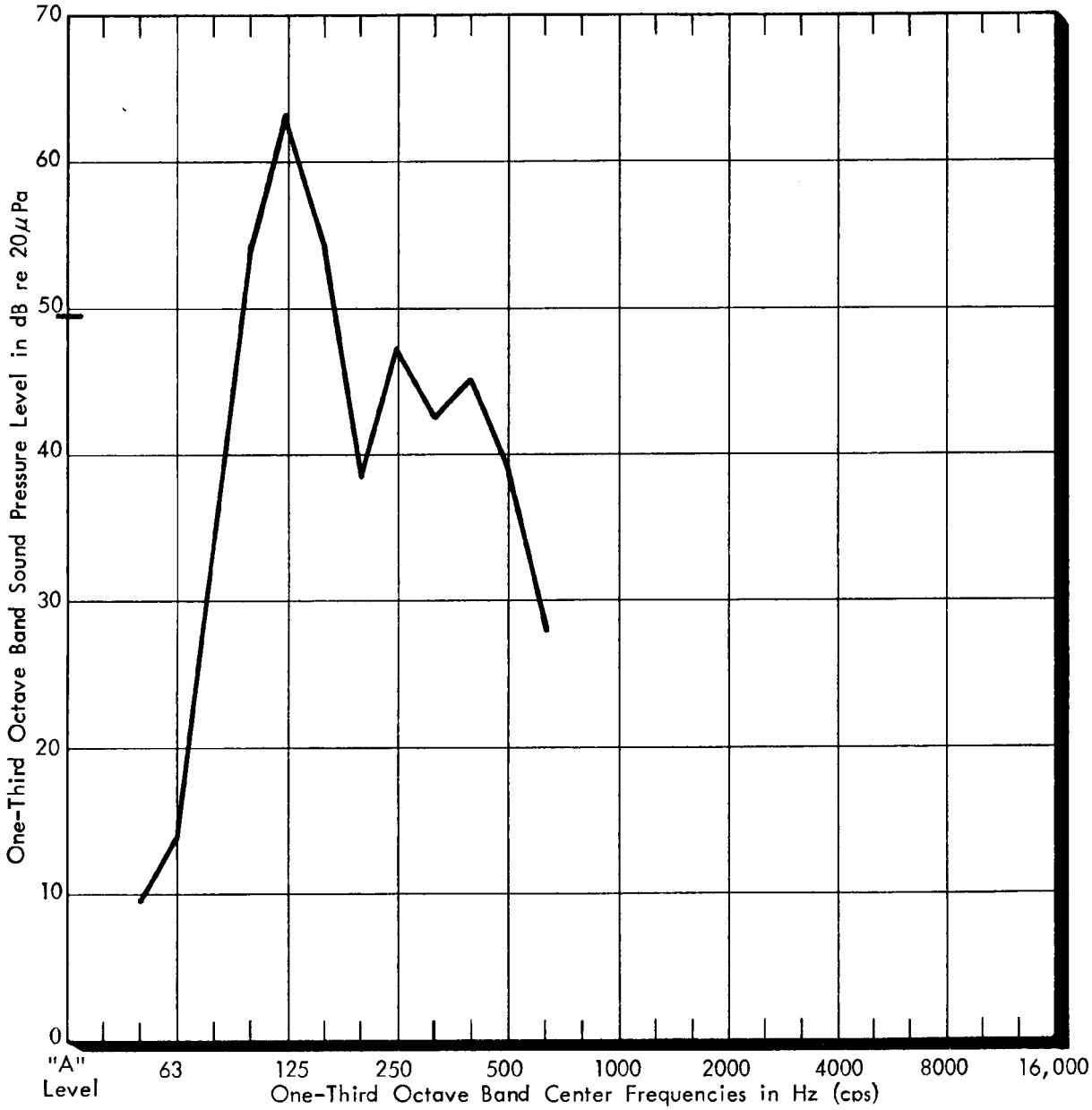

FIGURE C-9. STIMULUS 9 - SHAPED NOISE - SIMULATED TRANSFORMER

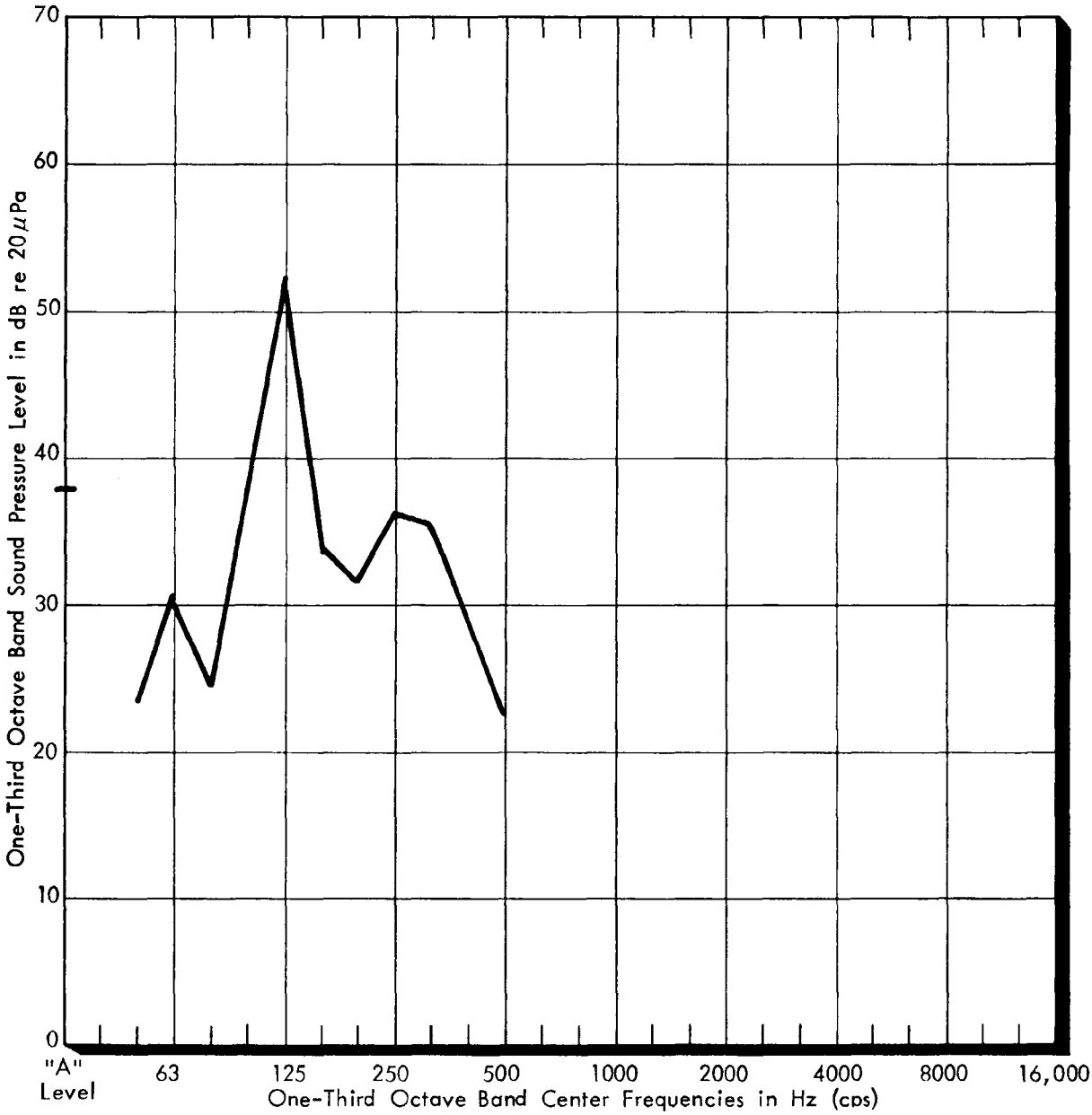

FIGURE C-10. STIMULUS 10 - TRANSMISSION LINE - WITH ONLY LOW FREQUENCY HUM

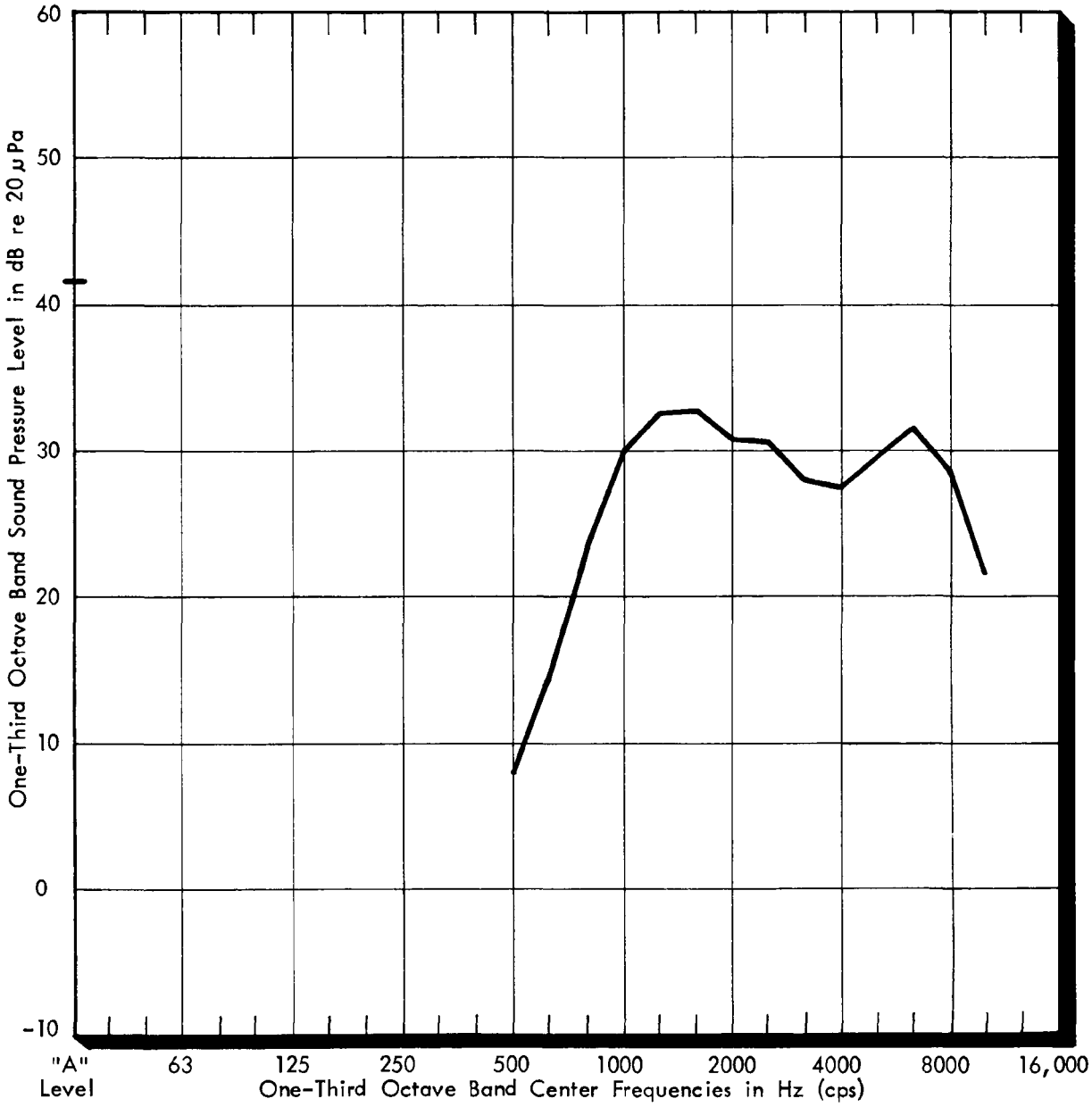

FIGURE C-11. STIMULUS 11 - TRANSMISSION LINE WITH ONLY HIGH FREQUENCY CRACKLE

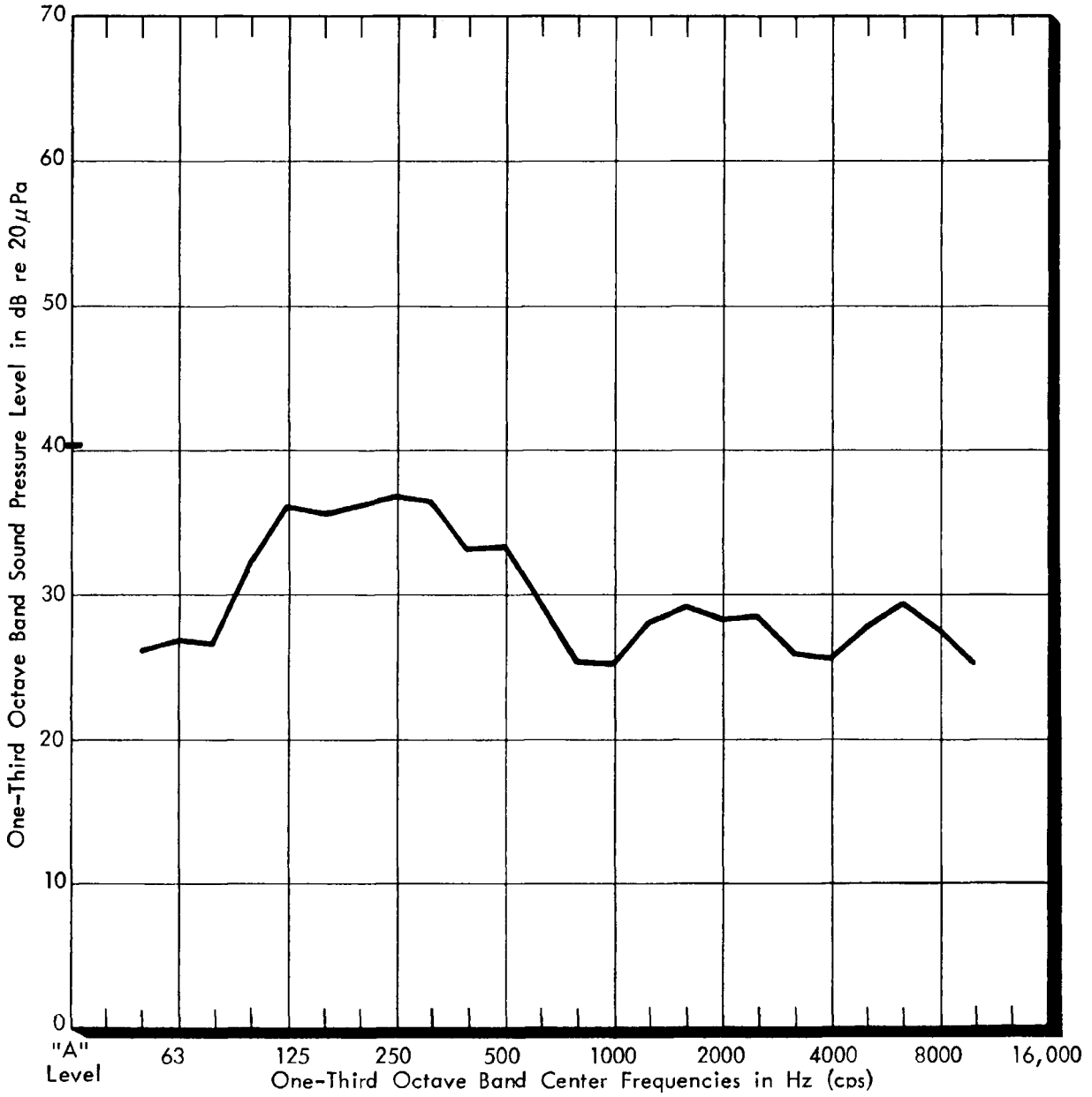

FIGURE C-12. STIMULUS 12 - RAIN

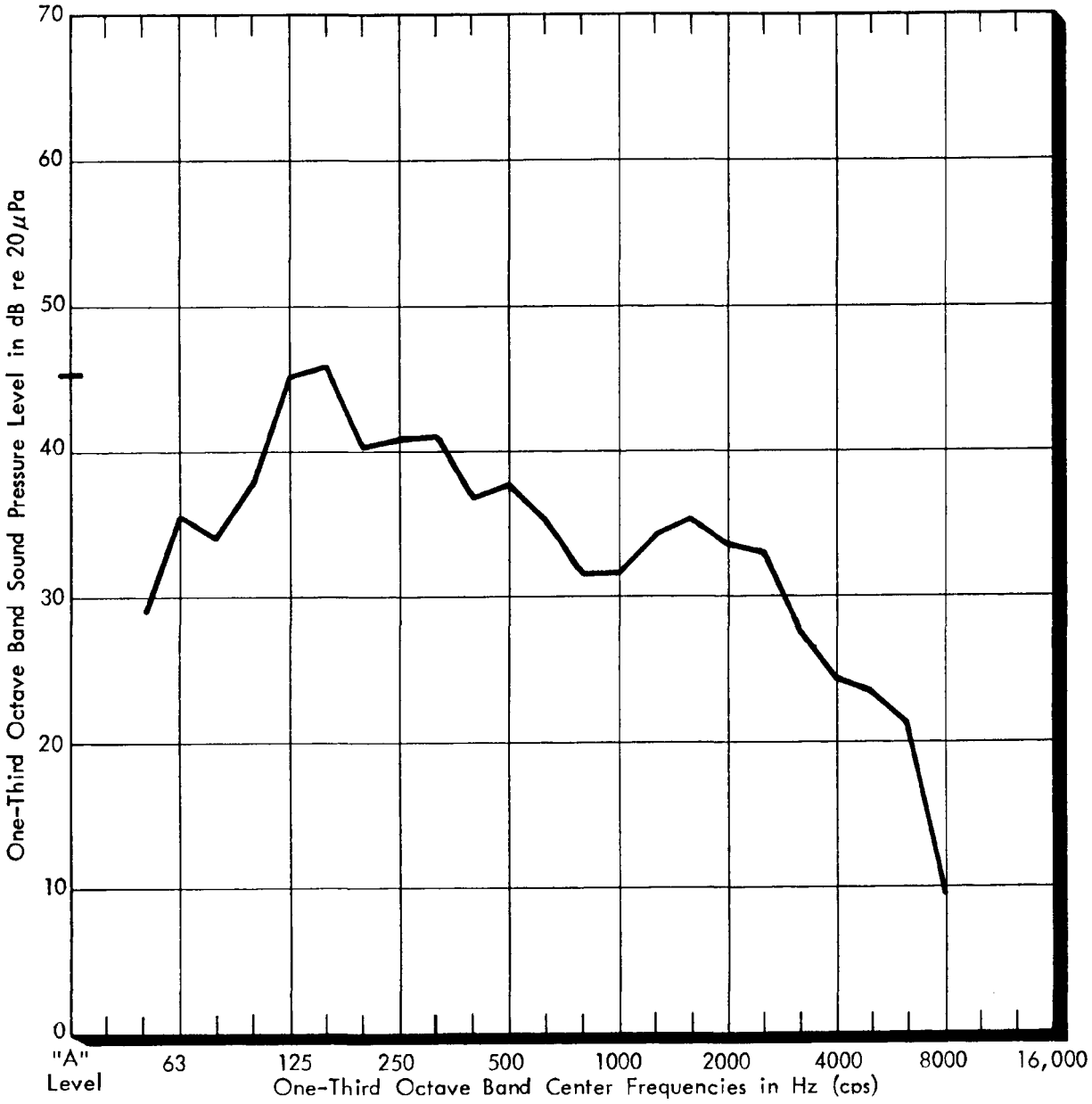

FIGURE C-13. STIMULUS 13 - DISTANT TRAFFIC

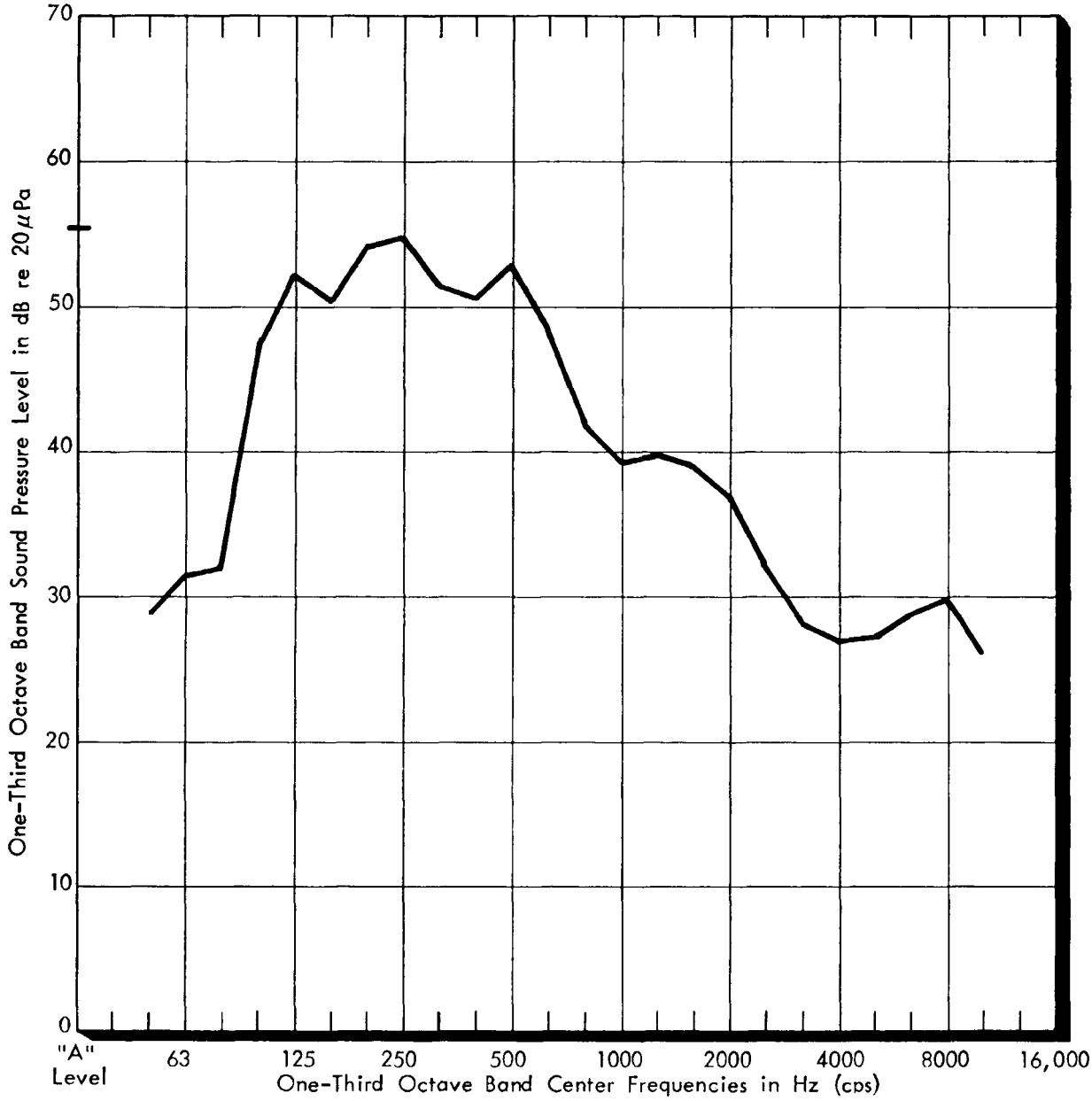

FIGURE C-14. STIMULUS 14 - MULTI-TALKER BABBLE

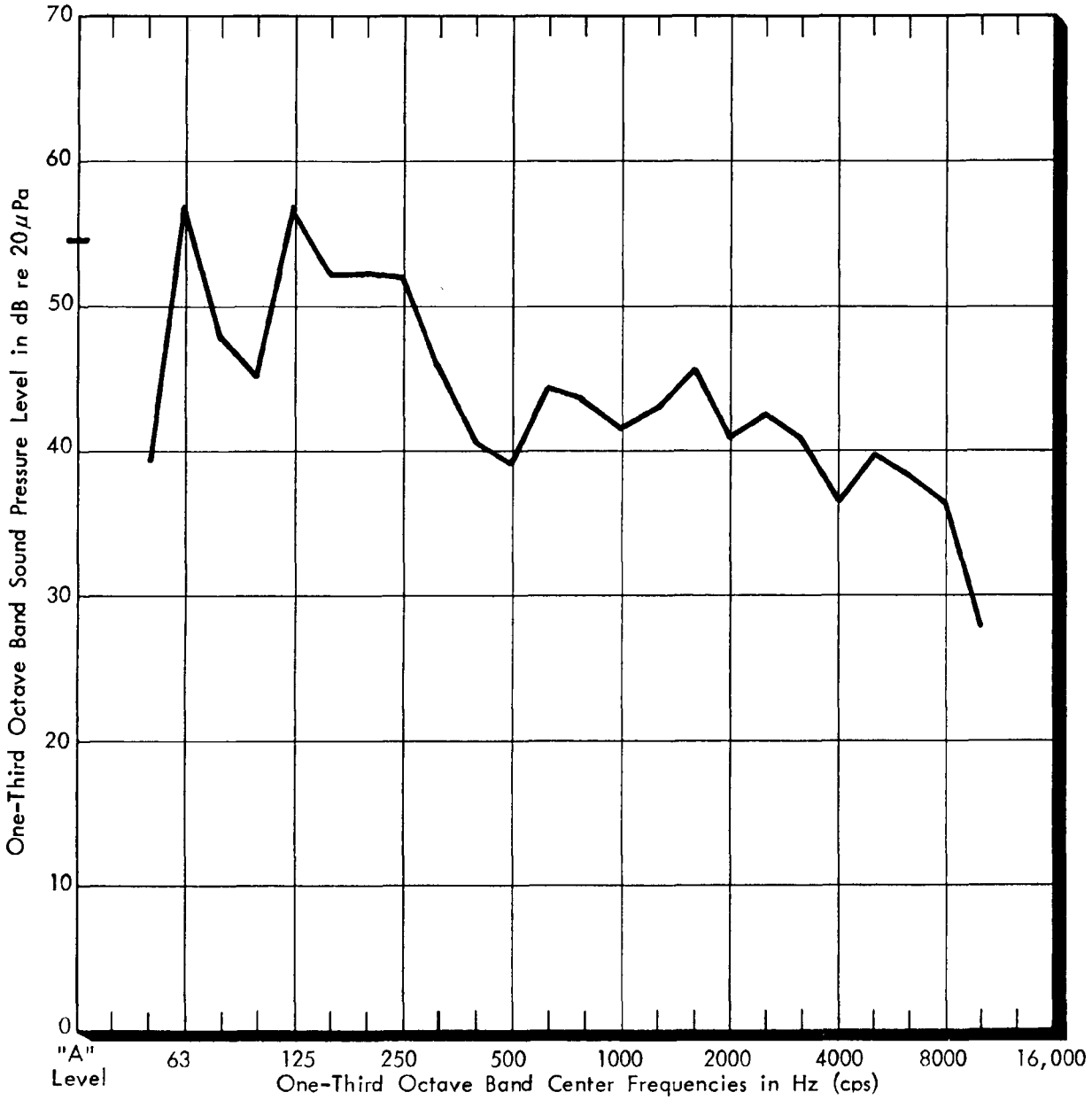

FIGURE C-15. STIMULUS 15 - TRACTOR

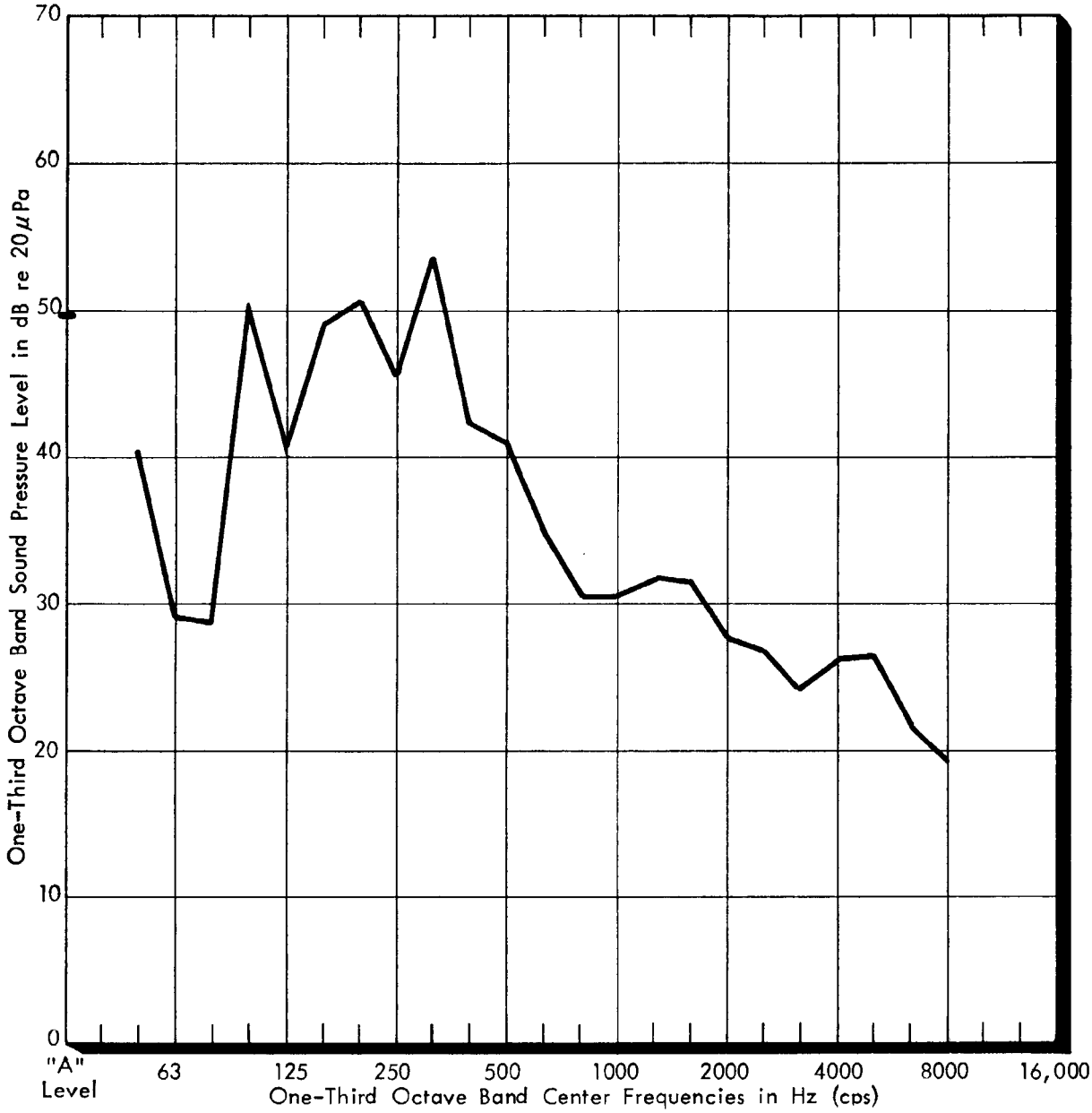

FIGURE C-16. STIMULUS 16 - LAWNMOWER

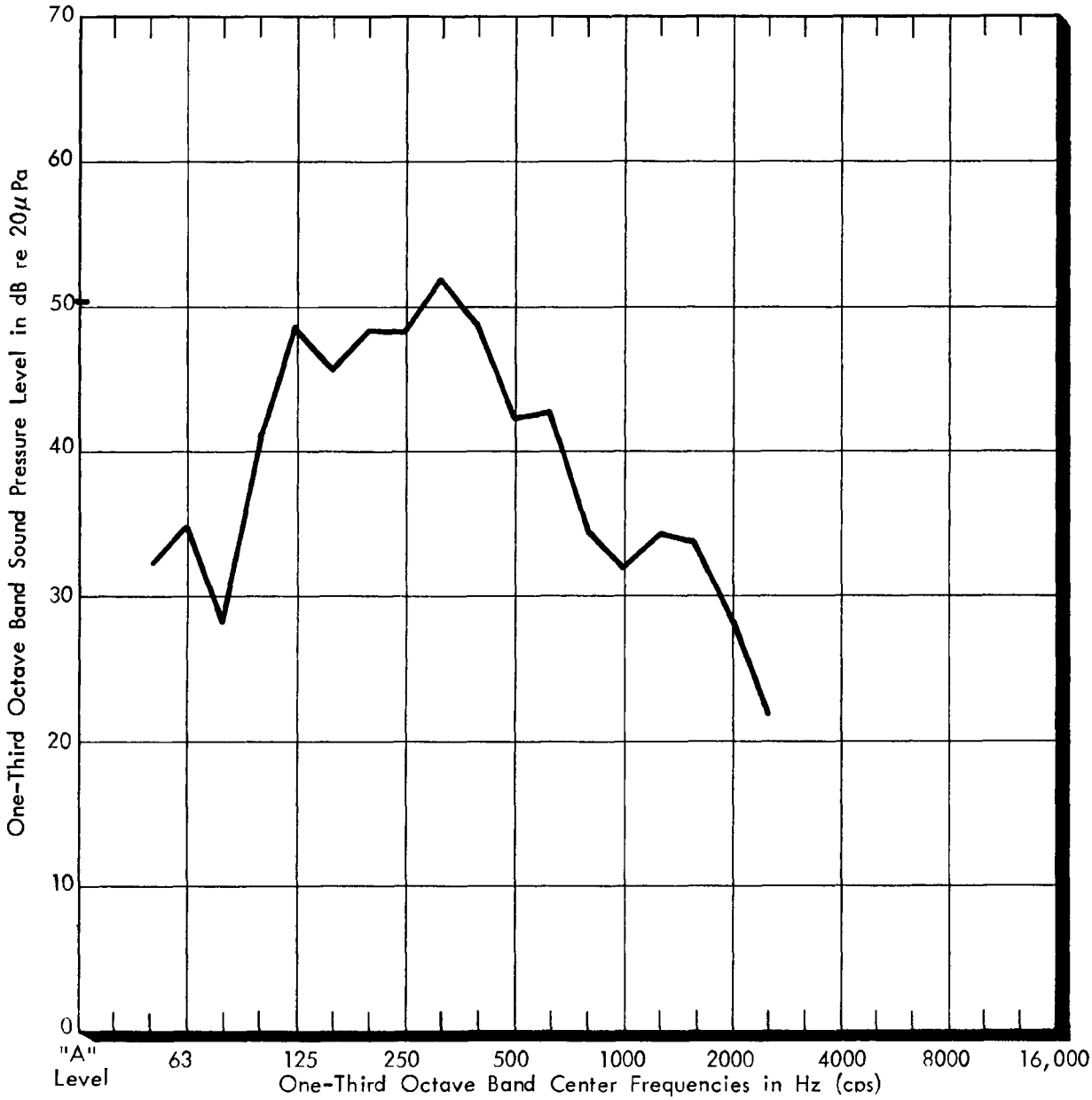

FIGURE C-17. STIMULUS 17 - DISHWASHER

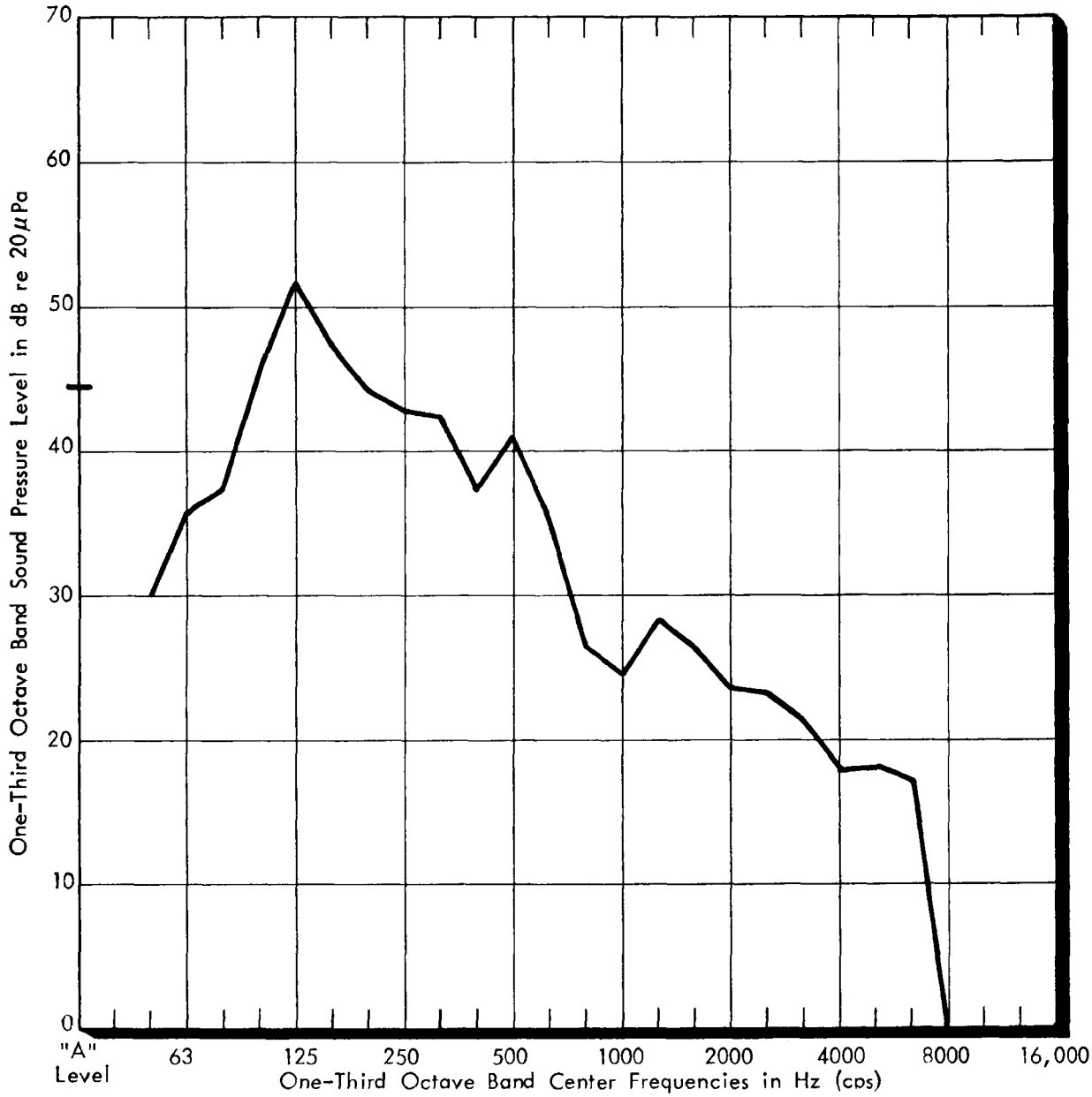

FIGURE C-18. STIMULUS 18 - AIR CONDITIONER

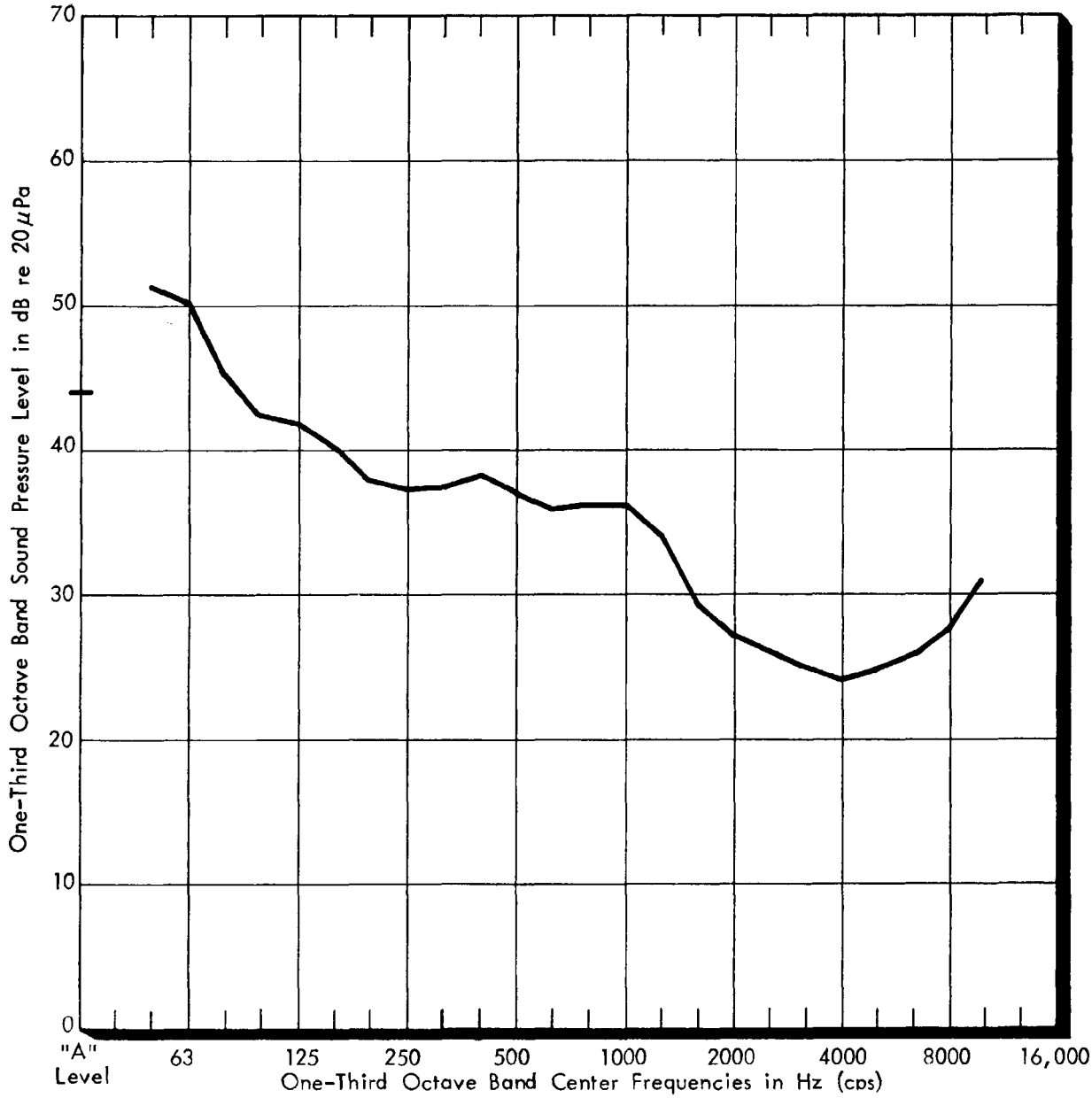

FIGURE C-19. STIMULUS 19 - 39.4 NOY CURVE

APPENDIX D

PILOT TESTS

PILOT TESTS

Two pilot tests were completed prior to the main experiments to determine which sounds would be designated as standards and the optimal duration for signal presentation.

1. Pilot Test I (Duration)

An initial laboratory test was conducted to determine the effects of duration on the relative annoyance of comparison and standard signals.

A 2 kHz octave band of pink noise and a sample of laboratory-generated transformer noise were the two stimuli tested at durations of 2, 5, 10, and 20 seconds. The test design counterbalanced for order of signal presentation and alternately designated each signal as the standard or comparison. The comparisons were made using the PEST procedure described in Appendix A. All the comparisons were played in a background noise similar to a PNC-20 curve shown in Figure 6.

The test results showed no significant difference between the four observation interval durations for either of the two signals. Since no difference in the relation between the two signals exists for the four different durations, then any of the tested durations would be equally effective in the main test.

2. Pilot Test II (Transitivity)

This pilot test was conducted to determine the stability of the rank order of annoyance of four signals which were under consideration as standards for the main study.

