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COMBINATION EFFECTS OF TONE AND DURATION PARAMETERS ON PERCEIVED NOISINESS

by Karl S. Pearsons

Prepared by
BOLT BERANEK AND NEWMAN INC.
Van Nuys, Calif.
for Langley Research Center

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SUMMARY

Three series of judgment tests were conducted to investigate the effects on perceived noisiness of tone content and duration parameters. Time patterns for the stimuli employed in the tests were triangular in shape to simulate aircraft flyover time histories. Stimuli for the first test (I-A) included durations of 4, 12, and 32 seconds measured 10 dB below the maximum level of the stimulus. Tone-to-noise ratios in 1/3 octave bands for the stimuli at 2000 and 4000 Hz were varied to include 10 and 25 dB and "no tone". In the second test (I-B), stimuli included recordings of test stand turbofan engine noise using the same time history shape and durations mentioned above. The third test (II) utilized pure-tone and broadband noise spectra like those used in Test I-A, however, the duration of the tone differed from the duration of the noise, and the maximum level of the tone did not always occur at the same point in time as the maximum level of the noise. Several different methods of measurement were used to evaluate the judgment results including overall sound pressure level, A-weighted sound pressure level, N-weighted sound pressure level, perceived noise level, perceived noise level with Kryter and Pearsons tone and duration corrections, and effective perceived noise level as suggested by the FAA. The results of these three tests indicate that perceived noise level with tone and duration corrections, developed independently in previous studies, provides better agreement with subjective judgments of acceptability than do the other measures that were investigated.

INTRODUCTION

Several studies have investigated the effects of duration while holding the pure-tone content of the stimulus constant (Refs. 1, 2). Other studies have varied the pure-tone content while holding the duration of the stimulus constant (Refs. 3,4). In aircraft flyovers, variations both in duration and in pure-tone content are simultaneously present. Therefore, it was decided to conduct additional tests using stimuli in which both duration and tone content were varied. The next section of this report describes the tests employed in this investigation. Following the test description, the results are presented. The final sections present a discussion of these results and the major conclusions derived from the study.

TEST DESCRIPTION

Test Organization

To accomplish the tasks set forth in the work statement, judgment tests were conducted using three different sets of stimuli compared to the same broadband standard. The comparison stimuli for the various tests were as follows:

Test I

A. Single tones combined with broadband noise spectra in various tone-to-noise ratios for three different durations.

B. A real turbofan engine runup was recorded to simulate an actual flyover. The amplitude of the jet-engine noise was shaped in time to provide a simulation of three different flyover durations.

Test II

Pure-tone and broadband noise spectra, like those used in Test I-A; however, the duration of the tone differed from the duration of the noise, and the maximum level of the tone did not always occur at the same point in time as the maximum level of the noise. Some of the comparison stimuli were compared to a standard containing a pure-tone, as well as the broadband noise standard.

For each of the tests above, 20 subjects were used. The subjects were college students ranging in age from 17 to 24 years with a median age of 19 years. All subjects were audiometrically screened prior to the test with a screening level held within 15 dB of the new ISO Standard Threshold (Ref. 5).

Procedure

The judgment tests were all conducted in an anechoic chamber 8 ft x 10 ft x 7.5 ft high. The testing method employed for this study was a paired comparison type known as the method of constant stimuli.

Tapes were prepared for presenting the sound samples, in pairs, to the subjects. Each pair of sounds included a standard and a comparison sound. For these tests either the standard or comparison sound may be presented first. To decrease any bias attributable to an order effect, both orders of presentation were used. The data was then averaged so that the order effect would tend to be cancelled. An effort was made to control other sources of bias that arise from the order of the stimuli on the test tapes by using a modified Graeco-Latin Square presentation.

The subjects were given printed instructions for the test which asked them to judge which sound in each pair was more objectionable or disturbing. The actual test instructions are given in Appendix A. The subjects indicated their choice by punching the appropriate positions on an IBM port-a-punch card. Generally, four subjects were tested at one time with the test sessions limited to approximately 90 minutes. In addition, several rest periods were given to the subjects to prevent possible fatigue.

Equipment

The equipment used to present the stimuli to the subjects is shown in block diagram form (Fig. 1). The electronic switch and the cue tone sensor and relay were employed so that no audible hiss or annotation was heard between the sound samples by the test subjects. These were triggered by cue tones placed on the second channel of the test tape at appropriate places so that the electronic switch was turned on only during the test stimuli. The voltmeter was used to set the levels of the test stimuli during the test sessions. Detailed acoustical analysis of the sound samples was later performed in the anechoic chamber with no subjects present. Further details of the stimulus generating equipment necessary for creating the paired comparison test tapes are given in Appendix B.

Test Stimuli

The test stimuli used in this study were varied both in their time patterns and tone content. Figure 2 shows a generalized time pattern of the type employed for these tests. The parameters under consideration were 1) noise duration, 2) tone duration, 3) the tone-to-noise ratio, and 4) the time the maximum level of the tone preceded the maximum level of the noise divided by the duration of the noise (Δt/noise duration). The values of the parameters for the stimuli used in this study are given in Tables I - III. Examples of the spectra used are given in Fig. 3. This figure shows the maximum 1/3 octave band noise levels which were determined from graphic level recordings for both a shaped band of noise and a steady-state engine noise.

The shaped band of noise is similar in spectrum to a jet aircraft flyover noise at 2000 feet altitude. The engine runup noise is that of a high thrust turbofan engine measured in a test stand configuration. For the other comparison stimuli, tones were added to the broadband simulated jet noise. Further details of all the spectra employed in the tests are tabulated in Appendix C. (As noted in the appendix, the levels listed are the maximum levels at which the spectra were presented to the test subjects. The levels are the average of those monitored at the various seat positions.)

Paired Comparison Judgment Test Analysis

For these tests, subjects were asked to choose which of the two sound stimuli was the more objectionable or disturbing. The subjects' responses, recorded on IBM cards, were entered into a digital computer for sorting and analysis. It was considered that the two sounds were equally acceptable when 50% of the subjects stated that one sound was less acceptable than the other. This 50% point was determined by plotting the percentage of people who felt the comparison sound was less acceptable than the standard versus the various levels employed during the test. These results were plotted on probability paper and a straight line regression line was fitted to the data to determine the 50% point. This method has been employed successfully in previous investigations (Refs. 4,6). One advantage of this method is that all data is used to determine the 50% point rather than only the data near the 50% levels. Also, the computer can be programmed to derive the 50% point directly. The 50% points were determined for the two orders of presentation as described earlier. The results of the two orders were then averaged to obtain the final level of judged equality. These equality levels for all of the data obtained from the tests are given in Appendix D in terms of dB relative to the maximum level of the comparison presented to the subjects.

Measures Employed During Analyses

Several different measures were employed in analyzing the judgment results of these tests. Some of the methods of measurement such as overall sound pressure level (OASPL) and A-weighted sound pressure level (A-level) need no explanation as to their application. N-weighted sound pressure level (N-level) uses a frequency weighting equivalent to the inverse of a 40 Noy (equal noisiness) contour which is used in the calculation of perceived noise level (Ref. 1,7).

More complicated measures such as perceived noise level with and without pure-tone and duration corrections are described here to avoid any confusion which might arise.

The perceived noise level (PNL) used in the analysis of the test results was calculated from the maximum levels in each third-octave band irrespective of the time at which they occurred. The maxima were determined from a graphic level recording of the sound pressure level in each 1/3 octave band. Perceived noise level was then calculated using standard techniques (Refs. 1, 7).

Other analysis was applied to the test data using perceived noise level modified by previously developed Kryter and Pearsons tone and duration corrections (PNL_{KP}) (Refs. 2,3). The table used to determine the tone corrections were determined by making measurements with an N-network and noting the duration at the 10-dB-down points. This duration was then related to a standard 15 second duration to determine a correction according to the formula:

$$\text{duration correction} = 10 \log \left(\frac{\text{duration}}{15}\right)$$

The effective perceived noise level (EPNL) suggested by the FAA in their certification procedure (Ref. 8) uses a different method of applying the tone correction. The tone correction varies as a function of the tone-to-noise ratio as does the Kryter-Pearsons tone correction, however, it is applied after calculation of perceived noise level rather than before as in the Kryter-Pearsons method. Basically, the EPNL method calculates a perceived noise level and a tone correction for every half second of the stimulus, from which the maximum value of the tone-corrected PNL is selected. Duration is defined as the amount of time that these series of calculations exceed a value that is within 10 dB of the maximum level. The same duration correction formula that is used in PNL_{KP} is used in obtaining the final EPNL value. Further details of the tone and duration correction procedure employed in determining the EPNL are given in Appendix E.

DESCRIPTION OF TEST RESULTS

Test I-A

The results of Test I-A are shown in Figs. 4 through 8 for the various methods of measurement. In these and succeeding figures the level of the comparison relative to the level of the standard at the judged equality of acceptability is depicted for a stated calculation procedure.

In this type of presentation, if the comparison calculated for the noise spectra at the level of equality is less than the standard, it will be plotted as a negative value. If the calculated comparison value for judged equality of acceptability is the same as the standard value, it will be plotted as zero on the graphs. Thus, it follows that the best measure is one for which the level of the standard and comparison values are equal (comparison re standard is zero).

Figure 4 shows the results of using perceived noise level calculations. In general, the results using this measure do not agree very closely with the judgment data, that is, most of the points do not lie near the zero line. Let us first look at the result obtained for the four second duration samples. For "no tone" the perceived noise level tends to overcorrect the judgment results, however, for the 10 and 25 dB tone-to-noise ratios the results are fairly close to the judgment results except for a slight over-correction. For the other durations, and tone-to-noise ratios, the agreement with judgment results is considerably poorer. This is particularly noticeable for the long duration stimulus with a high tone-to-noise ratio. Errors of as much as 13 dB can be observed in such cases. Similar types of errors are noted on the graph for the 4000 Hz stimuli.

Sound samples similar to the four-second, 10 dB tone-to-noise ratio were also used in Test I-B and Test II. As shown in Fig. 4, for Test I-A, this stimulus was rated as 1.2 PNdB higher than the standard. The measured difference in Test I-B was 2.8 PNdB and the measured result in Test II was -0.3 PNdB. This would indicate that the subjects appear to be consistent (within ± 1.6 PNdB) in their judgment over three different test series.

Since there are both tone and duration corrections, it may be of some interest to note the effect of applying the corrections separately to the perceived noise level results. Figure 5 shows the results of Test I-A for perceived noise level with only duration corrections applied. The results are brought into closer agreement with the judgment data using the duration correction especially for the "no tone" case. However, for those samples with high tone-to-noise ratio, this calculation procedure still underestimates the judgment data by about 5 to 9 dB.

In Fig. 6 we see the result of using perceived noise level with only the tone correction applied to Test I-A data. With this method of measurement, the results appear to overcorrect especially for the four-second duration data. It is interesting to note, however, that the longer duration data (12 and 32-seconds) is in fairly close agreement with the judgment data when perceived noise level with tone correction only is employed as a measure.

Figure 7 illustrates the perceived noise level results with both tone and duration corrections added. The results are in much closer agreement with the judgment data than either the perceived noise level alone, or the perceived noise level with tone or duration corrections added separately. There is some tendency to overcorrect, however, as indicated by the positive values on the graph.

Figure 8 shows the result of using effective perceived noise level as a measure. This measure, you recall, includes both tone and duration corrections. The results, are also closer in value to the judgment data than the perceived noise level without any tone and duration corrections. The results using EPNL, although comparable to those using PNL_{KP}, actually cluster more closely around the line of judged equality than do those of PNL_{KP}.

In order to graphically compare the methods of measurement, we have determined the mean difference values (comparison re standard) for all the stimuli used in Test I-A. These values along with the computed standard deviation for the various measures (OASPL, A-Level, N-Level, PNL, EPNL, PNL_{KP}) are illustrated in Fig. 9.

As shown in the mean difference portion of the figure, the comparison comes closer to the standard as the measures are varied from OASPL to PNL_{KP}. The magnitude of the difference is 6 dB for A-level and 9 dB for OASPL. The difference is about 1 PNdB for perceived noise level with the tone and duration corrections (PNL_{KP} AND EPNL). Actually, the PNL_{KP} tends to overcorrect the judgment results rather than undercorrect them as do the other measures. The N-level method of measurement shows less difference than A-level and is comparable to PNL for this test.

The standard deviation results shown in the lower portion of the figure indicate a similar trend. That is, there is less spread in the data for perceived noise level with the tone and duration corrections (PNL_{KP} and EPNL) than for the other measures. Values of the standard deviation range from 6 to 7 dB for the A-level and overall SPL down to 1-1/2 dB for PNL_{KP}, and EPNL. N-level shows less variation than A-level and PNL, although the variation difference is not large. Both the mean difference and standard deviation of these measures indicate a sizeable improvement when using the tone and duration corrections in comparison to the measures without the tone and duration corrections.

Test I-B

The results of the judgments on the high thrust turbofan engine noise are shown in Fig. 10. Durations of the samples include 4, 12, and 32 seconds measured at 10-dB-down points. As indicated in the figure, the perceived noise level with no corrections, underestimates the judged acceptability of the engine noise stimuli. The addition of tone and duration corrections, either by the Kryter-Pearsons method or effective perceived noise level (FAA), provides closer agreement but these results still underestimate the judged unacceptability of the engine noise. Possibly this may be an influence of the tone modulation in the engine noise. It appears that further investigations are required to completely explain the reason for this underestimation. Also shown in the figure are the results of using a filtered, broadband noise with tone, the same stimulus used in Test I-A. The results using this stimulus are in close agreement with the results of the earlier test.

