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FINAL REPORT

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THE EFFECTS OF TEMPORAL AND SPECTRAL COMBINATIONS ON THE JUDGED NOISINESS OF AIRCRAFT SOUNDS

JUNE 1969

Prepared for

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
OFFICE OF NOISE ABATEMENT

by

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ABSTRACT

Tests were performed in an anechoic chamber using twenty college students to determine the judged noisiness of stimuli varying both temporally and spectrally. The investigations were divided into three test series. The first test series used thirty stimuli with six different time patterns and five different spectra. The second test used stimuli selected from the first test but modified to include signal durations ranging from 1 to 100 seconds. Duration in this case is the amount of time the stimuli were within 10 dB of the maximum level. The stimuli for the third test consisted of recordings of turboprop, turbofan, turbojet and helicopter flyovers.

The results indicated that the most accurate predictor of the judged noisiness was perceived noise level using a tone correction suggested by the FAA and an integrated measure of duration. To illustrate the improvement in noisiness predicability of EPNL over PNL, the results of Test II (duration test) are used. For this test, 75% of the data was within 4 dB of the standard for EPNL with the FAA tone and integrated duration measure as compared to 11 dB for PNL.

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I. INTRODUCTION

The temporal pattern of propeller and jet flyovers usually follows a simple triangular or haystack form, while the sound pattern of the newer aircraft, especially the V/STOL aircraft, may generate a variety of flyover noise time patterns and durations. Previous attempts to predict the judged noisiness of these more involved flyover patterns have pointed out the inadequacy of some of the existing duration and pure-tone correction procedures (Ref.1). The reasons for this failure to predict the judged noisiness may be the unusual spectra associated with V/STOL aircraft. To investigate this problem and in an effort to find measurement procedures which best predict the subjective noisiness of V/STOL and other aircraft flyovers, tests have been conducted using stimuli with different spectral shapes and systematically varying time patterns. This report presents the results of such a study.

Three sets of judgment tests were conducted, differentiated by the sets of stimuli. The comparison stimuli for the various tests were as follows:

- Test I: Various spectral and temporal shapes were used, both with and without pure-tones.
- Test II: Selected samples from Test I were used, varying the range of durations from 1 to 100 seconds as measured 10 dB down from the maximum level.
- Test III: Recordings of real-life flyovers were used which included helicopter, turbofan, turbojet, and turboprop aircraft.

The primary objective of each test was to select a set of stimuli such that differences in certain calculation procedures would generate widely divergent predictions of judged noisiness. Given this additional experimental leverage, it was hoped that the psychoacoustic judgment tests would clearly indicate the best prediction procedure, and most certainly point out the relationship of the measures to each other.

II. TEST DESCRIPTION

A. Subjects

Twenty college students were used as subjects for each experiment. All subjects were screened to within 15 dB of the proposed ISO standard threshold (Ref.2). The total group consisted of approximately an equal number of males and females ranging in age from 17 to 32 years of age, with a median age of 20 years. Whenever possible, the same subjects participated throughout the entire test series.

B. Equipment

The basic equipment used to present the test stimuli to the subject consisted of a multiple cartridge tape recorder controlled by an on-line digital computer. The results of the signals were amplified and played back through a loudspeaker system in an anechoic chamber. The additional information on the playback and stimulus preparation equipment necessary for creating the comparison test tapes is given in Appendix A.

C. Procedure

The judgment tests were all conducted in an anechoic chamber 8 feet by 10 feet by 7 1/2 feet high. The testing method employed for this study was a modified form of the paired comparison testing procedure. Recent developments in methodology have produced several improved adaptive testing procedures, one of which is called Parameter Estimation by Sequential Testing (PEST) (Ref. 3,4). This method, adapted for use at Bolt Beranek and Newman Inc., is described in detail in Appendix B, along with examples of computer inputs and outputs produced during a single test session. Basically, the method utilizes an on-line computer to select "standard" and "comparison" stimuli iteratively. After a pair of stimuli is presented, the subject decides which of the two is the noisier (complete subject instructions are presented in Appendix C). The computer records the subject's response and adjusts the level of the comparison stimulus in a direction contingent upon that response, in order to make the sounds more equally noisy on the next trial. This technique is repeated until the subject's answers converge on a prescribed level of performance. Order effects are automatically averaged out by randomization of the order of presentation of the standard and comparison signals. Each complete test was four hours in duration; however, each test session was limited to approximately ninety minutes per subject with frequent rest periods provided to prevent fatigue.

D. Test Stimuli

Considerable care was taken in the selection of the stimuli used in these tests. Five spectra (identified by the letters at the end of the alphabet, V, W, X, Y, Z - Figure 1) were employed which yielded maximally different predictions according to the following calculation procedures:

1. Perceived Noise Level (PNL) (Ref.5).
2. Perceived Noise Level with a tone correction (PNLT)- this tone correction is employed in the calculation of Effective Perceived Noise Level (EPNL) in accordance with the current FAA proposal for certification (Ref.6).
3. A-Weighted sound pressure level (AL).
4. N-Weighted sound pressure level (NL).

Similar attention was given to the selection of the temporal patterns (identified by the letters at the beginning of the alphabet, A, B, C, D, E, F - Figure 2) so that maximal difference among various calculation schemes would again occur. Among the methods used to account for a duration correction were:

1. 10 Log d_{10}

2. 10 Log d_{20}

3. Integrated PNL (on a power basis)

In this instance, d_{10} and d_{20} are the amount of time the signal was within 10 dB and 20 dB of the maximum PNL, respectively.

Definitions of these and other measures which use the spectral and temporal information are given in Section III. The identifying characteristics of the stimuli which were employed in the three judgment tests are indicated in Tables I through III. The results of third-octave band analysis on each of the samples in the tests are included in Appendix D.

TABLE I

STIMULI FOR TEST I

TEMPORAL AND SPECTRAL COMBINATIONS

STIMULI	TEMPORAL[1] PATTERN	DURATION[2] 20dB	SPECTRA[3] SHAPE
1	A	20 Sec.	V
2	A	20 Sec.	W
3	A	20 Sec.	X
4	A	20 Sec.	Y
5	A	20 Sec.	Z
6	B	16 Sec.	V
7	B	16 Sec.	W
8	B	16 Sec.	X
9	B	16 Sec.	Y
10	B	16 Sec.	Z
11	C	30 Sec.	V
12	C	30 Sec.	W
13	C	30 Sec.	X
14	C	30 Sec.	Y
15	C	30 Sec.	Z
16	D	30 Sec.	V
17	D	30 Sec.	W
18	D	30 Sec.	X
19	D	30 Sec.	Y
20	D	30 Sec.	Z
21	E	14 Sec.	V
22	E	14 Sec.	W
23	E	14 Sec.	X
24	E	14 Sec.	Y
25	E	14 Sec.	Z
26	F	10 Sec.	V
27	F	10 Sec.	W
28	F	10 Sec.	X
29	F	10 Sec.	Y
30	F	10 Sec.	Z
STD	A	20 Sec.	Z

1. Refer to Figure 2
2. Duration is amount of time the signal is within 20dB of maximum level; the duration is always 10 seconds when the signal is within 10 dB of maximum level.
3. Refer to Figure 1.

TABLE II

STIMULI FOR TEST II

TEMPORAL AND SPECTRAL COMBINATIONS

STIMULI	TEMPORAL[1] PATTERN	DURATION[4] 10dB	20dB	SPECTRA[5] SHAPE
1	A	1.0	2.0	Z
2	A	1.0	2.0	X
3	E	1.0	1.4	X
4	F	1.0	1.0	X
5	A	4.0	8.0	Z
6	A	4.0	8.0	X
7	E	4.0	5.6	X
8	A	10.0	20.0	Z
9	A	10.0	20.0	X
10	E	10.0	14.0	X
11	F	10.0	10.0	X
12	A	20.0	40.0	Z
13	A	20.0	40.0	X
14	E	20.0	28.0	X
15	A	100.0	200.0	Z
16	A	100.0	200.0	X
17	E	100.0	140.0	X
18	F	100.0	100.0	X
19	F/O[2]	15.0	26.0	X
20	SPEC.[3]	9.0	10.0	X
STD	A	10.0	20.0	Z

1. Refer to Figure 2

2. Flyover: refer to "STD" Table III

3. Special trapezoidal time pattern with duration at the 10dB down points equal to 9 seconds; at the 20dB down points it is equal to 10 seconds.

4. Duration is the amount of time the signal is within 10dB or 20dB of maximum level.

5. Refer to Figure 1

TABLE III

STIMULI FOR TEST III

TEMPORAL AND SPECTRAL COMBINATIONS

STIMULI	TYPE OF AIRCRAFT	TAKE-OFF OR LANDING	ALTITUDE		DURATION[5] 10dB	20dB
1	Boeing 720 TJ[1]	T	370	Ft.	6	10
2	Douglas DC-8 TJ	T	1020	Ft.	11	20
3	Boeing 707B TF[2]	L	545	Ft.	5	10
4	Boeing 720B TF	L	---	Ft.	5	8
5	Boeing 720B TF	L	465	Ft.	6	9
6	Boeing 707B TF	L	---	Ft.	6	9
7	Boeing 727 TF	L	500	Ft.	5	10
8	Douglas DC-9 TF	T	---	Ft.	10	18
9	Douglas DC-8 TF	T	1580	Ft.	18	36
10	Douglas DC-9 TF	T	1240	Ft.	15	26
11	Lockheed Elect. TP[3]	T	1720	Ft.	10	24
12	Fairchild F-27 TP	T	1300	Ft.	9	21
13	Douglas DC-8 TJ				9	16
14	Boeing 707 TJ				14	30
15	Boeing 727 TF				9	18
16	Boeing 720B TF				8	20
17	Douglas DC-8:10 TJ				16	34
18	Vertol CH-46#1 H[4]				3	7
19	Sikorsky CH-34#3 H				5	20
20	Sikorsky CH-34#1 H		2220	Ft.	14	28
STD	Douglas DC-9 TF	T	1240	Ft.	15	26

1. Turbo-Jet

2. Turbo-Fan

3. Turbo-Prop

4. Helicopter

5. Duration is the amount of time the signal is within 10dB or 20dB of maximum level.

III. RESULTS

Upon the completion of a series of judgments for each subject, the computer prints out a relative gain setting for the comparison signal. This gain setting represents the level (±1.5) at which the subject judged the comparison and standard stimuli to be equally noisy. Averaging the gain setting across all subjects for each stimulus provides a number which is used to determine the overall sound pressure level, A-level, perceived noise level, etc. that is judged equal to the standard. Definitions of the prediction measures utilized in the analyses of the judgment test results are shown in Table IV and V with further details of the calculation procedures included in Appendix E. Test results for each stimulus are given in terms of various measures in Appendix F.

A. Test I

The results of Test I are plotted as a function of duration as shown in Figure 3. It is noted in the top frame of the figure that the data with the PNL measurement procedure applied does not exhibit a great deal of variation as the duration ranges from 14 to 30 seconds. However, there is a noticable increase in the perceived noise level as the duration moves from 10 to 14 seconds. The relatively low perceived noise level at 10 seconds indicates that the subjects felt the stimuli with that duration and time pattern were noisier than the other stimuli. This increased perceived noisiness may be due to a startle effect, i.e., the particular time pattern associated with the 10 second duration (temporal pattern F) reaches the maximum level in 100 milliseconds whereas all of the other stimuli reach their maximum level more gradually (in one second or longer).

In the middle part of Figure 3, a tone correction has been applied to the data, which appears to decrease the

TABLE IV

DEFINITIONS OF NOISE MEASUREMENTS

EMPLOYED IN JUDGMENT TEST ANALYSIS*

OASPL	Overall sound pressure level in dB re 0.0002 μ bar.
AL	A-weighted sound pressure level.
NL	N-weighted sound pressure level equivalent to D-weighted sound pressure plus 7dB (Ref. 7).
PNL	Perceived noise level calculated in accordance with proposed ISO Standard (Ref. 6).
PNL_C	Perceived noise level calculated from maximum one-third octave band measurements.
PNLT	Perceived noise level with some type of tone correction (PNL + T).
PNLD	Perceived noise level with some type of duration correction (PNL + D).
EPNL	Effective perceived noise level, PNL with some type of tone and duration correction.

* Further information on some of the measures appear in Appendix E.

TABLE V

DEFINITION OF SUBSCRIPTS FOR TONE & DURATION

CORRECTIONS USED WITH VARIOUS MEASUREMENT SCHEMES

CORRECTION TYPE	SUBSCRIPT	EXAMPLE	DEFINITION
General	C	PNL_C	Spectrum is composite of maximum RMS one-third octave band sound pressure levels.
Tone	KP	$PNLT_{KP}$	Kryter-Pearsons tone correction method (Ref. 8).
Tone	F	$PNLT_F$	FAA tone correction method (Ref. 6).
Duration	10	$PNLD_{10}$	Duration within 10dB of maximum RMS level.
Duration	20	$PNLD_{20}$	Duration within 20dB of maximum RMS level.
Duration	I10	$PNLD_{I10}$	Integration of levels within 10dB of maximum RMS level.
Duration	I20	$PNLD_{I20}$	Integration of levels within 20dB of maximum RMS level.

The use of any measure preceded by an "E" (e.g. EPNL, EAL, etc.) implies the incorporation of some type of tone and duration measure.

Further details regarding tone and duration corrections are given in Appendix E.

variance among the stimuli of a given duration. However, for the values at 10 seconds the tone correction does not appreciably raise their average perceived noise level. If both a tone and a duration correction are added, as in the bottom frame of Figure 3, the 10 second duration samples are brought closer in level to the other samples used in the test. This indicates that the duration correction is accounting somewhat for the increased noisiness of the 10 second samples.

In order to provide some idea of the repeatability of the subjects' judgments over time, seven subjects were asked to make second judgments at a later time, on one of the stimuli. The results from the repeated trials were subtracted from the results for the first trials for each participant. Averaging across subjects, the data yielded a mean difference in judgments of 0 dB, with a standard deviation of 5.2 dB.

Let us now take a more detailed look at the various prediction measures which are used to correct for the spectral shape of the sound samples. Figures 4 and 5 show a plot of the Test I results as a function of the five spectral measures for the six temporal patterns.

The ordinate of these and subsequent graphs is labelled "Level of Comparison in dB (PNdB) re Standard". This simply means that the level of the standard stimulus was subtracted from the level of the comparison stimulus at judged equality and the result plotted for the various measurement schemes. It is as if we had labelled the standard line in Figure 3 at 0 dB and adjusted the values of the other points on the graph accordingly. Since any predictor of judged noisiness would hopefully be one that exhibited the same value for tw signals which were judged equally noisy, it may be said that a good predictor is one whose results cluster about the zero line (i.e., provides a value closer to the value of the standard). Thus, for

Figures 4, 5, and 6, the smaller the range of data the better the noisiness predictor for the various temporal and spectral patterns employed in Test I.

It is noted in Figures 4 and 5 by the large spread in the data for time patterns A through F that overall sound pressure level (OASPL) does not do a particularly good job of predicting the judged noisiness for these stimuli, i.e., it consistently exhibits the greatest range as compared to the other measures employed. Some reduction in spread is gained with various weighting networks such as those indicated by the A and N levels with NL showing a smaller range than AL. However, the greatest improvement is attained with the tone corrected perceived noise level as suggested by FAA ($PNLT_F$). The Kryter-Pearsons tone correction method ($PNLT_{CKP}$) provides a good measure of noisiness for all of the spectral samples except spectral pattern Y. This stimulus had a strong tone at 4000 Hz which was the dominate feature of that particular noise spectra. It would appear that the $PNLT_{CKP}$ overcorrects for the noisiness due to this tone. That is, it provides a level which is greater than the level of the standard at judged equality.

All of the measurement schemes underestimate the noisiness of stimuli in temporal pattern F; thus, indicating the need for some additional correction. This same effect was seen in Figure 3 as the 10 second stimulus results.

To illustrate the magnitude of the relative noisiness predicability of the various measurement schemes, we note the ranges for the data using time pattern D. The least accurate measure is OASPL with a range of 12 dB. AL follows with a range of 10.5 dB; NL is an improvement with 6.5 dB. PNL_C and PNL both have a range of 5 dB. The reason these two measures yield practically identical results is because the samples are taken from temporally shaped steady state noise and thus the relative spectra is constant as a function of time. The range of $PNLT_{CKP}$ is also 5 dB but the results are clustered closer to the standard (zero line) than the previous non-tone corrected PNL measures. The greatest improvement is $PNLT_F$ with a range of only 3.5 dB, thus achieving a reduction in range of 7.0 dB from AL.

Figure 6 shows a comparison of the various duration correction methods. The types of prediction schemes for this test include perceived noise level with no duration correction (PNL), perceived noise level with a duration correction determined from 10- and 20-dB down measurements ($PNLD_{10}$, $PNLD_{20}$) and an integrated correction $PNLD_{I10}$. $PNLD_{I20}$ was also calculated but it is not presented since the results were very close to those for $PNLD_{I10}$. The reason for such close agreement is that most of the energy is contained within the time the signal is within 10 dB of the maximum level. For all of the spectra in this judgment test, the smallest spread and thus the best measure is found for the integrated duration correction procedure. There appears to be little difference in range between the perceived noise level without a duration correction and that using the 10-dB-down correction procedure. This is because the samples in the test were all chosen to have about the same duration when measured 10-dB-down from the maximum level. Actually, after the addition of a duration correction for 20-dB-down duration, as in $PNLD_{20}$, the measure became a less accurate predictor.

To illustrate the magnitudes of these effects, we note for sound spectrum V that PNL has a range of 5 PNdB. By adding a 10 log duration correction, the range is increased to 6 PNdB for $PNLD_{10}$ and 8 PNdB for $PNLD_{20}$. In both cases the noisiness predictability becomes less accurate. By adding the integration correction in $PNLD_{I10}$, the range is reduced to 3 dB, an overall improvement of 2 dB over the PNL measure without a duration correction.

It has been shown that between the measures, $PNLT_F$ provides the best spectral measure and $PNLD_{I10}$ proves to be the best duration measure. A logical progression would be to examine the outcome of a combination of tone and duration measures. Figure 7 illustrates these combinations and the difference between them and other measurement techniques. This figure (like Figures 10 and 11 for Test I and II respectively) shows the total range, the 75% range (this is the range from the standard within which 75% of the data lies), the mean, and standard deviation of the comparison relative to the standard. Table F-IV in Appendix F gives a detailed account of the statistical results for all the measurement procedures used in Test I through III.

Many familiar and some new innovative measurement procedures were applied to the data of all three tests. The particular rank ordering of these measures was designed to show their relationship to each other from the poorest to the best predictor of judged noisiness. Thus, the least accurate measures (OASPL, AL) appear on the left and the most accurate prediction measures ($EPNL_{FI10}$, $EPNL_{F10}$) appear on the right hand side of the graph. It is first seen in Figure 7 that the most accurate measures are those which incorporate both a tone and a duration correction. In particular, the FAA tone correction and an integrated measure of duration appear to provide the smallest standard deviation (2 dB) as contrasted to that of OASPL and AL (4.5 dB).

The mean of the comparison relative to the standard (mean difference) at judged equality is also an important factor in determining an accurate estimator of noisiness. That is, even though the spread in the data is small, the mean difference between the comparison and standard levels must also be small. Thus, AL with a mean of 0.5 dB is an improvement over OASPL with a mean of 4.0 dB even though the standard deviations (4.5 dB) of the two measures are identical. The measures which appear on the right side of Figure 7 are among those with the smallest mean differences which again provides an indication that they are among the more reliable measures of judged noisiness.

Although the mean and standard deviation are the classical ways of expressing the spread and central tendency of data, they must be used together in order to provide the necessary information for determining the best predictor of noisiness. It would be desirable to have a single measure which would incorporate the philosophy of both the mean and standard deviation measures. A relatively simple measure that is purposed to meet these requirements is the range (in dB) from the level of the standard which includes 75% of the data. This measure is indicated on Figure 7 by the shaded area. The number then, for a given measure in the row labelled "75% range" in Table F-IV, is the comparison level range from the standard below which 75% of the data lies or conversely, above which 25% of the data lies. Using the 75% range to rank order the noisiness predictability of the various integrated duration and tone corrected measures ($EPNL_{F10}$, $EPNL_{F20}$, $EPNL_{FI10}$, $EPNL_{FI20}$) appears to do the best job. To illustrate, the 75% range is 2.5 dB for $EPNL_{FI10}$, while for OASPL and AL it is 8.5 and 5.0 dB respectively. NL_{I10} with 4 dB is an improvement of 2 dB over AL_{I10} which has 6 dB. The 75% range of the other measures varies from [illegible] to 5.5 dB which suggests that both a tone and duration correction should be employed for maximum noisiness prediction reliability.

B. Test II

Test II was concerned with exploring the effects of varying duration in certain spectral and temporal patterns chosen from the stimuli in Test I. The results for Test II are plotted in Figure 8 in terms of the tone corrected perceived noise level ($PNLT_F$) as a function of 10-dB-down duration. It is quite apparent from this figure that duration has an appreciable effect on the results with the long samples being judged noisier than the short ones. Results for the long durations of 100 seconds show differences from the standard of as much as 17 dB while for short durations the difference is 10 dB. A least squares regression line is drawn through the points showing a slope of 2.6 dB per doubling which is in reasonable agreement with the 3 dB per doubling slope associated with the equal energy concept noted in a previous report (Ref.9). The single point at 15 seconds represents the result for the recorded flyover stimulus. This result would suggest that people do not find the flyover as annoying as the broadband noise although it is difficult to draw any conclusions from this single measurement.

The samples with an "F" time pattern and an "X" spectra (stimuli FX) follow about the same slope but are lower in level than the other data in Figure 8. At 10 second duration, for example, it is about 6 dB lower than the average of the results for the three other samples. Possibly, this is due to some "startle effect" associated with the fast rise of the signal. However, the point at the nine second duration is a modification of the "F" temporal pattern with a one second rise time instead of a 100 millisecond rise time and the result, although closer to the standard, is only closer by 1.5 dB.

To show the effect of a duration correction, the results of Test II are plotted in Figure 9 using $EPNL_{FI10}$ as the measure. These results do not vary as dramatically with duration as those in Figure 8; thus indicating that the duration effect depicted in the previous figure has been accounted for by the $EPNL_{FI10}$ measure. In general, however, this prediction undercorrects for the judged noisiness of the stimuli. This is particularly noticeable for the FX stimuli which lies 5.5 dB below the standard regardless of duration, thus supporting the phenomena attributed to the "startle effect" as discussed regarding Figure 8. It is also noted that the AZ stimuli is particularly low (6.5 dB lower than the standard) at the one second duration. It was originally thought that this might be associated with the same "startle" phenomena but a sample with an identical time pattern (AX) did not exhibit such a low value (it was only 0.5 dB lower than the standard).