The four signals are listed in Table D-I. The signals included two samples of recorded sounds associated with transmission corona noise and transformer noise and two samples of artificial sounds, a four-tone simulation of transformer noise, and a band of noise. Each signal was presented both as comparison (at a fixed level) and a standard (at a variable level). This counterbalanced test design also took into consideration the effect of background noise on the annoyance judgments. Therefore, the nine subjects assessed the signals in an environment both with and without a PNC-20 shaped background noise.

The rank ordering of the annoyance of the signals was not at all affected by the presence or absence of the background ambient. The final results revealed the test transmission line as the most annoying (Table D-II). The recorded transformer was ranked second in annoyance followed by the simulated transformer. The 2 kHz octave band of noise was the least annoying.

For all possible combinations of paired comparisons the rank order of the four signals remained the same. It was reasonable to assume then that the rank order for the 17 signals in the main test would not be affected by background ambient or choice of standard signal. On this basis, it was decided to choose a laboratory-generated stimulus such as the 2 kHz octave band of noise and an electrical source signal such as the simulated transformer as the two standards for the main annoyance test.

TABLE D-I

TRANSITIVITY TEST

STIMULI PRESENTATION LEVEL

Signal No.	Type	A-Level (dBA)
		L_{eq}
1	Simulated Transformer	49.7
2	2 kHz Octave Band	49.6
3	Test Transmission Line	49.5
4	20 MVA Transformer	50.2
Background	PNC-20	31.2

TABLE D-II

TRANSITIVITY TEST

RANKED ORDER OF STIMULI ANNOYANCE

A-Level

Standard Signal	Relative Ranking				Overall Ranking
Transmission Line (TTL)	*	1	1	1	1
20 MVA Transformer (SMT)	1	*	2	2	2
Simulated Transformer (ST)	2	2	*	3	3
2 kHz Octave (2 kHz)	3	3	3	*	4
	Test Transmission Line (TTL)	20 MVA Transformer (SMT)	Simulated Transformer (ST)	2 kHz Octave (2 kHz)	
	Comparison Signal				

APPENDIX E

ADAPTIVE FREE CHOICE PROCEDURE

ADAPTIVE FREE CHOICE PROCEDURE

An adaptive free choice test was conducted after the paired comparison study to explore the effects of test methodology on subjective judgments, and to explore the utility of a multiple choice test procedure.

I. METHOD

Nine test signals, including both naturally occurring environmental noises and sounds associated with outdoor electrical noises were compared using an adaptive free choice test procedure. The procedure, test signals and equipment used in this experiment are described below.

A. Procedure