In order to graphically compare the different methods of measurement, we determined their mean differences and standard deviations. The results of those determinations are shown in Fig. 11. Note that again there is considerable difference between the overall SPL and the perceived noise level with the Kryter-Pearsons tone and duration corrections. Also note the rank ordering of various measures both on the basis of mean differences and standard deviation difference are in general agreement with those for the previous test (I-A). The absolute values of the standard deviations are somewhat higher, probably because of the smaller number of samples used in this test.

Test II

A plot of the results of Test II are shown in Fig. 12. This graph illustrates the results as a function of the percentage of the noise duration that the tone peak precedes the noise peak. Negative values on the absissa indicate that the tone peak occurred after the noise peak. The results are shown for perceived noise level, perceived noise level with the Kryter-Pearsons tone corrections and effective perceived noise level. It is apparent that those measures which incorporate tone and duration corrections exhibit a smaller spread than the measure of perceived noise level without the corrections. It is interesting to note that if the tone precedes the noise by 50% or if the tone follows the noise by 25% the unacceptability of the stimulus increases somewhat (as indicated by the larger negative values in the figures). However, the amount of increase is very slight and appears to be well within the normal variation associated with judgment tests of this type. It is also of some interest to observe that the samples of the greatest judged unacceptability (again, the largest negative values in the figures) tend to be those of the largest tone-to-noise ratio even for the cases where tone corrections have been applied.

As noted in Fig. 12, one of the stimuli groups (Δ) was compared to a standard which contained a pure-tone. A more detailed look at this comparison indicates that the pure-tone corrections do not make an appreciable change in the results of the three different methods of measurement. This might be expected since both the standard and comparison samples have tone components. As both are corrected for the tone, the effect is cancelled out when differences between standard and comparison are taken in analysis. There is still a tendency, however, for the EPNL measure to undercorrect and the PNL_{KP} measure to overcorrect.

The results of Test II were also plotted as a function of duration for both EPNL and PNLKP (Fig. 13). The results plotted in this manner indicate no duration effect, thus implying that the measures have accounted for any duration effects using the 3 dB per doubling as a correction procedure. The results of the EPNL measure, however, do indicate an underestimation which is probably due to the tone correction rather than the duration correction.

The various methods of measurement for the Test II results were compared to each other in terms of mean difference and standard deviation (Fig. 14). As noted in the previous tests, the various measures rank order in approximately the same manner. One exception is that the EPNL appears to have a slightly larger mean difference than the PNL for this group of judgment results. However, the spread of the results for the EPNL is less than the PNL, which is consistent with the results of the previous two tests. The other exception is that N-level exhibits a higher mean difference and standard deviation than PNL. In this test, the graph illustrates that the standard deviation values do not cover as great a range as in the previous two tests, however, the spread of EPNL and the perceived noise level with Kryter-Pearsons tone and duration corrections, has been reduced by a factor of two over that of the overall SPL.

CONCLUSIONS

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

1. The tone and duration corrections developed previously appear to be additive when applied to sounds varying both in pure-tone content and duration. In other words, there appears to be no obvious interaction between the pure tone and duration corrections.

2. The corrections developed previously to account for pure-tone and duration by Kryter and Pearsons appear to be adequate in predicting the noisiness of laboratory generated sounds varying both in tone content and duration.

3. The effective perceived noise level suggested by FAA appears to provide an adequate duration correction but tends to underestimate the pure-tone effect by on the average of from 1 to 5 dB.

4. Neither the duration of the tone nor its location within the flyover noise appear to affect the magnitude of the pure-tone correction required to predict the judged noisiness.

5. Despite the success of both the pure-tone and duration correction the single real life engine used in the test appeared to be judged consistently noisier than the corrected PNL would predict. A noticeable low frequency random modulation may be responsible for this discrepancy. In a previous study on modulated tones reported in NASA CR-117, it was noted that, in general, modulated tones were not greatly different in judged noisiness from unmodulated tones. However, it was concluded that low frequency amplitude modulated tones were noisier than tone corrected PNL predicted. Also there may be some additional influence due to the random character of the modulation in the real life case versus the periodic character of the test stimuli described in the earlier report.

6. The N-level measure, although not in as close agreement with the judgment results as the tone and duration corrected measures, nevertheless provides better agreement than A-level and is quite comparable to calculated perceived noise level for these test stimuli.

TABLE I

STIMULI FOR TEST I-A

Simulated Flyovers (Shaped Broadband Noise Plus Tone)

	Noise	Noise or Tone Duration[2]	Tone Frequency	T/N[3]
Std	Jet[1]	12 sec	-	No Tone
	Jet	4	-	No Tone
	Jet	4	2000 Hz	10 dB
	Jet	4	2000	25 dB
	Jet	12	-	No Tone
	Jet	12	2000	10 dB
	Jet	12	2000	25 dB
	Jet	32	-	No Tone
	Jet	32	2000	10 dB
	Jet	32	2000	25 dB
	Jet	4	4000	25 dB
	Jet	32	4000	35 dB

TABLE II

STIMULI FOR TEST I-B

Real Engine Simulated Flyovers (Recorded Jet Engine Noise)

	Noise	Noise or Tone Duration[2]	Tone Frequency	T/N[3]
Std	Jet[1]	12 sec	-	No Tone
	Engine[4]	4	-	-
	Engine	12	-	-
	Engine	32	-	-
	Jet	4	2000 Hz	10 dB

1 Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

2 Duration is the amount of time the signal is within 10 dB of maximum level.

3 T/N is tone-to-noise ratio in a 1/3 octave band using maximum level in each band.

4 High thrust turbofan engine.

TABLE III

STIMULI FOR TEST II

Simulated Flyovers (Delayed Tone Peaks)

	Jet Noise[1] Duration[2]	2000 Hz Tone Duration	T/N[3]	Δt[4]	Δt / Noise Duration
Std	12 sec	No Tone	-	-	-
	4	4 sec	5 dB	0 sec	0
	4	4	5	-1	-0.25
	4	4	5	+1	+0.25
	4	4	5	+2	+0.50
	4	4	15	0	0
	4	4	15	-1	-0.25
	4	4	15	+1	+0.25
	4	4	15	+2	+0.50
	12	4	5	0	0
	12	4	5	-3	-0.25
	12	4	5	+3	+0.25
	12	4	5	+6	+0.50
	32	4	5	+8	+0.25
	32	12	5	+8	+0.25
Std	12	12	5	0	0
	12	4	5	0	0
	12	4	5	-3	-0.25
	12	4	5	+3	+0.25
	12	4	5	+6	+0.50

1 Broadband noise with spectrum shape similar to turbojet flyover at 2000 feet.

2 Duration is the amount of time the signal is within 10 dB of maximum level.

3 T/N is tone-to-noise ratio in a 1/3 octave band using maximum levels in each band.

4 Δt is the amount of time that the maximum level of the tone precedes the maximum level of the noise.