Another possible explanation is that people may not have wanted to listen to the necessary high level for the short duration sounds (the short duration sample would have been judged 10 dB higher (i.e. 92 dB, OASPL) than the standard signal, and therefore biased their results somewhat by stating that the short duration sound was noisier before it had reached maximum level. This hypothesis was examined by holding the normally varied signal constant and varying the standard signal. The results of that examination indicated that the level of the AZ stimulus would be raised 2.5 dB over the results obtained when the standard was the fixed stimulus as opposed to being the variable stimulus. If this "correction" of 2.5 dB were applied to the AZ stimulus result at one second, it would bring the judged level closer to the standard. This suggests that equipment range limitation is at least partially responsible for the low value of the AZ stimulus. (Since no other stimulus needed to be raised as high for judged equality to the standard, this limitation did not affect the results for the other stimuli.)

In comparing other noisiness prediction measures, as shown in Figure 10, it may be noted that there is a great difference between the uncorrected measures such as A-level and perceived noise level as compared to the tone and duration correction measures of EPNL. This can be attributed to the very large duration corrections necessary for the stimuli. The most accurate measures again are those which use a correction for both tone and duration, with both types of tone corrections ("F" and "KP") and both types of duration corrections ("I10" and "10") doing an equivalent job. To illustrate the improvement, note that the standard deviation for AL, NL, and PNL are 7.5 dB while for $EPNL_{FI10}$ and $EPNL_{CKP10}$ the standard deviation drops 5 dB to approximately 2.5 dB. Also, 75% of the data lies within 9 dB of the standard for AL and NL but is reduced to 4 dB and 4.5 dB respectively for $EPNL_{FI10}$ and $EPNL_{CKP10}$.

C. Test III

The stimuli for Test III consisted of recordings of various types of aircraft flyovers. The analysis showed that there were not large individual differences between the various types such as helicopter, turbofan, turbojet or turboprop. Therefore, the results are presented in summary form in Figure 11 enabling comparison of the same prediction measures that were used in the previous two tests. Although OASPL is by far the least accurate of the prediction measures, there is not a large difference between the other measures in predicting judged noisiness. For example, the standard deviation of OASPL is 4.5 dB while for all other measurement schemes it varies between 1.5 dB and 2.5 dB. The 75% range shown in Figure 11 provides a somewhat more observable discrimination between measures. For OASPL, 75% of the data fall within 8.5 dB of the standard; for AL_{I10} and AL the values are 4.5 dB. The best predictors are the tone and integrated duration correction measures ($EPNL_{F10}$, $EPNL_{F20}$, $EPNL_{FI10}$, $EPNL_{FI20}$, $EPNL_{CKP20}$) with a value of 2.5 dB. For the remaining measures the

the values for the 75% range vary slightly from 3 dB to 3.5 dB. In general, for real life flyovers most of these prediction measures do an adequate job.

For certain stimuli employed in Test III, each of the subjects was asked to repeat his judgment to provide some measure of subject repeatability in judging recorded flyover noise stimuli. These results for stimuli consisting of two turbojet (#2,#17) flyovers and a helicopter (#18) flyover yielded a mean difference of 0.3 dB across subjects (the results for the repeated stimuli were subtracted from the results taken during the first trial; the difference was averaged across subjects). Standard deviation of the differences was 5.3 dB. The standard error of the means are closely comparable for the repeated stimuli of Test I (1.9 dB) and for Test III which has a standard error of 1.2 dB.

IV. SUMMARY AND DISCUSSION

Figure 12 shows a comparison of the results of the three tests using all of the noisiness prediction measures for this study. The parameter used for comparison is the range from the standard in dB of 75% of the data. This is the same parameter that was depicted in Figures 7, 10 and 11 by the shaded area. Although the ranking of the individual measures is not completely consistent over the three tests, it appears that the best measures are $EPNL_{FI10}$, $EPNL_{FI20}$ or $EPNL_{F10}$.

Looking at the Test I results for a moment, we see that the N-level measure is 1 dB improved over the A-level measure; and further that tone corrected perceived noise level is an improvement over the uncorrected perceived noise level, e.g., 1.0 dB for $PNLT_{CKP}$ and 2.0 dB for $PNLT_F$. These findings are not as pronounced for the real life flyovers used in Test III, but it should be remembered that the test stimuli for Test I were specifically selected to show differences between the various measures which indeed accounts for the greater difference between the prediction procedures. Test II was designed to examine differences between measures corrected for duration or not corrected for duration. Since tones were employed in the stimuli as well as gross changes made in the duration of the stimuli, both a tone and duration correction were required to provide the greatest improvement in the noisiness prediction measures. However, AL_{I10} shows a 3 dB improvement over AL. This improvement was not noted for AL_{I10} in Tests I and III. The fact that Test III stimuli did not indicate large differences between the various measures does not mean that all measures are equal in their ability to predict for aircraft noises of the future. We should be guided by the results of the tests which utilized the more unusual spectra and time patterns which, as stated above, were chosen specifically to show difference between measures. On this basis, we feel that $EPNL_{FI10}$ is the most accurate measure when all of the data is evaluated using mean, standard deviation and the 75% range.

Other aspects of the tests which have not been mentioned previously include the variation of judgments across subjects and the repeatability of judgments from one test to another. The average standard deviation across subjects for each stimuli was 6.0 dB for Test I, 9.0 dB for Test II, and 5.0 dB for Test III. The reason the standard deviation across subjects in Test II is higher in contrast to the other two tests is that the judgment task was much more difficult due to extreme ranges of duration.

Some of the stimuli in Test II were the same as in Test I, in particular stimuli AZ, AX, EX and FX with 10-dB-down-durations of 10 seconds. For those subjects who participated in both Test I and Test II, it may be shown that they repeated their judgments higher by 1.5 dB, 2 dB and 1.0 dB respectively for AZ, AX and EX stimuli. For the FX stimuli the increase on repeating was 5.5 dB. The repeat for FX is higher than might be expected. Possibly there is some adaptation to the 100 millisecond rise time of the sample. The average standard deviation of the repeats is 5.8 dB for the AZ, AX, EX, and FX stimuli. The value of the average standard deviation of these repeat measurements agrees with those average standard deviations made across subjects for the three tests which suggests that people vary between one and another about as much as their own repeatability from one test to another.

The variation across the subjects' responses may be compared with those of an earlier test involving judgments of recorded helicopter noise judged equally noisy to recorded jet flyover noise (Ref.1). For that case the average standard deviation was 5.3 dB. This agreed closely with the average standard deviation across subjects for the helicopter noises in Test III (5.9 dB) or, for that matter, with an average for all of Test III stimuli (5.1 dB).

V. CONCLUSIONS

The following conclusions may be drawn as a result of the tests described in this report:

1. $EPNL_{FI10}$ is the most accurate prediction measure of judged noisiness for the unusual temporal and spectral patterns employed in this test.

2. AL and NL, although not as accurate as $EPNL_{FI10}$, are an improvement over OASPL with NL providing some improvement over AL.

3. Tone and duration corrections for PNL (PNLT and PNLD) are not as effective when used separately as when used in combination (EPNL).

4. For samples of flyover noise employed in this test, most measures including PNL or NL agree closely with $EPNL_{FI10}$ in noisiness predictability but for possible unusual time patterns of future aircraft noise $EPNL_{FI10}$ is recommended.

5. To improve the ability of EPNL to predict judgments of noisiness, some scheme should be explored which would provide a correction to account for the increased noisiness (5 dB) of sounds with sudden onsets.

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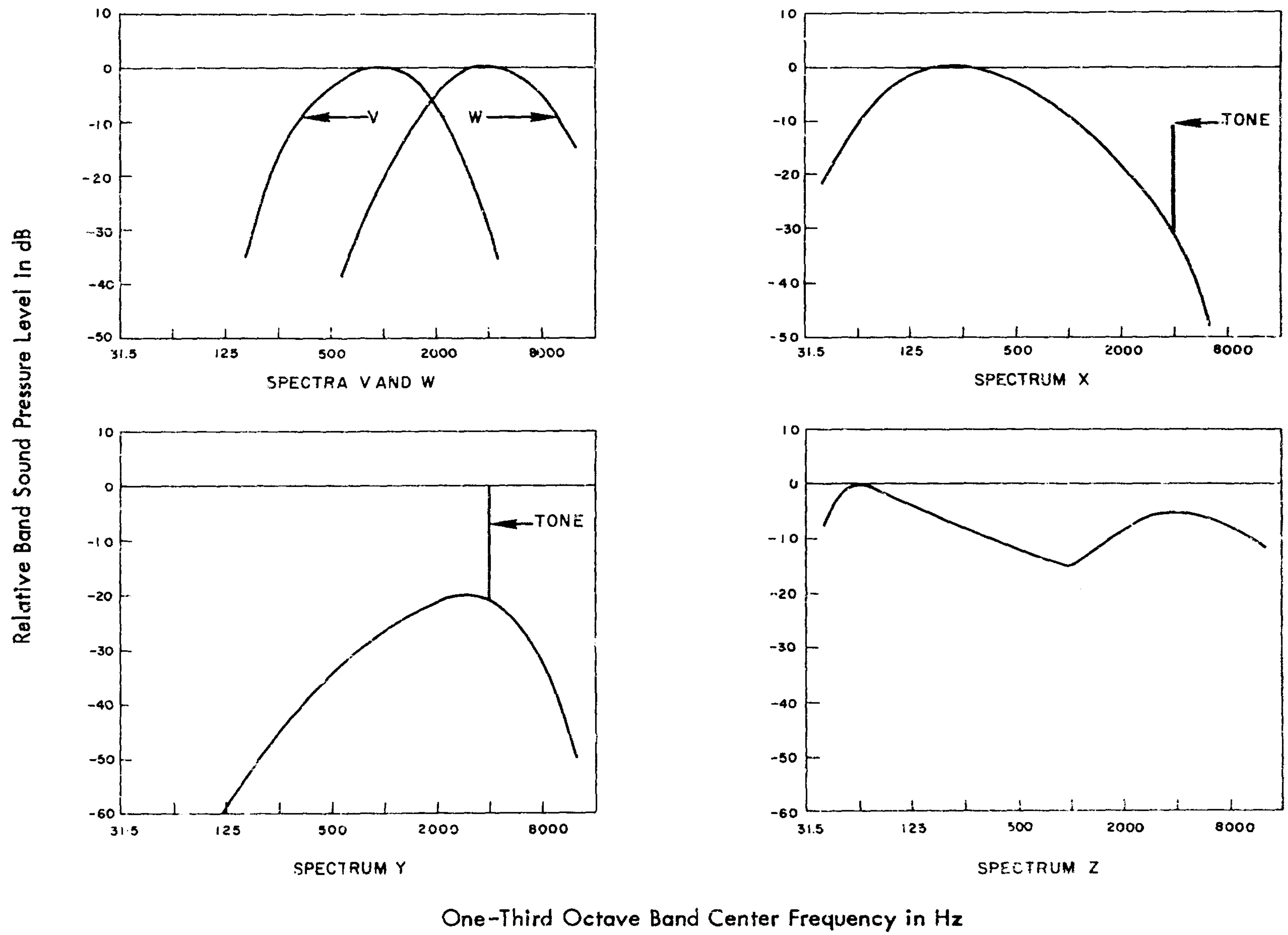

FIGURE 1. SPECTRA OF STIMULI EMPLOYED IN JUDGMENT TESTS

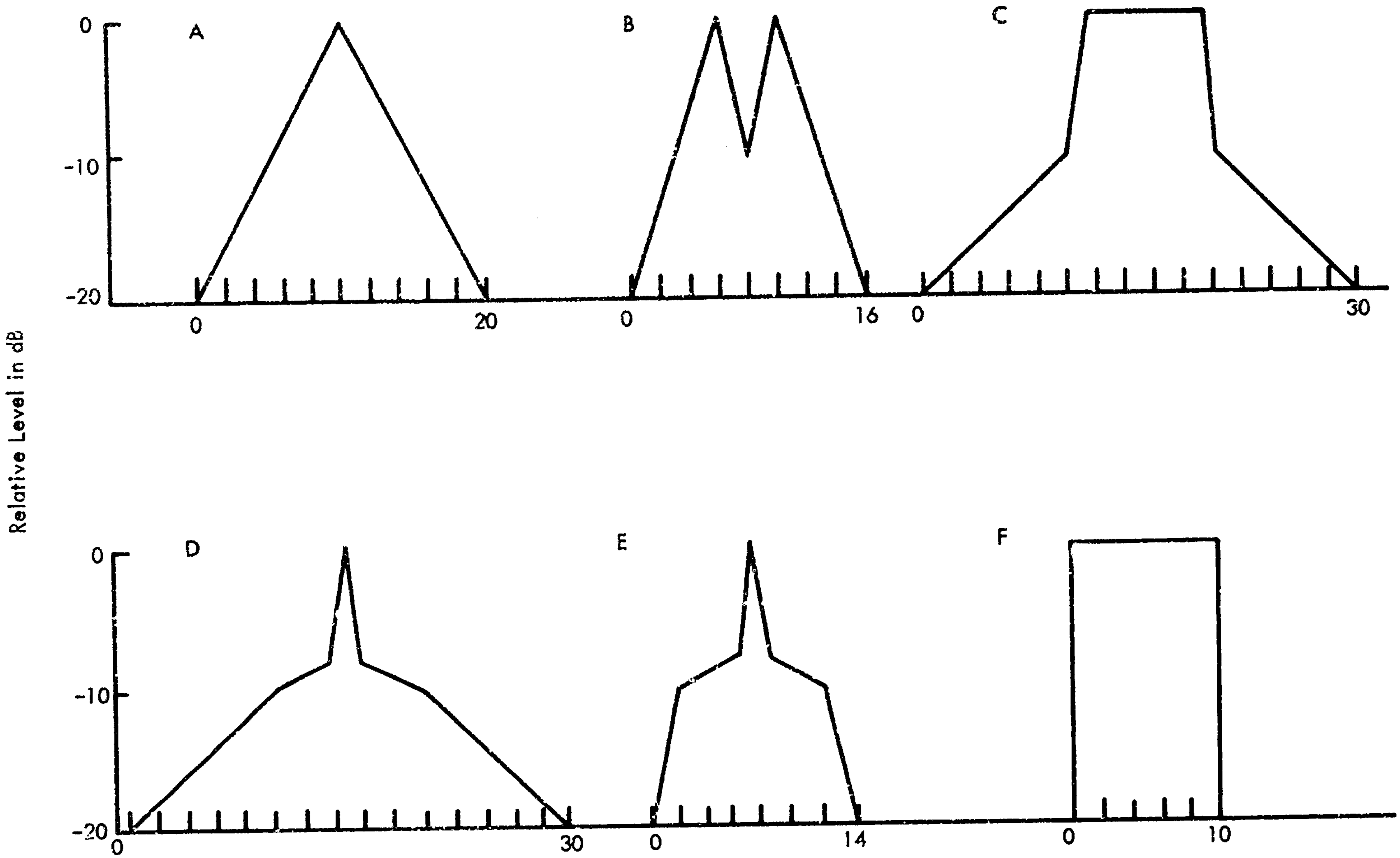

FIGURE 2. TEMPORAL PATTERNS OF STIMULI EMPLOYED IN JUDGMENT TESTS

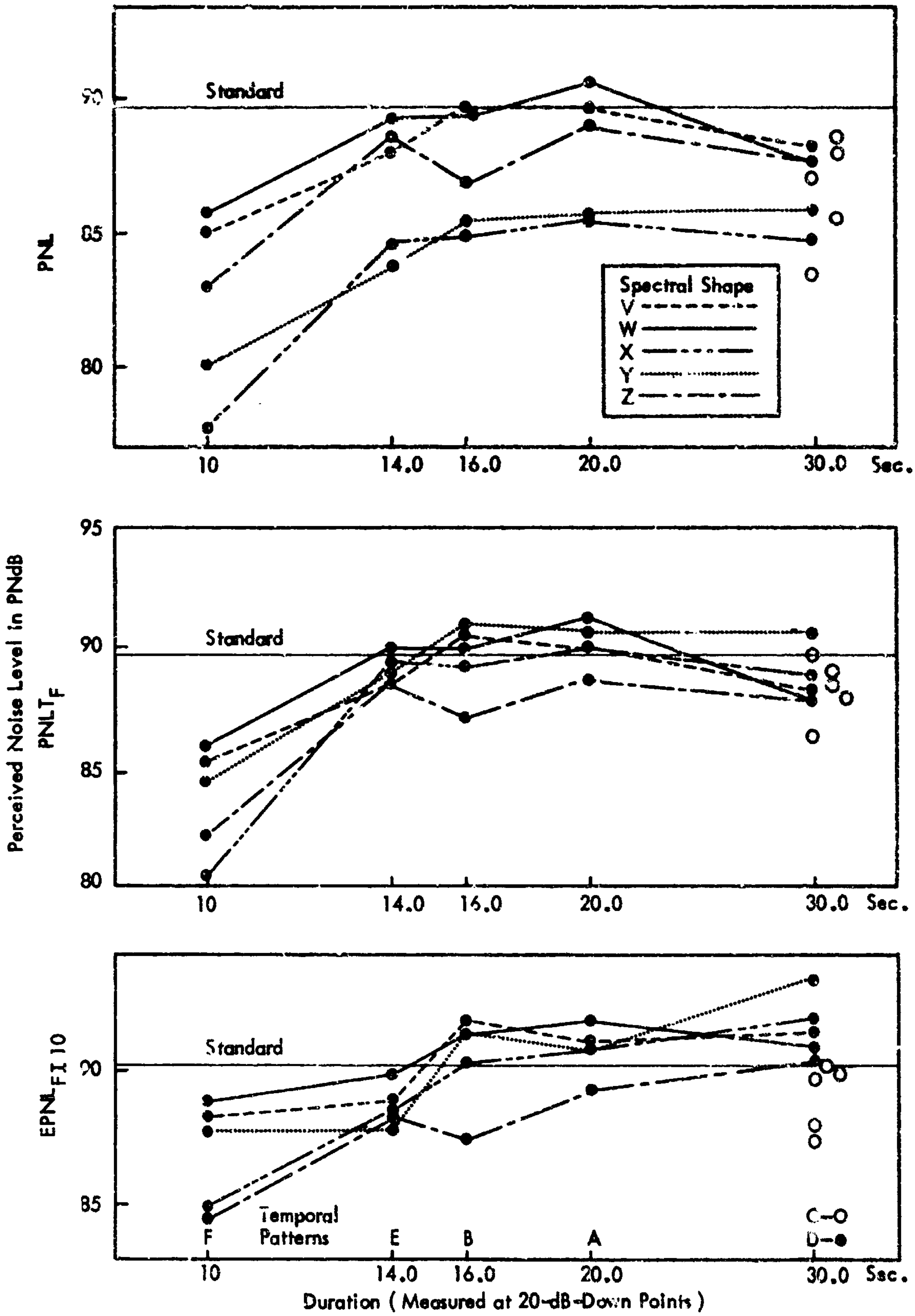

FIGURE 3 . TEST I RESULTS AS A FUNCTION OF DURATION FOR PNL, $PNLT_F$, AND $EPNL_{FI10}$ - STIMULI JUDGED EQUAL IN NOISINESS TO STANDARD

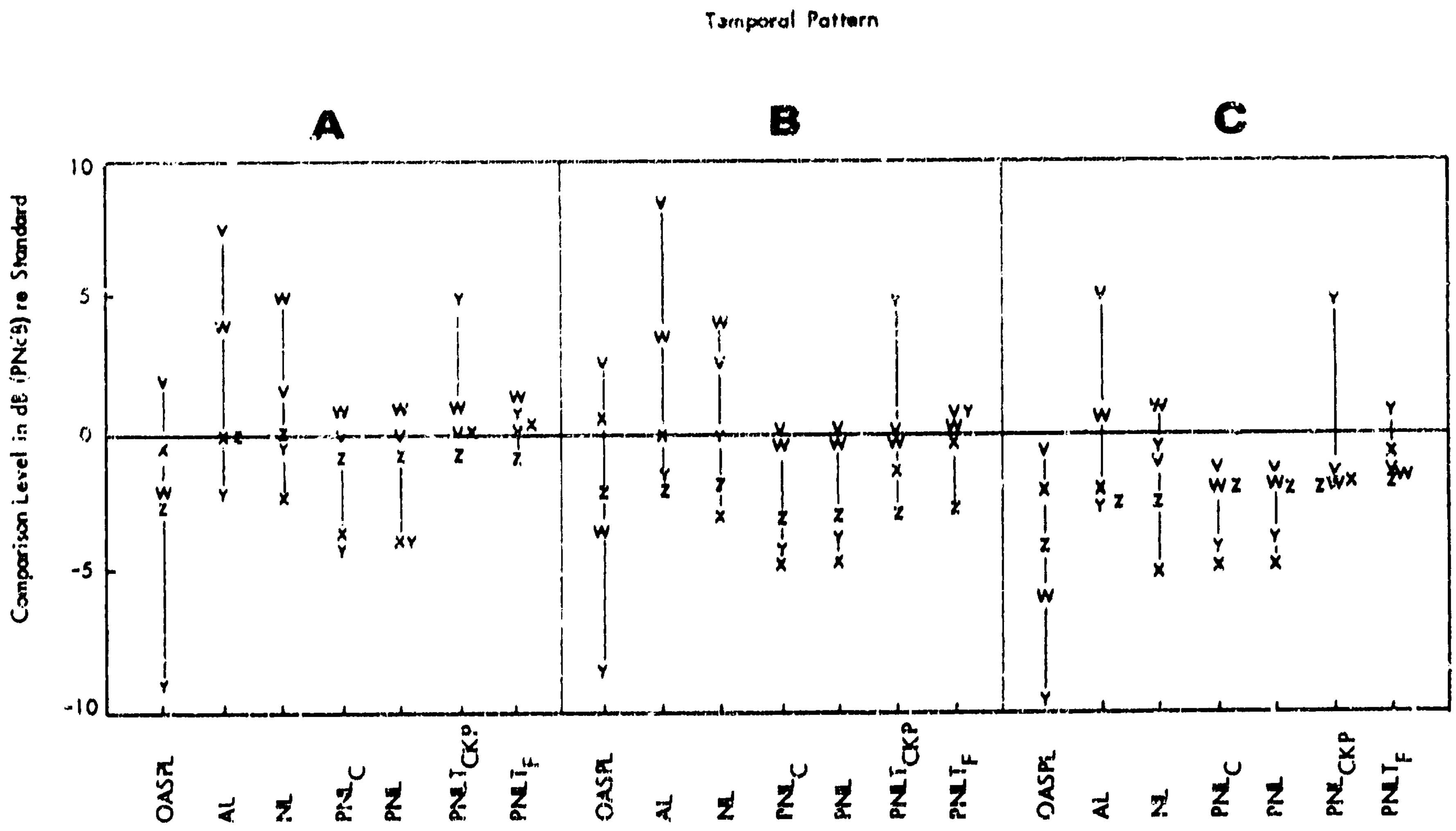

FIGURE 4. RESULTS (TEMPORAL PATTERNS A, B, C) EMPLOYING VARIOUS SPECTRAL MEASURES -STIMULI JUDGED EQUAL IN NOISINESS TO STANDARD TEST I