The test procedure is called "adaptive" because the levels at which signals are presented to subjects vary over the course of data collection in accordance with accumulating information. It is called a "free choice procedure" to emphasize that the subject is not required to make a paired comparison-like decision. The computer controlled test procedure is as follows.

A subject is first familiarized with each member of a heterogeneous set of six signals. He is informed that during the course of data collection, he will continuously hear one of the set at all times. If he does not wish to hear the sound that is being presented at any given moment, he may press a button to hear another of the signals in the set. (The instructions are

at the end of this Appendix.) The sequence in which the signals are presented is randomized with the constraint that each signal follows every other signal equally often, and that no signal may follow itself.

If the subject makes no immediate response to the present signal (either out of indifference or preference to it), the signal is automatically terminated and replaced with one of five other sounds. These default exposure durations are exponentially distributed with a mean of about ten seconds. From the subject's point of view, exposure to any particular signal may be actively avoided at any time, at the risk of unpredictable exposure to another signal. There is no way of anticipating how long exposure to the current signal will persist.

The computer continues to present signals for subjective evaluation until one or both of the following criteria are met: (1) the adjustments made to the levels of the sounds were smaller than the criterion of 1 or 2 dB difference, and/or (2) the distribution of responses did not differ from a random distribution (thus inferring that the subject was equally annoyed by all of the test sounds).

In order to meet these two criteria, the computer recorded the number of times the subjects pressed the response button to terminate each sound, and it noted the time lapse from signal onset to termination. At the end of a block of sixty trials, the numbers of avoidance responses made to the presentations of each signal are analyzed by a chi square test (χ^2) to determine whether the distribution of responses differs significantly from a rectangular distribution. As long as the likelihood that the distribution of

responses over signals differs from a chance distribution is high enough, testing continues.

Before the start of the next block of 60 trials, however, the levels of the six signals are all adjusted in accordance with actual exposure duration. Deviations from the mean exposure duration are calculated for each signal, and signal levels are either raised or lowered to preserve constant energy in the signal set. Thus, if a subject spends little time listening to a particular signal, its level will be lowered. If a subject spends a lot of time listening to a signal, its level will be raised.