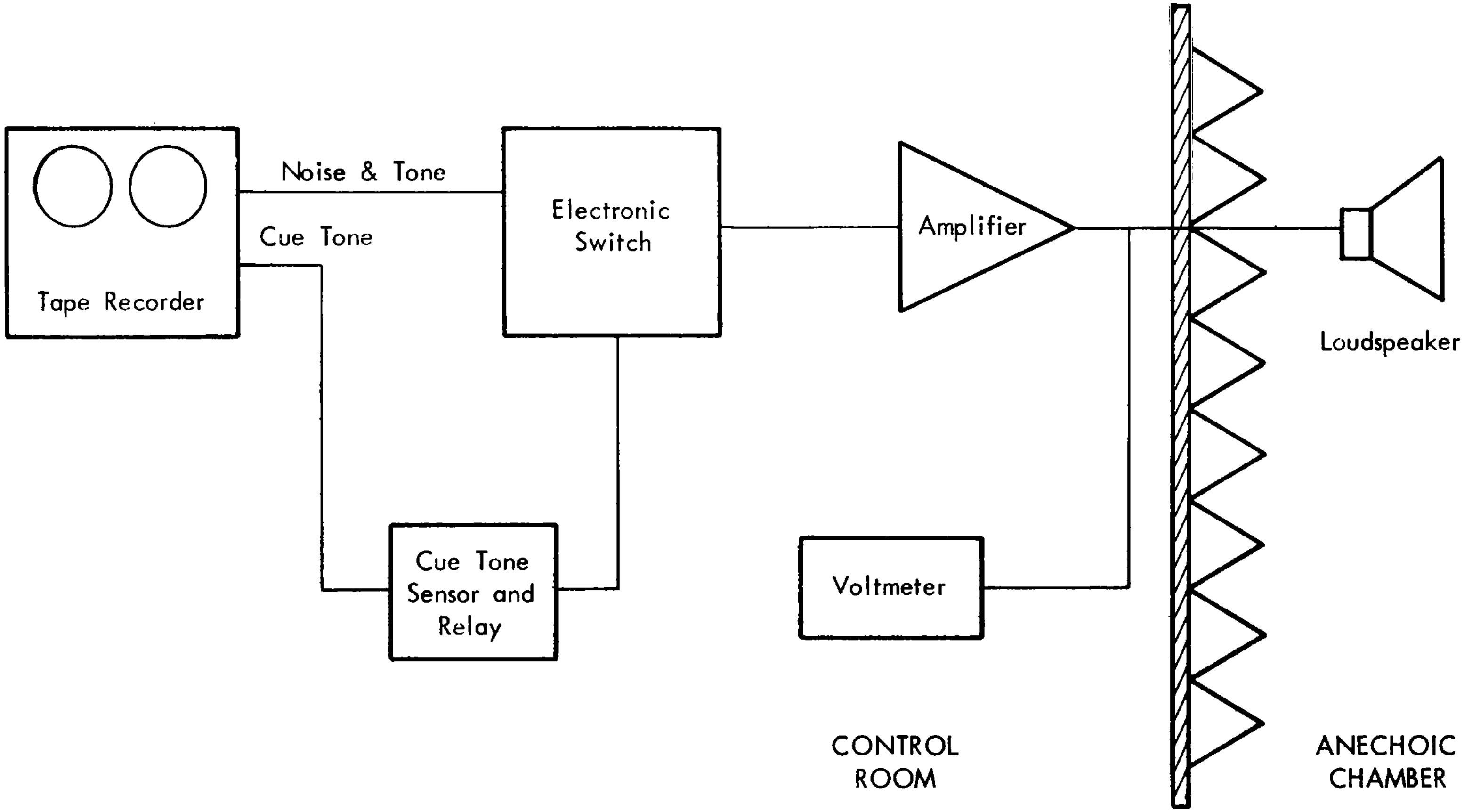


FIGURE 1. BLOCK DIAGRAM OF PLAYBACK SYSTEM FOR ALL JUDGMENT TESTS

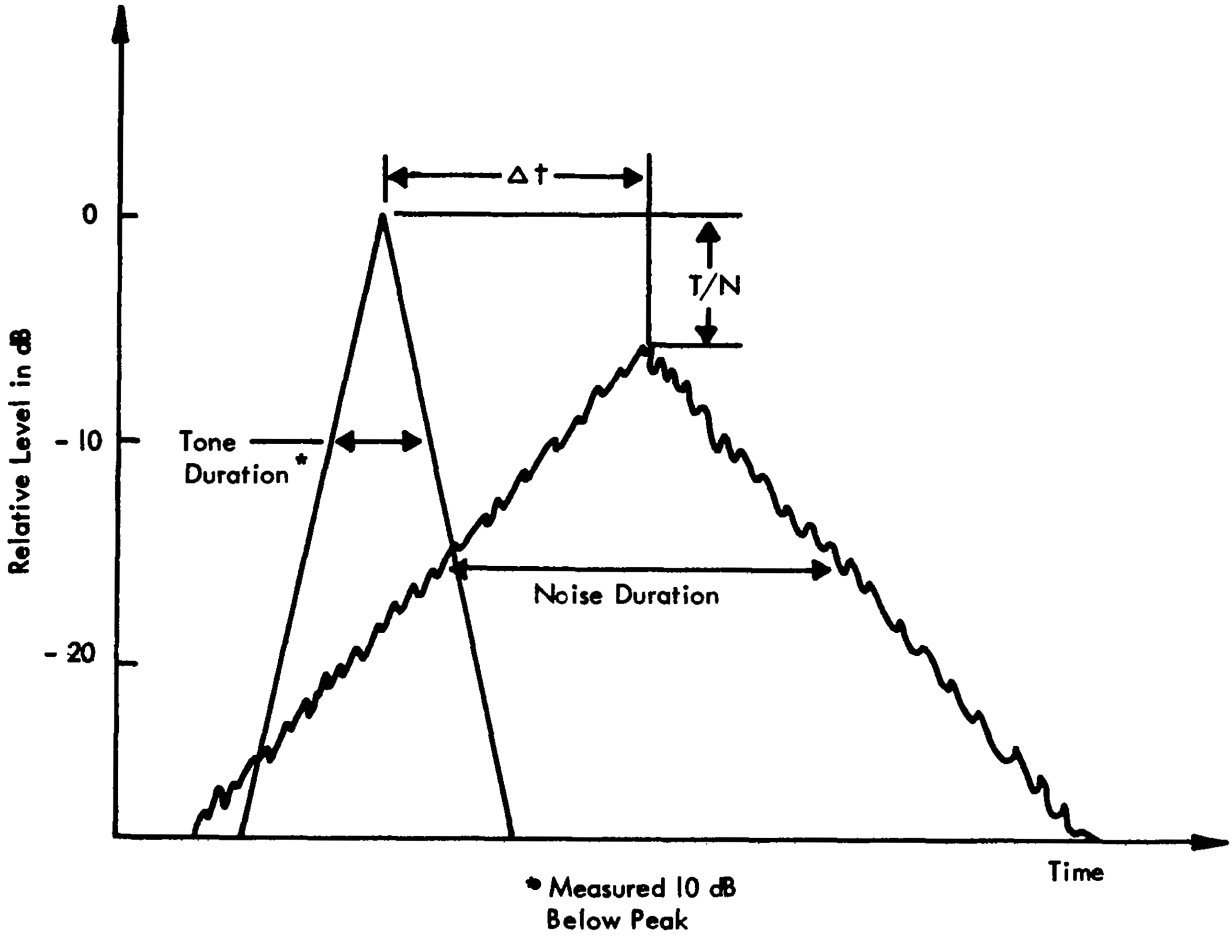


FIGURE 2. GENERAL TIME PATTERN OF STIMULUS USED IN ALL JUDGMENT TESTS

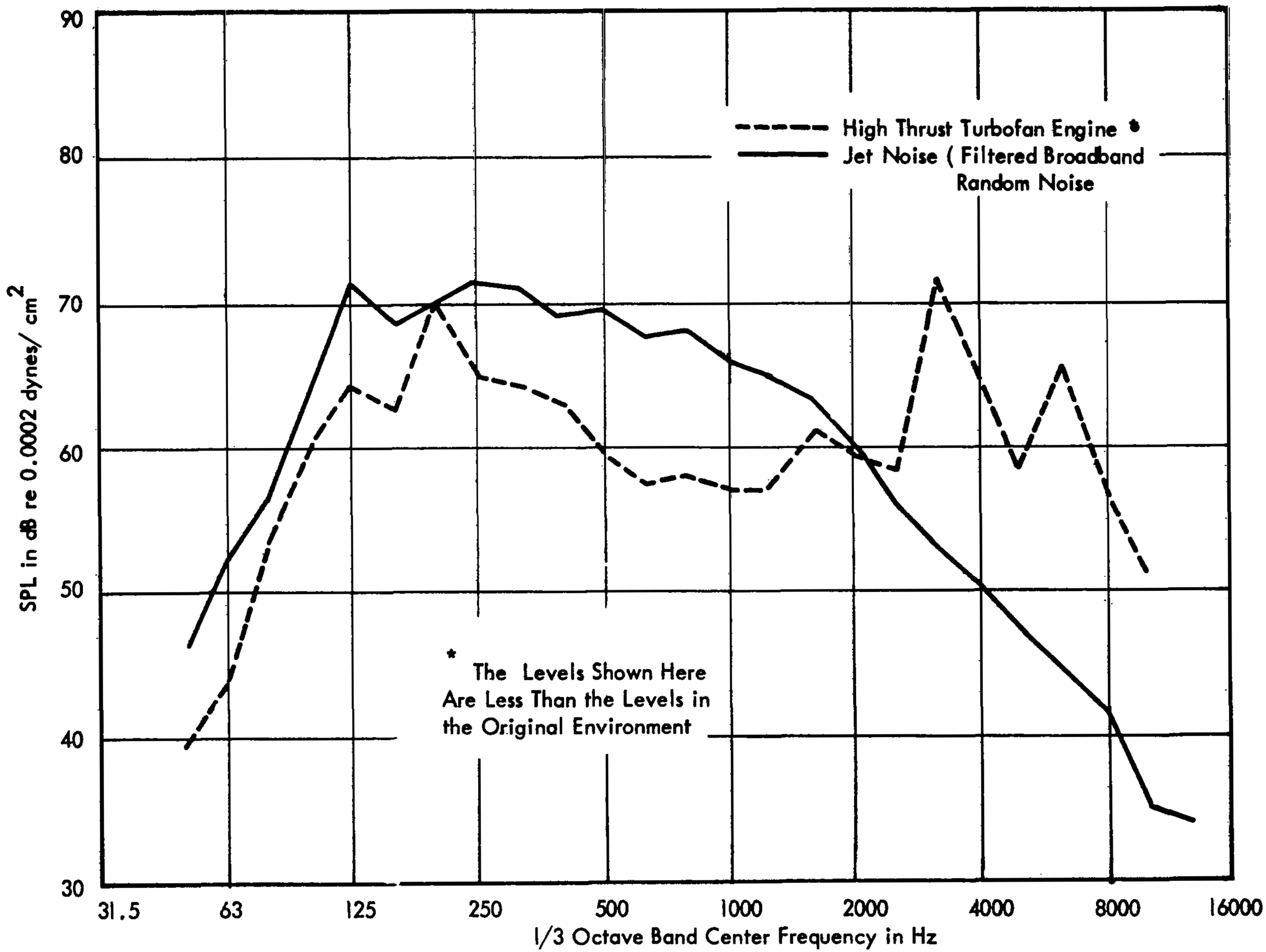


FIGURE 3. EXAMPLE OF NOISE SAMPLES AT LEVELS PRESENTED TO SUBJECTS IN JUDGMENT TESTS

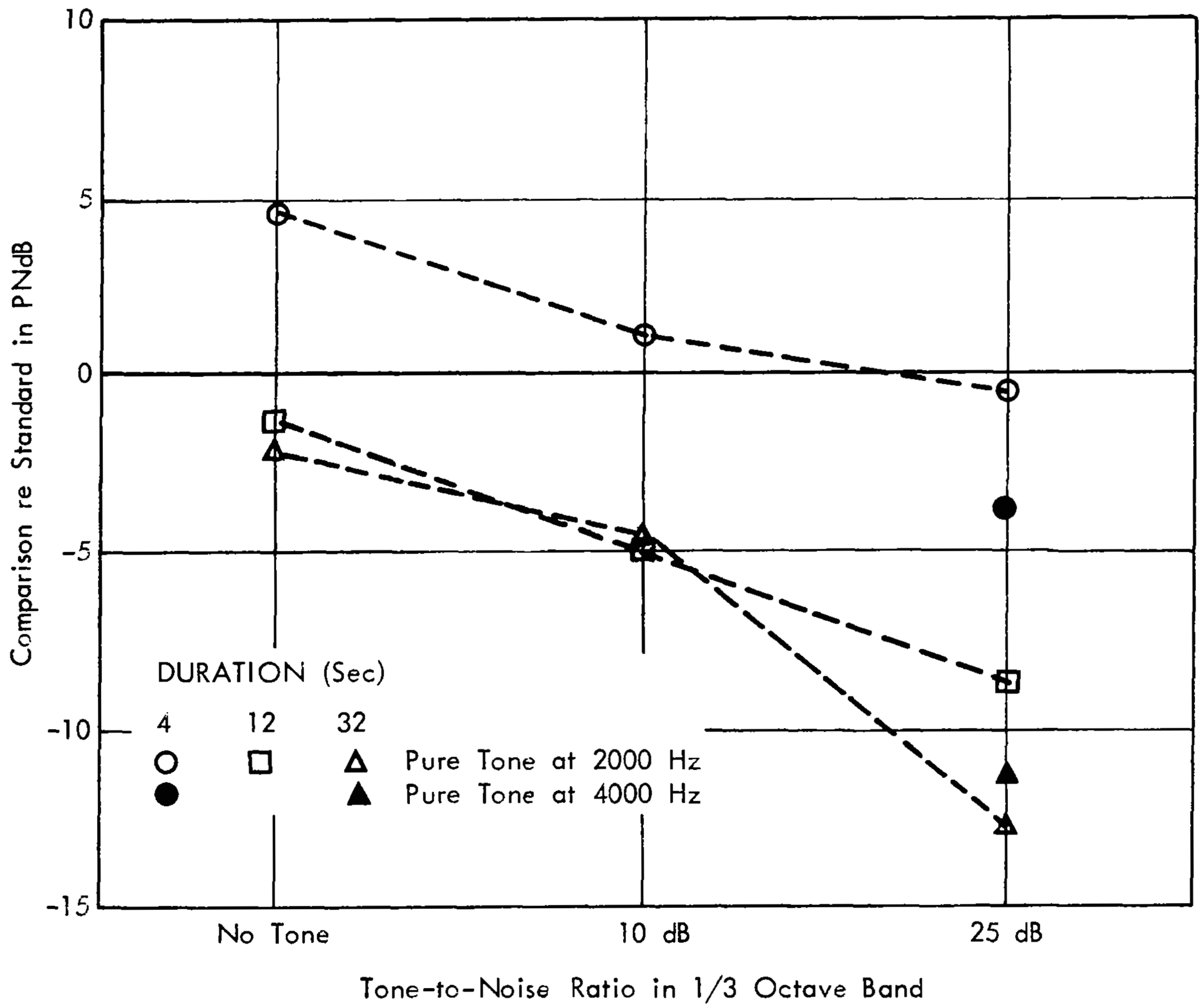


FIGURE 4. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST I-A USING PNL AS A MEASURE. - SINGLE TONES PLUS BROADBAND JET NOISE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)

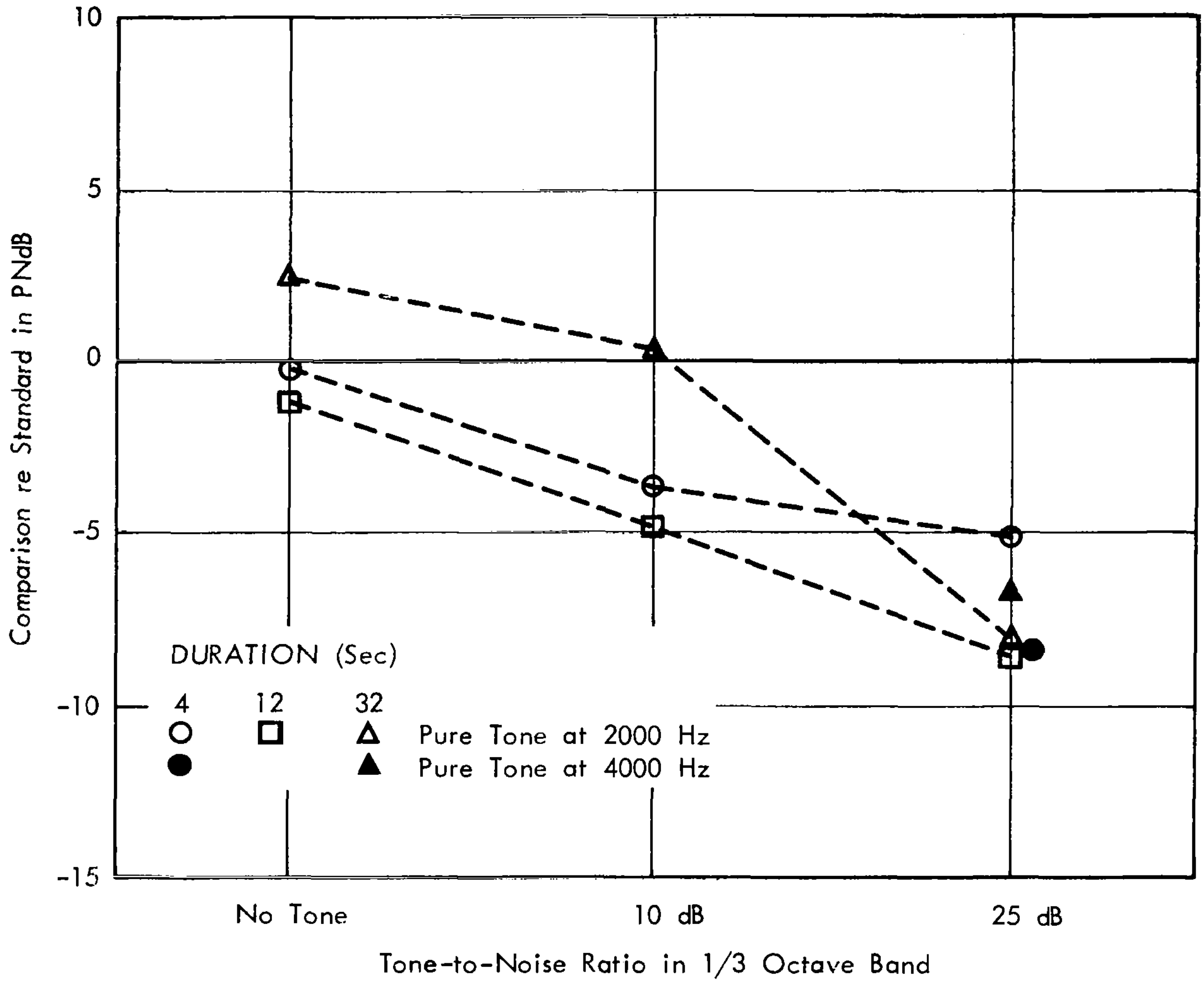


FIGURE 5. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST I-A USING PNL WITH DURATION CORRECTION AS A MEASURE. - SINGLE TONES PLUS BROADBAND JET NOISE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)