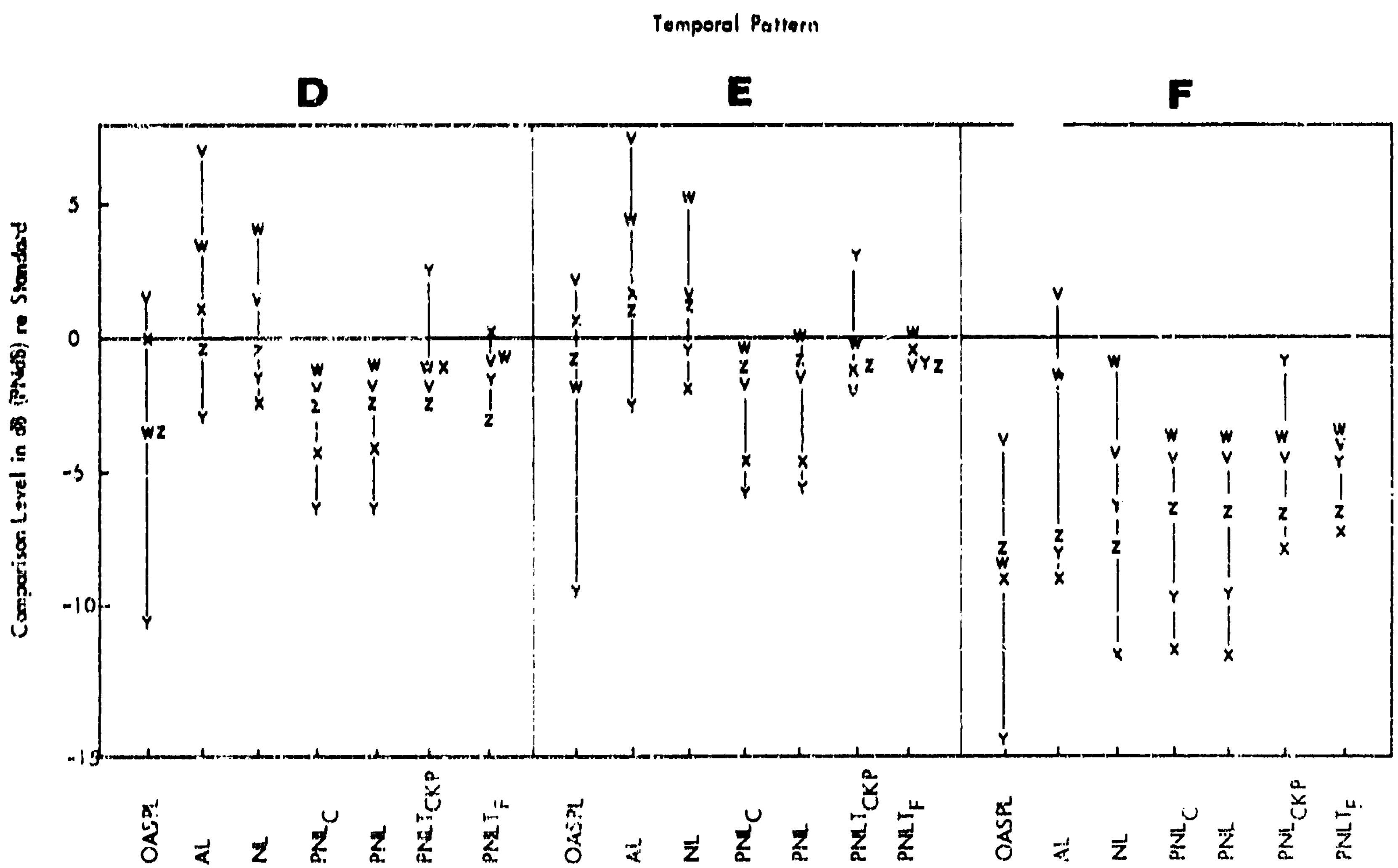

FIGURE 5. RESULTS (TEMPORAL PATTERNS D, E, F) EMPLOYING VARIOUS SPECTRAL MEASURES
-STIMULI JUDGED EQUAL IN NOISINESS TO STANDARD
TEST I