The amounts by which signal levels are adjusted is a function of the progress of the test and the history of adjustments. Large adjustments are made initially, until the first reversal in direction of adjustment is encountered for any signal. At this point the step sizes are halved for all subsequent adjustments. This process continues until a minimal adjustment size criterion is reached (1 or 2 dB), or until the distribution of responses is not discriminably different from chance at some predetermined level of confidence.

The total experimental time for each subject was two hours. The test was designed to present 6 signals in each of four test sessions. The subject was given a 10 minute rest between each test session. Three of the nine signals were present in each test session. They were the simulated transformer, and the 2 kHz octave band of noise at the two different levels. The other six signals were alternatively assigned to the four test sessions.

B. Test Signals

The nine signals employed in this experiment are listed in Table E-I. They were selected from those signals used in the previous paired comparison laboratory test (PEST) (Table I). The spectra of the signals are illustrated in Figures E-1 through E-8. Two signals represented outdoor electrical sounds. Four signals were classified as naturally occurring sounds, and two signals were shaped noise. The 2 kHz octave band of noise was listed as two individual signals, distinguished by the initial 20 dB difference in presentation level. The spectra of two of the signals (the simulated transformer and the transmission line) were corrected for outdoor-to-indoor transmission loss in order to simulate an indoor listening environment for the subject. The other signals were heard by the subject as if he were listening in an outdoor environment.

All the signals were judged by the subjects in the presence of a PNC-30 background (Figure E-9) noise which was felt to be indicative of the ambient background found around homes.

C. Subjects

The average age of the eight subjects who participated in this test was 22 years. The age range for the five male subjects was 18 to 27 years and for the three female subjects the range was 18 to 22 years. Each subject was audiometrically tested and took part in the study if they were within 20 dB of normal hearing as defined by the ISO recommended standards (1964).