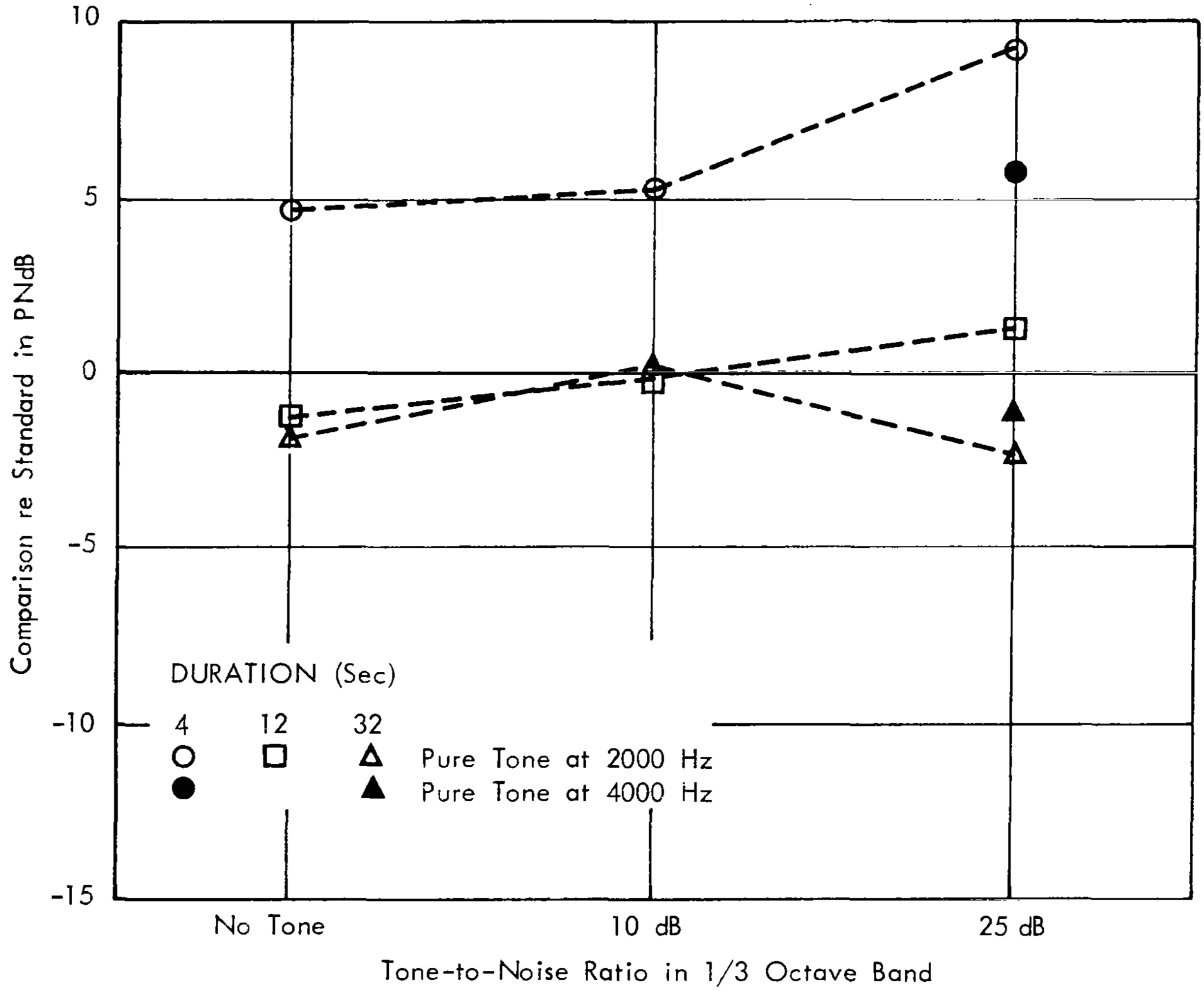


FIGURE 6. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST I-A USING PNL WITH TONE CORRECTION AS A MEASURE. - SINGLE TONES PLUS BROADBAND JET NOISE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)

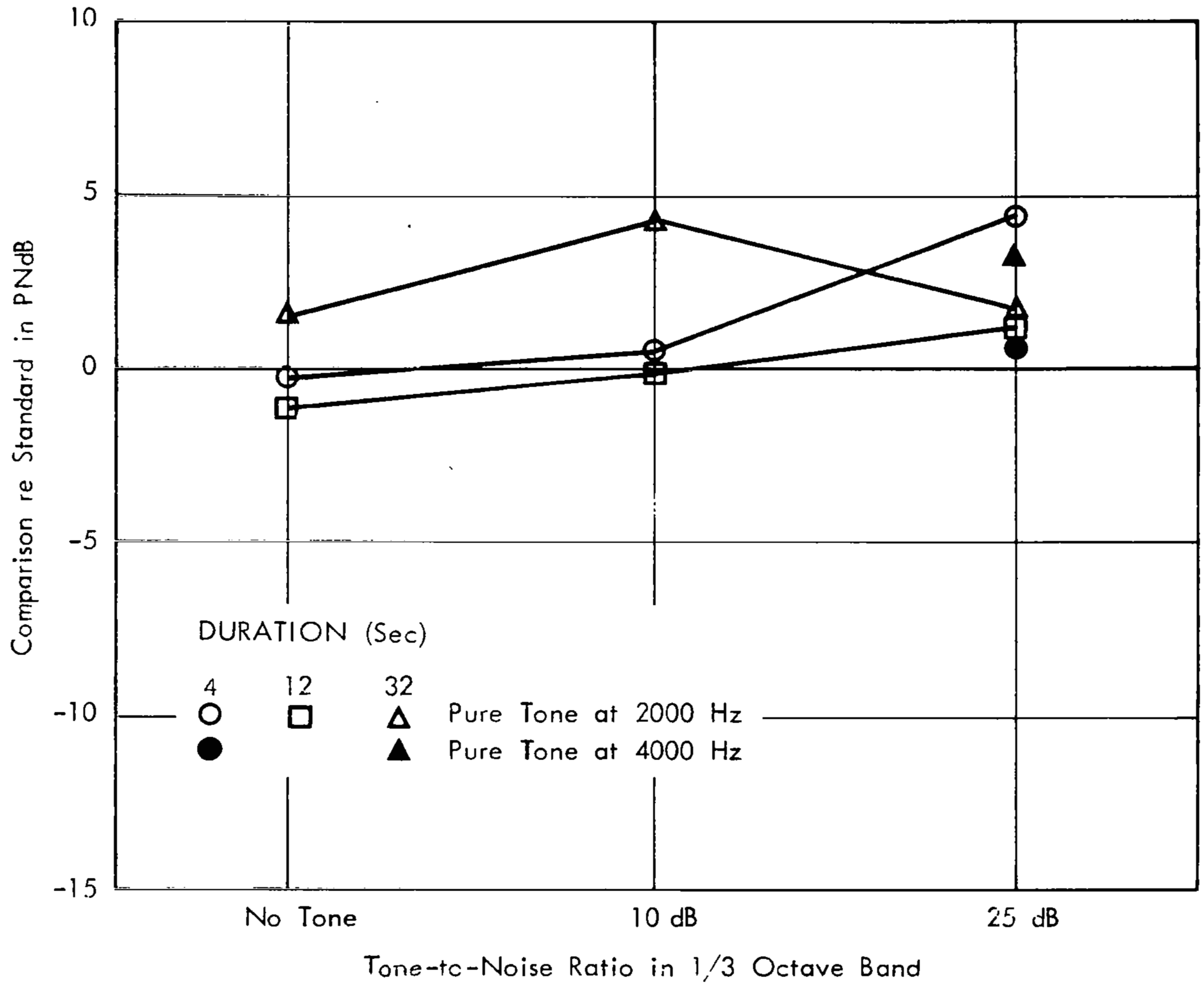


FIGURE 7. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST I-A USING PNL_{KP} (TONE AND DURATION CORRECTED) AS A MEASURE.- SINGLE TONES PLUS BROADBAND JET NOISE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)

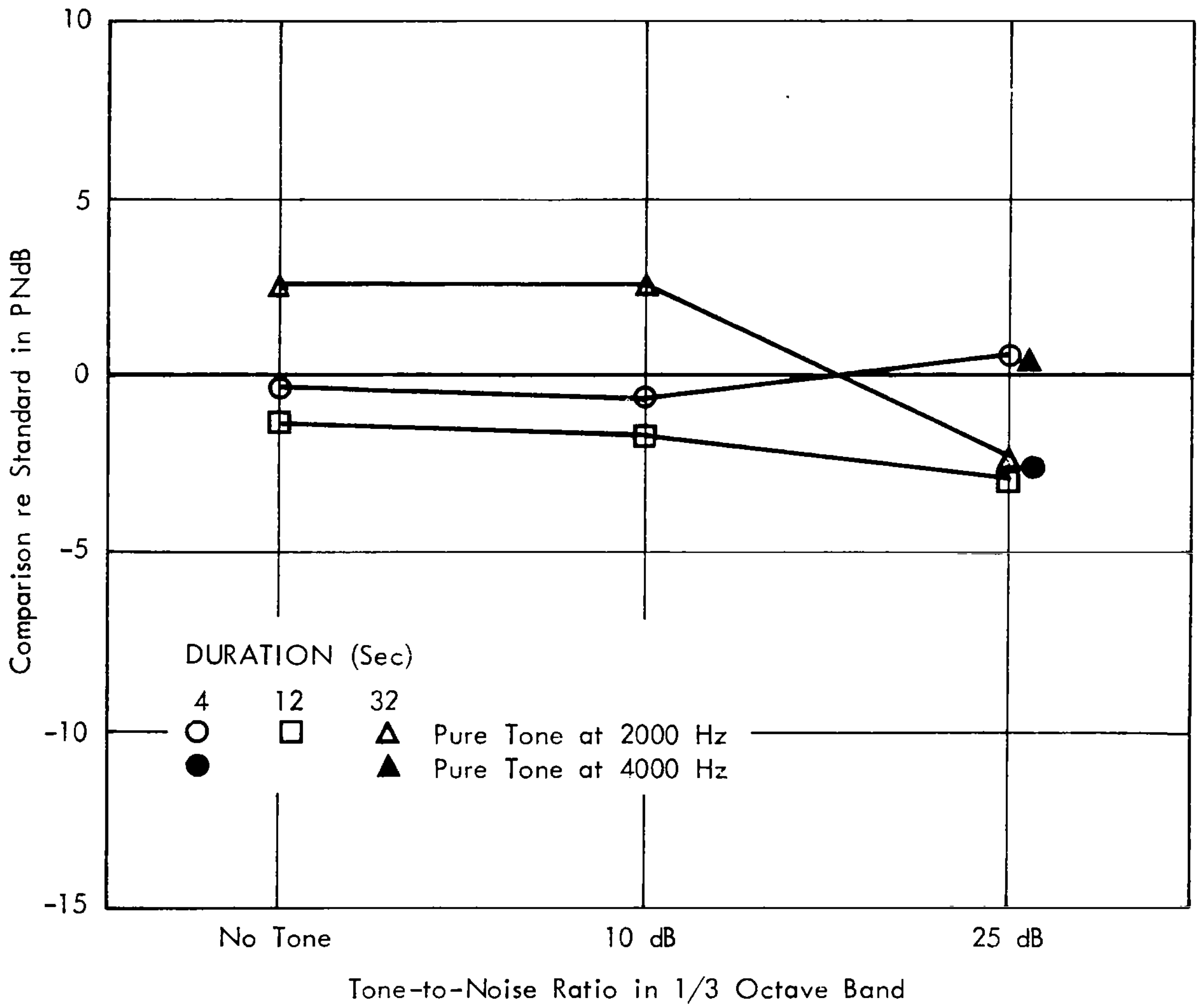


FIGURE 8. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST I-A USING EPNL (TONE AND DURATION CORRECTED) AS A MEASURE.- SINGLE TONES PLUS BROADBAND JET NOISE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)