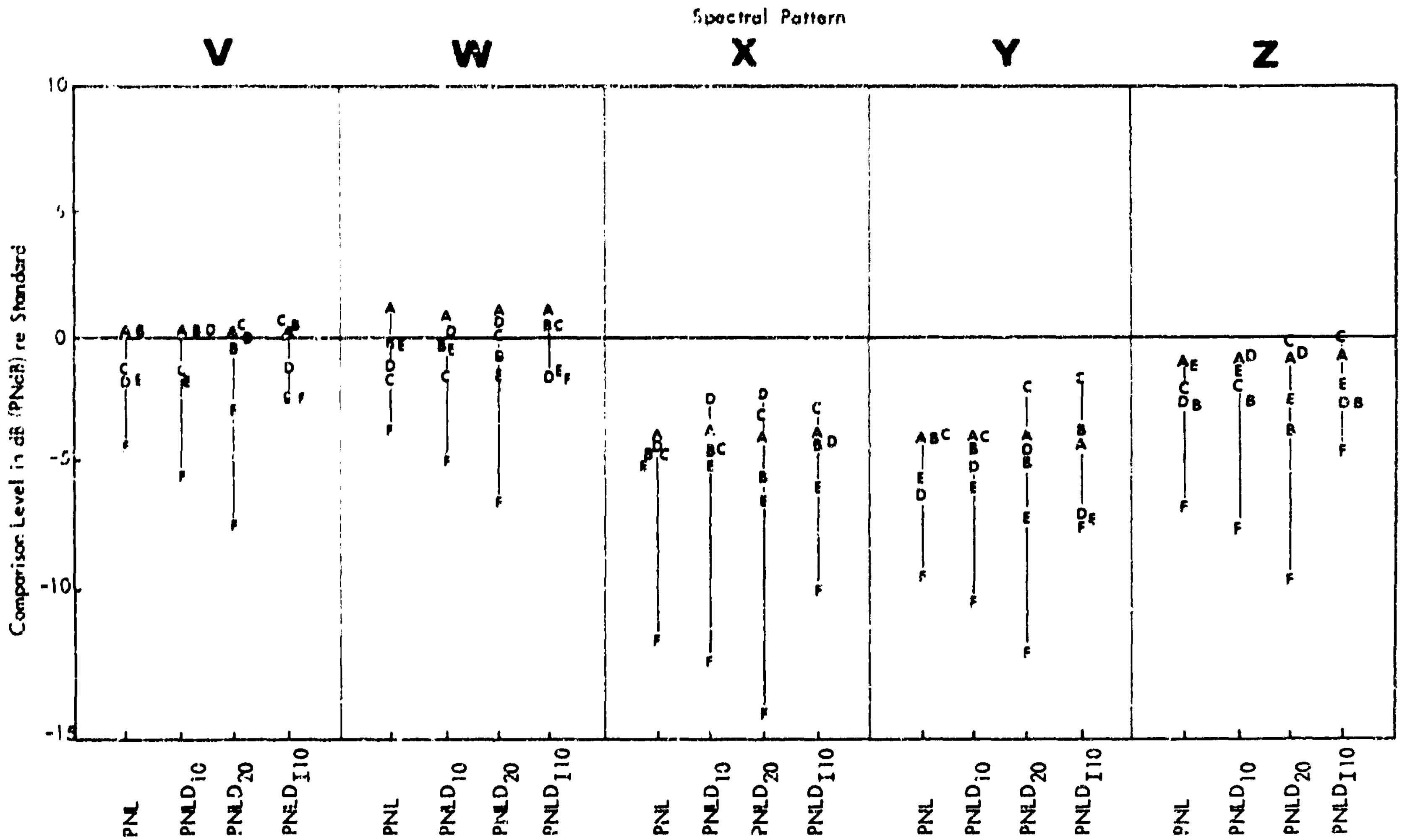

FIGURE 6. TEST I RESULTS EMPLOYING VARIOUS DURATION CORRECTION MEASURES -STIMULI JUDGED EQUAL IN NOISINESS TO STANDARD

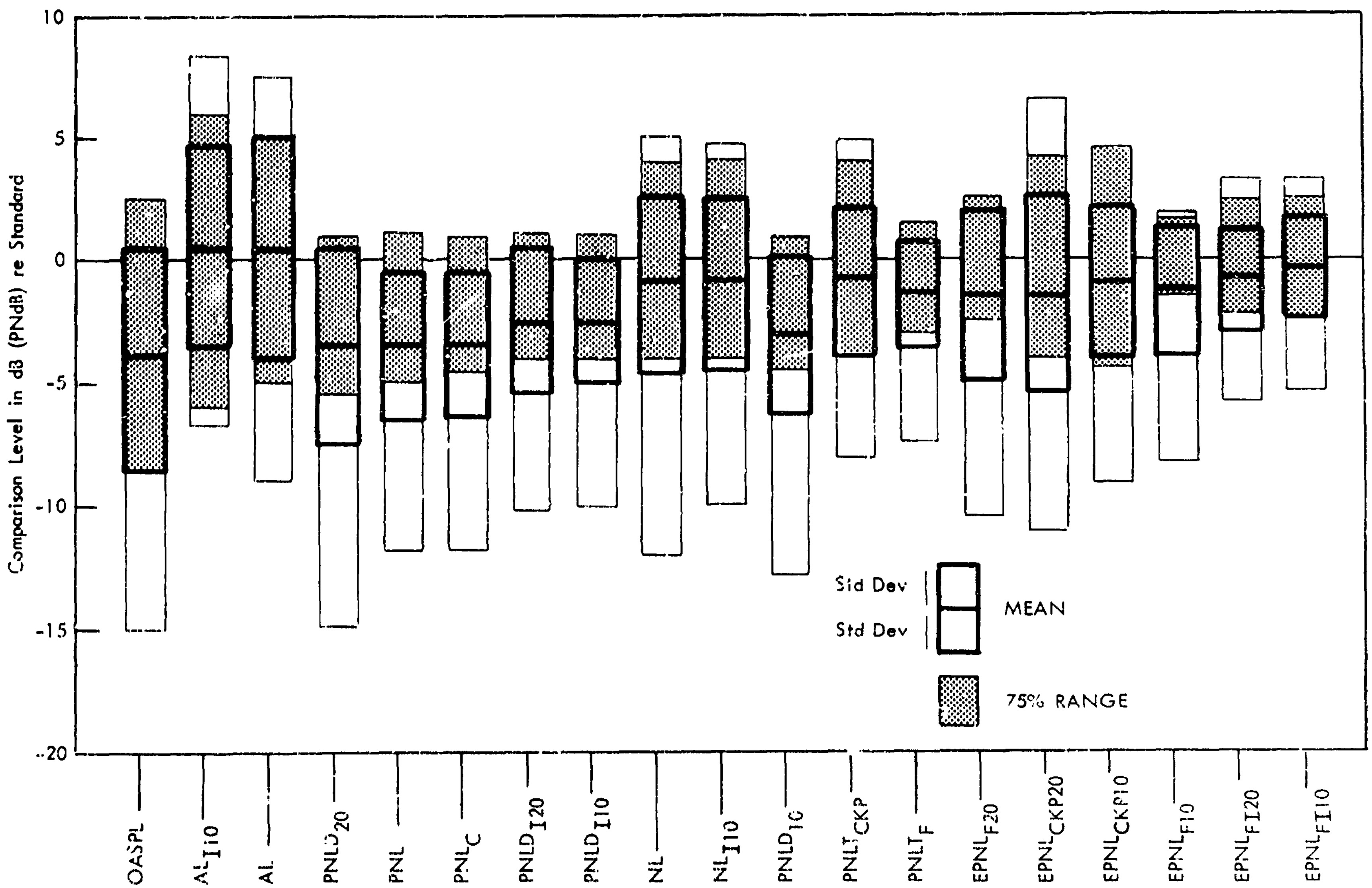

FIGURE 7. COMPARISON OF VARIOUS MEASURES FOR RESULTS OF TEST I

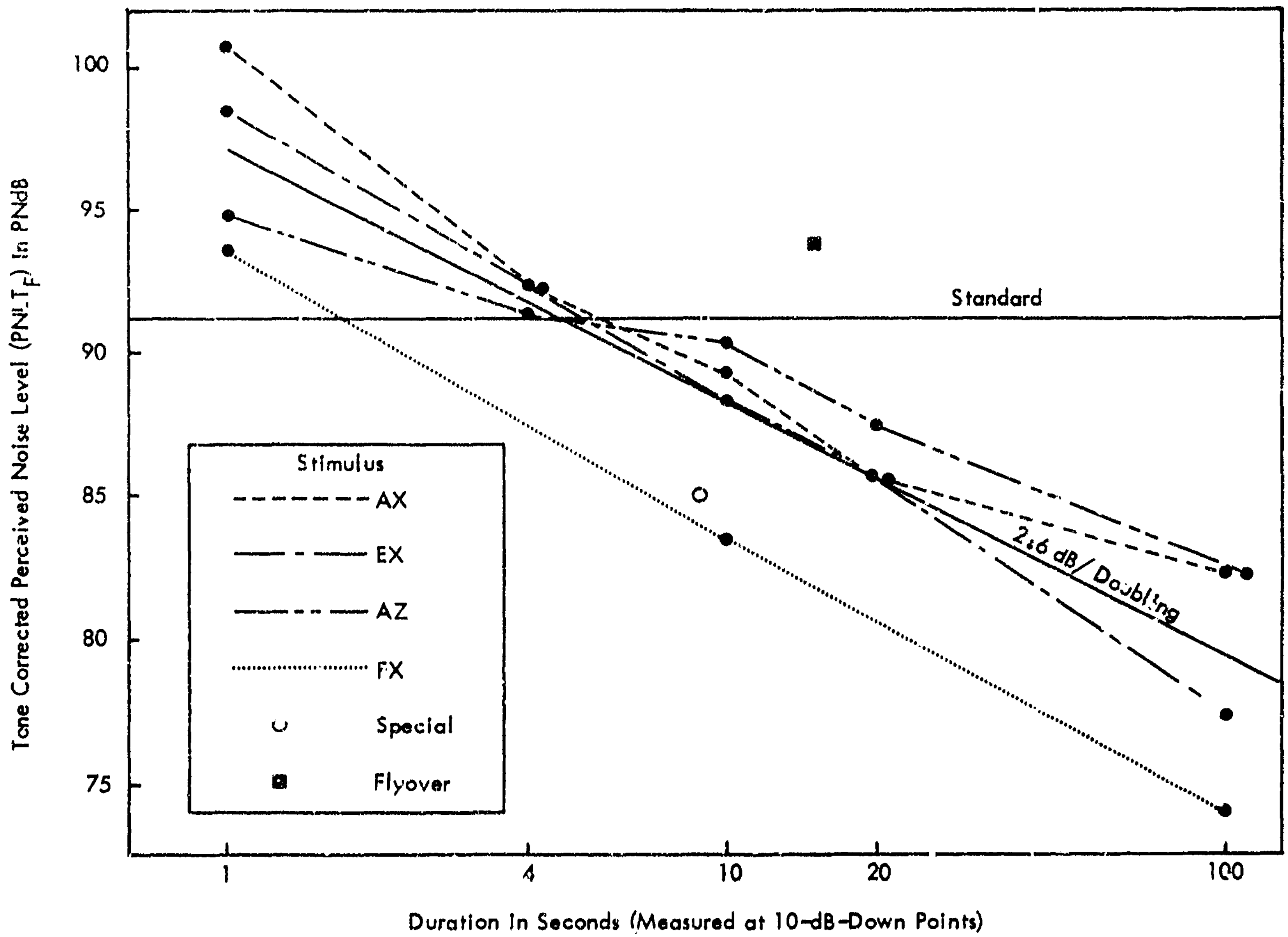

FIGURE 8. TEST II RESULTS AS A FUNCTION OF DURATION FOR $PNLT_F$

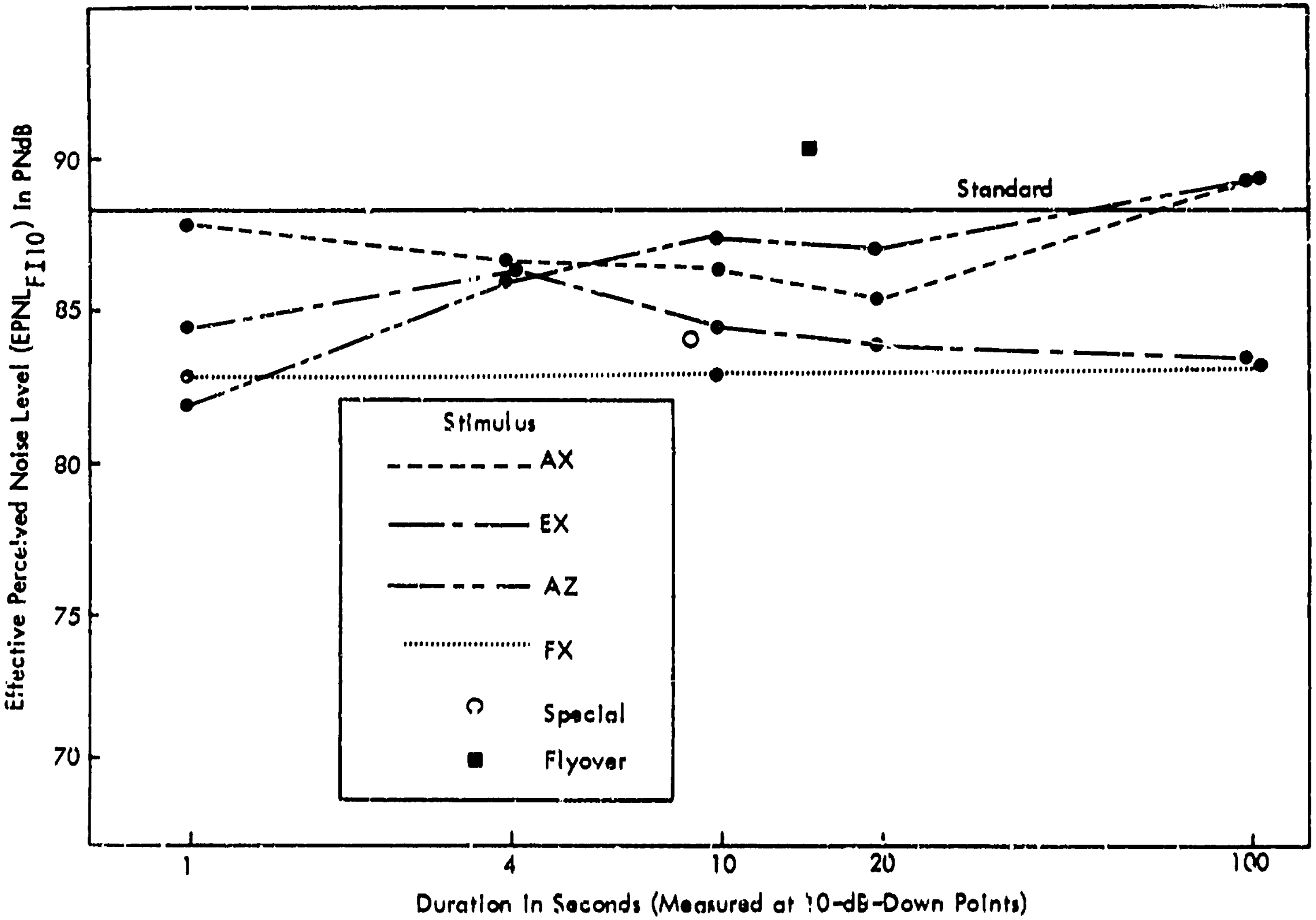

FIGURE 9. TEST II RESULTS AS A FUNCTION OF DURATION FOR $EPNL_{F\,I\,10}$

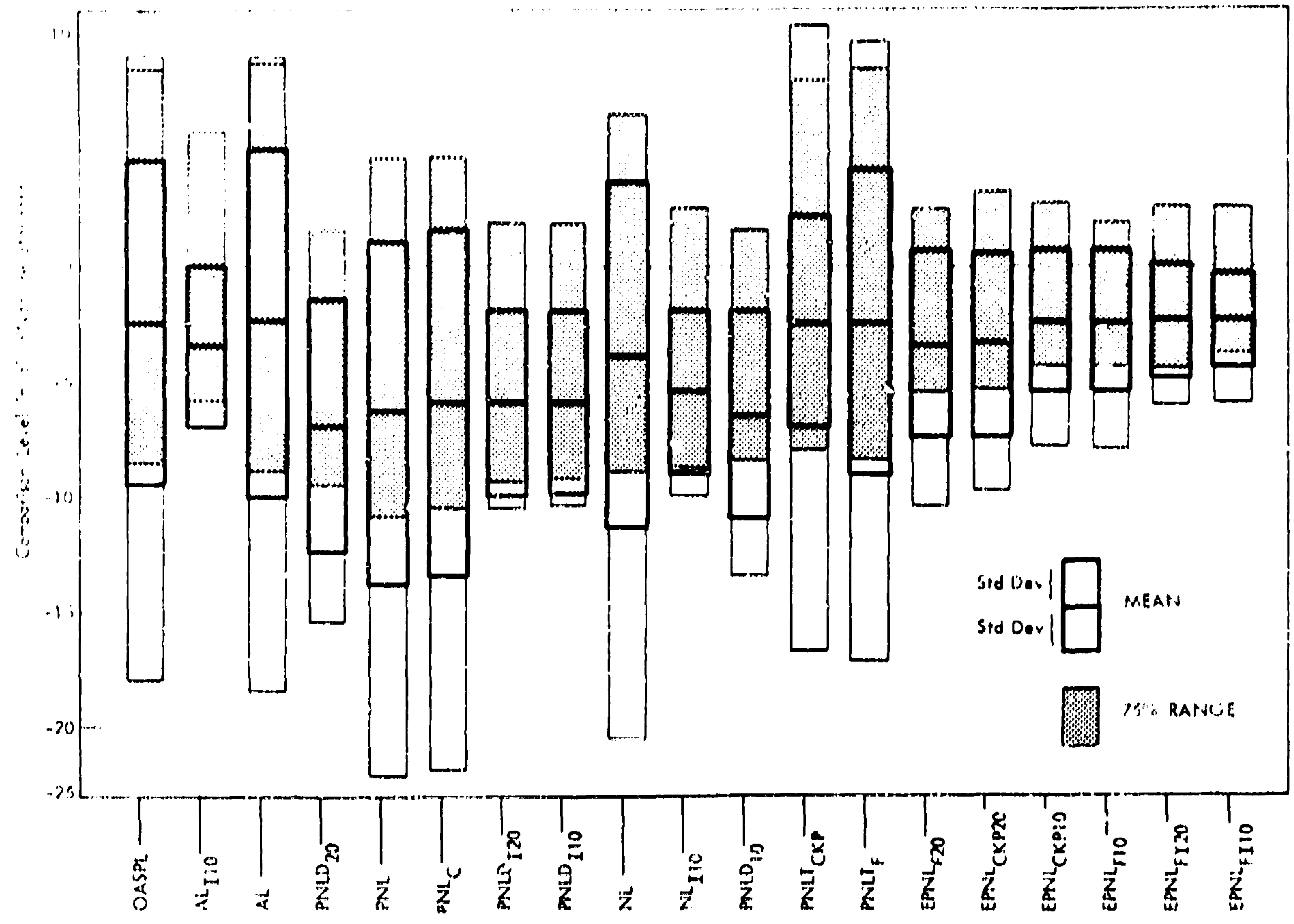

FIGURE 10. COMPARISON OF VARIOUS MEASURES FOR RESULTS OF TEST II

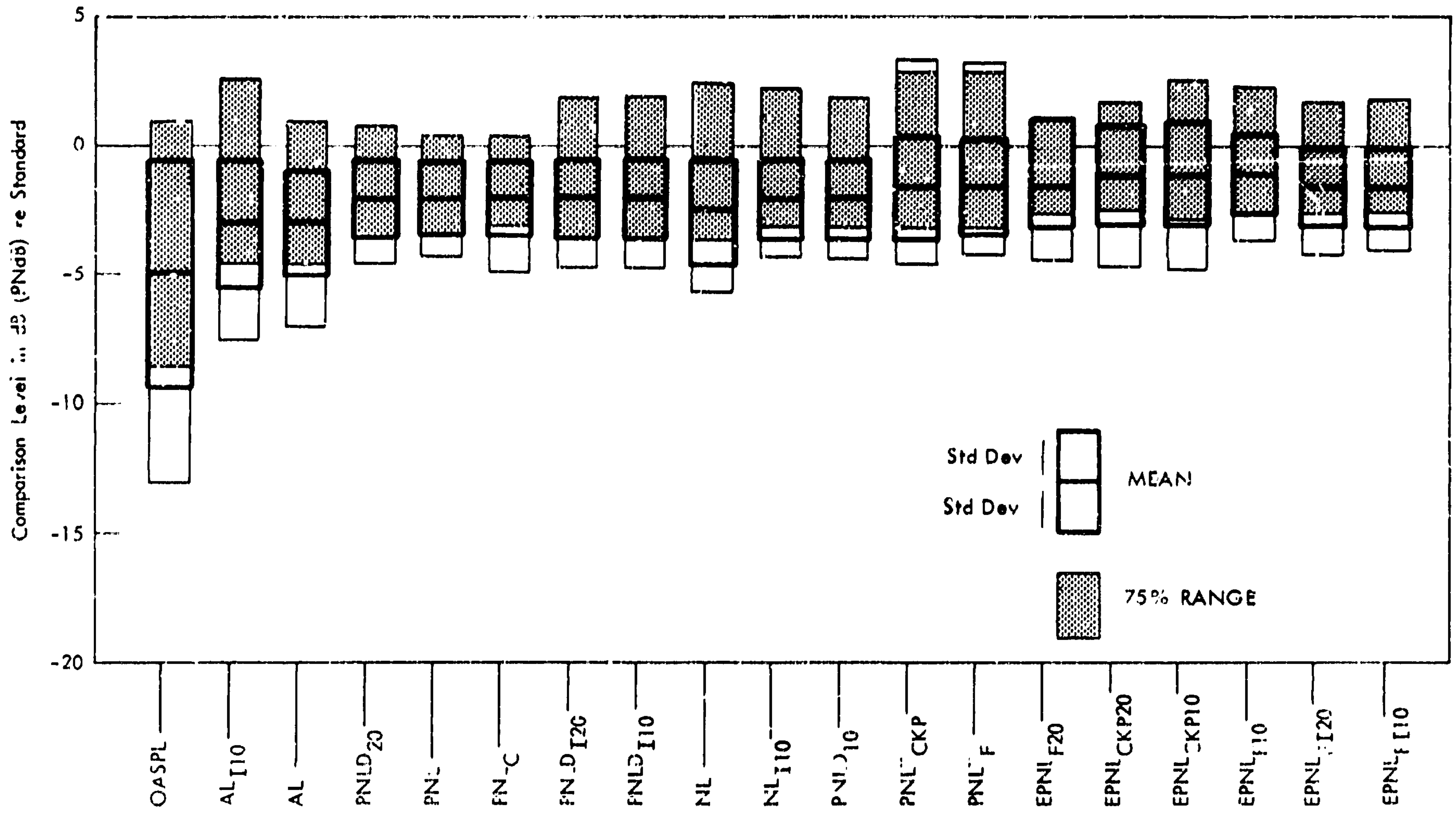

FIGURE 11. COMPARISON OF VARIOUS MEASURES FOR RESULT OF TEST III

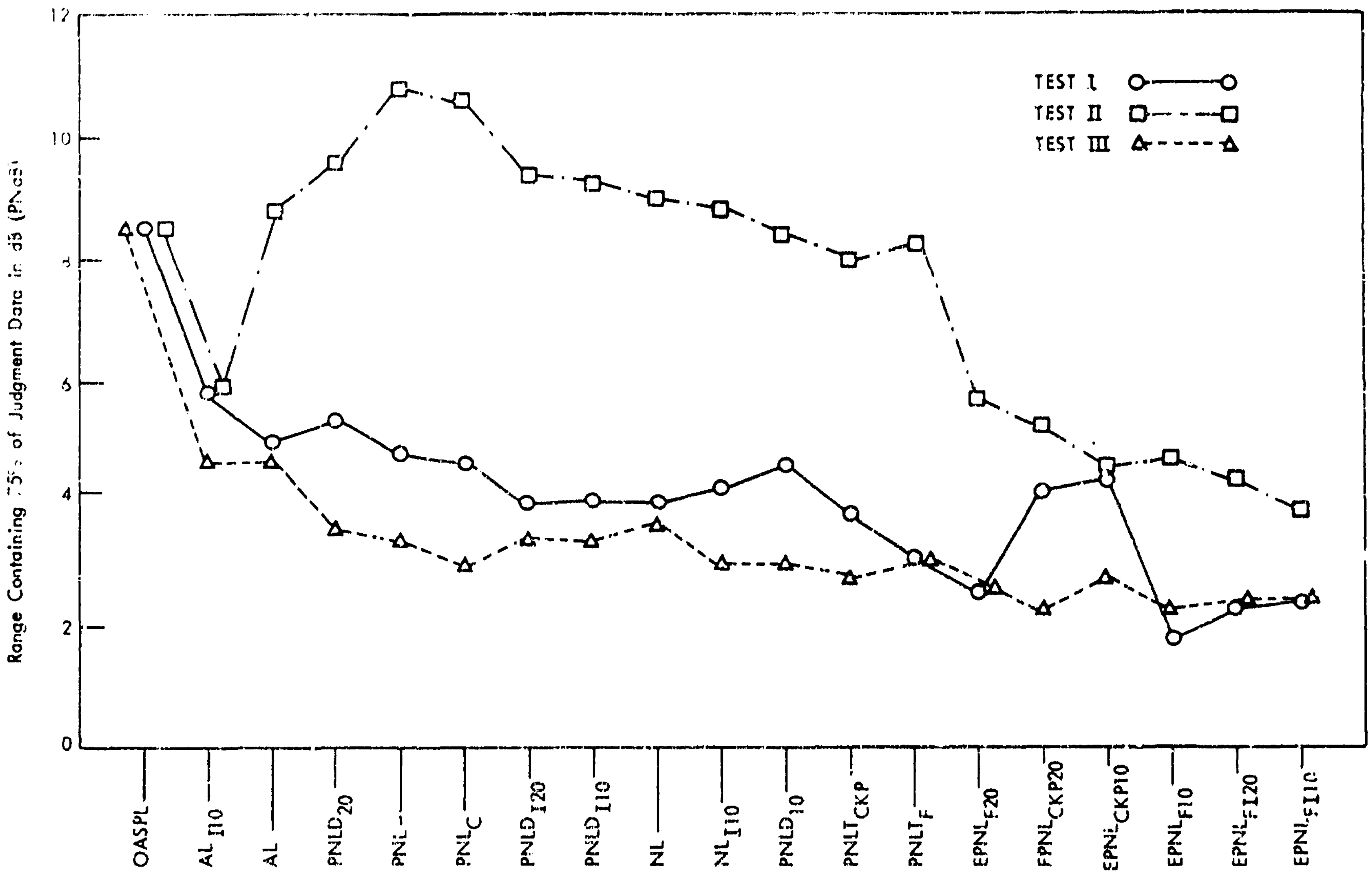

FIGURE 12. COMPARISON OF THE THREE JUDGMENT TESTS FOR ALL PREDICTION MEASURES

APPENDIX A

EQUIPMENT FOR JUDGMENT TESTS

EQUIPMENT FOR JUDGMENT TESTS

In order to conduct the types of judgment tests described in this report, different equipment systems were employed in the various phases. The equipment systems can be divided into three groups:

I. Stimulus preparation equipment

II. Stimulus playback equipment

III. Sound analysis equipment

I. Stimulus Preparation Equipment

The equipment utilized for preparing the test samples used in the judgment experiments is indicated by the block diagram in Figure A-1. The sounds are comprised of shaped broadband noise both with and without a tone. The shaping is accomplished using the one-third octave band spectrum shaper. The time patterns are produced using a computer and a voltage controlled amplifier to temporally shape the noise signals. The spectral shaping was accomplished using a monitoring system in the anechoic chamber while adjusting the various filters on the spectrum shaper. The monitor equipment utilized in this case is identical to that described in Section III of this appendix. The temporal shapes employed during the tests were all represented by a series of straight-line segments.

II. Stimulus Playback Equipment

The stimulus playback equipment employed for this test is indicated by a block diagram in Figure A-2. The multiple cartridge tape recorder supplied the sound stimuli for the test. Each cartridge has two channels, one with the signal on it and the other with cue-tones which are used to control an electronic switch to prevent objectionable tape hiss between sound samples. In addition, the cue-tones are utilized to stop the cartridges and to indicate to the computer when to select another cartridge or await the subject's response.

The rise-decay time of the electronic switch is 100 milliseconds to prevent any undesirable click in the signal. The subject response box in the anechoic chamber allows the subject to choose which of the two sounds he thought was noisier. This response is stored in the computer for use in determining the level of the next comparison signal. The computer then selects another pair of sounds to present to the subject. The loudspeaker in the chamber is placed in front of the subject while the test stimuli are presented.

III. Sound Analysis Equipment

As indicated in the block diagram in Figure A-3, a stimulus analysis was performed in two parts; first the signal was recorded while being played back in the anechoic chamber, and second, this tape was analyzed using the Hewlett-Packard sound spectrum analyzer in conjunction with a digital computer. The microphone used for measurement in the chamber was a one-half inch B and K condenser microphone Model 4133. This microphone was placed approximately where the subject's ear normally would be located in the chamber. However, all measurements were performed without any subjects in the chamber. Sweep frequency tones were placed on the tape to measure the frequency responses of the recording system. These frequency calibrations were applied by the computer in the final analysis of the data. The tape was played back through the Hewlett-Packard spectrum analyzer and the band sound pressure levels read by the digital computer. A one-third octave band analysis was made every one-half second of the stimulus duration. The computer then determined perceived noise level measures for each of these one-half second intervals and the effective perceived noise level of the total stimulus. These were the primary measures employed in the analysis of the subjective data.

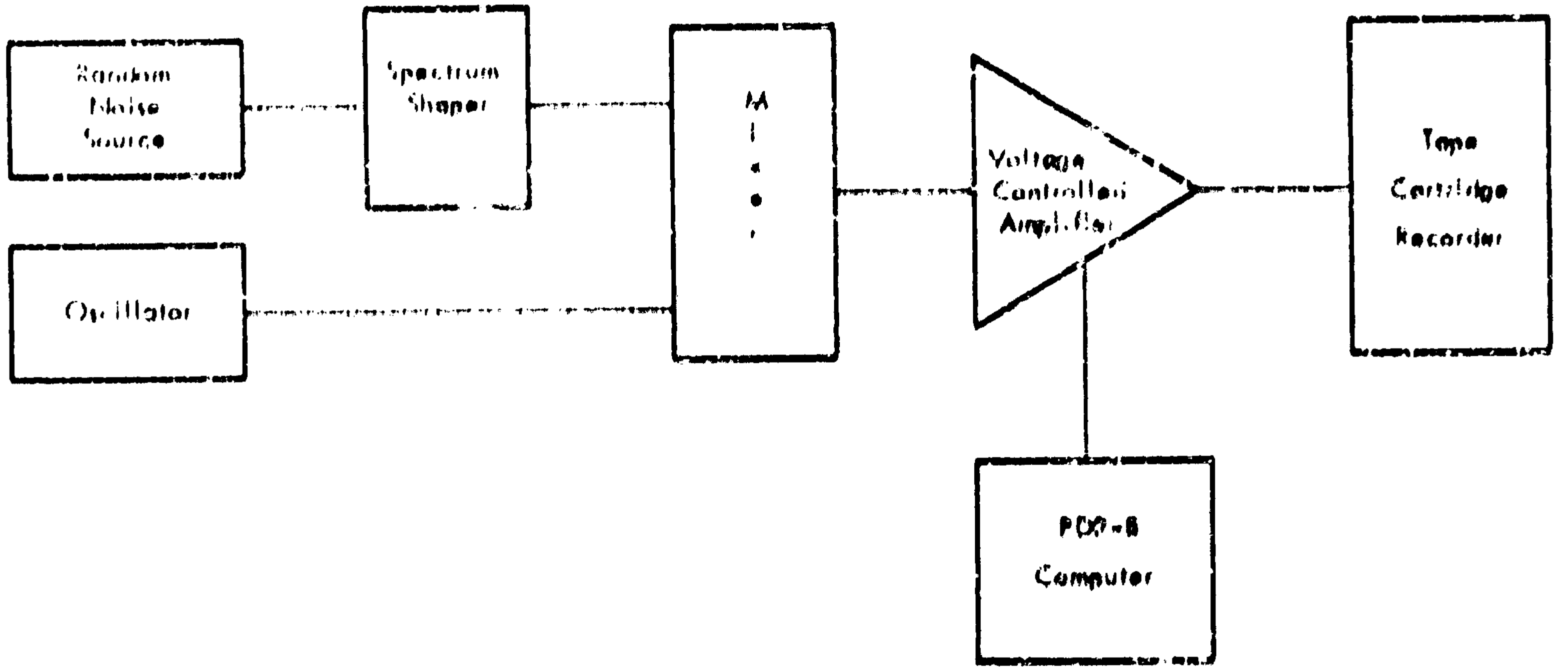

FIGURE A-1. BLOCK DIAGRAM OF STIMULUS PREPARATION EQUIPMENT FOR JUDGMENT TESTS

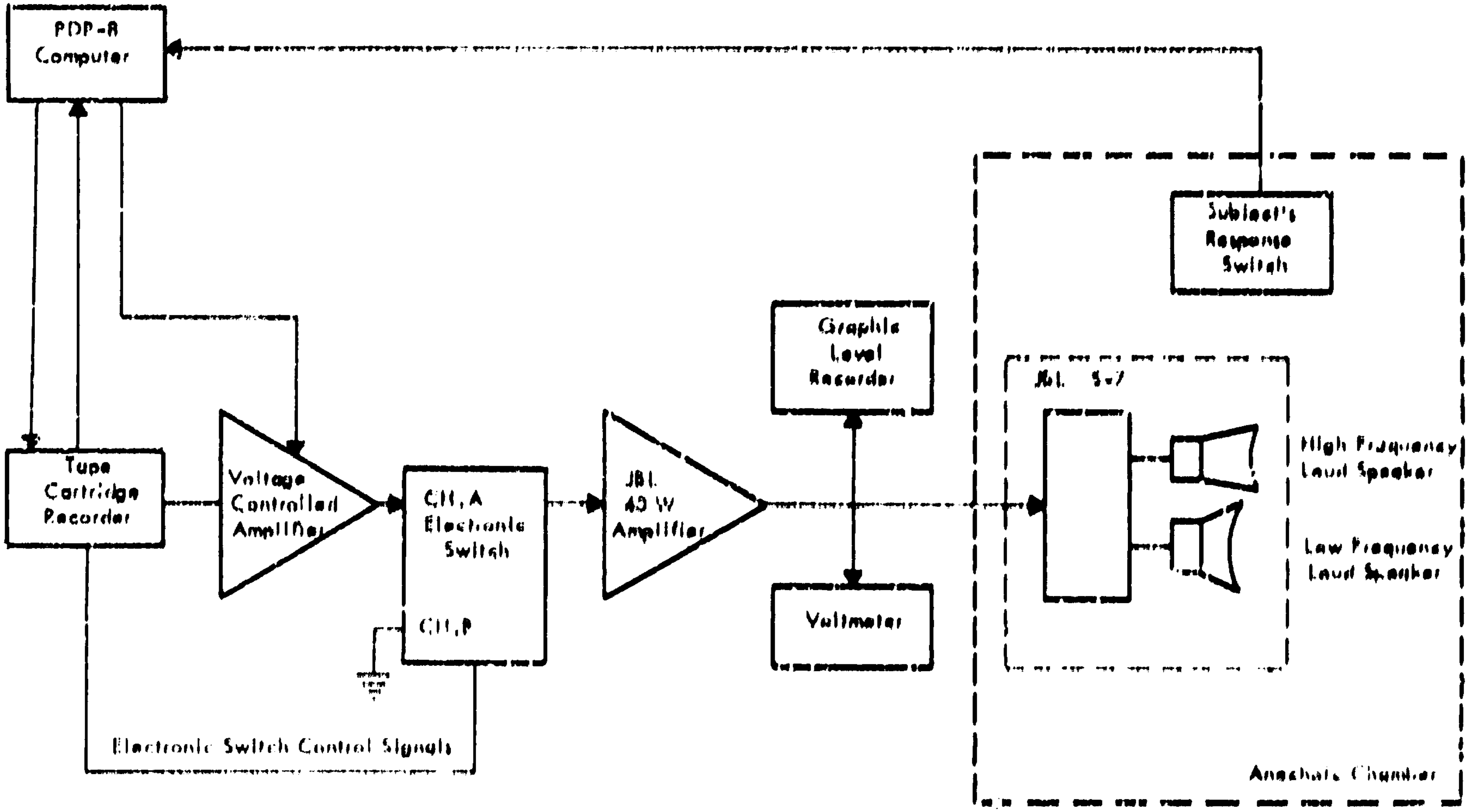

FIGURE A-2. BLOCK DIAGRAM OF PLAYBACK SYSTEM FOR JUDGMENT TESTS

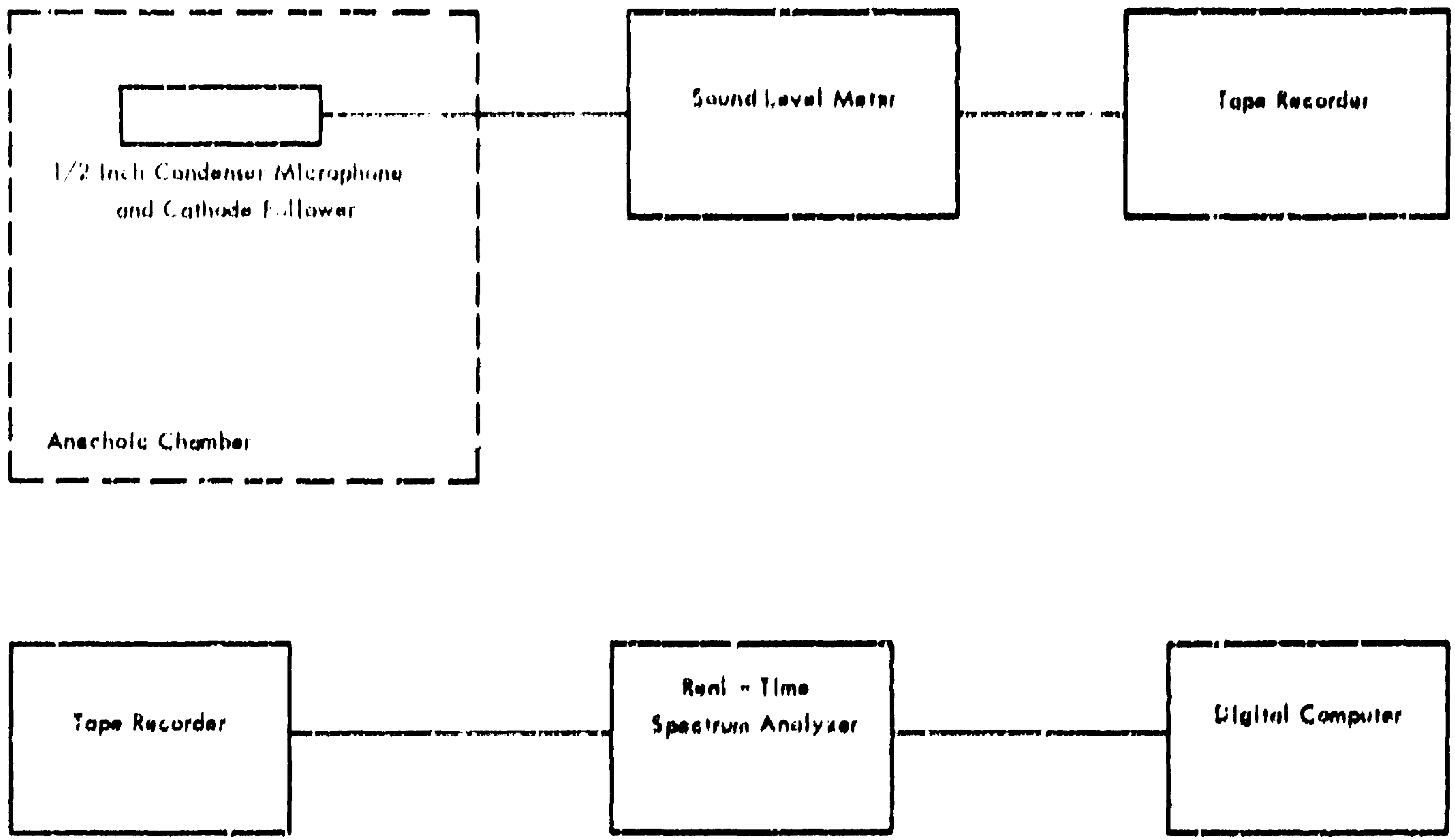

FIGURE A-3. BLOCK DIAGRAM OF STIMULUS ANALYSIS EQUIPMENT FOR JUDGMENT TESTS.