TABLE E-I

ACOUSTIC MENU STIMULI

INITIAL PRESENTATION LEVEL

Signal No.	Abbrev.	Type*	L_{eq} dB
1	ST	Simulated Transformer+	55
2	2 kHz	2 kHz Octave Band of Noise	55
3	NTL	Shaped Noise - Operating Transmission Line	70
4	BAB	Multi-Talker Babble	75
5	TRC	Tractor	45
6	AC	Air Conditioner	60
7	TRF	Distant Traffic	50
8	TTL	Test Transmission Line+	65
9	2 kHz	2 kHz Octave Band of Noise	75
Background		PNC-30	39

*Outdoor spectra unless otherwise noted.

+Indoor spectra.

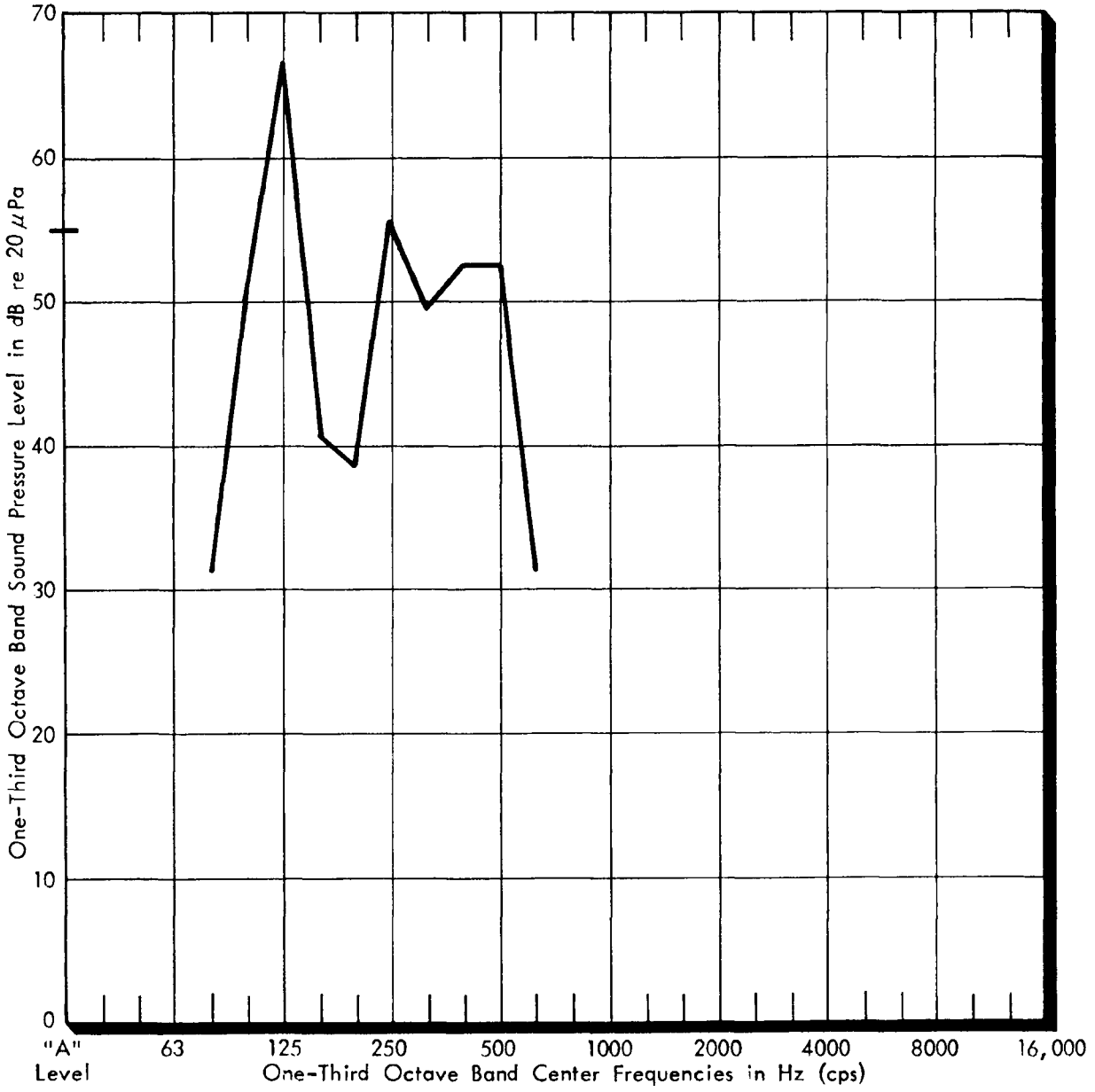

FIGURE E-1. STIMULUS 1 - SIMULATED TRANSFORMER

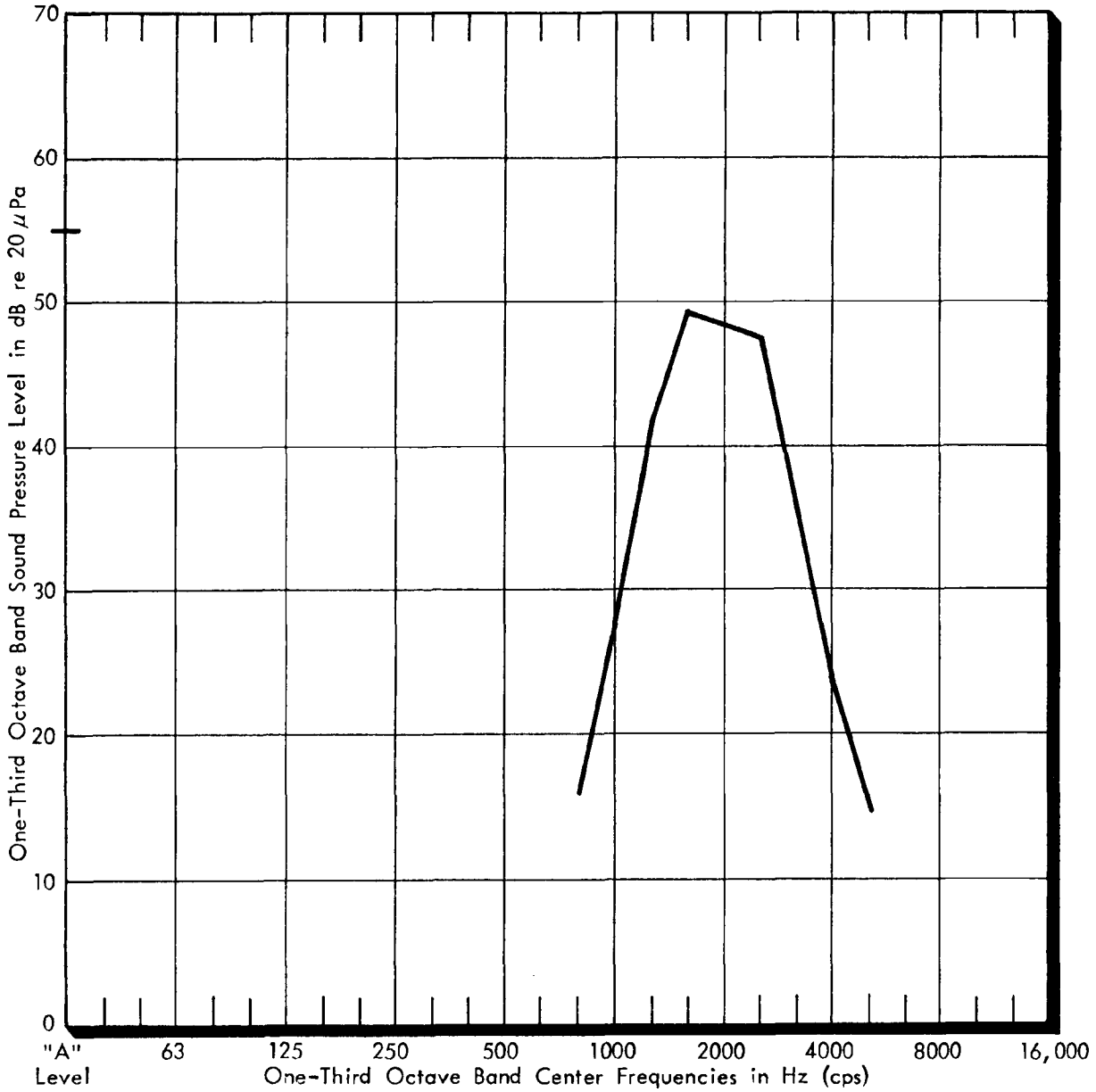

FIGURE E-2. STIMULI 2 & 9 - 2KHz OCTAVE BAND OF NOISE

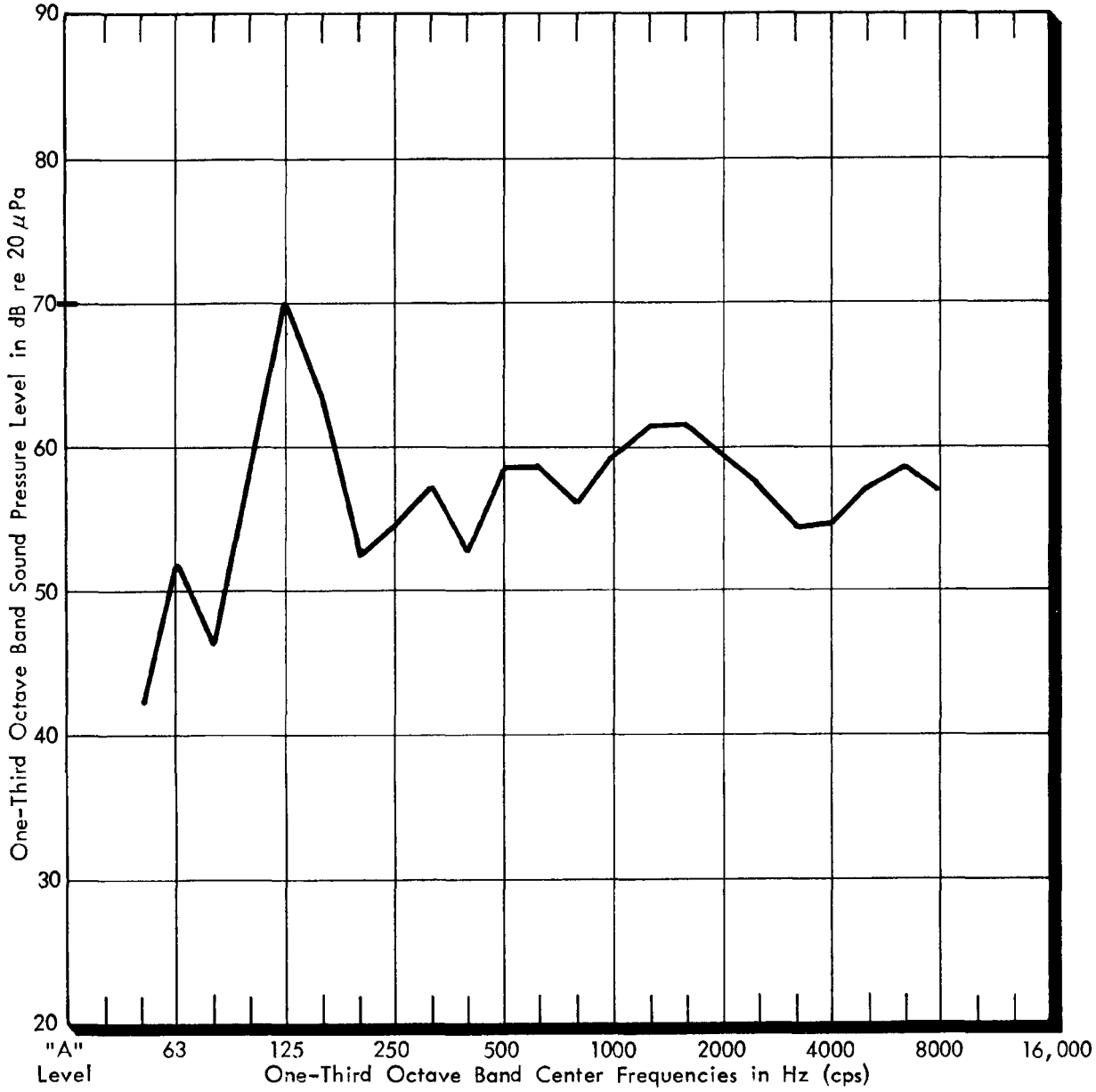

FIGURE E-3. STIMULUS 3 - SHAPED NOISE - OPERATING TRANSMISSION LINE

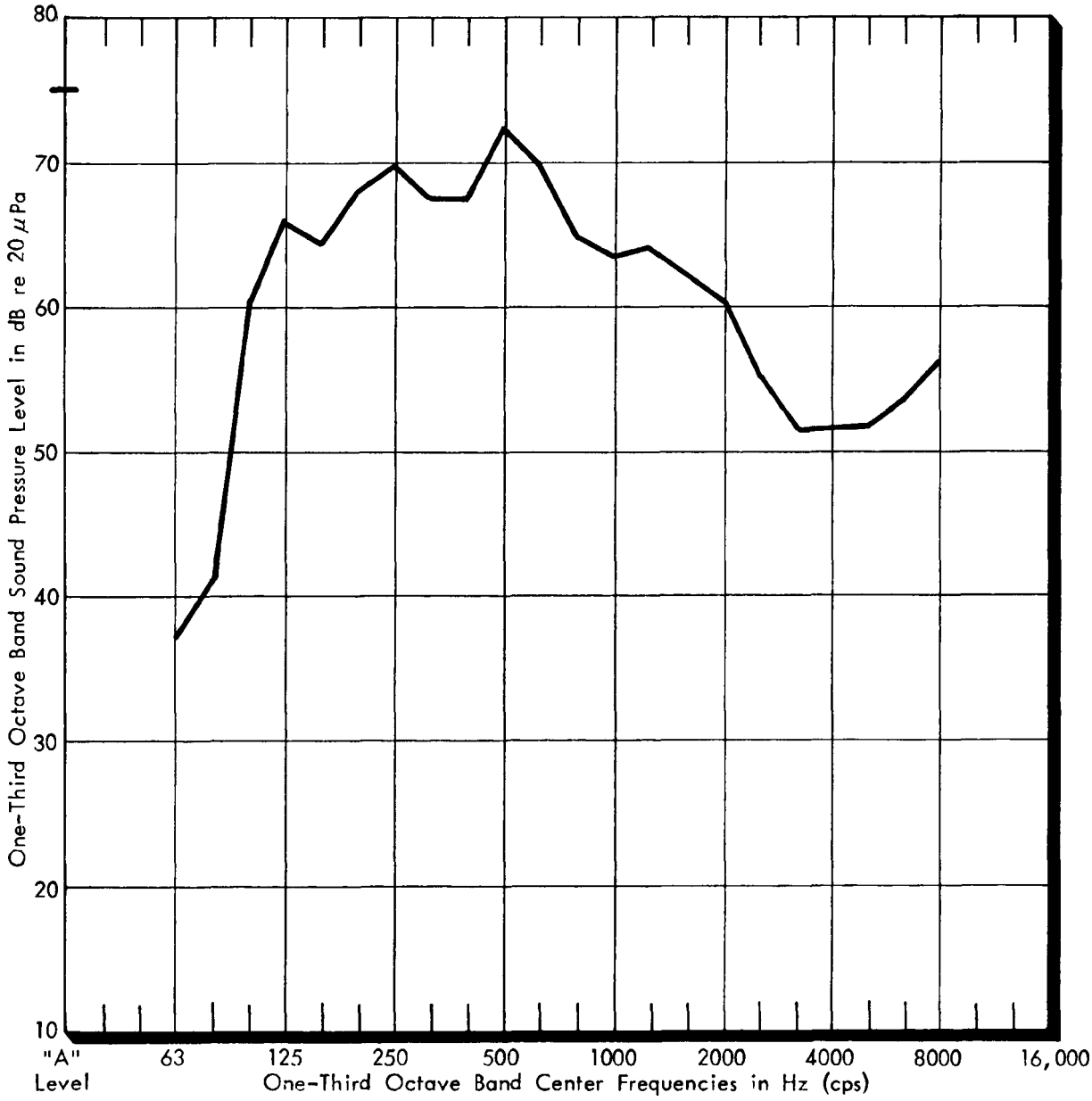

FIGURE E-4. STIMULUS 4 - MULTI-TALKER BABBLE

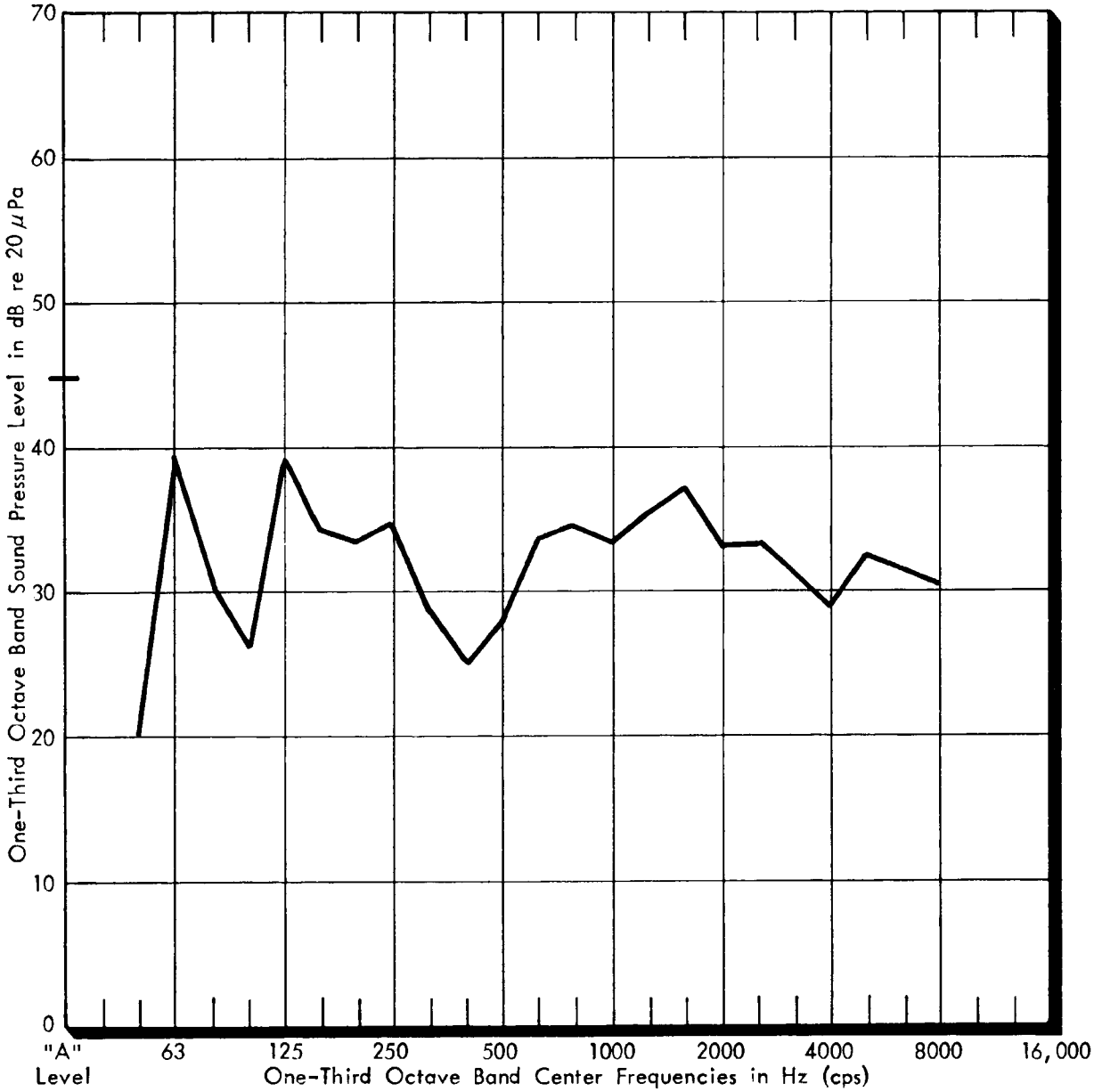

FIGURE E-5. STIMULUS 5 - TRACTOR

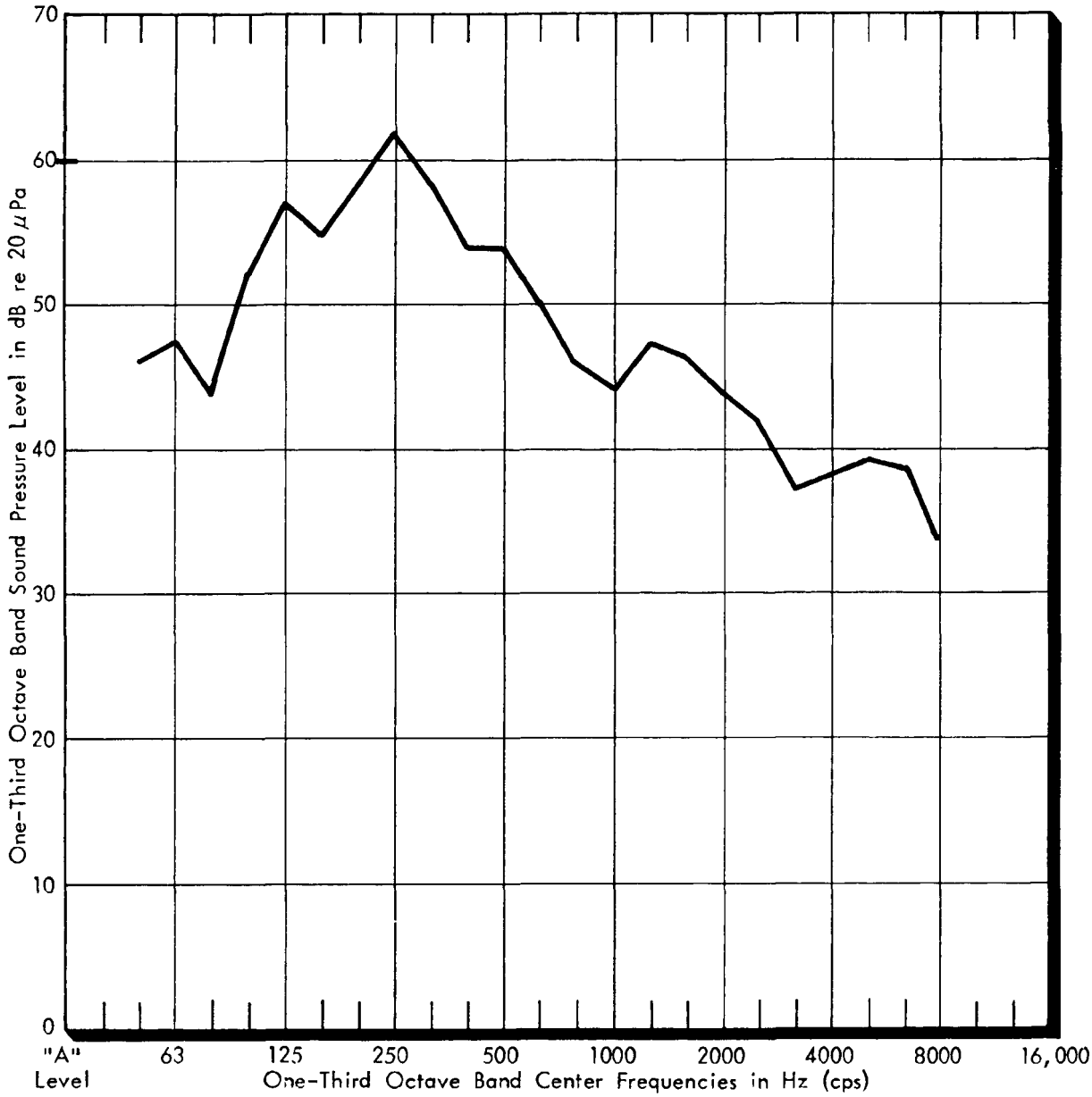