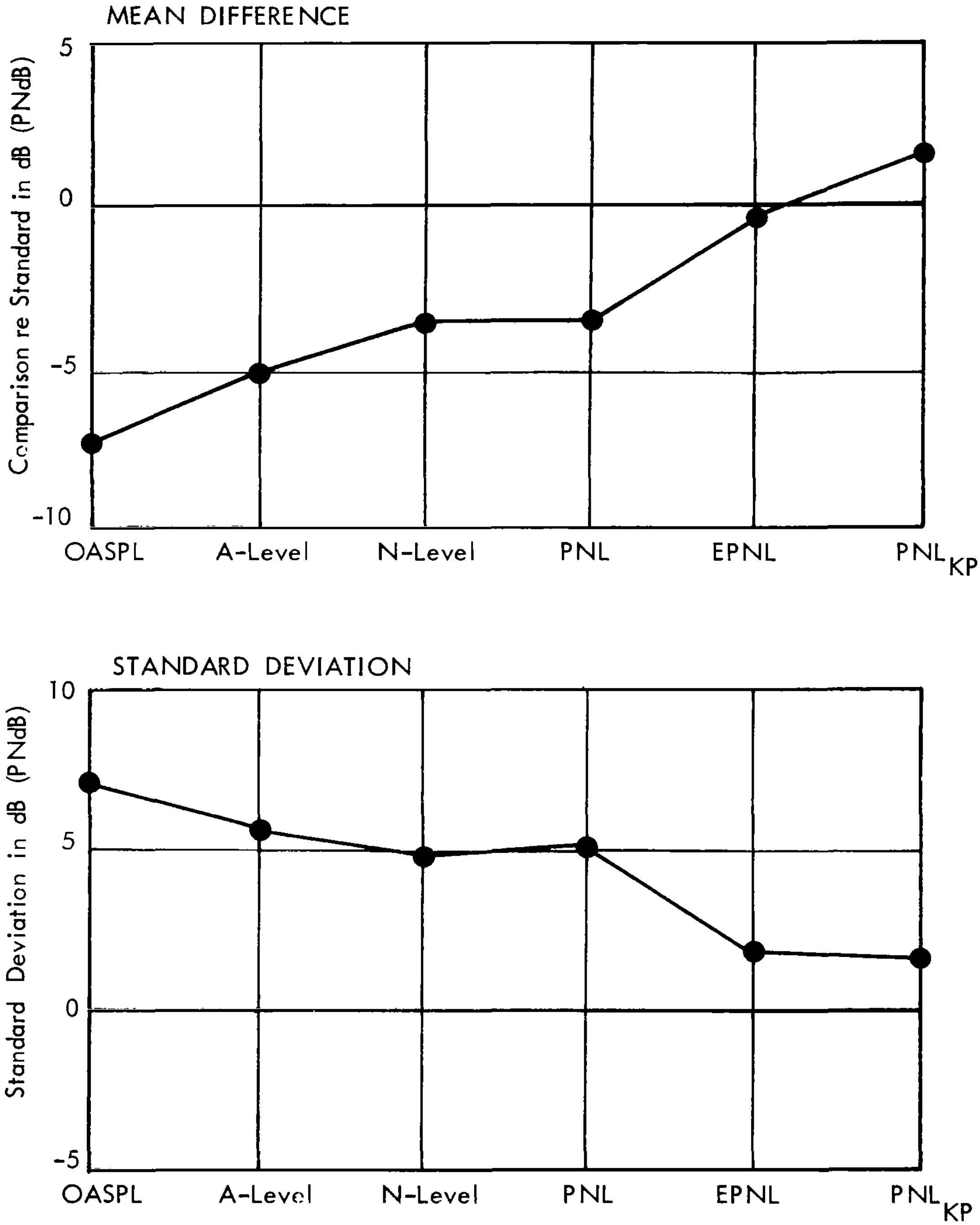


FIGURE 9. COMPARISON OF RESULTS OF VARIOUS MEASURES FOR TEST I-A

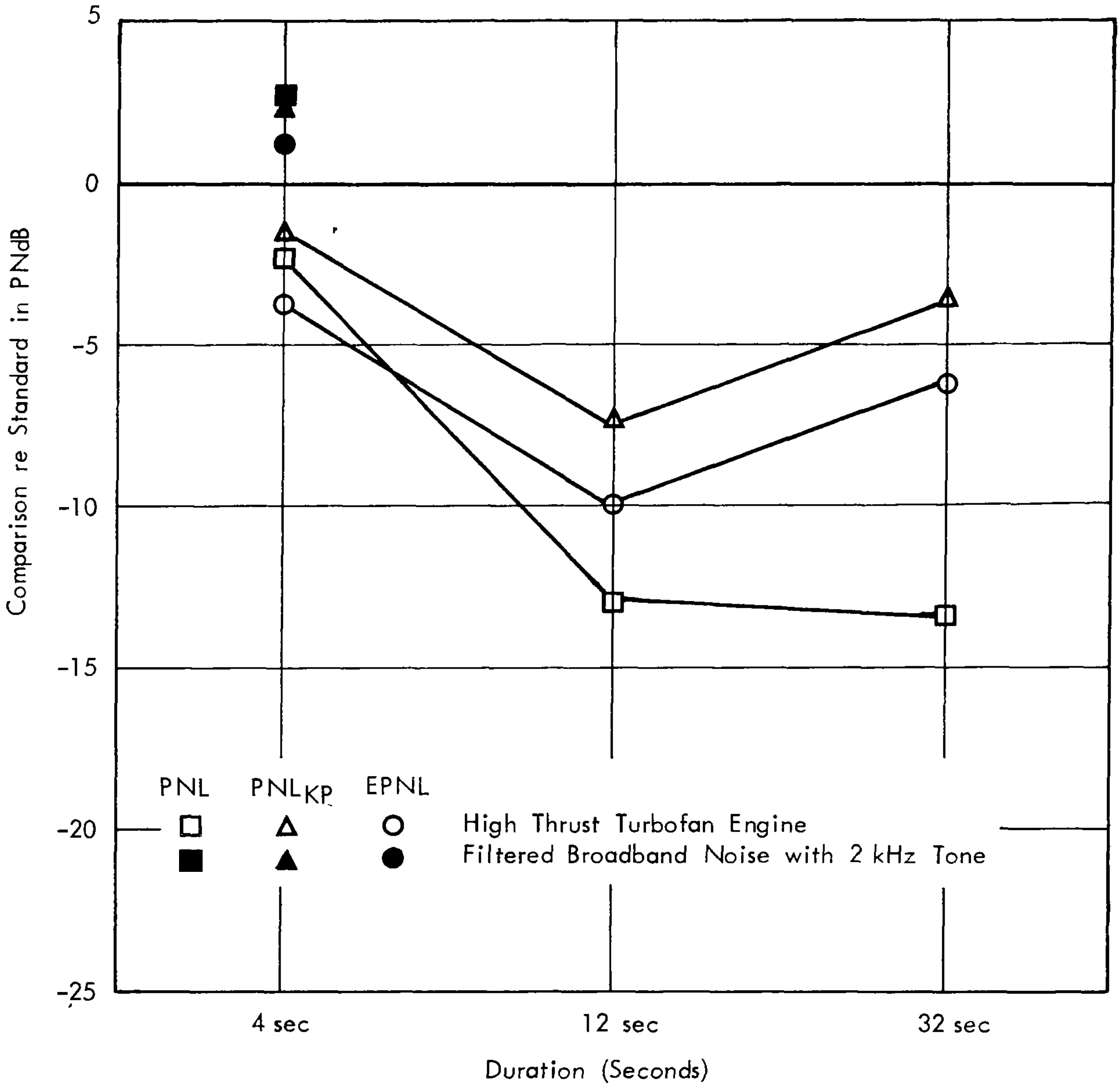
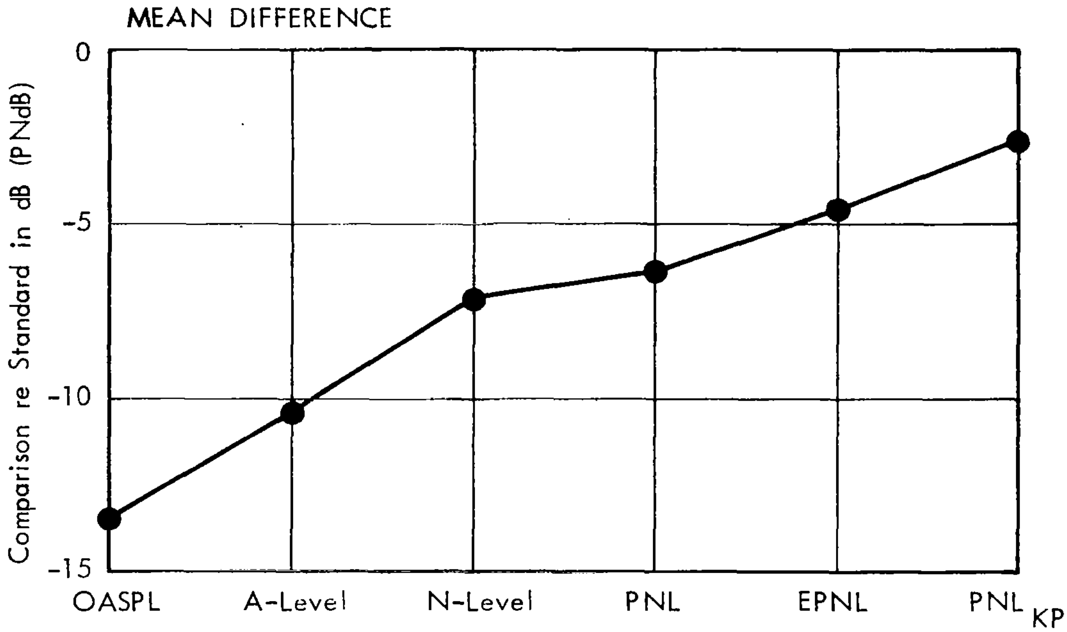


FIGURE 10. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST I-B COMPARING PNL, PNL_{KP}, EPNL. - RECORDED HIGH THRUST TURBOFAN ENGINE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)



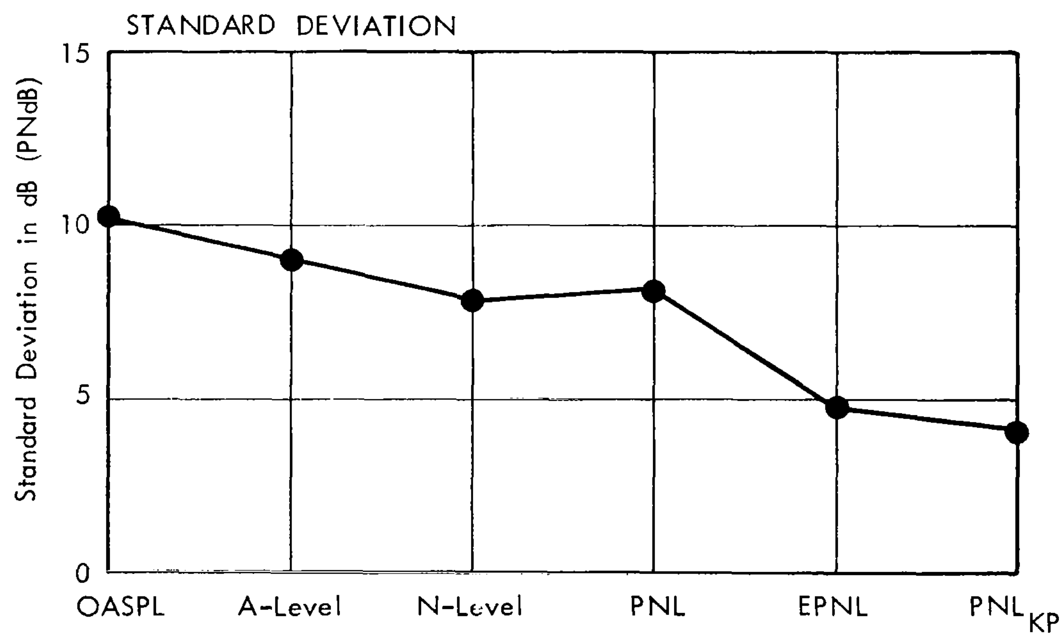


FIGURE 11. COMPARISON OF RESULTS OF VARIOUS MEASURES FOR TEST I-B

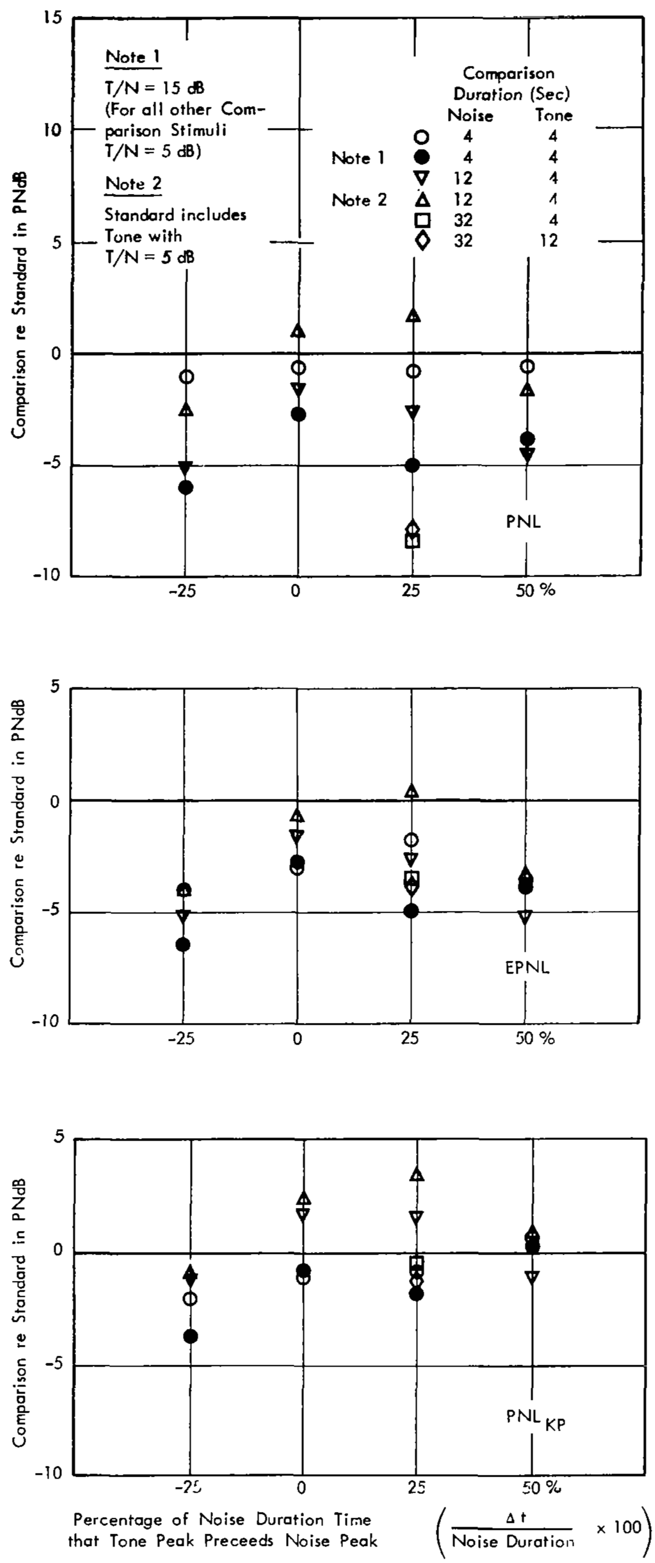


FIGURE 12. JUDGMENTS OF EQUAL ACCEPTABILITY FOR TEST II COMPARING STIMULI OF VARYING Δt (REFER TO FIG.2) - SINGLE TONES PLUS BROADBAND JET NOISE (COMPARISON) JUDGED EQUAL TO 12-SECOND BROADBAND JET NOISE (STANDARD)