APPENDIX B

PEST PROCEDURES EMPLOYED FOR THE JUDGMENT TESTS

PEST PROCEDURE AS EMPLOYED FOR THE JUDGMENT TESTS

Basically, PEST is an iterative procedure that adjusts the level of a test stimulus until the subject's responses indicate that it is subjectively equal to some standard stimulus. The computer uses a paired-comparison paradigm in presenting the standard stimulus at some fixed level and the comparison stimulus at a variable level. The order of presentation is randomized to counterbalance for various order errors. The subject indicates which of the two sounds is the noisier and the computer adjusts the level of the comparison stimulus depending on the subject's response. Thus, this procedure preserves the advantages of the paired comparison technique while utilizing the speed and convenience of the adjustment procedure.

This procedure was first reported in 1965 by Taylor and Creelman (Ref. 2). We shall only describe the particulars of PEST as they are used in obtaining the results reported here. For further details of the technical features of the PEST procedure, the reader is referred to the original article.

Probably the easiest way to explain our use of PEST is to describe the computer output of a typical thirty-minute test session. Figure B-1 is an example of a computer print out of a single test subject's results. There is one standard signal which the experimenter has set at a level of 48dB (the decibel levels indicated on the print out are relative gain settings). The computer is then instructed to compare five different signals with the standard signal; with each comparison signal starting at a gain of 36dB. As PEST was used in these experiments, five PEST runs were intermingled so that no signal was presented repeatedly against the standard. This technique was used so that signals of different duration would occur within the same test series and subjects would be encouraged not to respond simply on the basis of peak level.

The exact way in which the computer adjusts the level of the comparison signal is detailed in Reference 2. It will suffice to say that the level of the comparison signal is moved in the direction of equality using step sizes in accordance with the subject's responses. After a degree of consistency in the subject's responses is attained in accordance with a preset criteria, the computer terminates the run and records the value of equality.

The experimental test was designed in such a way that five different comparison signals were interspersed so that an observer had an equal probability of hearing any comparison signal unless the PEST procedure for that signal had previously terminated. The actual order of presentation of signal pairs is printed by the computer immediately below the heading "RUN ORDER" (see Figure B-1, Section C) after termination of all runs. Thus, in the example shown in Figure B-1, the first comparison signal presented with the standard was signal four, on the next trial signal three was compared with the standard, then signal three again, then signal five, etc.

A PEST run is terminated when the computer decides that the point of equality can be determined to within 1.5dB. As each run terminates the computer prints the run number, the variable signal level on the last trial, the number of trials in the run, and the direction ("U" is up, "D" is down) of the next (the final) increment (1.5dB) in the comparison signal level. Thus, referring to Figure B-1, Section B, it may be seen that run three terminated first, in three trials, with the variable signal level (which had started at 36dB) at 33dB, and that the next presentation of the variable signal would have been at a lower level (31.5dB).**

The complete history of each run is printed after all runs have terminated (Figure B-1, Section D). The run history is specified by three parameters per trial. The INTERVAL parameter describes the position (first or second) of the standard stimulus within the stimulus pair; the RESPONSE parameter describes the stimulus specified by the observer as being noisier; and the DIRECTION parameter describes direction (up or down) of change of the comparison signal level calculated by PEST for the next trial. Table B-I is a key to the printing code employed for reporting trial parameters. Thus, Figure B-1, Section D shows that on the first trial of run one, the standard signal was presented in the second interval; the observer decided the signal occurring in the second interval (i.e. the standard signal) was the noisier of the trial pair; and PEST determined to raise the level of the comparison signal on the next trial of run one.

**A termination after only three judgments is atypical. It is in fact the fewest number of trials that can lead to a termination. The average number of trials is about seven.

TABLE B-I

TRIAL PARAMETER CODE

	INTERVAL	RESPONSE	DIRECTION
0000	Standard First	First Signal Noisier	Comparison Signal Level Incremented on Next Trial
0001	Standard Second	Second Signal Noisier	Comparison Signal Level Decremented on Next Trial

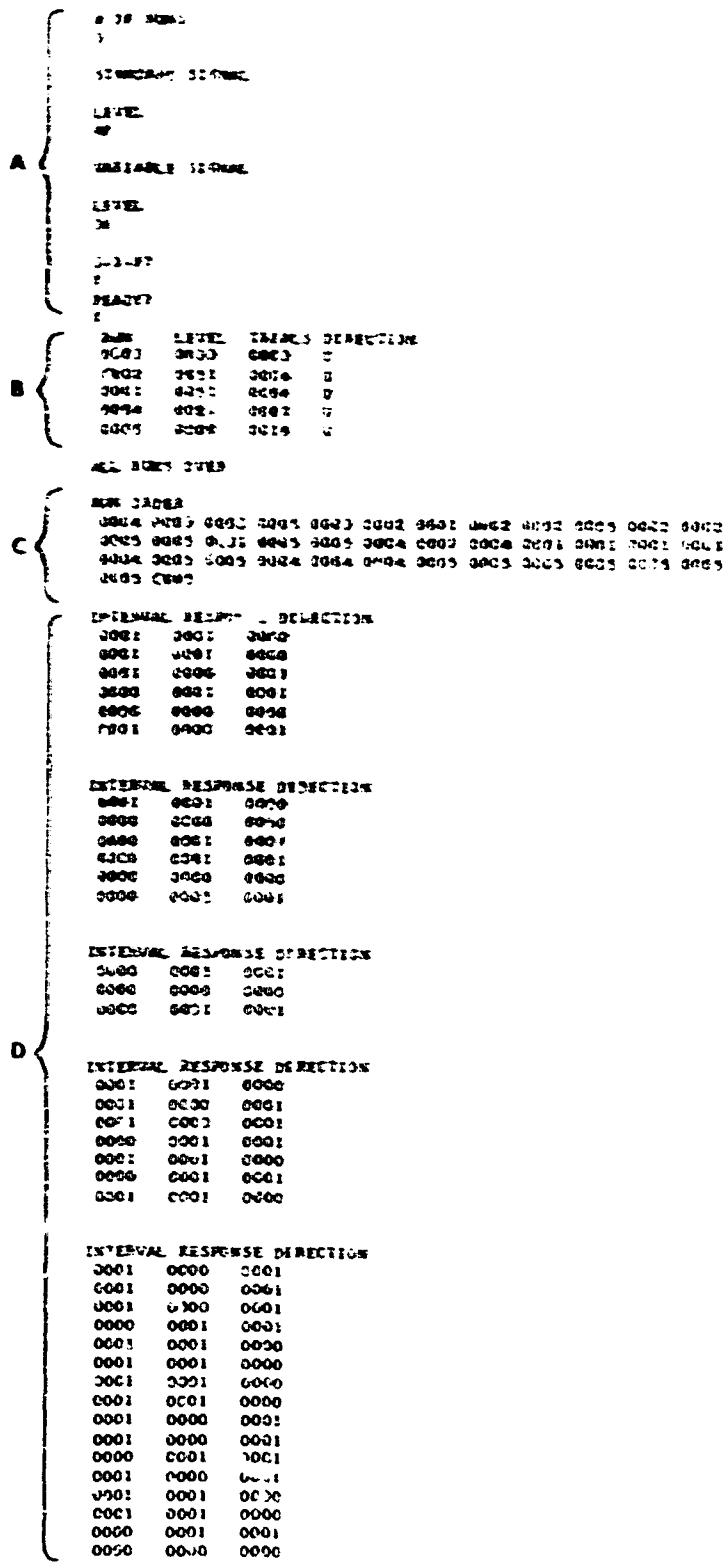

FIGURE B-1. EXAMPLE OF TYPICAL COMPUTER PRINTOUT FOR JUDGMENT TESTS

APPENDIX C

INSTRUCTIONS USED FOR JUDGMENT TESTS

INSTRUCTIONS

The purpose of this test is to gather information about the relative noisiness of various sounds. The test is part of a program of research designed to obtain information that will be of aid in the planning of airports, airplanes, and for noise control purposes in general.

The computer will present a series of pairs of sounds. After each pair of sounds is presented, your task is to decide which of the two sounds, the first or the second, is the more noisy. Regardless of how you have previously defined noisy, by <u>noisy, we mean that sound which is the more annoying, unacceptable, objectionable</u> and disturbing if heard in your home during the day and night. Pick that sound which you would <u>less</u> like to have in your home, even though you might not want <u>either</u> of them.

The computer varies the characteristics of the two sounds in each pair on each trial. If you think the first sound of a pair is the more noisy, push button 1 on the metal response box. If you think the second sound is the more noisy, press the button labeled 2. It is more important that you judge each pair of sounds on its own merits regardless of any similarities or differences you may hear among successive pairs of sounds. There are no right or wrong answers. We are interested only in how noisy or unacceptable the sounds seem to you.

The response buttons will light up when the computer has been informed of your decision. The computer will wait for you to reach a decision about each pair of sounds before it will present the next pair of sounds. Therefore, you control the pace of the experiment directly. The more quickly you decide which sound was more noisy the more quickly the experiment will end. Most people find that they can make good decisions within a second or two after hearing the second sound of a pair.

The START button commands the computer to present the first pair of sounds. I will tell you when to push START. If you push the STOP button the computer will interrupt the test series. There should be no ordinary reason for pushing the STOP button during a series of trials. If you do have a reason for pushing STOP, please tell me before pushing START again. I will tell you when a series of trials has ended.

In summary, select the sound (the first or the second) which, you feel is the more noisy, unacceptable, or disturbing. Remember to listen carefully to each pair of sounds, and to base your decision solely upon the current pair. If you have any questions, please feel free to discuss them with me at the end of a test series.

APPENDIX D

ONE-THIRD OCTAVE BAND LEVELS OF SPECTRA USED IN JUDGMENT TESTS

TABLE D-1 [illegible]

[illegible]

1. [illegible]
2. [illegible] When the signal is within 1 dB of maximum level, the duration is always 1 seconds.
3. Refer to Figure 1

TABLE D-II

STIMULI FOR TEST II

MEASURED AT 12 dB BELOW MAXIMUM LEVELS

Comp.	Temporal Pattern[1]	Duration[4] 10 dB	Duration[4] 20 dB	Spectral Shape[5]	OASPL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
						Sound Pressure Level in dB re 0.0002 dyn/sq. cm. One-Third Octave Band Center Frequency, Hz.																							
1	A	1.0 Sec	2.0 Sec	Z	82.5	74.0	76.0	72.5	71.0	72.5	69.5	68.0	65.5	64.5	65.0	61.0	[illegible]	59.5	58.0	60.5	62.0	63.5	64.5	45.0	65.5	64.0	62.5	62.0	59.5
2	A	1.0 Sec	2.0 Sec	X	90.0	65.5	69.5	74.0	78.0	80.5	80.5	81.0	79.5	80.5	79.0	77.0	75.5	71.5	69.5	67.0	64.5	61.5	56.5	52.0	69.0	52.5	38.0	37.5	37.0
3	E	1.0 Sec	1.4 Sec	X	90.0	64.0	68.5	73.0	77.0	78.0	78.0	79.0	78.0	79.0	77.5	75.0	73.5	69.5	67.0	65.0	62.5	59.0	54.0	49.5	67.0	50.5	37.0	37.0	[illegible]
4	F	1.0 Sec	1.0 Sec	X	90.5	67.5	72.5	76.5	80.0	82.0	81.0	82.0	80.5	82.0	80.5	78.0	76.5	73.0	70.5	67.5	65.0	62.0	57.0	52.5	69.0	52.5	37.5	37.5	37.0
5	A	4.0 Sec	8.0 Sec	Z	82.0	70.0	74.5	72.0	69.5	70.5	68.0	66.0	63.5	62.5	63.0	60.0	59.5	58.0	56.5	59.0	60.5	62.5	64.0	64.0	65.0	63.5	61.5	61.0	58.5
6	A	4.0 Sec	8.0 Sec	X	90.0	66.5	70.5	74.0	77.5	79.5	78.5	80.0	79.5	80.0	79.0	76.5	74.5	71.0	69.0	66.0	62.5	60.0	55.0	50.5	67.5	51.0	36.5	37.0	36.5
7	E	4.0 Sec	5.6 Sec	X	89.0	62.0	68.5	70.0	74.0	76.0	76.0	76.5	75.0	76.5	76.0	73.5	715.	68.0	65.5	63.0	[illegible]	57.0	52.5	48.0	65.0	48.5	36.5	37.0	36.5
8	A	10.0 Sec	20.0 Sec	Z	82.5	74.0	76.0	72.5	71.0	72.5	69.5	68.0	65.5	64.0	65.0	61.0	60.5	59.5	58.0	60.5	62.0	63.5	64.5	65.0	65.5	64.0	62.5	62.0	59.5
9	A	10.0 Sec	20.0 Sec	X	90.0	65.5	69.5	74.0	78.0	80.5	80.5	81.0	79.5	80.5	79.0	77.0	75.5	71.5	69.5	67.0	64.5	61.5	56.5	52.0	69.0	52.5	38.0	37.5	37.0
10	E	10.0 Sec	14.0 Sec	X	90.0	64.0	68.5	73.0	77.0	78.0	78.0	79.0	78.0	79.0	77.5	75.0	73.5	69.5	67.0	65.0	62.5	59.0	54.0	49.5	67.0	50.5	37.0	37.0	36.5
11	F	10.0 Sec	10.0 Sec	X	90.5	67.5	72.5	76.5	80.0	82.0	81.0	82.0	80.5	82.0	80.5	78.0	76.5	73.0	70.5	67.5	65.0	62.0	57.0	52.5	69.0	52.5	37.5	37.5	37.0
12	A	20.0 Sec	40.0 Sec	Z	83.5	73.0	77.5	74.5	73.0	73.0	70.5	67.5	65.5	64.0	63.5	61.5	58.5	59.5	58.5	61.0	62.5	64.0	65.5	66.0	66.5	[illegible]	63.5	63.5	61.5
13	A	20.0 Sec	40.0 Sec	X	90.0	64.5	71.0	76.0	79.0	80.5	80.5	81.0	79.5	80.5	79.5	76.5	75.0	72.0	69.5	67.0	64.0	61.5	56.0	51.5	68.5	52.0	37.5	37.5	37.0
14	E	20.0 Sec	28.0 Sec	X	89.5	64.5	69.5	74.0	77.5	80.0	79.0	79.5	79.0	79.0	78.0	76.5	74.0	71.0	69.5	66.5	63.5	60.0	55.5	58.5	67.5	51.0	37.0	37.0	56.5
15	A	100.0 Sec	200.0 Sec	Z	82.5	74.0	76.0	72.5	71.0	72.5	69.5	68.0	65.5	64.5	65.0	61.0	60.5	59.5	58.0	60.5	62.0	63.5	64.5	65.0	65.5	64.0	62.5	62.0	59.5
16	A	100.0 Sec	200.0 Sec	X	90.0	65.5	69.5	74.0	78.0	80.5	80.5	81.0	79.5	80.5	79.0	77.0	75.5	71.5	69.5	67.0	64.5	61.5	56.5	52.0	69.0	52.5	38.0	37.5	37.0
17	E	100.0 Sec	140.0 Sec	X	90.0	64.0	68.5	73.0	77.0	78.0	78.0	79.0	78.0	79.0	77.5	75.0	73.5	69.5	67.0	65.0	62.5	59.0	54.0	49.5	67.0	50.5	37.0	37.0	36.5
18	F	100.0 Sec	100.0 Sec	X	90.5	67.5	72.5	76.5	80.0	82.0	81.0	82.0	80.5	82.0	80.5	78.0	76.5	73.0	70.5	67.5	65.0	62.0	57.0	52.5	69.0	52.5	37.5	37.5	37.0
19	F/O[2]	15.0 Sec	26.0 Sec	X	90.0	57.0	61.0	64.5	74.5	81.5	83.5	81.5	80.5	81.0	78.5	78.0	73.0	72.5	73.5	73.5	71.5	69.5	64.0	63.0	64.0	58.0	81.0	43.0	37.5
20	Spec.[3]	9.0 Sec	10.0 Sec	X	90.5	67.0	73.0	76.5	79.5	82.0	82.0	82.5	81.0	81.5	80.5	79.0	76.5	73.0	[illegible]	68.5	65.0	62.0	57.0	52.5	69.0	52.5	38.0	37.5	37.5
Std	A	10.0 Sec	20.0 Sec	Z	82.0	71.5	76.0	73.5	71.5	72.5	70.0	67.5	65.0	64.0	64.0	61.5	60.5	59.5	58.0	60.5	62.5	63.5	64.5	65.0	66.0	64.5	62.5	62.0	59.0

1. Refer to Figure 2
2. Flyover: refer to "STD", Table III
3. Special trapezoidal time pattern with duration at the 10 dB down points equal to nine seconds; at the 20 dB down points it is equal to 10 seconds.
4. Duration is the amount of time the signal is within 10 dB or 20 dB of maximum level.
5. Refer to Figure 1

TABLE D-III

STIMULI FOR TEST III

MEASURED AT 12 dB BELOW MAXIMUM LEVELS

Comp.	Type of Aircraft	Duration[1] 10 dB	20 dB	OASPL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
					Sound Pressure Level in dB re 0.0002 dyn/sq.cm. One-Third Octave Band Center Frequency, Hz.																							
1	Boeing 720	6 Sec	10 Sec	87.5	58.0	61.0	59.5	69.0	77.0	78.5	74.5	75.5	77.0	75.0	76.0	73.0	74.0	75.5	76.5	76.0	76.5	73.0	72.0	72.0	69.0	67.5	64.0	56.0
2	Douglas DC-8	11 Sec	20 Sec	87.0	56.5	62.0	61.0	63.5	69.5	74.5	78.0	80.5	76.0	76.5	77.5	74.0	72.5	72.0	73.5	74.0	75.0	77.5	69.0	69.5	69.5	67.5	58.5	42.0
3	Boeing 707B	5 Sec	10 Sec	83.5	54.5	55.0	54.0	61.5	68.5	69.0	66.0	67.0	65.5	63.5	65.0	62.5	61.0	63.5	67.0	66.0	67.5	80.5	79.0	71.0	73.5	66.0	67.5	55.5
4	Boeing 720B	5 Sec	8 Sec	85.5	52.0	53.5	53.5	62.5	69.0	70.5	68.5	68.0	67.0	65.5	66.0	62.5	61.5	65.0	69.0	72.5	77.5	81.5	77.0	73.0	72.0	66.0	62.0	49.5
5	Boeing 720B	6 Sec	9 Sec	85.0	53.5	54.5	56.0	63.5	70.0	68.5	67.0	69.5	67.0	66.5	67.5	63.5	63.0	67.0	71.5	73.0	78.0	81.5	79.0	72.0	73.5	69.0	65.5	52.0
6	Boeing 707B	6 Sec	9 Sec	85.5	52.5	52.0	52.0	62.5	67.5	75.5	65.0	66.5	64.5	64.0	64.0	61.0	60.0	63.5	69.5	67.5	78.0	81.0	73.5	72.0	71.5	67.5	64.5	53.5
7	Boeing 727	5 Sec	10 Sec	86.5	59.8	64.0	64.5	72.0	77.5	76.5	77.0	76.5	76.0	74.5	75.0	70.5	69.5	69.5	71.0	70.0	72.0	74.0	75.5	76.0	72.0	71.5	69.0	59.0
8	Douglas DC-9	10 Sec	18 Sec	86.5	55.5	62.5	62.5	71.5	78.5	81.0	79.0	78.5	78.5	76.5	76.0	71.0	70.0	71.0	71.0	69.0	67.5	62.0	61.5	62.5	56.0	49.0	42.0	37.0
9	Douglas DC-8	18 Sec	36 Sec	91.0	58.5	62.5	69.0	82.0	88.0	83.5	80.0	82.0	80.0	81.5	81.0	75.5	73.5	72.5	72.0	70.5	69.0	62.5	64.5	61.5	47.0	39.5	39.0	38.0
10	Douglas DC-9	15 Sec	26 Sec	90.0	61.5	68.5	72.5	75.5	77.0	82.0	83.5	84.5	80.5	80.5	80.5	77.0	74.0	73.5	73.0	70.5	68.5	62.0	59.5	57.0	46.5	39.5	39.0	38.0
11	Lockheed Elect.	10 Sec	24 Sec	81.5	55.0	72.0	76.5	68.5	69.5	69.0	73.5	73.0	69.0	68.0	72.5	68.5	67.0	66.5	62.0	59.0	57.0	49.5	38.0	35.5	36.0	37.0	39.0	38.0
12	Fairchild F-27	9 Sec	21 Sec	83.0	47.6	54.5	75.5	72.0	69.0	77.5	80.5	75.0	69.5	67.5	68.5	65.0	63.5	65.0	64.5	63.5	59.0	51.5	46.5	41.5	39.5	37.0	39.0	38.0
13	Douglas DC-8	9 Sec	16 Sec	87.0	54.6	58.0	61.0	69.0	77.5	79.5	79.0	76.0	80.0	76.5	77.5	75.0	74.0	74.0	74.5	74.5	74.5	69.0	67.5	68.5	64.5	60.0	[illegible]	64.0
14	Boeing 707	14 Sec	30 Sec	87.0	54.0	58.5	62.0	69.0	78.0	79.0	80.0	76.5	79.0	77.0	78.0	75.0	74.0	73.5	73.5	74.0	74.5	68.5	65.5	65.0	60.0	53.0	48.5	39.5
15	Boeing 727	9 Sec	18 Sec	86.5	55.5	59.0	62.5	69.5	75.5	79.5	81.5	77.0	78.0	76.0	75.5	70.5	68.0	67.0	66.0	63.0	60.5	54.5	52.0	48.5	38.0	35.5	37.0	36.5
16	Boeing 720B	8 Sec	20 Sec	88.0	56.5	60.5	67.0	78.5	84.0	81.5	76.5	80.0	76.5	74.0	75.0	72.0	70.0	70.5	71.0	69.5	69.0	64.0	72.5	71.5	58.5	57.0	53.5	39.5
17	Douglas DC-8; 10	16 Sec	34 Sec	86.0	54.5	57.0	58.0	69.5	77.5	77.0	78.5	74.5	78.5	74.5	76.5	73.0	71.0	72.0	72.0	70.5	58.0	60.5	55.0	49.5	41.0	37.0	38.0	37.0
18	Vertol CH-46 #1	3 Sec	7 Sec	84.0	57.5	56.0	67.5	78.0	[illegible]	79.5	76.5	78.0	73.0	70.0	67.5	63.5	57.5	56.0	55.0	53.5	53.0	47.5	46.0	43.0	41.5	42.5	41.0	38.0
19	Sikorsky CH-34-#3	5 Sec	20 Sec	87.0	50.5	52.5	61.5	72.5	77.5	82.5	78.0	79.0	78.0	74.5	75.0	70.5	70.0	70.0	69.5	68.0	68.0	63.0	61.5	58.5	56.5	57.0	55.0	46.5
20	Sikorsky CH-34 #1	14 Sec	28 Sec	87.5	53.5	53.5	63.0	73.5	81.5	85.0	79.5	80.0	78.0	76.0	78.0	72.5	70.0	69.5	69.0	67.0	66.0	60.5	56.5	51.5	46.5	45.0	44.5	37.0
Std.	Douglas DC-9	15 Sec	26 Sec	86.5	56.5	62.0	62.5	71.5	79.0	81.0	78.5	78.5	78.0	76.0	75.5	70.5	69.5	70.5	70.5	68.5	67.0	61.5	61.0	62.0	55.5	49.0	41.5	37.0