FIGURE E-6. STIMULUS 6 - AIR CONDITIONER

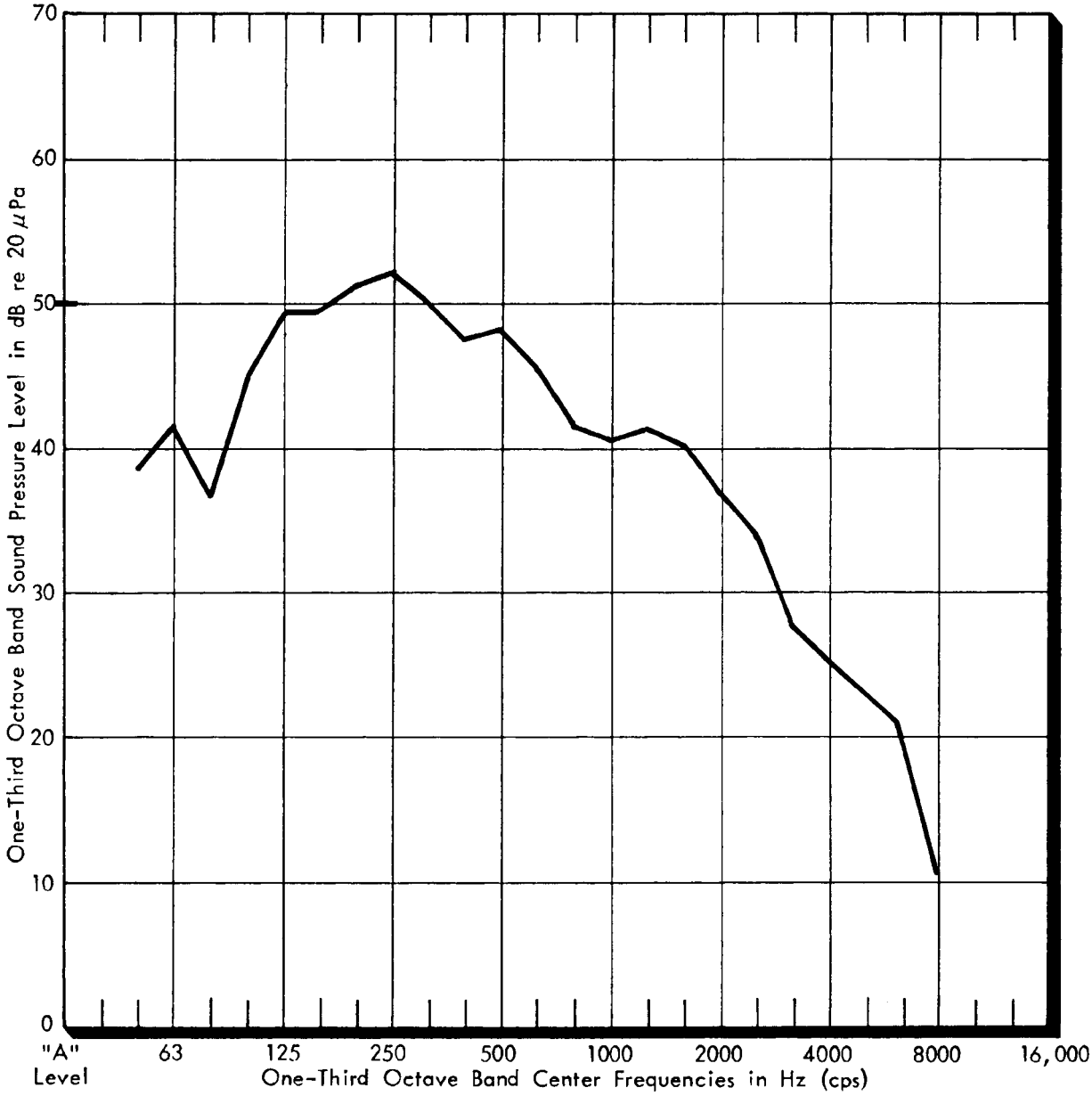

FIGURE E-7. STIMULUS 7 - DISTANT TRAFFIC

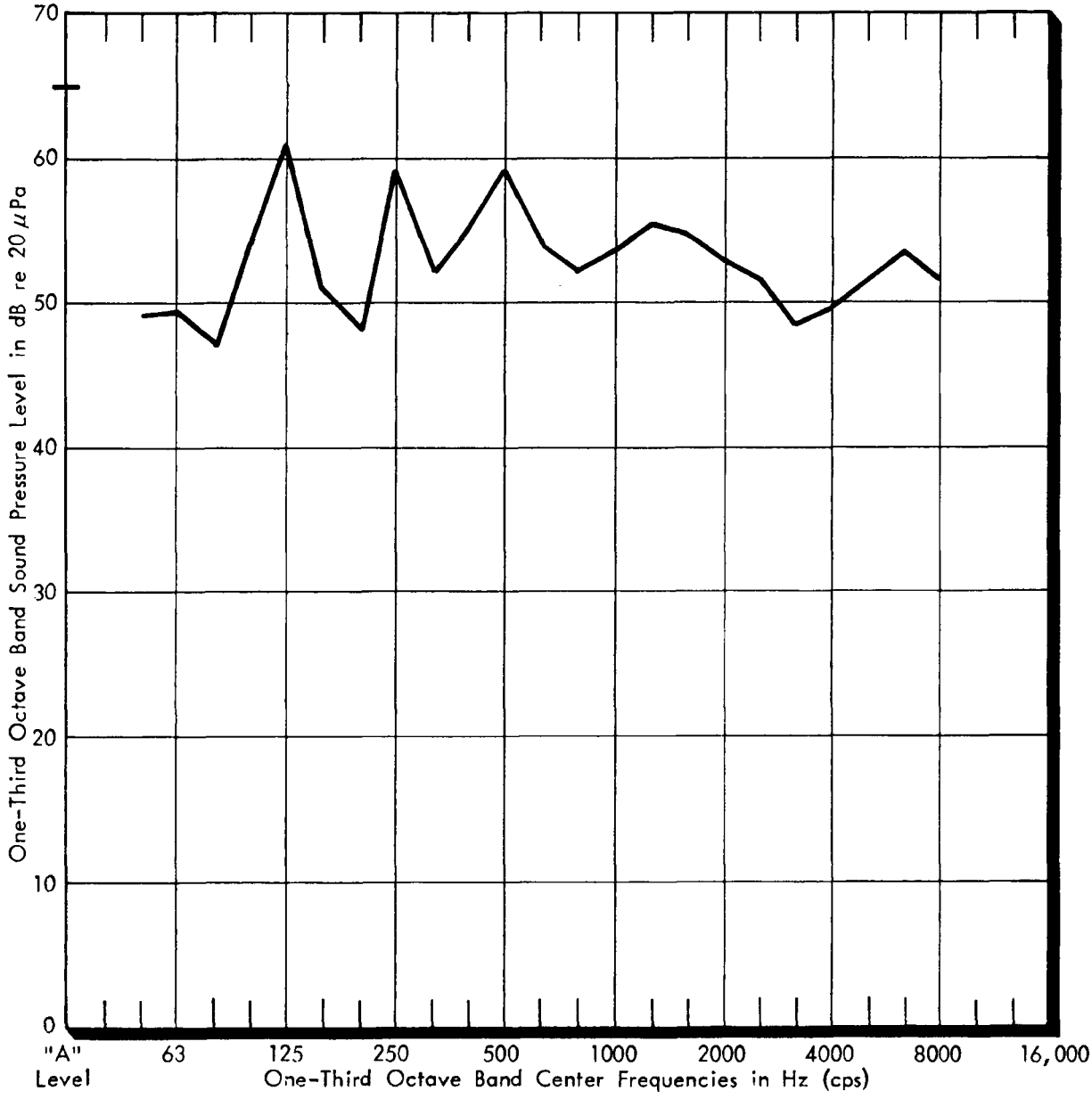

FIGURE E-8. STIMULUS 8 - TEST TRANSMISSION LINE

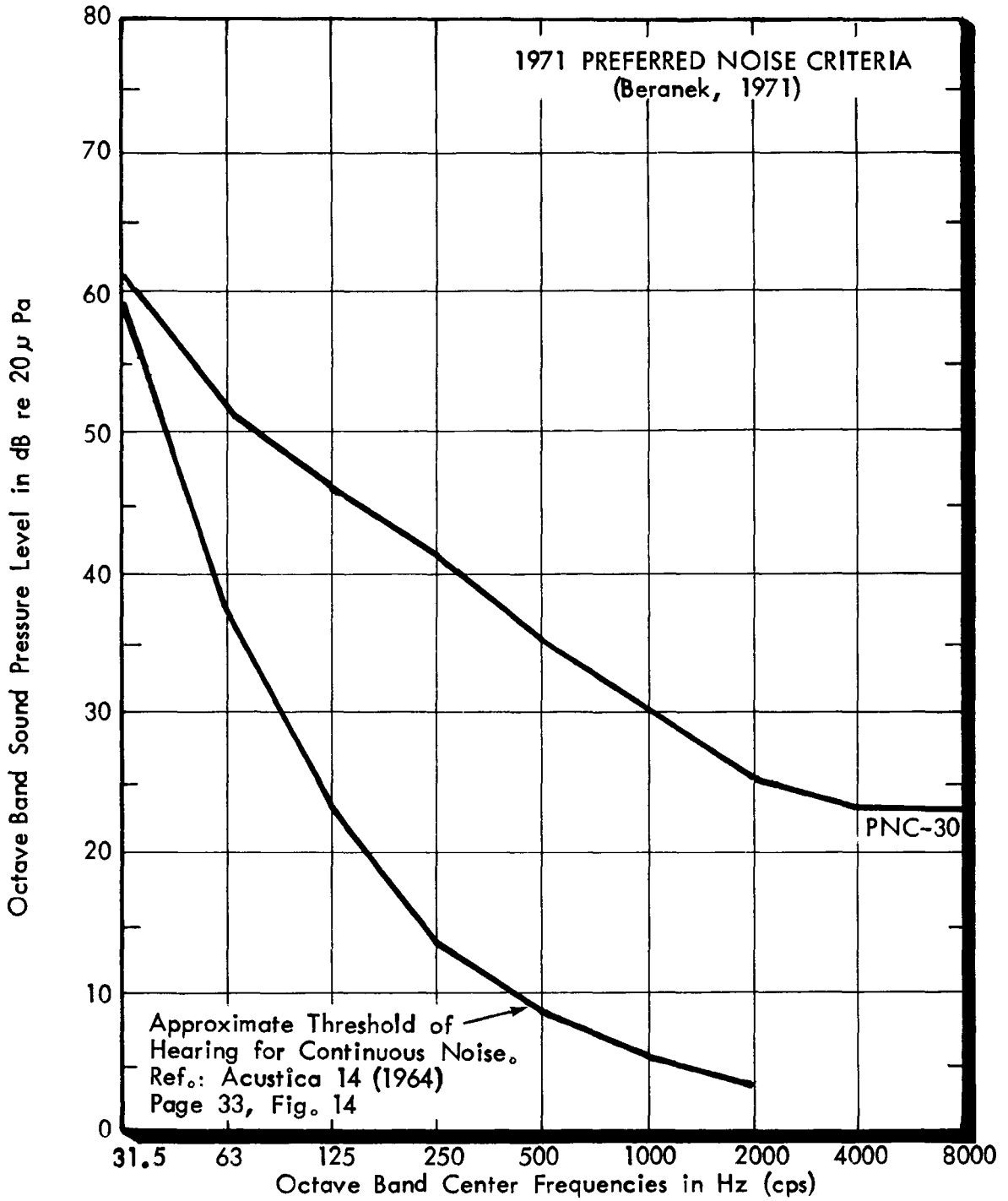

FIGURE E-9. BACKGROUND FOR ADAPTIVE FREE CHOICE TEST

D. Equipment

The block diagram in Figure E-10 illustrates the equipment utilized in this test. As in the previous paired comparison test, the digital computer regulated the order of presentation and the relative levels of the signals which were heard at all times in the anechoic chamber. Two of the signals, the 2 kHz octave band of noise and the simulated transformer, were generated in real-time, while the other stimuli were pre-recorded and played back on the tape cartridge recorder. The electronic switch prevented the feed through to the anechoic chamber of an audible signal onset cue.

II. RESULTS

The results of the adaptive free choice test are plotted in Figure E-11. There was no "standard" signal in this test, that is, one signal against which the subject would make comparison judgments. However, for this analysis, the 2 kHz octave band of noise which was initially presented at 55 dB(A) was chosen as the "standard". The difference between this "standard" and the other eight signals was then calculated for each subject and plotted in Figure E-11. The signals were placed on the graph according to the descending rank order of the mean differences. Although the signals rank in a different order from those employed in the PEST annoyance test, the test transmission line (TTL) noise still appears to be judged the most annoying. It is also noted that the spread of the individual judgments is comparable to the results from the PEST annoyance test. The standard deviations for over one-half of the signals used in the free choice test were greater than 8 dB for individual judgments.