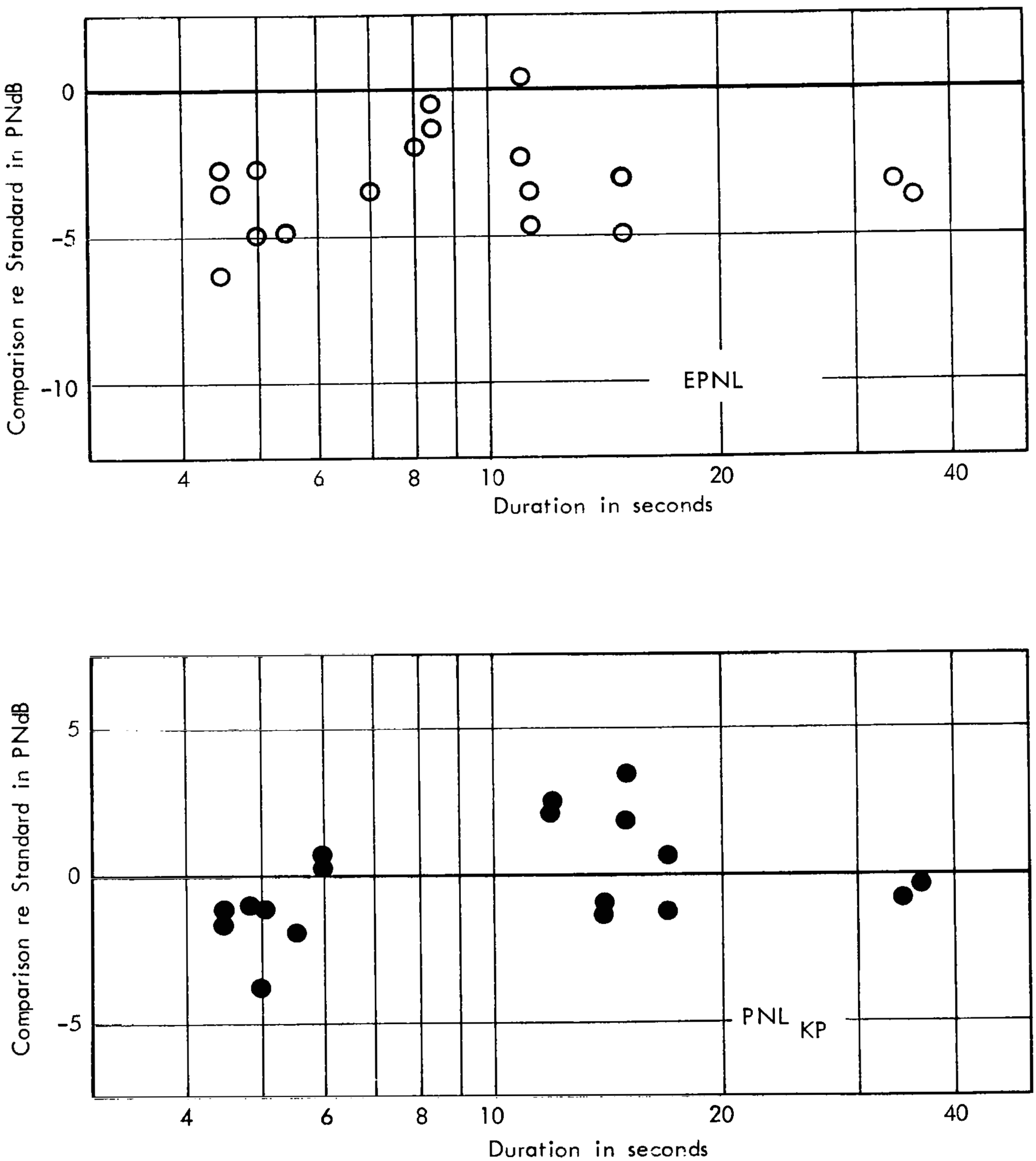
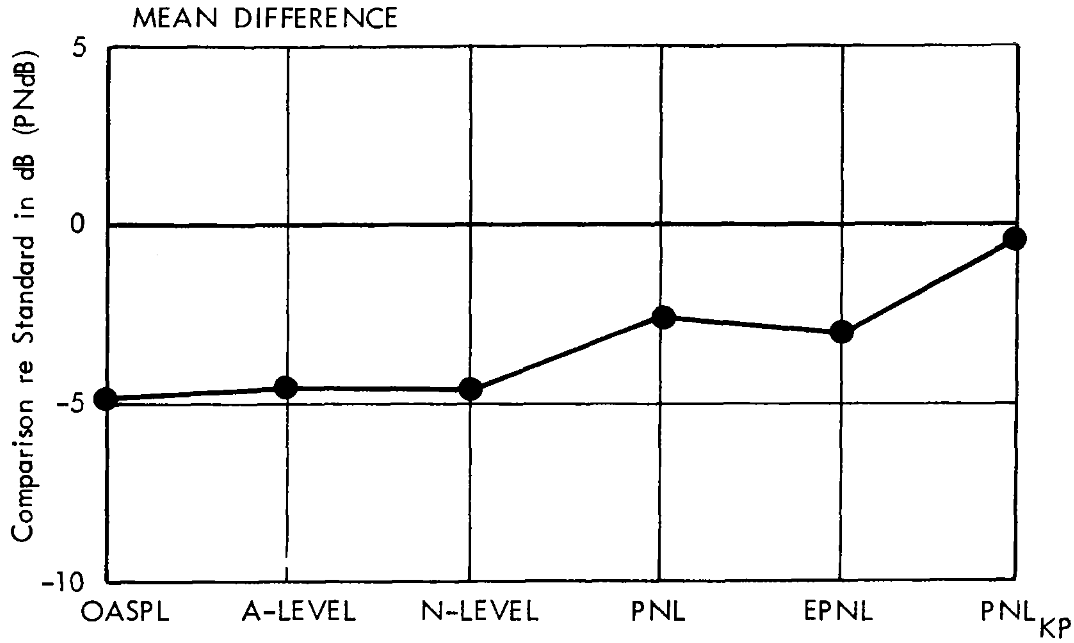


FIGURE 13. JUDGMENT OF EQUAL ACCEPTABILITY FOR TEST II COMPARING EPNL AND PNL_{KP} WITH STIMULI OF VARYING DURATION (REPLOT OF DATA SHOWN IN FIG.10)



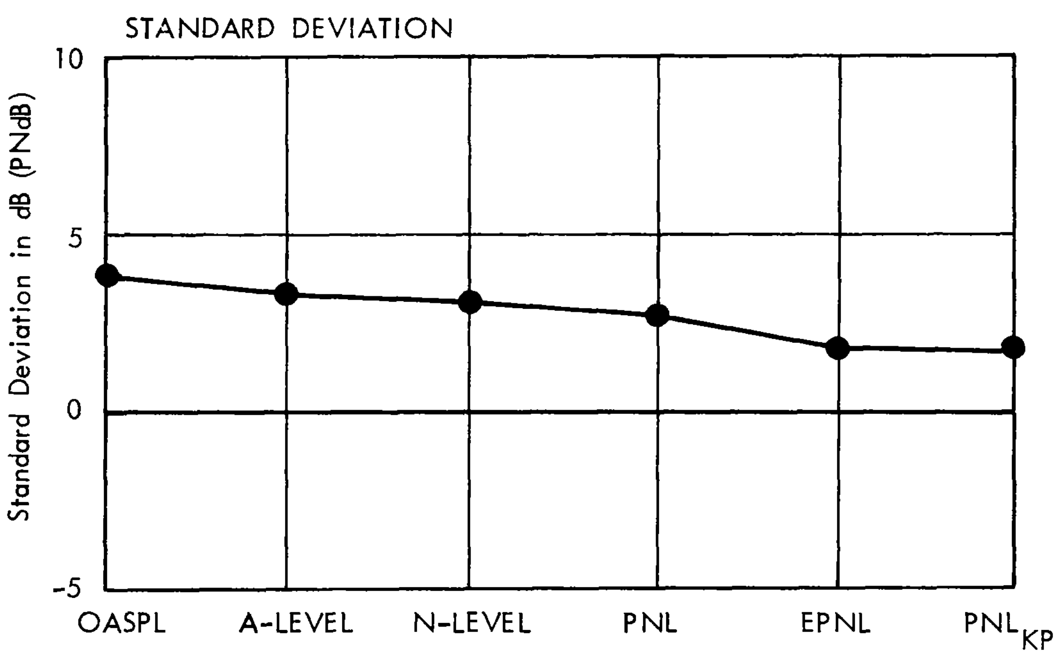


FIGURE 14. COMPARISON OF RESULTS OF VARIOUS MEASURES FOR TEST II

APPENDIX A

JUDGMENTS OF ACCEPTABILITY

The purpose of these tests is to determine the relative acceptability of different sounds. The tests are part of a program of research designed to obtain information that will be of aid in the planning of military and civilian airports and for noise control purposes in general.

On the following recording, you will hear a sound followed immediately by a second sound. Your job is to punch a hole in Column 1 or Column 2 corresponding to the sound (the first or the second) which you feel would be more objectionable or disturbing if heard regularly in your home. In other words, pick the sound you would least like to have in your home, even though you might not want either of them. Please make a judgment for each pair of sounds, even though you feel you may be guessing.

Please record your answers according to how the sounds affect you--there are no right or wrong answers, and it is important that we find out how people differ, if they do, in their judgments of these sounds. It does not matter whether your answers agree or disagree with others taking the test as long as you make the best judgment you can for each pair of sounds.

In summary, select the sound (the first or the second) which, if heard in your home, you feel would be more objectionable or disturbing.

Please write on the back of your answer card your name, seat number and the date. Remember to use the same seat location each time you take the test.

APPENDIX B

STIMULUS GENERATING EQUIPMENT

General

For each of the three tests, the entire sequence of acoustic stimuli was prerecorded on 1/4-inch magnetic tape. These "master tapes" were recorded on a two-channel recorder. The stimuli, along with some verbal annotation to identify each pair of stimuli, was recorded on Channel A of the tape. Channel B contained special cue signals to be used for control of the playback system. The function of these cue signals will be explained shortly.

A block diagram of the stimulus playback system is shown in Fig. 1. A requirement of the test environment was to have freedom from any extraneous noise other than the test stimuli. Meeting this requirement necessitated eliminating any audible tape hiss and verbal annotation on the tape from the test environment. Tape hiss was objectionable only during the "dead time" between stimuli since the stimulus itself effectively masked any tape hiss. Thus, it was desirable to be able to switch the power amplifier input from a "dead quiet" input to the tape recorder only while a stimulus was being played. This was accomplished by taking the signal from Channel A of the tape recorder and first passing it through an electronic switch before going to the amplifier and speaker. The electronic switch acted as a gate which opened and closed upon command from the cue signals on Channel B of the tape. At the beginning of each stimulus the gate would open and remain open until end of the stimulus at which time the gate would close. Through use of this system, the test subject was allowed to hear only the intended stimuli. At all other times (with the gate closed) the sound pressure level at the subject's seat position (due to noise generated by the playback equipment) was within 10 dB of the standard ISO threshold.

Tests I-A and I-B

A block diagram of the equipment used to produce the master tapes for tests I-A and I-B is shown in Fig. B-1. All stimuli could be produced by combining one or more of the three noise sources shown in the left of the figure. The levels of each of these sources were controlled independently by means of 0.1 dB step attenuators.

The three sources included a shaped broadband noise, a recording of turbofan engine noise, and a sine wave oscillator. The broadband noise was shaped such that its spectrum approximated that of an airborne four-engine turbojet aircraft approximately 2000 ft from the observer. This noise was produced by filtering the output of a random noise source through a special BBN designed filter. The recording of turbofan engine noise was made during static runups of a high thrust turbofan engine. The bare engine was mounted on a static thrust stand and the acoustic recordings were made at a distance of 250 ft from the engine at an angle of approximately 80 degrees from the engine inlet. A portion of this recording was made into a continuous tape loop for playback on a tape cartridge recording machine. The oscillator was used to generate either a 2 kHz or 4 kHz tone.

The resultant stimuli produced from these sources were passed to Channel A of an electronic switch. The switch was manually triggered in order to switch between Channel A or Channel B which was equipped with a microphone for annotation purposes between stimulus pairs. The electronic switch was employed to allow switching between Channels A and B without audible "clicks" or other electrical noise being generated and recorded on the master tape.

The signal level was then controlled by a "special amplitude modulator". The function of this modulator was to vary the level of the input signal with time in order to simulate a jet aircraft flyover noise time history. This special device provided the capability of increasing the signal level a total of 20 dB at a preset rate (i.e. some fixed number of decibels per second) and then decreasing the signal to its original level at the same rate. Used in conjunction with the electronic switch, the signal was turned on, the level increased 20 dB at a constant rate, then decreased 20 dB at the same rate, and turned off.

The resultant stimuli and annotation were recorded onto one channel of the two-channel tape recorder. On the second channel the cue signals for control of the playback system were recorded. These cue signals were fixed frequency sine waves of approximately 100 msec duration. They were generated by independent fixed frequency oscillators, with differing frequencies corresponding to particular control functions. The two functions used in this experiment were "turn-on electronic switch" and "turn-off electronic switch". Upon playback, these signals were decoded to perform their respective functions.