1. Duration is the amount of time the signal is within 10 or 20 dB of maximum level.

APPENDIX E

PROCEDURES FOR COMPUTING PERCEIVED NOISE LEVEL

WITH TONE AND DURATION CORRECTIONS

PROCEDURES FOR COMPUTING PERCEIVED NOISE LEVEL
WITH TONE AND DURATION CORRECTIONS

I. Perceived Noise Level (PNL)

Perceived noise level (PNL) in PNdB is calculated according to the following procedure:

Step 1 - The sound pressure level in each one-third octave frequency band is converted to a noy value by reference to Table E-I, entering the Table at the appropriate band center frequency (or by use of the equations and constants given in Table E-II at the appropriate band center frequency).

Step 2 - The noy values found in Step 1 are combined in the manner described in the following formula:

$$\underline{N} = n_{max} + 0.15 \left(\sum n - n_{max}\right)$$

where n_{max} is the number of noys in the band having the greatest noy value, and $\sum n$ is the sum of the noy values in all the bands.

Step 3 - $\underline{N}$ is converted into the perceived noise level (PNL) in PNdB by the following expression:

$$PNL = 40 + 33.22 \log_{10} \underline{N}$$

NOTE: For $\underline{N}$ values of 1.0 or greater, the PNL can be found from Table E-I by treating the quantity in the 1000 Hz column as the noy value and reading SPL as PNL.

As an alternative to using the values in Table E-I, we may use the following set of equations:

The value N, in noys, given in Table E-I for a particular frequency band is related to the band sound pressure level, L, by the general basic equation

$$N=A \cdot 10^{M_j (L-L_k)} \quad \text{for}$$

$$N \le 0.1 \text{ and } L \le 150$$

TABLE E-I - NOYS AS A FUNCTION OF SOUND PRESSURE LEVEL

SPL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
	⅓ OCTAVE BAND CENTER FREQUENCIES IN Hz (c/s)																							
[illegible]																			0.10					
5																		0.10	0.11	0.10				
6																		0.11	0.12	0.11	0.10			
7																		0.12	0.14	0.13	0.11			
8																		0.14	0.16	0.14	0.13			
9																	0.10	0.16	0.17	0.16	0.14			
10																	0.11	0.17	0.19	0.18	0.16	0.10		
11																	0.13	0.19	0.22	0.21	0.18	0.12		
12																0.10	0.14	0.22	0.24	0.24	0.21	0.14		
13																0.11	0.15	0.24	0.27	0.27	0.24	0.16		
14																0.13	0.18	0.27	0.30	0.30	0.27	0.19		
15															0.10	0.14	0.21	0.30	0.33	0.33	0.30	0.22		
16										0.10	0.10	0.10	0.10	0.10	0.11	0.16	0.24	0.33	0.35	0.35	0.33	0.26		
17										0.11	0.11	0.11	0.11	0.11	0.13	0.18	0.27	0.35	0.38	0.38	0.35	0.30	0.10	
18									0.10	0.13	0.13	0.13	0.13	0.13	0.15	0.21	0.30	0.38	0.41	0.41	0.38	0.33	0.12	
19									0.11	0.14	0.14	0.14	0.14	0.14	0.17	0.24	0.33	0.41	0.45	0.45	0.41	0.36	0.14	
20									0.13	0.16	0.16	0.16	0.16	0.16	0.20	0.27	0.36	0.45	0.49	0.49	0.45	0.39	0.17	
21								0.10	0.14	0.18	0.18	0.18	0.18	0.18	0.23	0.30	0.39	0.49	0.53	0.53	0.49	0.42	0.21	0.10
22								0.11	0.16	0.21	0.21	0.21	0.21	0.21	0.26	0.33	0.42	0.53	0.57	0.57	0.53	0.46	0.25	0.11
23								0.13	0.18	0.24	0.24	0.24	0.24	0.24	0.30	0.36	0.46	0.57	0.62	0.62	0.57	0.50	0.30	0.13
24							0.10	0.14	0.21	0.27	0.27	0.27	0.27	0.27	0.33	0.40	0.50	0.62	0.67	0.67	0.62	0.55	0.33	0.15
25							0.11	0.16	0.24	0.30	0.30	0.30	0.30	0.30	0.35	0.43	0.55	0.67	0.73	0.73	0.67	0.60	0.36	0.17
26							0.13	0.18	0.27	0.33	0.33	0.33	0.33	0.33	0.38	0.48	0.60	0.73	0.79	0.79	0.73	0.65	0.39	0.20
27						0.10	0.14	0.21	0.30	0.35	0.35	0.35	0.35	0.35	0.41	0.52	0.65	0.79	0.85	0.85	0.79	0.71	0.42	0.23
28						0.11	0.16	0.24	0.33	0.38	0.38	0.38	0.38	0.38	0.45	0.57	0.71	0.85	0.92	0.92	0.85	0.77	0.46	0.26
29						0.13	0.18	0.27	0.35	0.41	0.41	0.41	0.41	0.41	0.49	0.63	0.77	0.92	1.00	1.00	0.92	0.84	0.50	0.30
30					0.10	0.14	0.21	0.30	0.38	0.45	0.45	0.45	0.45	0.45	0.53	0.69	0.84	1.00	1.07	1.07	1.00	0.92	0.55	0.33
31					0.11	0.16	0.24	0.33	0.41	0.49	0.49	0.49	0.49	0.49	0.57	0.76	0.92	1.07	1.15	1.15	1.07	1.00	0.60	0.37
32					0.13	0.18	0.27	0.36	0.45	0.53	0.53	0.53	0.53	0.53	0.62	0.83	1.00	1.15	1.23	1.23	1.15	1.07	0.66	0.41
33					0.14	0.21	0.30	0.39	0.49	0.57	0.57	0.57	0.57	0.57	0.67	0.91	1.07	1.23	1.32	1.32	1.23	1.15	0.71	0.45
34				0.10	0.16	0.24	0.33	0.42	0.53	0.62	0.62	0.62	0.62	0.62	0.73	1.00	1.15	1.32	1.41	1.41	1.32	1.23	0.77	0.50
35				0.11	0.18	0.27	0.36	0.46	0.57	0.67	0.67	0.67	0.67	0.67	0.79	1.07	1.23	1.41	1.51	1.51	1.41	1.32	0.84	0.55
36				0.13	0.21	0.30	0.40	0.50	0.62	0.73	0.73	0.73	0.73	0.73	0.85	1.15	1.32	1.51	1.62	1.62	1.51	1.41	0.92	0.61
37				0.15	0.24	0.33	0.43	0.55	0.67	0.79	0.79	0.79	0.79	0.79	0.92	1.23	1.41	1.62	1.74	1.74	1.62	1.51	1.00	0.67
38				0.17	0.27	0.37	0.48	0.60	0.73	0.85	0.85	0.85	0.85	0.85	1.00	1.32	1.51	1.74	1.86	1.86	1.74	1.62	1.10	0.74
39			0.10	0.20	0.30	0.41	0.52	0.65	0.79	0.92	0.92	0.92	0.92	0.92	1.07	1.41	1.62	1.86	1.99	1.99	1.86	1.74	1.21	0.82
40			0.12	0.23	0.33	0.45	0.57	0.71	0.85	1.00	1.00	1.00	1.00	1.00	1.15	1.51	1.74	1.99	2.14	2.14	1.99	1.86	1.34	0.90
41			0.14	0.26	0.37	0.50	0.63	0.77	0.92	1.07	1.07	1.07	1.07	1.07	1.23	1.62	1.86	2.14	2.29	2.29	2.14	1.99	1.49	1.00
42			0.16	0.30	0.41	0.55	0.69	0.84	1.00	1.15	1.15	1.15	1.15	1.15	1.32	1.74	1.99	2.29	2.45	2.45	2.29	2.14	1.63	1.10
43			0.19	0.33	0.45	0.61	0.76	0.92	1.07	1.23	1.23	1.23	1.23	1.23	1.41	1.86	2.14	2.45	2.63	2.63	2.45	2.29	1.79	1.21
44		0.10	0.22	0.37	0.50	0.67	0.83	1.00	1.15	1.32	1.32	1.32	1.32	1.32	1.52	1.99	2.29	2.63	2.81	2.81	2.63	2.45	1.99	1.34
45		0.12	0.26	0.42	0.55	0.74	0.91	1.08	1.24	1.41	1.41	1.41	1.41	1.41	1.62	2.14	2.45	2.81	3.02	3.02	2.81	2.63	2.14	1.48
46		0.14	0.30	0.46	0.61	0.82	1.00	1.16	1.33	1.52	1.52	1.52	1.52	1.52	1.74	2.29	2.63	3.02	3.23	3.23	3.02	2.81	2.29	1.63
47		0.16	0.34	0.52	0.67	0.90	1.08	1.25	1.42	1.62	1.62	1.62	1.62	1.62	1.87	2.45	2.81	3.23	3.46	3.46	3.23	3.02	2.45	1.79
48		0.19	0.38	0.58	0.74	1.00	1.17	1.34	1.53	1.74	1.74	1.74	1.74	1.74	2.00	2.63	3.02	3.46	3.71	3.71	3.46	3.23	2.63	1.98
49	0.10	0.22	0.43	0.65	0.82	1.08	1.26	1.45	1.64	1.87	1.87	1.87	1.87	1.87	2.14	2.81	3.23	3.71	3.97	3.97	3.71	3.46	2.81	2.19

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TABLE E-I CONTINUED

	1/3 OCTAVE BAND CENTER FREQUENCIES IN Hz (c/s)																							
	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.17	1.36	1.56	1.76	2.00	2.00	2.00	2.00	2.00	2.30	3.02	3.46	3.97	4.26	4.26	3.97	3.71	3.02	2.40
51	[illegible]	[illegible]	[illegible]	[illegible]	1.00	1.26	1.47	1.68	1.89	2.14	2.14	2.14	2.14	2.14	2.46	3.23	3.71	4.26	4.56	4.56	4.26	3.97	3.23	2.63
52	[illegible]	[illegible]	[illegible]	[illegible]	1.09	1.36	1.59	1.80	2.03	2.30	2.30	2.30	2.30	2.30	2.64	3.46	3.97	4.56	4.89	4.89	4.56	4.26	3.46	2.81
53	[illegible]	[illegible]	.70	1.00	1.19	1.47	1.71	1.94	2.17	2.46	2.46	2.46	2.46	2.46	2.83	3.71	4.26	4.89	5.24	5.24	4.89	4.56	3.71	3.02
54	[illegible]	[illegible]	[illegible]	1.09	1.28	1.58	1.85	2.09	2.33	2.64	2.64	2.64	2.64	2.64	3.03	3.97	4.56	5.24	5.61	5.61	5.24	4.89	3.97	3.23
55	[illegible]	[illegible]	[illegible]	1.19	1.35	1.71	2.00	2.25	2.50	2.83	2.83	2.83	2.83	2.83	3.25	4.26	4.89	5.61	6.01	6.01	5.61	5.24	4.26	3.46
56	[illegible]	[illegible]	[illegible]	1.29	1.50	1.85	2.15	2.42	2.69	3.03	3.03	3.03	3.03	3.03	3.48	4.56	5.24	6.01	6.44	6.44	6.01	5.61	4.56	3.71
57	[illegible]	[illegible]	1.09	1.40	1.63	2.00	2.33	2.61	2.88	3.25	3.25	3.25	3.25	3.25	3.73	4.89	5.61	6.44	6.90	6.90	6.44	6.01	4.89	3.97
58	[illegible]	[illegible]	1.18	1.53	1.77	2.15	2.51	2.81	3.10	3.48	3.48	3.48	3.48	3.48	4.00	5.24	6.01	6.90	7.39	7.39	6.90	6.44	5.24	4.26
59	[illegible]	[illegible]	1.29	1.66	1.92	2.33	2.71	3.03	3.32	3.73	3.73	3.73	3.73	3.73	4.29	5.61	6.44	7.39	7.92	7.92	7.39	6.90	5.61	4.56
60	[illegible]	1.00	1.40	1.81	2.09	2.51	2.93	3.26	3.57	4.00	4.00	4.00	4.00	4.00	4.59	6.01	6.90	7.92	8.49	8.49	7.92	7.39	6.01	4.89
61	[illegible]	1.10	1.53	1.97	2.26	2.71	3.16	3.51	3.83	4.29	4.29	4.29	4.29	4.29	4.92	6.44	7.39	8.49	9.09	9.09	8.49	7.92	6.44	5.24
62	[illegible]	1.21	1.66	2.15	2.45	2.93	3.41	3.79	4.11	4.59	4.59	4.59	4.59	4.59	5.28	6.90	7.92	9.09	9.74	9.74	9.09	8.49	6.90	5.61
63	[illegible]	1.32	1.81	2.34	2.65	3.16	3.69	4.06	4.41	4.92	4.92	4.92	4.92	4.92	5.66	7.39	8.49	9.74	10.4	10.4	9.74	9.09	7.39	6.01
64	[illegible]	1.45	1.97	2.54	2.88	3.41	3.98	4.35	4.73	5.28	5.28	5.28	5.28	5.28	6.06	7.92	9.09	10.4	11.2	11.2	10.4	9.74	7.92	6.44
65	1.11	1.60	2.15	2.77	3.12	3.69	4.30	4.71	5.08	5.66	5.66	5.66	5.66	5.66	6.50	8.49	9.74	11.2	12.0	12.0	11.2	10.4	8.49	6.90
66	1.22	1.75	2.34	3.01	3.39	3.99	4.64	5.07	5.45	6.06	6.06	6.06	6.06	6.06	6.96	9.09	10.4	12.0	12.8	12.8	12.0	11.2	9.09	7.39
67	1.35	1.92	2.54	3.28	3.68	4.30	5.01	5.46	5.85	6.50	6.50	6.50	6.50	6.50	7.46	9.74	11.2	12.8	13.8	13.8	12.8	12.0	9.74	7.92
68	1.49	2.11	2.77	3.57	3.99	4.64	5.41	5.88	6.27	6.96	6.96	6.96	6.96	6.96	8.00	10.4	12.0	13.8	14.7	14.7	13.8	12.8	10.4	8.49
69	1.65	2.32	3.01	3.88	4.33	5.01	5.84	6.33	6.73	7.46	7.46	7.46	7.46	7.46	8.57	11.2	12.8	14.7	15.8	15.8	14.7	13.8	11.2	9.09
70	1.82	2.55	3.28	4.23	4.69	5.41	6.31	6.81	7.23	8.00	8.00	8.00	8.00	8.00	9.19	12.0	13.8	15.8	16.9	16.9	15.8	14.7	12.0	9.74
71	2.02	2.79	3.57	4.60	5.09	5.84	6.81	7.33	7.75	8.57	8.57	8.57	8.57	8.57	9.85	12.8	14.7	16.9	18.1	18.1	16.9	15.8	12.8	10.4
72	2.23	3.07	3.88	5.01	5.52	6.31	7.36	7.90	8.32	9.19	9.19	9.19	9.19	9.19	10.6	13.8	15.8	18.1	19.4	19.4	18.1	16.9	13.8	11.2
73	2.46	3.37	4.23	5.45	5.99	6.81	7.94	8.50	8.93	9.85	9.85	9.85	9.85	9.85	11.3	14.7	16.9	19.4	20.8	20.8	19.4	18.1	14.7	12.0
74	2.72	3.70	4.60	5.94	6.50	7.36	8.57	9.15	9.59	10.6	10.6	10.6	10.6	10.6	12.1	15.8	18.1	20.8	22.3	22.3	20.8	19.4	15.8	12.8
75	3.01	4.06	5.01	6.46	7.05	7.94	9.19	9.85	10.3	11.3	11.3	11.3	11.3	11.3	13.0	16.9	19.4	22.3	23.9	23.9	22.3	20.8	16.9	13.8
76	3.32	4.46	5.45	7.03	7.65	8.57	9.85	10.6	11.0	12.1	12.1	12.1	12.1	12.1	13.9	18.1	20.8	23.9	25.6	25.6	23.9	22.3	18.1	14.7
77	3.67	4.89	5.94	7.66	8.29	9.19	10.6	11.3	11.8	13.0	13.0	13.0	13.0	13.0	14.9	19.4	22.3	25.6	27.4	27.4	25.6	23.9	19.4	15.8
78	4.06	5.37	6.46	8.33	9.00	9.85	11.3	12.1	12.7	13.9	13.9	13.9	13.9	13.9	16.0	20.8	23.9	27.4	29.4	29.4	27.4	25.6	20.8	16.9
79	4.49	5.90	7.03	9.07	9.76	10.6	12.1	13.0	13.6	14.9	14.9	14.9	14.9	14.9	17.1	22.3	25.6	29.4	31.5	31.5	29.4	27.4	22.3	18.1
80	4.96	6.48	7.66	9.85	10.6	11.3	13.0	13.9	14.6	16.0	16.0	16.0	16.0	16.0	18.4	23.9	27.4	31.5	33.7	33.7	31.5	29.4	23.9	19.4
81	5.48	7.11	8.33	10.6	11.3	12.1	13.9	14.9	15.7	17.1	17.1	17.1	17.1	17.1	19.7	25.6	29.4	33.7	36.1	36.1	33.7	31.5	25.6	20.8
82	6.06	7.81	9.07	11.3	12.1	13.0	14.9	16.0	16.9	18.4	18.4	18.4	18.4	18.4	21.1	27.4	31.5	36.1	38.7	38.7	36.1	33.7	27.4	22.3
83	6.70	8.57	9.87	12.1	13.0	13.9	16.0	17.1	18.1	19.7	19.7	19.7	19.7	19.7	22.6	29.4	33.7	38.7	41.5	41.5	38.7	36.1	29.4	23.9
84	7.41	9.41	10.7	13.0	13.9	14.9	17.1	18.4	19.4	21.1	21.1	21.1	21.1	21.1	24.3	31.5	36.1	41.5	44.4	44.4	41.5	38.7	31.5	25.6
85	8.19	10.3	11.7	13.9	14.9	16.0	18.4	19.7	20.8	22.6	22.6	22.6	22.6	22.5	26.0	33.7	38.7	44.4	47.6	47.6	44.4	41.5	33.7	27.4
86	9.05	11.3	12.7	14.9	16.0	17.1	19.7	21.1	22.4	24.3	24.3	24.3	24.3	24.3	27.9	36.1	41.5	47.6	51.0	51.0	47.6	44.4	36.1	29.4
87	10.0	12.1	13.9	16.0	17.1	18.4	21.1	22.6	24.0	26.0	26.0	26.0	26.0	26.0	29.9	38.7	44.4	51.0	54.7	54.7	51.0	47.6	38.7	31.5
88	11.1	13.0	14.9	17.1	18.4	19.7	22.6	24.3	25.8	27.9	27.9	27.9	27.9	27.9	32.0	41.5	47.6	54.7	58.6	58.6	54.7	51.0	41.5	33.7
89	12.2	13.9	16.0	18.4	19.7	21.1	24.3	26.0	27.7	29.9	29.9	29.9	29.9	29.9	34.3	44.4	51.0	58.6	62.7	62.7	58.6	54.7	44.4	36.1
90	13.5	14.9	17.1	19.7	21.1	22.6	26.0	27.9	29.7	32.0	32.0	32.0	32.0	32.0	36.8	47.6	54.7	62.7	67.2	67.2	62.7	58.6	47.6	38.7
91	14.9	16.0	18.4	21.1	22.6	24.3	27.9	29.9	31.8	34.3	34.3	34.3	34.3	34.3	39.4	51.0	58.6	67.2	72.0	72.0	67.2	62.7	51.0	41.5
92	16.0	17.1	19.7	22.6	24.3	26.0	29.9	32.0	34.2	36.8	36.8	36.8	36.8	36.8	42.2	54.7	62.7	72.0	77.2	77.2	72.0	67.2	54.7	44.4
93	17.1	18.4	21.1	24.3	26.0	27.9	32.0	34.3	36.7	39.4	39.4	39.4	39.4	39.4	45.3	58.6	67.2	77.2	82.7	82.7	77.2	72.0	58.6	47.6
94	18.4	19.7	22.6	26.0	27.9	29.9	34.3	36.8	39.4	42.2	42.2	42.2	42.2	42.2	48.5	62.7	72.0	82.7	88.6	88.6	82.7	77.2	62.7	51.0
95	19.7	21.1	24.3	27.9	29.9	32.0	36.8	39.4	42.2	45.3	45.3	45.3	45.3	45.3	52.0	67.2	77.2	88.6	94.9	94.9	88.6	82.7	67.2	54.7
96	21.1	22.6	26.0	29.9	32.0	34.3	39.4	42.2	45.3	48.5	48.5	48.5	48.5	48.5	55.7	72.0	82.7	94.9	102	102	94.9	88.6	72.0	58.6
97	22.6	24.3	27.9	32.0	34.3	36.8	42.2	45.3	48.5	52.0	52.0	52.0	52.0	52.0	59.7	77.2	88.6	102	109	109	102	94.9	77.2	62.7
98	24.3	26.0	29.9	34.3	36.8	39.4	45.3	48.5	52.0	55.7	55.7	55.7	55.7	55.7	64.0	82.7	94.9	109	117	117	109	102	82.7	67.2
99	26.0	27.9	32.0	36.8	39.4	42.2	48.5	52.0	55.7	59.7	59.7	59.7	59.7	59.7	68.6	88.6	102	117	125	125	117	109	88.6	72.0