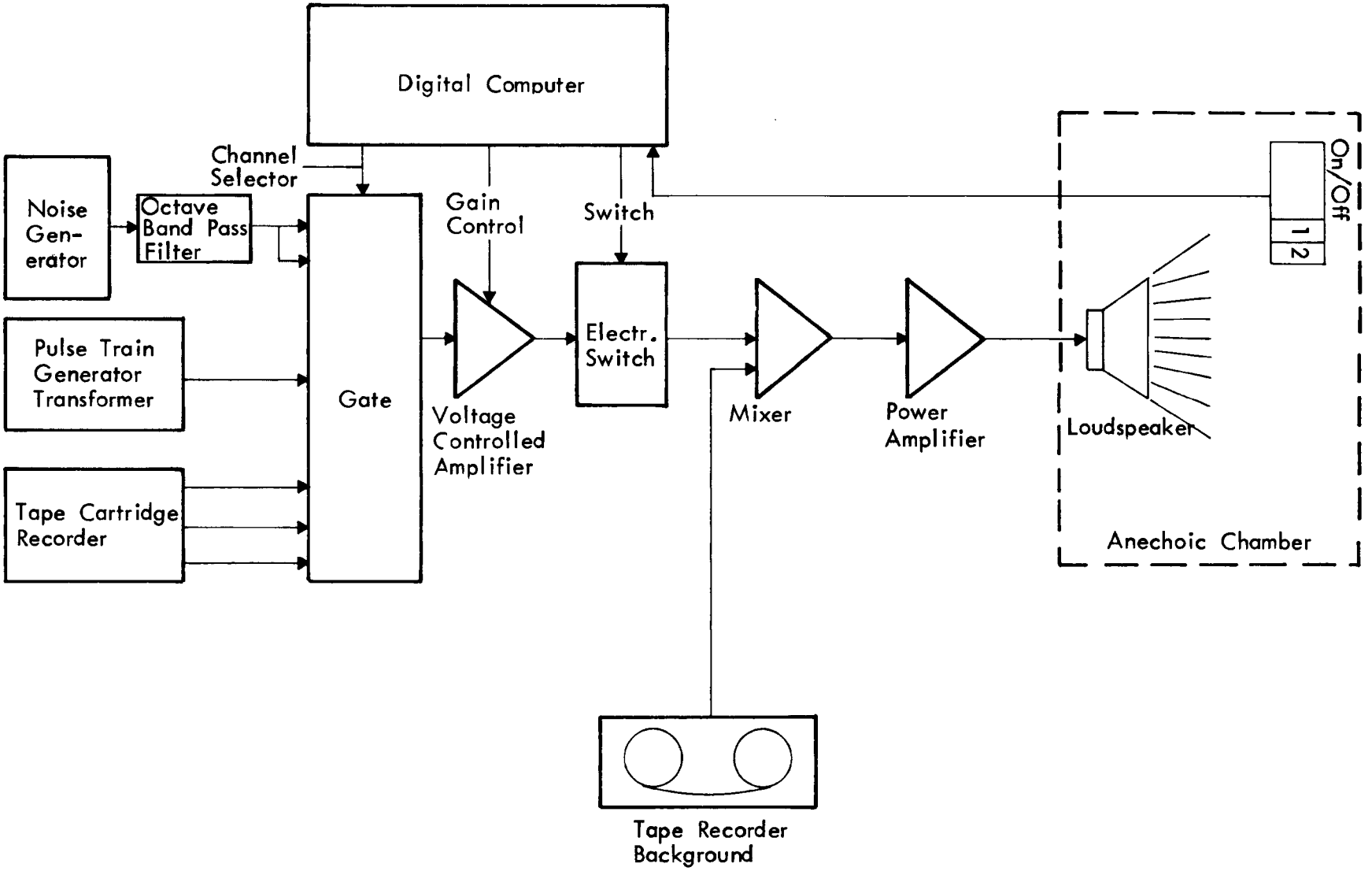

FIGURE E-10. BLOCK DIAGRAM OF EQUIPMENT USED IN ADAPTIVE FREE CHOICE TEST

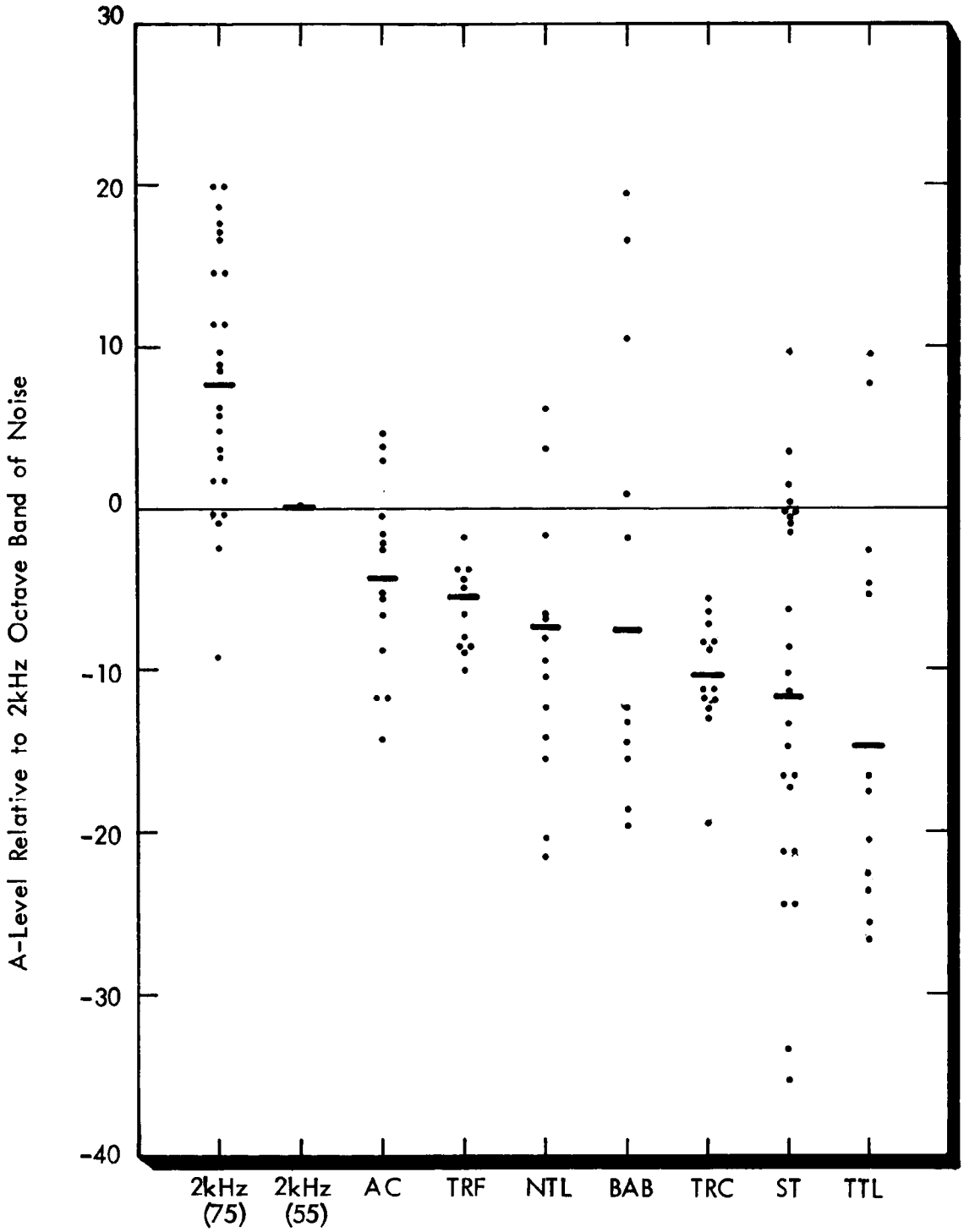

FIGURE E-11. A-LEVEL OF TEST SIGNALS RELATIVE TO 2kHz OCTAVE BAND NOISE (55 dBA) AT POINT OF SUBJECTIVE EQUALITY (ADAPTIVE FREE CHOICE TEST)

The results of the adaptive free choice test were also analyzed in terms of other noise measurement methods. Figure E-12 contains the data analyses utilizing the five different noise measures. The measure with the greatest standard deviation is considered the least accurate annoyance predictor, while the measure with the smallest standard deviation is considered the most accurate annoyance predictor. Thus overall sound pressure level (OASPL) is among the least accurate predictor and D-level with its small standard deviation for all signals appears to be the most accurate measure for evaluating people's estimation of annoyance. However the difference between the worst and best measure for the test is relatively small.

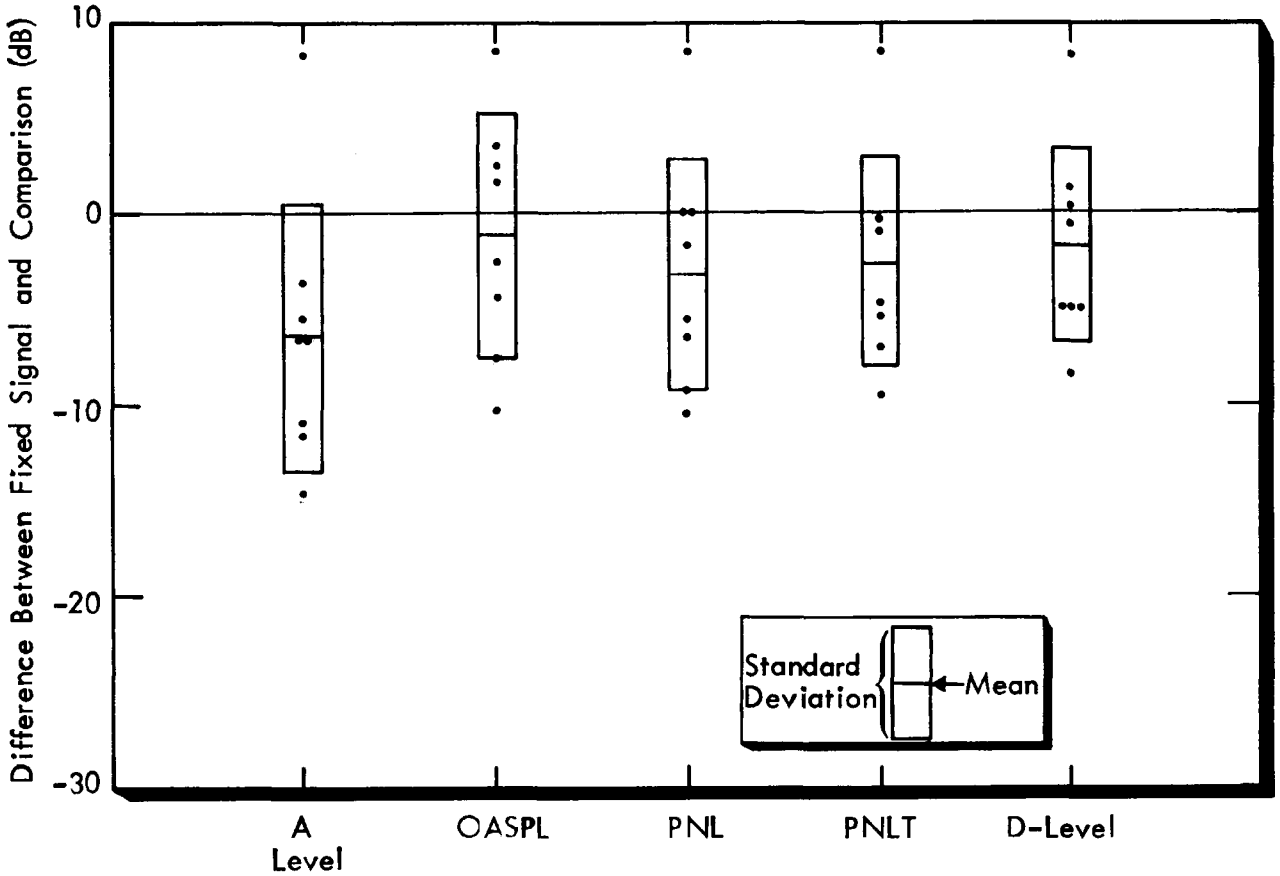

FIGURE E-12. RESULTS OF ADAPTIVE FREE CHOICE TESTS FOR VARIOUS NOISE MEASURES

INSTRUCTIONS FOR ADAPTIVE FREE CHOICE

In this experiment, you will continuously hear one of a number of sounds. If at any time you would rather not hear one of the sounds, press the lighted button on the box in front of you. Pressing the button will immediately stop the sound, but another sound picked at random will be heard in its place.

If you do not push the button while a sound is being presented to you, the sound can continue for an indefinitely long period of time, or it may be replaced by another sound after a while. There is absolutely no way to predict how long any particular sound heard at any time will last, so if you would rather not hear it, press the button to stop it right away.

The computer that is selecting and presenting the sounds to you is also keeping track of your responses (button pushes). The computer may from time to time vary the sounds that you hear for statistical reasons. Most people find that they can complete their participation in this study most efficiently by listening carefully to each sound and deciding soon after each one starts whether they would rather hear it or some other sound.

There are no right or wrong answers, but the computer does keep track of the consistency of your decisions. All we ask of you is careful consideration of each sound as it is heard.