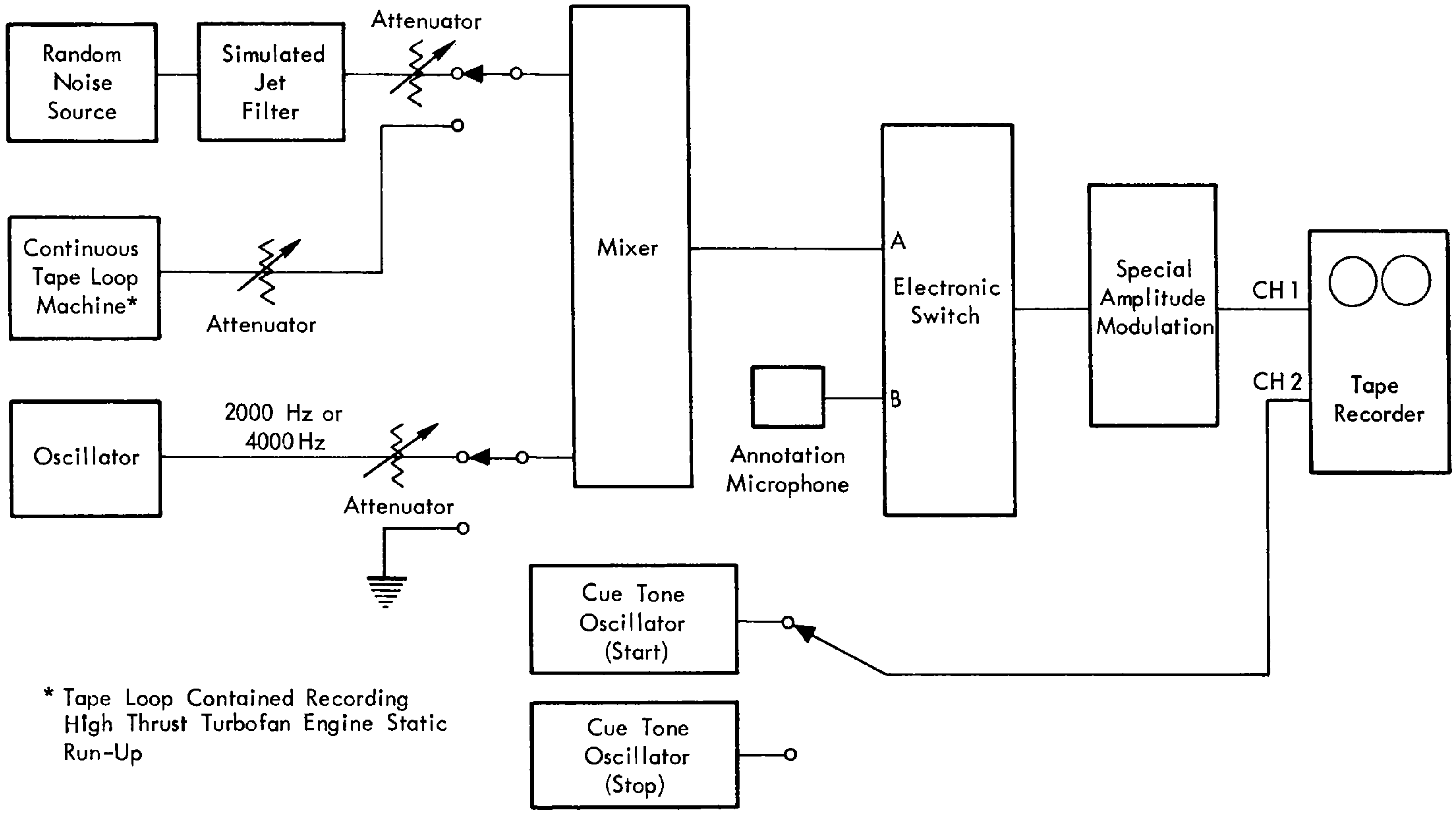
Test II

Preparation of the master tape for Test II was a two-step process. Step One involved the recording of each of the different types of stimuli onto tape loops. The master tape was then recorded from the pre-recorded stimuli on the tape loops. A block diagram of the stimulus-generating equipment for this test is shown in Fig. B-2.

Two tape loops for each stimulus type were prepared. One loop contained only a shaped broadband noise. This noise was produced by filtering the output of a random noise source with a special BBN-designed filter such that the resulting spectrum shape was similar to that produced by an airborne turbojet aircraft 2000 ft away. The second loop contained only the discrete tone component of the stimulus. A sine wave oscillator was employed for this purpose. The tone and noise were recorded on separate tapes to facilitate the proper synchronization of the two signals on final playback of the signal. In order to simulate the changing levels experienced during aircraft flyovers, a special function generator and voltage controlled amplifier combination was utilized. This device varied the signal level as a function of time by controlling the logarithmic rate of increase and decrease (i.e. the rate, in decibels per second, at which the signal level was changing) of the signal. The tape loops were inserted into continuous loop tape cartridges so that they could be played on a multi-cartridge tape playback machine. Cue signals were placed on both loops of the pair so that they could be synchronized for the start of each play.

The master tape was recorded from these previously produced tape cartridges. The tape cartridge player was capable of playing the noise and tone cartridges simultaneously. The relative levels of the tone and noise were controlled by separate 0.1 dB step attenuators and these signals were then mixed before going to one channel of an electronic switch. The function of the electronic switch was to select either the stimulus (Channel A) or an annotation microphone (Channel B) without introducing "clicks" or other electrical noise into the system. The annotation microphone was used to place verbal annotation on the tape between stimulus pairs.

The resultant stimuli and annotation were recorded onto one channel of the two-channel tape recorder. On the second channel the cue signals for control of the playback system were recorded. These cue signals were fixed frequency sine waves of approximately 100 msec duration. They were generated by independent fixed frequency oscillators, with differing frequencies corresponding to particular control functions. The two functions used in this experiment were "turn-on electronic switch" and "turn-off electronic switch". Upon playback, these signals were decoded to perform their respective functions.



* Tape Loop Contained Recording High Thrust Turbofan Engine Static Run-Up

FIGURE B-1. BLOCK DIAGRAM OF STIMULUS GENERATING EQUIPMENT FOR TEST I A AND I B

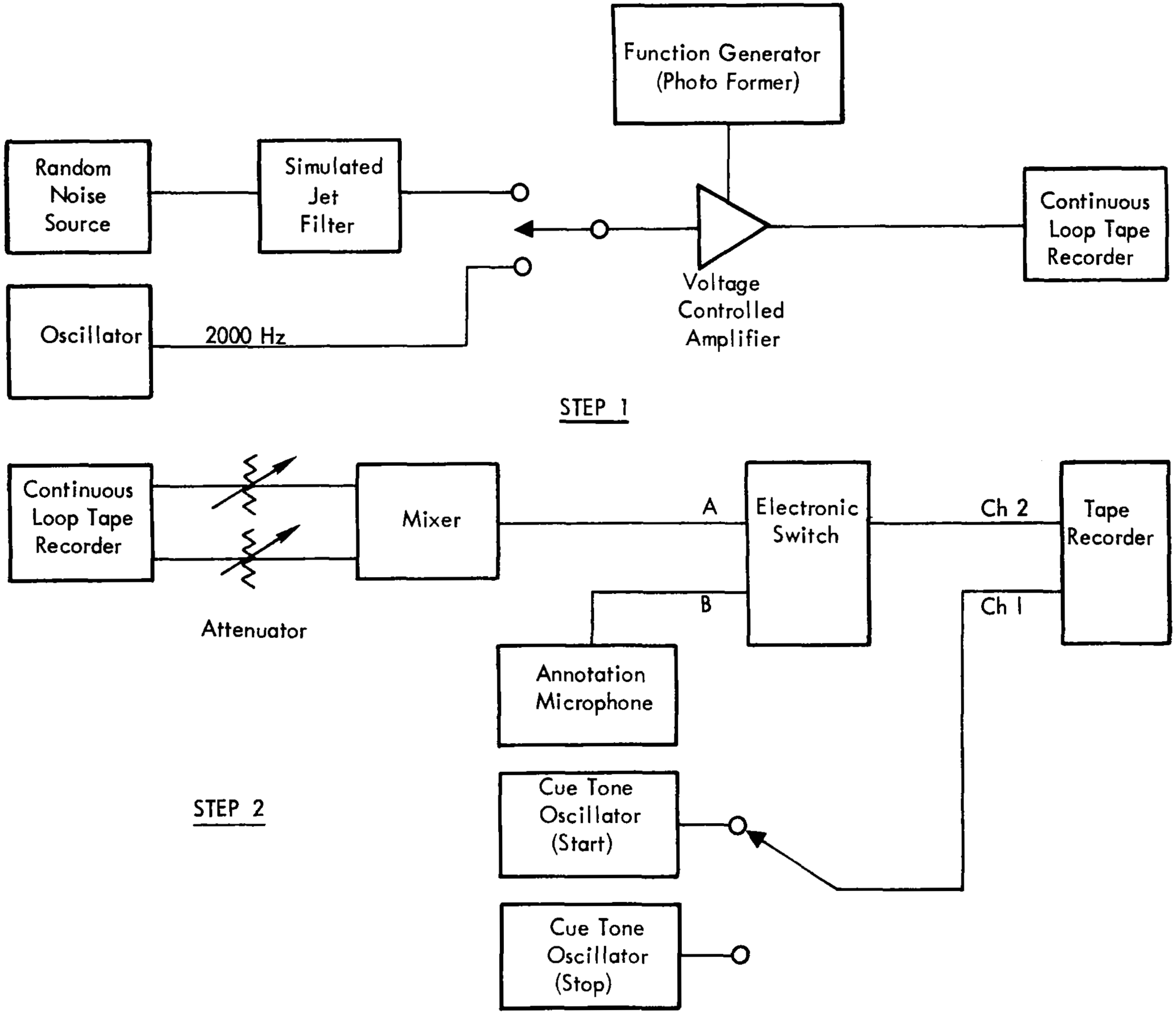


FIGURE B-2. BLOCK DIAGRAM OF STIMULUS GENERATING EQUIPMENT FOR TEST II

APPENDIX C

MAXIMUM LEVELS PRESENTED DURING JUDGMENT TESTS

TABLE C-I

MAXIMUM LEVELS OF STIMULI FOR TEST I-A

	Stimulus[1] Std. or Comp.	Noise Type	Noise or Tone Duration	Tone Frequency	T/N
1.	Std	Jet[2]	12 Sec	-	No Tone
2.	Comp	Jet	4	-	No Tone
3.	Comp	Jet	4	2000 Hz	10 dB
4.	Comp	Jet	4	2000	25
5.	Comp	Jet	12	-	No Tone
6.	Comp	Jet	12	2000	10
7.	Comp	Jet	12	2000	25
8.	Comp	Jet	32	-	No Tone
9.	Comp	Jet	32	2000	10
10.	Comp	Jet	32	2000	25
11.	Comp	Jet	4	4000	25
12.	Comp	Jet	32	4000	25

Sound Pressure Level in dB re 0.0002 dyn/sq. cm.
One-Third Octave Band Center Frequency, Hz.

	OA	50	63	80	100	125	160	200	250	315	400	500
1.	80.0	46.0	52.5	56.5	64.0	71.5	68.5	70.0	71.5	71.0	69.0	69.5
2.	94.0	60.0	66.5	70.5	78.0	85.5	82.5	84.0	85.5	85.0	83.0	83.5
3.	86.5	52.0	58.5	62.5	70.0	77.5	74.5	76.0	77.5	77.0	75.0	75.5
4.	58.5	38.0	44.5	48.5	56.0	63.5	60.5	62.0	63.5	63.0	61.0	61.5
5.	89.0	55.0	61.5	65.5	73.0	80.5	77.5	79.0	80.5	80.0	78.0	78.5
6.	81.5	47.0	53.5	57.5	65.0	72.5	69.5	71.0	72.5	72.0	70.0	70.5
7.	73.5	33.0	39.5	43.5	51.0	58.5	55.5	57.0	58.5	58.0	56.0	56.5
8.	86.0	52.0	58.5	62.5	70.0	77.5	74.5	76.0	77.5	77.0	75.0	75.5
9.	79.0	44.0	50.5	54.5	62.0	69.5	66.5	68.0	69.5	69.0	67.0	67.5
10.	70.5	30.0	36.5	40.5	48.0	55.5	52.5	54.0	55.5	55.0	53.0	53.5
11.	78.0	43.0	49.5	53.5	61.0	68.5	65.5	67.0	68.5	68.0	66.0	66.5
12.	70.0	35.0	41.5	45.5	53.0	60.5	57.5	59.0	60.5	60.0	58.0	58.5

	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000
1.	67.5	68.0	66.0	65.0	63.5	60.5	56.0	53.0	50.0	47.0	44.5	41.0
2.	81.5	82.0	80.0	79.0	77.5	74.5	70.0	67.0	64.0	61.0	58.5	55.0
3.	73.5	74.0	72.0	71.0	69.5	76.5	62.0	59.0	56.0	53.0	50.5	47.0
4.	59.5	60.0	58.0	57.0	55.5	77.5	48.0	45.0	42.0	39.0	36.5	33.0
5.	76.5	77.0	75.0	74.0	72.5	69.5	65.0	62.0	59.0	56.0	53.5	50.0
6.	68.5	69.0	67.0	66.0	64.5	71.5	57.0	54.0	51.0	48.0	45.5	42.0
7.	54.5	55.0	53.0	52.0	50.5	72.5	43.0	40.0	37.0	34.0	31.5	28.0
8.	73.5	74.0	72.0	71.0	69.5	66.5	62.0	59.0	56.0	53.0	50.5	47.0
9.	65.5	66.0	64.0	63.0	61.5	68.5	54.0	51.0	48.0	45.0	42.5	39.0
10.	51.5	52.0	50.0	49.0	47.5	69.5	40.0	37.0	34.0	31.0	28.5	25.0
11.	64.5	65.0	63.0	62.0	60.5	57.5	53.0	50.0	72.0	44.0	41.5	38.0
12.	56.5	57.0	55.0	54.0	52.5	49.5	45.0	42.0	64.0	36.0	33.5	30.0

1. See Figure 2 and Table I for description of parameters ($\Delta t = 0$ for this test).

2. Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

TABLE C-II

MAXIMUM LEVELS OF STIMULI FOR TEST I-B

	Stimulus[1]				
	Std. or Comp.	Noise Type	Noise or Tone Duration	Tone Frequency	T/N
1.	Std.	Jet[2]	12 Sec	-	No Tone
2.	Comp.	Engine[3]	4	-	-
3.	Comp.	Engine	12	-	-
4.	Comp.	Engine	32	-	-
5.	Comp.	Jet	4	2000 Hz	10 dB

Sound Pressure Level in dB re 0.0002 dyn/sq. cm.
One-Third Octave Band Center Frequency, Hz.