TABLE E-I CONTINUED

	1/3 OCTAVE BAND CENTER FREQUENCIES IN Hz (c/s)																							
100	27.9	29.9	34.3	39.4	42.2	45.3	52.0	55.7	59.7	64.0	64.0	64.0	64.0	64.0	73.5	94.9	109	125	134	134	125	117	94.9	77.2
101	29.9	32.0	36.8	42.2	45.3	48.5	55.7	59.7	64.0	68.6	68.6	68.6	68.6	68.6	78.8	102	117	134	144	144	134	125	102	82.7
102	32.0	34.3	39.4	45.3	48.5	52.0	59.7	64.0	68.6	73.5	73.5	73.5	73.5	73.5	84.4	109	125	144	154	154	144	134	109	88.6
103	34.3	36.8	42.2	48.5	52.0	55.7	64.0	68.6	73.5	78.8	78.8	78.8	78.8	78.8	90.5	117	134	154	165	165	154	144	117	94.9
104	36.8	39.4	45.3	52.0	55.7	59.7	68.6	73.5	78.8	84.4	84.4	84.4	84.4	84.4	97.0	125	144	165	177	177	165	154	125	102
105	39.4	42.2	48.5	55.7	59.7	64.0	73.5	78.8	84.4	90.5	90.5	90.5	90.5	90.5	104	134	154	177	189	189	177	165	134	109
106	42.2	45.3	52.0	59.7	64.0	68.6	78.8	84.4	90.5	97.0	97.0	97.0	97.0	97.0	111	144	165	189	203	203	189	177	144	117
107	45.3	48.5	55.7	64.0	68.6	73.5	84.4	90.5	97.0	104	104	104	104	104	119	154	177	203	217	217	203	189	154	125
108	48.5	52.0	59.7	68.6	73.5	78.8	90.5	97.0	104	111	111	111	111	111	128	165	189	217	233	233	217	203	165	134
109	52.0	55.7	64.0	73.5	78.8	84.4	97.0	104	111	119	119	119	119	119	137	177	203	233	249	249	233	217	177	144
110	55.7	59.7	68.6	78.8	84.4	90.5	104	111	119	128	128	128	128	128	147	189	217	249	267	267	249	233	189	154
111	59.7	64.0	73.5	84.4	90.5	97.0	111	119	128	137	137	137	137	137	158	203	233	267	286	286	267	249	203	165
112	64.0	68.6	78.8	90.5	97.0	104	119	128	137	147	147	147	147	147	169	217	249	286	307	307	286	267	217	177
113	68.6	73.5	84.4	97.0	104	111	128	137	147	158	158	158	158	158	181	233	267	307	329	329	307	286	233	189
114	73.5	78.8	90.5	104	111	119	137	147	158	169	169	169	169	169	194	249	286	329	352	352	329	307	249	203
115	78.8	84.4	97.0	111	119	128	147	158	169	181	181	181	181	181	208	267	307	352	377	377	352	329	267	217
116	84.4	90.5	104	119	128	137	158	169	181	194	194	194	194	194	223	286	329	377	404	404	377	352	286	233
117	90.5	97.0	111	128	137	147	169	181	194	208	208	208	208	208	239	307	352	404	433	433	404	377	307	249
118	97.0	104	119	137	147	158	181	194	208	223	223	223	223	223	256	329	377	433	464	464	433	404	329	267
119	104	111	128	147	158	169	194	208	223	239	239	239	239	239	274	352	404	464	497	497	464	433	352	286
120	111	119	137	158	169	181	208	223	239	256	256	256	256	256	294	377	433	497	533	533	497	464	377	307
121	119	128	147	169	181	194	223	239	256	274	274	274	274	274	315	404	464	533	571	571	533	497	404	329
122	128	137	158	181	194	208	239	256	274	294	294	294	294	294	338	433	497	571	611	611	571	533	433	352
123	137	147	169	194	208	223	256	274	294	315	315	315	315	315	362	464	533	611	655	655	611	571	464	377
124	147	158	181	208	223	239	274	294	315	338	338	338	338	338	388	497	571	655	702	702	655	611	497	404
125	158	169	194	223	239	256	294	315	338	362	362	362	362	362	416	533	611	702	752	752	702	655	533	433
126	169	181	208	239	256	274	315	338	362	388	388	388	388	388	446	571	655	752	806	806	752	702	571	464
127	181	194	223	256	274	294	338	362	388	416	416	416	416	416	478	611	702	806	863	863	806	752	611	497
128	194	208	239	274	294	315	362	388	416	446	446	446	446	446	512	655	752	863	925	925	863	806	655	533
129	208	223	256	294	315	338	388	416	446	478	478	478	478	478	549	702	806	925	991	991	925	863	702	571
130	223	239	274	315	338	362	416	446	478	512	512	512	512	512	588	752	863	991	1062	1062	991	925	752	611
131	239	256	294	338	362	388	446	478	512	549	549	549	549	549	630	806	925	1062	1137	1137	1062	991	806	655
132	256	274	315	362	388	416	478	512	549	588	588	588	588	588	676	863	991	1137	1219	1219	1137	1062	863	702
133	274	294	338	388	416	446	512	549	588	630	630	630	630	630	724	925	1062	1219	1306	1306	1219	1137	925	752
134	294	315	362	416	446	478	549	588	630	676	676	676	676	676	776	991	1137	1306	1399	1399	1306	1219	991	806
135	315	338	388	446	478	512	588	630	676	724	724	724	724	724	832	1062	1219	1399	1499	1499	1399	1306	1062	863
136	338	362	416	478	512	549	630	676	724	776	776	776	776	776	891	1137	1306	1499	1606	1606	1499	1399	1137	925
137	362	388	446	512	549	588	676	724	776	832	832	832	832	832	955	1219	1399	1606	1721	1721	1606	1499	1219	991
138	388	416	478	549	588	630	724	776	832	891	891	891	891	891	1024	1306	1499	1721	1844	1844	1721	1606	1306	1062
139	416	446	512	588	630	676	776	832	891	955	955	955	955	955	1098	1399	1606	1844	1975	1975	1844	1721	1399	1137
140	446	478	549	630	676	724	832	891	955	1024	1024	1024	1024	1024	1176	1499	1721	1975			1975	1844	1499	1219
141	478	512	588	676	724	776	891	955	1024	1098	1098	1098	1098	1098	1261	1606	1844					1975	1606	1306
142	512	549	630	724	776	832	955	1024	1098	1176	1176	1176	1176	1176	1351	1721	1975						1721	1399
143	549	588	676	776	832	891	1024	1098	1176	1261	1261	1261	1261	1261	1448	1844							1844	1499
144	588	630	724	832	891	955	1098	1176	1261	1351	1351	1351	1351	1351	1552	1975							1975	1606
145	630	676	776	891	955	1024	1176	1261	1351	1448	1448	1448	1448	1448	1564									1721
146	676	724	832	955	1024	1098	1261	1351	1448	1552	1552	1552	1552	1552	1783									1844
147	724	776	891	1024	1098	1176	1351	1448	1552	1664	1664	1664	1664	1664	1911									1975
148	776	832	955	1098	1176	1261	1448	1552	1664	1783	1783	1783	1783	1783	2048									
149	832	891	1024	1176	1261	1351	1552	1664	1783	1911	1911	1911	1911	1911										
150	891	955	1098	1261	1351	1448	1664	1783	1911	2048	2048	2048	2048	2048										

where M_j, L_k and A depend upon the band center frequency and the magnitude of L.

For $L_1 \leq L < L_2$

$$N = 0.1 \left(10^{M_1 (L-L_1)}\right) \quad 0.1 \leq N \leq 0.3$$

For $L_2 \leq L < L_3$

$$N = 10^{M_2 (L-L_3)} \quad 0.3 \leq N \leq 1.0$$

For $L_3 \leq L < L_c$

$$N = 10^{M_3 (L-L_3)} \quad 1.0 \leq N_1 \quad L \leq 150$$

For $L_c \leq L \leq 150$

$$N = 10^{M_4 (L-L_4)}$$

Note that for frequency bands having center frequencies from 400 to 6300 Hz inclusive, $L_3 = L_4$ and $M_3 = M_4$ (i.e. one set of values of L_k and M_j suffice to define noy values for $N \leq 1$ and $L \leq 150$). The values of M_j and L_k are tabulated in Table E-II.

II. Tone Corrected Perceived Noise Level (PNLT)

Two methods of tone correction for perceived noise levels were employed in the analysis of the judgment test results. One of the methods was based on the Kryter-Pearsons studies (Ref. 5) and the other was based on the proposed FAA certification procedure (Ref. 6).

The basic difference between the two methods is that in the Kryter-Pearsons method the tone correction is added as a correction to the one-third octave band level before the PNL calculation whereas in the FAA method the tone correction is added after the PNL calculation.

TABLE E-II

CONSTANTS USED TO DEFINE NOY TABLE BY EQUATIONS

Band Center Frequency (Hz)	L_1	M_1	L_2	M_2	L_3	M_3	L_c	M_4	L_4
50	49	0.079520	55	0.058098	64	0.043478	91.01	0.030103	52
63	44	0.068160	51	0.058098	60	0.040570	85.88	0.030103	51
80	39	0.068160	46	0.052288	56	0.036831	87.32	0.030103	49
100	34	0.059640	42	0.047534	53	0.036831	79.85	0.030103	47
125	30	0.053013	39	0.043573	51	0.035336	79.76	0.030103	46
160	27	0.053013	36	0.043573	48	0.033333	75.96	0.030103	45
200	24	0.053013	33	0.040221	46	0.033333	73.96	0.030103	43
250	21	0.053013	30	0.037349	44	0.032051	74.91	0.030103	42
315	18	0.053013	27	0.034859	42	0.030675	94.63	0.030103	41
400	16	0.053013	25	0.034859	40	0.030103	100.00	0.030103	40
500	16	0.053013	25	0.034859	40	0.030103	100.00	0.030103	40
630	16	0.053013	25	0.034859	40	0.030103	100.00	0.030103	40
800	16	0.053013	25	0.034859	40	0.030103	100.00	0.030103	40
1000	16	0.053013	25	0.034859	40	0.030103	100.00	0.030103	40
1250	15	0.059640	23	0.034859	38	0.030103	100.00	0.030103	38
1600	12	0.053013	21	0.040221	34	0.029960	100.00	0.029960	34
2000	9	0.053013	18	0.037349	32	0.029960	100.00	0.029960	32
2500	5	0.047712	15	0.034859	30	0.029960	100.00	0.029960	30
3150	4	0.047712	14	0.034859	29	0.029960	100.00	0.029960	29
4000	5	0.053013	14	0.034859	29	0.029960	100.00	0.029960	29
5000	6	0.053013	15	0.034859	30	0.029960	100.00	0.029960	30
6300	10	0.068160	17	0.037349	31	0.029960	100.00	0.029960	31
8000	17	0.079520	23	0.037349	37	0.042285	44.29	0.029960	34
10,000	21	0.0596401	29	0.043573	41	0.042285	50.72	0.029960	37

Kryter Pearsons Tone Correction Method

The Kryter-Pearsons method (identified by the subscript "KP") for determining the tone correction employs the one-third octave band. If one of the one-third octave bands exceeds the adjacent two levels by more than 3dB then it is assumed to contain a pure tone. To determine the amount of correction necessary the adjacent bands are averaged and subtracted from the band containing the tone. This difference is entered into Table E-III to determine the noise level correction. After all appropriate bands are so corrected, the perceived noise level is calculated in accordance with the procedure outlined above.

FAA Tone Correction Method

The FAA method (identified by the subscript "F") uses a somewhat different approach to determine the tone correction. The one-third octave band levels for this measure are determined for each one-half second interval during the flyover noise. The perceived noise levels are determined for each of these one-half second intervals and a pure tone correction is included for each interval using the following procedure.

Step 1

Compute D_{ji} where:

i = 1/3 octave band number, and $j = i+1$.

$i = 1$ corresponds to the band with center frequency of 80 Hz

L_i = Band sound pressure of the ith frequency band.

D_{ji} = Arithmetic difference between the level (L_i) in the frequency bands j and i.

Step 2

Encircle those values of D_{ji} where:

$$|D_{ji} - D_{j-1,i-1}| > 5 \text{ dB}$$

TABLE E-III

[illegible]
[illegible]*

1/3 Octave Band, Center Frequency in Hz	Difference between SIL of 1/3 octave band containing tones and SIL of adjacent band, dB																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
80																									
100																									
125																									
160																									
200												0.3	0.6	[illegible]	1.0	1.2	1.4	1.6	1.7	1.8	2.0	[illegible]	[illegible]	2.5	[illegible]
250							0.2	0.6	1.0	1.4	1.6	1.8	2.2	2.5	2.9	3.2	3.5	3.8	4.[illegible]	4.3	4.5	4.8	[illegible]	[illegible]	[illegible]
320				0.7	1.2	1.8	2.0	2.4	2.7	3.0	3.[illegible]	3.5	3.8	4.1	4.5	4.8	5.0	5.4	5.7	6.0	6.4	6.7	7.0	7.[illegible]	[illegible]
400			1.0	1.7	2.4	3.0	3.4	3.8	4.1	4.5	4.8	5.0	5.4	5.6	6.0	6.3	6.5	6.8	7.1	7.4	7.6	7.8	[illegible]	[illegible]	8.5
500		1.3	2.1	2.8	3.5	3.9	4.4	4.8	5.1	5.5	5.8	6.1	6.5	6.8	7.1	7.3	7.5	7.8	8.0	8.3	[illegible]	8.6	8.8	[illegible]	[illegible]
630		1.5	2.4	3.0	3.6	4.0	4.5	5.0	5.4	5.8	6.1	6.4	6.7	7.0	7.4	7.6	8.0	8.3	8.5	8.8	9.0	9.2	9.4	9.6	9.7
800	0.3	1.9	2.6	3.4	3.0	4.5	5.0	5.3	5.8	6.2	6.6	7.0	7.4	7.5	8.0	8.4	8.6	8.8	9.1	9.4	9.5	9.8	10.[illegible]	10.2	10.3
1000	0.5	2.0	3.0	3.8	4.5	5.0	5.5	5.9	6.3	6.7	7.1	7.5	7.9	8.3	8.6	8.9	9.1	9.5	9.8	10.0	10.2	10.5	10.7	10.9	11.0
1250	1.5	2.9	3.7	4.4	5.0	5.4	5.9	6.3	6.8	7.2	7.6	8.0	8.3	8.6	9.0	9.2	9.5	9.8	10.0	10.3	10.5	10.8	11.1	11.3	11.4
1600	1.7	3.3	4.1	4.8	5.5	6.0	6.5	7.0	7.5	7.8	8.2	8.5	8.8	9.1	9.5	9.8	10.2	10.5	10.8	11.0	11.3	11.6	11.8	12.0	12.2
2000	2.2	3.8	4.8	5.6	6.2	6.7	7.2	7.6	8.0	8.5	8.8	9.1	9.5	9.9	10.2	10.5	10.8	11.1	11.4	11.6	11.9	12.2	12.4	12.6	12.8
2500	2.5	4.2	5.2	6.0	6.6	7.2	7.6	8.0	8.4	8.8	9.2	9.5	9.9	10.2	10.5	10.8	11.2	11.5	11.8	12.2	12.5	12.9	13.2	13.6	14.0
3200	3.0	4.6	5.6	6.4	7.0	7.5	8.1	8.6	9.0	9.5	9.9	10.2	10.6	11.0	11.3	11.6	12.0	12.3	12.6	13.0	13.3	13.5	13.8	14.0	14.3
4000	3.0	4.6	5.6	6.4	7.0	7.5	8.0	8.4	8.8	9.2	9.6	10.0	10.4	10.7	11.1	11.4	11.7	12.0	12.4	12.6	12.9	13.1	13.4	13.6	14.0
5000	3.0	4.3	5.2	5.8	6.2	6.6	7.0	7.3	7.5	7.8	8.0	8.3	8.4	8.5	8.8	9.0	9.3	9.5	9.3	10.0	10.2	10.5	10.7	10.9	11.0
6300	1.7	2.4	2.8	3.1	3.3	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.9	5.0	5.1	5.2	5.4	5.5	6.0	6.1	6.2	6.3	6.4	6.5
8000	0.4	0.5	0.4	0.4	0.4	0.4	0.6	0.7	0.9	0.8	1.0	0.9	1.0	1.2	1.2	1.2	1.1	1.3	1.2	2.0	2.0	1.9	1.9	1.9	2.0
10,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* This table was obtained from extrapolation of previous data. Ref.6.

Step 3

A. If the encircled D_{ji} is positive and algebraically greater than $D_{j-1,i-1}$, encircle L_j.

B. If the encircled D_{ji} is zero or negative and $D_{j-1,i-1}$ is positive, encircle L_i.

Step 4

A. For all non-encircled Li, set $L_i' = L_i$

B. For encircled values L_i set L_i' equal to the arithmetic average of L_{i-1} and L_{i+1}.* If the SPL value in the highest frequency band is encircled, set $L_{22}' = L_{21} + D_{21,20}$.

Step 5

Compute D_{ji} where D'_{ji} is the arithmetic difference between the levels L_i in the frequency bands j and i.

Step 6

Compute $\overline{D}_{ji}$ as the arithmetic average of $D'_{j-1,i-1}$, D'_{ji} and $D'_{j+1,i+1}$.

Where i = 1, set $D'_{j-1,i-1}$ equal to D'_{ji}.

Where i = 21, set $D'_{j+1,i+1}$ equal to D'_{ji}

Step 7

Set $\overline{L_1}$ equal to L_1. Determine all other values of $\overline{L_j}$ by adding D_{ji} to L_i.

*Recent experience has shown that this method of averaging the sound pressure levels of adjacent bands will result in too low a discrete frequency correction when the presence of a tone (or tones) influences the sound pressure levels of two adjacent bands. The procedure used in the study averaged the sound pressure levels of the two nearest non-circled adjacent bands rather than those of the two directly adjacent bands.

Step 8

Determine F_i where:

$$F_i = L_i - \bar{L}_i$$

Step 9

Determine the discrete frequency correction, C, from the following equations:

$C = 0$	$F<3$	For one-third octave bands between 500 and 5000 Hz.
$C = F/3$	$3 \leq F<20$	
$C = 6.7$	$20 \leq F$	
$C = 0$	$F<3$	For all other one-third octave bands in the frequency range 100 Hz up to 10,000 Hz.
$C = f/6$	$3 \leq F<20$	
$C = 3.3$	$20 \leq F$	

Step 10

The maximum value of C determined in Step 9 defines the discrete frequency correction.

III. Duration Corrected Perceived Noise Level (PNLD)

Four methods of duration correction for perceived noise levels were employed in the analysis of the judgment results. Basically, the measures can be divided into two groups. One, an integrated measure of duration correction and the other a log duration correction. Further variations of the measures were determined by the choice of different parameters used in the two correction methods.

TABLE E-IV

ILLUSTRATION OF THE USE OF FAA TONE CORRECTION

PROCEDURE DESCRIBED IN STEPS 1 THROUGH 10

Step		3	1+2	4	5	6	7	8	9
Band i	f_i	L_i	D_{ji}	L_i	D_{ji}	$\bar{D}_{ji}$	$\bar{L}_i$	F_i	C
1	80	70		70			70	-	
			- 8		- 8	-2 1/3			
2	100	62		62			67 2/3	-	
			+ 8		+ 9	+3 1/3			
3	125	70		(71)			71	-	
			+10		+ 9	+6 2/3			
4	160	80		80			77 2/3	2 1/3	
			+ 2		+ 2	+2 2/3			
5	200	82		82			80 1/3	1 2/3	
			+ 1		- 3	-1 1/3			
6	250	83		(79)			79	4	2/3
			- 7		- 3	-1 1/3			
7	315	76		76			77 2/3	-	
			+ 4		+ 2	+ 1/3			
8	400	80		(78)			78	2	
			0		+ 2	+1			
9	500	80		80			79	1	
			- 1		- 1	0			
10	630	79		79			79	-	
			- 1		- 1	0			
11	800	78		78			79	-	
			+ 2		+ 2	- 1/3			
12	1000	80		80			78 2/3	1 1/3	
			- 2		- 2	- 2/3			
13	1250	78		78			78	-	
			- 2		- 2	- 1/3			
14	1600	76		76			77 2/3	-	
			+ 3		+ 3	+ 1/3			
15	2000	79		79			78	1	
			+ 6		0	+1			
16	2500	85		(79)			79	6	2
			- 6		0	- 1/3			
17	3150	79		79			78 2/3	1/3	
			- 1		- 1	-2 2/3			
18	4000	78		78			76	2	
			- 7		- 7	-6 1/3			
19	5000	71		71			69 2/3	1 1/3	
			-11		-11	-8			
20	6300	60		60			61 2/3	-	
			- 6		- 6	-8 2/3			
21	8000	54		54			53	1	
			- 9		- 9	-8			
22	10000	45		45			45	-	

According to Step 10, the discrete frequency correction is 2.

Integrated Duration Correction

The integrated duration correction D_I is defined by the expression:

$$D_I = 10 \log \left[(1/T) \int_{t(1)}^{t(2)} \log^{-1} (PNLT/10)\,dt \right] - PNLT(MAX)$$

where T is a normalizing time constant, PNLT is the expression for tone corrected perceived noise level as a function of time, PNLT(MAX) is the maximum value of the tone corrected perceived noise level, and t(1) and t(2) are the limits of the time interval d during which PNLT is within a specified value h of PNLT(MAX). Figure E-1 illustrates the above conditions.

Since PNLT is calculated from measured values of SPL, there will, in general, be no obvious equation for PNLT as a function of t. Consequently, the above equation can be rewritten with a summation sign instead of the integral sign as follows:

$$D_I = 10 \log \left[(1/T) \sum_{k=0}^{d/\Delta t} \Delta t \ \log^{-1} \left[PNLT(k)/10 \right] \right] - PNLT(MAX)$$

where Δt is the equal increment of time for which PNLT is calculated and PNLT(k) is the value of PNLT at the k-th increment of time.

At this date, the following values are considered representative of the current state-of-the-art for the integration procedure and are presented as basic requirements:

$$T = 10 \text{ sec}$$

$$\Delta t = 0.5 \text{ sec}$$

$$h = 10 \text{ dB}$$

Using the above values, the previous equation becomes,

$$D_{I10} = 10 \log \left[\sum_{k=0}^{2d} {}_{10} \log^{-1} \left[PNLT(k)/10 \right] \right] - PNL(MAX) - 13$$

where d is the duration time defined by the 10 dB-down points.

For comparison, additional parameters were employed giving rise to a different duration correction as follows:

$$T = 10 \text{ sec}$$

$$\Delta t = 0.5 \text{ sec}$$

$$h = 20\text{dB}$$

Using these values the new equation becomes:

$$D_{I20} = 10 \log \left[\sum_{K=0}^{2d_{20}} \log^{-1} \left[PNL(k)/10 \right] \right] - PNL(MAX) - 13$$

Approximate Duration Correction

The integrated duration calculation procedure is considered to be the most representative of the current methods. However, an alternative method is given below which is simpler to use and has been used in the past with some success.

The approximate duration correction D is defined by the expression:

$$D = 10 \log (d/T)$$

where d is the time interval between the limits of t(1) and t(2) during which PNLT is within a specified value h of PNLT(MAX) and T is a normalizing time constant. At this date, the following values are considered representative of the current state-of-the-art for the approximate procedure and are presented as basic requirements:

$$T = 15 \text{ sec}$$

$$h = 10\text{dB}$$

Using the above values, equation becomes

$$D_{10} = 10 \log (d_{10}/15)$$

Other parameters were also employed to determine a different duration correction. The parameters were as follows:

$$T = 30 \text{ sec}$$

$$h = 20\text{dB}$$

Using the above values, the duration correction equation becomes

$$D_{20} = 10 \log d_{20}/30$$

where d_{20} is the duration time defined by the 20dB down points.

The two approximate duration corrections above will produce the same correction if the time pattern shape is triangular. Since most aircraft flyovers are generally of this time pattern, the two duration corrections should be quite similar. However, since the time patterns employed in the judgment tests differ greatly from the basic triangular pattern, the two corrections will become quite different from one another.

IV. Effective Perceived Noise Level (EPNL)

The effective perceived noise level of aircraft flyover includes both the tone and duration corrections outlined above. That is,

$$EPNL = PNLT + D$$

where PNLT is the maximum tone correction perceived noise level and D is the duration correction based on the duration of the tone corrected perceived noise level.

In cases where the integrated duration correction is employed the measure which is integrated is indeed always the same measure which is used to determine the level. However, when the approximate D correction is employed in some cases it is difficult to determine the duration of the sample using the tone corrected perceived noise level or even perceived noise level measure. In these cases, a substitute measure is sometimes employed such as N-level or A-level to determine the duration of the sound sample. When this approximation is employed in this report, appropriate notes have been made regarding the details of the approximation. It is assumed unless otherwise noted, that the duration correction is based upon the same measure which is being employed to determine the maximum level of the sound stimulus.

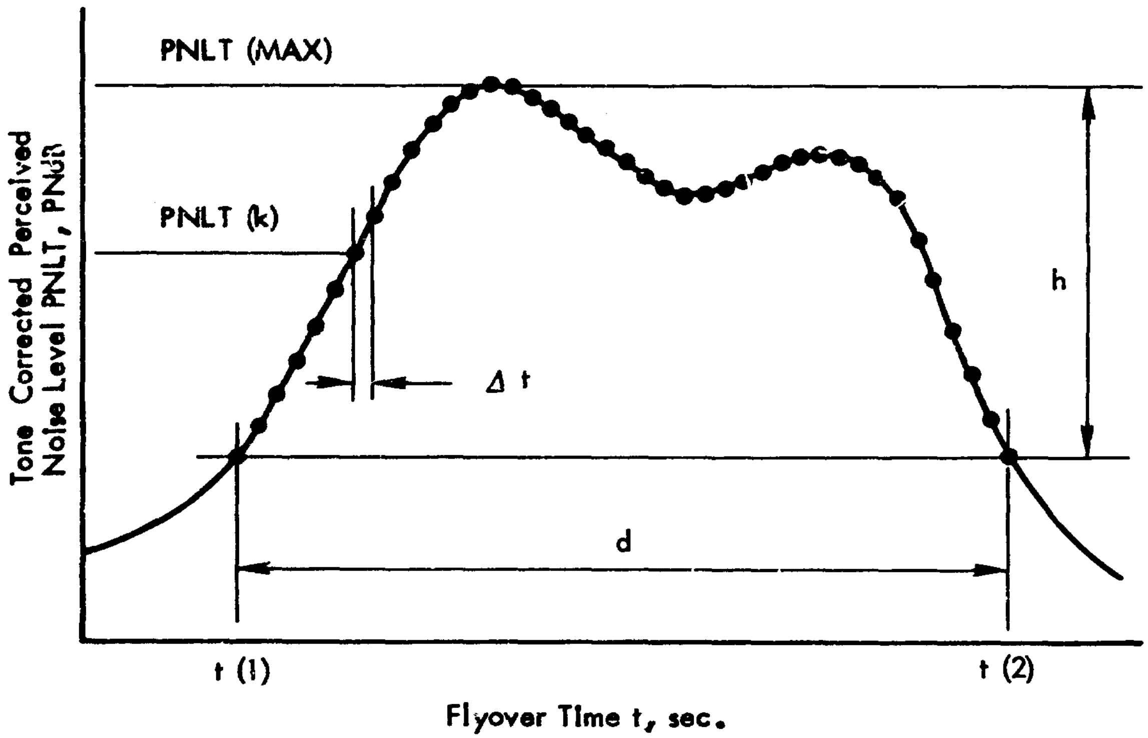

FIGURE E1 PERCEIVED NOISE LEVEL CORRECTED FOR TONES AS A FUNCTION OF AIRCRAFT FLYOVER TIME

APPENDIX F

RESULTS OF JUDGMENT TESTS

TABLE F-1

RESULTS OF TEST I

LEVEL OF COMPARISON JUDGED EQUALLY NOISY TO STANDARD

TONE	TEMPORAL PATTERN[1]	DURATION[2]	SPECTRA SHAPE[3]	REL. COMP. LEVEL[4]	OASPL	AL	NL	PNL_C	PNL	$EPNL^5_{CKF10}$	$EPNL_{FI10}$
1	A	20 Sec.	V	- 7.0	83.0	82.5	92.0	89.8	89.8	88.6	88.2
2	A	20 Sec.	W	-11.0	79.0	79.0	95.5	90.7	90.7	89.5	89.1
3	A	20 Sec.	X	- 7.5	80.5	75.0	87.5	86.0	85.8	89.3	88.0
4	A	20 Sec.	Y	-18.0	72.0	73.0	90.0	85.7	85.7	93.6	88.0
5	A	20 Sec.	Z	- 2.5	78.5	75.0	90.5	89.0	88.9	88.2	86.7
6	B	16 Sec.	V	- 7.0	83.5	83.5	93.0	89.9	89.8	88.9	89.0
7	B	16 Sec.	W	-11.5	77.5	78.5	94.5	89.5	89.5	88.7	88.5
8	B	16 Sec.	X	- 7.0	81.5	75.0	87.5	85.1	85.0	87.6	87.4
9	B	16 Sec.	Y	-17.5	72.5	73.5	90.5	85.6	85.6	93.6	88.4
10	B	16 Sec.	Z	- 4.0	79.0	73.0	88.0	87.0	86.8	86.2	85.1
11	C	40 Sec.	V	-10.0	80.5	80.0	89.5	88.4	88.2	87.6	88.7
12	C	40 Sec.	W	-15.0	75.0	75.5	91.5	87.9	87.9	87.1	88.2
13	C	40 Sec.	X	- 9.5	79.0	73.0	85.5	85.1	84.8	87.6	88.9
14	C	40 Sec.	Y	-18.5	71.5	72.5	90.0	85.8	85.8	93.7	90.6
15	C	40 Sec.	Z	- 4.5	77.0	72.5	88.0	87.8	87.6	87.2	87.7
16	D	30 Sec.	V	- 7.0	83.0	82.5	92.0	88.0	87.9	88.9	87.3
17	D	30 Sec.	W	-11.5	78.0	78.5	94.5	88.5	88.5	89.0	86.8
18	D	30 Sec.	X	- 6.0	81.5	76.0	88.0	85.4	85.4	89.8	87.1
19	D	30 Sec.	Y	-18.0	71.0	72.0	89.0	83.3	83.3	92.6	85.0
20	D	30 Sec.	Z	- 2.0	78.0	74.5	90.0	87.2	87.1	88.0	84.6
21	E	14 Sec.	V	- 7.0	83.0	82.5	92.0	88.0	88.0	87.0	86.0
22	E	14 Sec.	W	-10.5	79.0	79.5	95.5	89.4	89.4	88.4	87.0
23	E	14 Sec.	X	- 6.5	81.5	76.5	88.5	85.1	84.7	87.8	85.7
24	E	14 Sec.	Y	-17.5	71.5	72.5	90.0	83.9	83.9	91.7	84.9
25	E	14 Sec.	Z	0.0	80.0	76.0	91.5	88.6	88.6	87.8	85.5
26	F	10 Sec.	V	-13.5	77.0	76.5	86.0	85.3	85.1	83.5	85.4
27	F	10 Sec.	W	-16.5	72.5	73.5	89.5	86.0	85.9	84.2	86.0
28	F	10 Sec.	X	-18.0	72.0	66.0	78.5	78.0	77.7	80.0	82.0
29	F	10 Sec.	Y	-24.0	66.0	67.0	84.0	80.2	80.1	87.2	84.9
30	F	10 Sec.	Z	- 8.5	73.0	67.5	82.5	83.3	83.0	81.5	82.8
STD	A	20 Sec.	Z	0.0	81.0	75.0	90.5	89.8	89.6	89.2	87.4

1. See Figure 2.
2. Duration is amount of time the signal is within 20 dB of maximum level; when the signal is within 10 dB of maximum level, the duration is always 10 seconds.
3. Refer to Figure 1.
4. Relative Comparison Level - Comparison gain judged equality in dB re standard gain.
5. Duration correction derived from N-level measurements.

TABLE F-II

RESULTS OF TEST II

LEVELS OF COMPARISON JUDGED EQUALLY NOISY TO STANDARD

COMP	TEMPORAL PATTERN[1]	DURATION[4] 10dB	DURATION[4] 20dB	SPECTRA SHAPE[5]	REL. COMP. LEVEL[6]	OASPL	AL	NL	PNL_C	PNL	$EPNL_{CKF10}$	$EPNL_{F110}$
1	A	1.0	2.0	Z	4.0	86.5	79.5	95.5	94.4	94.4	[illegible]	[illegible]
2	A	1.0	2.0	X	1.0	91.0	84.5	97.5	95.2	95.2	[illegible]	[illegible]
3	E	1.0	1.4	X	0.5	90.5	84.0	97.0	92.8	92.8	87.5	84.5
4	F	1.0	1.0	X	- 7.0	83.5	76.5	90.5	[illegible]	[illegible]	[illegible]	[illegible]
5	A	4.0	8.0	Z	1.5	83.5	77.0	93.0	[illegible]	90.9	[illegible]	[illegible]
6	A	4.0	8.0	X	- 6.5	83.5	77.0	90.0	[illegible]	86.7	[illegible]	[illegible]
7	E	4.0	5.6	X	- 3.5	85.5	80.0	93.0	86.8	86.8	85.1	[illegible]
8	A	10.0	20.0	Z	- 0.5	82.0	75.0	91.0	89.0	89.0	89.3	87.4
9	A	10.0	20.0	X	-10.5	79.5	73.0	86.0	83.7	83.7	88.5	86.4
10	E	10.0	14.0	X	- 9.5	80.5	74.0	[illegible]	82.8	82.8	87.6	84.5
11	F	10.0	10.0	X	-17.0	73.5	66.5	79.5	78.2	77.9	81.3	82.3
12	A	20.0	40.0	Z	- 4.5	79.0	71.0	87.0	86.9	86.8	88.5	87.0
13	A	20.0	40.0	X	-14.0	75.0	69.0	82.5	80.2	80.1	87.7	85.5
14	E	20.0	28.0	X	-13.0	76.5	70.0	83.5	80.5	80.1	87.1	83.9
15	A	100.0	200.0	Z	- 8.5	74.5	67.0	83.0	81.9	81.9	91.3	83.4
16	A	100.0	200.0	X	-17.5	72.5	66.0	79.0	76.7	76.7	91.5	83.4
17	E	100.0	140.0	X	-20.5	69.5	62.5	76.0	71.8	71.8	86.6	83.5
18	F	100.0	100.0	X	-26.5	64.0	57.0	70.5	68.7	68.4	82.4	83.4
19	F/O[2]	15.0	26.0	X	- 1.5	88.5	82.0	94.0	93.9	92.4	92.4	90.4
20	SPEC.[3]	9.0	10.0	Y	-15.5	75.0	68.0	81.5	79.6	79.5	82.9	84.1
STD	A	10.0	20.0	Z	0.0	82.0	75.5	91.0	90.6	90.6	89.8	88.3

1. Refer to Figure 2.
2. Flyover: Refer to "STD" Table III.
3. Special trapezoidal time pattern with duration at the 10 dB down points equal to 9 seconds; at the 20 dB down points it is equal to 10 seconds.
4. Duration is the amount of time in seconds the signal is within 10 dB or 20 dB of maximum level.
5. Refer to Figure 1.
6. Relative Comparison Level - comparison gain judged equality in dB re standard gain.

TABLE F-III

RESULTS OF TEST III

LEVELS OF COMPARISON JUDGED EQUALLY NOISY TO STANDARD

TONE	TYPE OF AIRCRAFT	DURATION 10dB	DURATION 20dB	REL. COMP. LEVEL[2]	OASPL	AL	NL	PNL$_C$	PNL	EPNL$_{CKP10}$	EPNL$_{F110}$
1	Boeing 720	6	10	- 8.0	79.5	77.0	89.0	90.5	89.5	86.9	85.9
2	Douglas DC-8	11	20	- 9.5	77.5	75.0	87.5	89.4	86.6	89.3	87.6
3	Boeing 707B	5	10	-10.0	73.5	74.0	89.0	88.8	88.0	90.6	87.6
4	Boeing 720B	5	8	-10.0	75.5	76.0	89.5	89.9	89.1	90.6	87.3
5	Boeing 720B	6	9	-10.0	75.0	75.5	90.0	90.4	89.7	90.6	88.2
6	Boeing 707B	6	9	- 7.0	78.5	79.0	92.5	92.2	91.4	93.5	89.5
7	Boeing 727	5	10	- 9.0	77.5	76.0	90.0	90.3	89.9	86.7	85.6
8	Douglas DC-9	10	18	- 4.0	82.5	77.0	89.5	89.1	87.8	87.6	85.7
9	Douglas DC-8	18	36	- 7.0	84.0	78.0	89.5	89.6	87.9	91.0	88.6
10	Douglas DC-9	15	26	- 3.0	87.0	81.0	93.0	93.2	90.9	94.0	91.5
11	Lockheed Elect.	10	24	4.0	85.5	82.0	93.0	90.1	88.6	90.2	89.2
12	Fairchild F-27	9	21	2.5	85.5	78.0	92.5	91.5	89.6	90.2	89.0
13	Douglas DC-8	9	16	- 5.5	81.5	79.5	89.5	91.6	90.3	89.7	87.8
14	Boeing 707	14	30	- 6.0	81.0	77.0	88.0	90.2	88.2	91.0	89.0
15	Boeing 727	9	18	0.5	87.0	80.5	93.0	91.8	90.3	90.5	88.5
16	Boeing 720B	8	20	- 5.5	82.5	76.5	89.5	91.0	90.0	93.0	89.4
17	Douglas DC-8:10	16	34	- 4.0	82.0	78.0	89.0	88.0	87.3	89.5	87.9
18	Vertol CH-46#1	3	7	3.5	87.5	78.0	95.5	92.1	91.9	86.9	85.9
19	Sikorsky CH-34#3	5	20	- 1.5	85.5	80.0	92.5	91.7	91.2	88.4	86.9
20	Sikorsky CH-34#1	14	28	- 2.5	85.0	78.5	90.5	91.1	89.6	91.0	89.2
STD	Douglas DC-9	15	26	0.0	86.5	81.0	93.0	92.3	91.5	91.3	89.5

1. Duration is the amount of time in seconds the signal is within 10 or 20dB of maximum level.
2. Relative Comparison Level - comparison gain judged equality in dB re standard gain.

TABLE F-IV

STATISTICAL SUMMARY OF RESULTS[1] FOR TESTS I, II, III

LEVELS OF COMPARISON JUDGED EQUALLY NOISY TO STANDARD

	CASPL	AL_{I10}	AL	$PNLD_{20}$	PNL	PNL_C	$PNLD_{I20}$	$PNLD_{I10}$	NL	NL_{I10}	$PNLD_{10}$	$PNLT_{CKP}$	$PNLT_P$	$EPNL_{P20}$	$EPNL_{CKP20}$	$EPNL_{CKP10}$	$EPNL_{P10}$	$EPNL_{PI20}$	$EPNL_{PI10}$
Test I																			
Full Range	17.5	15.0	16.5	16.0	13.0	12.5	11.5	11.0	17.0	15.0	14.0	13.0	9.0	13.0	17.5	13.5	10.0	9.0	8.5
75% Range[2]	8.5	6.0	5.0	5.5	5.0	4.5	4.0	4.0	4.0	4.0	4.5	4.0	3.0	2.5	4.0	4.5	1.5	2.5	2.5
Mean	-4.0	0.5	0.5	-3.5	-3.5	-3.5	-2.5	-3.0	-1.0	-1.0	-3.0	-1.0	-1.5	-1.5	-1.5	-1.0	-1.5	-1.0	-0.5
Std. Dev.	5.5	4.0	4.5	4.0	3.0	3.0	3.0	3.0	4.0	3.5	3.0	3.0	2.0	3.5	4.0	3.0	2.5	2.0	2.0
Test II																			
Full Range	27.0	12.5	25.5	17.0	27.0	26.5	12.5	12.0	27.0	12.5	15.0	27.0	27.0	12.5	13.0	10.5	10.0	8.5	8.5
75% Range	8.5	6.0	9.0	9.5	11.0	10.5	9.5	9.5	9.0	9.0	8.5	8.0	8.5	5.5	5.5	4.5	4.5	4.5	4.0
Mean	-2.5	-3.5	-2.5	-7.0	-6.5	-6.0	-6.0	-6.0	-4.0	-5.5	-6.5	-2.5	-3.0	-3.5	-3.5	-2.5	-2.5	-2.5	-2.5
Std. Dev.	7.0	3.0	7.5	5.5	7.5	7.5	4.0	4.0	7.5	4.0	4.5	6.5	6.5	4.0	4.0	3.0	3.0	2.5	2.0
Test III																			
Full Range	14.0	10.0	8.0	5.5	4.5	5.0	6.5	6.5	8.0	6.5	6.0	8.0	7.5	5.5	6.5	7.5	6.0	6.0	6.0
75% Range	8.5	4.5	4.5	3.5	3.5	3.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	3.0	2.5	2.5	2.5
Mean	-5.0	-3.0	-3.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.5	-2.0	-2.0	-1.5	-1.5	-1.5	-1.0	-1.0	-1.0	-1.5	-1.5
Std. Dev.	4.5	2.5	2.0	1.5	1.5	1.5	1.5	1.5	2.0	1.5	1.5	2.0	2.0	1.5	2.0	2.0	1.5	1.5	1.5

1. Values in this table are derived from levels of comparison relative to standard.
2. Seventy-five percent of the data from the standard lies within this range.

Bolt Beranek and Newman Inc., Los Angeles, California
THE EFFECTS OF TEMPORAL AND SPECTRAL COMBINATIONS ON THE JUDGED NOISINESS OF AIRCRAFT SOUNDS, Final Report June 1969, 76 pp., incl. illus., 9 refs. (Contract No. FA68WA-1978, Report No. FAA-NO-69-3)

Unclassified Report

Tests were performed in an anechoic chamber using twenty college students to determine the judged noisiness of stimuli varying both temporally and spectrally. The investigations were divided into three test series. The first test series used thirty stimuli with six different time patterns and five different spectra. The second test used stimuli selected from the first test but modified to include signal durations ranging from 1 to 100 seconds. Duration in this case is the amount of time the stimuli were within 10 dB of the maximum level. The stimuli for the third test consisted of recordings of turboprop, turbofan, turbojet and helicopter flyovers.

The results indicated that the most accurate predictor of judged noisiness was perceived noise level using a tone correction suggested by the FAA and an integrated measure of duration. To illustrate the improvement in noisiness predictability of EPNL over PNL, the results of Test II (duration test) are used. For this test, 75% of the data was within 4 dB of the standard for EPNL with the FAA tone and integrated duration measure as compared to 11 dB for PNL.

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I. Pearsons, K.S., Bennett, R.L.
II. Contract No. FA68-WA-1978
III. BBN Report No. 1722
IV. Report No. FAA-NO-69-3

Descriptors

Noisiness Judgment Tests
Perceived Noise Level
Noise Duration
Effective Perceived Noise Level
Aircraft Flyover Noise

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