	OA	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000
1.	80.0	46.0	52.5	56.5	64.0	71.5	68.5	70.0	71.5	71.0	69.0	69.5	67.5	68.0	66.0	65.0	63.5	60.5	56.0	53.0	50.0	47.0	44.5	41.0
2.	82.0	44.5	48.5	57.5	65.0	69.0	67.5	74.5	70.0	70.0	68.5	64.5	62.5	63.0	62.0	63.0	66.0	65.0	64.5	76.0	70.0	63.5	70.5	63.0
3.	77.0	39.5	43.5	52.5	60.0	64.0	62.5	69.5	65.0	65.0	63.5	59.5	57.5	58.0	57.0	57.5	61.0	60.0	59.5	71.0	65.0	58.5	65.5	58.0
4.	74.0	36.5	40.5	49.5	57.0	61.0	59.5	66.5	62.0	62.0	60.5	56.5	54.5	55.0	54.0	54.5	58.0	57.0	55.5	68.0	62.0	55.5	62.5	55.0
5.	86.5	52.0	58.5	62.5	70.0	77.5	74.5	76.0	77.5	77.0	75.0	75.5	73.5	74.0	72.0	71.0	69.5	76.5	62.5	59.0	56.0	53.0	50.5	47.0

1 See Figure 2 and Table II for description of parameters ($\Delta t = 0$ for test).

2 Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

3. High thrust turbofan engine.

TABLE C-III

MAXIMUM LEVELS OF STIMULI FOR TEST II

	Std. or Comp.	Noise Type	Jet Noise Duration	2000 Hz Tone Duration	Measured Duration of Comp. Stimulus[2]	T/N	Δt	Δt / Noise Duration
	Stimulus[1]							
1.	Std.	Jet[3]	12 Sec	No Tone	12.5 Sec			
2.	Comp.	Jet	4	4 Sec	4.5	5 dB	0 Sec	0
3.	Comp.	Jet	4	4	4.5	5	-1	-0.25
4.	Comp.	Jet	4	4	5.0	5	+1	+0.25
5.	Comp.	Jet	4	4	6.0	5	+2	+0.50
6.	Comp.	Jet	4	4	5.0	15	0	0
7.	Comp.	Jet	4	4	5.0	15	-1	-0.25
8.	Comp.	Jet	4	4	5.5	15	+1	+0.25
9.	Comp.	Jet	4	4	6.0	15	+2	+0.50
10.	Comp.	Jet	12	4	12.0	5	0	0
11.	Comp.	Jet	12	4	13.0	5	-3	-0.25
12.	Comp.	Jet	12	4	13.5	5	+3	+0.25
13.	Comp.	Jet	12	4	14.5	5	+6	+0.50
14.	Comp.	Jet	32	4	34.0	5	+8	+0.25
15.	Comp.	Jet	32	12	36.0	5	+8	+0.25
16.	Std.	Jet + Tone	12	12	12.0	5	0	0
17.	Comp.	Jet	12	4	12.0	5	0	0
18.	Comp.	Jet	12	4	13.0	5	-3	-0.25
19.	Comp.	Jet	12	4	13.5	5	+3	+0.25
20.	Comp.	Jet	12	4	14.5	5	+6	+0.50

Sound Pressure Level in dB re 0.0002 dyn/sq.cm.
One-Third Octave Band Center Frequency, Hz.

	OA	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000
1.	80.0	48.5	51.0	57.5	65.5	71.5	69.5	71.0	71.5	71.0	69.0	69.0	67.5	67.5	65.0	63.5	62.0	58.0	53.0	48.5	44.5	40.0	37.5	33.0
2.	90.0	54.5	59.5	67.0	73.5	80.0	78.0	79.5	79.0	79.0	77.5	78.0	77.0	77.0	74.5	73.0	70.5	76.0	63.5	58.5	54.0	50.0	47.0	43.0
3.	90.5	56.0	61.0	68.0	73.5	80.0	79.0	79.5	79.5	80.0	78.5	79.5	75.5	76.5	75.0	73.5	71.5	75.0	64.0	59.5	54.5	50.0	48.5	44.0
4.	89.0	57.0	60.5	68.0	72.5	79.0	78.5	78.5	79.5	80.0	77.5	77.0	77.0	75.5	74.5	72.0	70.5	76.0	63.0	59.0	54.5	50.0	47.0	44.0
5.	90.0	56.0	60.0	67.5	75.0	82.0	78.0	79.5	80.5	79.5	78.0	79.0	77.5	76.5	74.0	73.0	71.5	75.5	63.0	59.0	56.0	51.0	48.0	43.5
6.	84.5	51.5	56.0	61.0	66.5	73.0	71.0	72.0	72.5	74.0	71.5	72.5	70.0	70.5	68.0	66.0	66.0	77.5	60.5	53.0	48.5	45.0	42.0	40.0
7.	84.0	52.0	55.0	62.0	67.5	73.5	70.5	72.5	72.5	70.5	71.0	71.0	69.0	69.0	66.5	65.5	64.5	77.0	61.0	52.0	48.0	43.5	41.0	37.0
8.	82.0	49.0	53.5	59.5	67.0	71.5	70.0	72.0	70.5	71.0	70.5	69.5	68.5	69.0	67.0	63.5	64.0	78.0	60.5	51.0	47.0	43.0	39.5	35.5
9.	82.0	47.5	53.5	58.5	65.0	73.5	70.0	71.0	71.0	72.5	70.0	70.0	68.0	69.0	67.0	66.0	63.0	77.5	60.0	51.5	47.0	42.5	39.0	35.5
10.	85.0	43.0	58.0	62.5	70.0	76.5	75.0	76.0	76.5	76.0	73.5	74.0	72.0	72.5	70.5	69.0	67.0	70.5	59.0	54.0	50.5	46.5	43.5	40.0
11.	85.0	59.0	51.5	62.5	70.0	76.0	75.5	76.0	76.5	75.5	74.5	74.0	72.5	73.0	70.5	68.0	66.5	70.0	57.0	54.0	50.5	46.0	43.0	40.5
12.	85.0	58.5	57.5	63.0	69.5	76.0	75.0	76.0	75.5	74.5	74.5	74.5	72.5	72.5	70.5	68.5	67.0	70.0	57.5	54.5	50.5	46.0	43.5	40.0
13.	85.0	53.5	58.0	63.5	70.0	76.0	74.5	75.5	76.5	76.0	74.5	74.5	72.5	72.5	70.5	69.0	67.5	69.5	57.5	54.5	50.0	46.0	43.0	40.0
14.	80.0	49.0	53.0	58.5	65.0	72.5	74.0	72.0	72.5	72.0	70.0	71.0	68.5	68.5	67.5	64.0	63.0	65.5	54.5	51.0	46.0	41.5	38.0	34.0
15.	80.5	48.0	53.0	58.5	66.5	73.0	70.5	72.0	72.0	72.0	69.5	79.5	68.0	68.5	66.5	64.0	63.5	66.5	54.5	51.0	47.0	42.5	38.5	35.0
16.	80.0	47.0	51.0	57.0	65.0	72.0	70.5	71.0	71.5	71.0	69.5	69.0	67.5	67.5	65.0	67.0	62.0	61.5	53.0	50.0	45.0	41.0	37.0	33.0
17.	85.0	43.0	58.0	62.5	70.0	76.5	75.0	76.0	76.5	76.0	73.5	74.0	72.0	72.5	70.5	69.0	67.0	70.5	59.0	54.0	50.5	46.5	43.5	
18.	85.0	59.0	51.5	62.5	70.0	76.0	75.5	76.0	76.5	75.5	74.5	74.0	72.5	73.0	70.5	68.0	66.5	70.0	57.0	54.0	50.5	46.0	43.0	40.5
19.	85.0	58.5	57.5	63.0	69.5	76.0	75.0	76.0	75.5	74.5	74.5	74.5	72.5	72.5	70.5	68.5	67.0	70.0	57.5	54.5	50.5	46.0	43.5	40.0
20.	85.0	53.0	58.0	63.5	70.0	76.0	74.5	75.5	76.5	76.0	74.5	74.5	72.5	72.5	70.5	69.0	67.5	69.5	57.5	54.5	50.0	46.0	43.0	40.0

1. See Figure 2 and Table III for description of parameters.
2. Measured with N-weighting network.
3. Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

APPENDIX D

RESULTS OF JUDGMENT TESTS USING A METHOD OF PAIRED COMPARISON

TABLE D-I

RESULTS OF TEST I-A

Stimulus					Comparison 50% Level (Judged Equality Level in dB re Max)
Standard[1]	Comparison[2]				
Noise	Noise	Noise or Tone Duration	Tone Frequency	T/N	
Jet[3]	Jet	4 sec	-	No Tone	-10.0
Jet	Jet	4	2000-Hz	10 dB	-8.5
Jet	Jet	4	2000	25	-4.5
Jet	Jet	12	-	No Tone	-10.5
Jet	Jet	12	2000	10	-9.5
Jet	Jet	12	2000	25	-8.0
Jet	Jet	32	-	No Tone	-8.0
Jet	Jet	32	2000	10	-6.0
Jet	Jet	32	2000	25	-8.5
Jet	Jet	4	4000	25	-8.5
Jet	Jet	32	4000	25	-7.5

1 Duration of standard is 12 seconds.

2 See Figure 2 and Table I for description of parameters (Δt = 0 for this test).

3 Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

TABLE D-II

RESULTS OF TEST I-B

Stimulus					Comparison 50% Level (Judged Equality Level in dB re Max)
Standard[1]	Comparison[2]				
Noise	Noise	Duration	Tone Frequency	T/N	
Jet[3]	Engine[4]	4 sec	-	-	-12.5
Jet	Engine	12	-	-	-18.0
Jet	Engine	32	-	-	-15.5
Jet	Jet	4	2000 Hz	10 dB	-7.0

1 Duration of standard is 12 seconds.

2 See Figure 2 and Table II for description of parameters (Δt = 0 for this test)

3 Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

4 High thrust turbofan engine.

TABLE D-III

RESULTS OF TEST II

Stimulus							
Standard[1]	Comparison[2]					Comparison 50% Level (Judged Equality Level in dB re Max)
Noise	Jet Noise Duration	2000 Hz Tone Duration	T/N	Δt	Δt / Noise Duration	
Jet[3]	4 sec	4 sec	5 dB	0 sec	0.0	-12.0
Jet	4	4	5	-1	-0.25	-12.5
Jet	4	4	5	+1	+0.25	-11.5
Jet	4	4	5	+2	+0.50	-11.5
Jet	4	4	15	0	0.0	-11.5
Jet	4	4	15	-1	-0.25	-14.0
Jet	4	4	15	+1	+0.25	-13.5
Jet	4	4	15	+2	+0.50	-12.0
Jet	12	4	5	0	0.0	-8.0
Jet	12	4	5	-3	-0.25	-11.5
Jet	12	4	5	+3	+0.25	-8.5
Jet	12	4	5	+6	+0.50	-11.0
Jet + Tone[4]	12	4	5	0	0.0	-5.5
Jet + Tone	12	4	5	-3	-0.25	-8.5
Jet + Tone	12	4	5	+3	+0.25	-4.5
Jet + Tone	12	4	5	+6	+0.50	-7.5
Jet	32	4	5	+8	+0.25	-10.5
Jet	32	12	5	+8	+0.25	-10.5

1 Duration of standard is 12 seconds.

2 See Figure 2 and Table III for description of parameters.

3 Broadband noise with spectrum similar to turbojet flyover at 2000 feet.

4 Standard

Jet Noise Duration	12 sec
Tone 2000 Hz Duration	12 sec
T/N	5 dB
Δt	0
Δt/Noise Duration	0

APPENDIX E

PURE TONE AND DURATION CORRECTIONS FOR PERCEIVED NOISE LEVEL

Two methods of tone and duration 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. 1,7) and the other was based on the proposed FAA certification procedure (Ref. 8).

The Kryter-Pearsons method for determining the tone correction uses the maximum band levels determined in each one-third octave band. If one of the one-third octave bands exceeds the adjacent two by more than 3 dB 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 "toned band". This difference is entered into Table E-I to determine the correction to be added to the toned band prior to calculating perceived noise level. After all appropriate bands are so corrected, the perceived noise level is calculated.

The duration correction is determined from the 10 dB down duration measured using an N-weighting network. The correction itself is determined according to the formula

$$\text{duration correction} = 10 \log \frac{\text{duration}}{15}$$

The effective perceived noise level (EPNL) measure is also a tone and duration corrected perceived noise level. This measure proposed by the FAA for noise certification of aircraft uses a somewhat different approach to determine the tone and duration corrections. 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 corrections is included for each interval using the following procedure:

Step 1

Compute for each one-third octave band a value composed of the arithmetic average of the levels of the nearest two bands above the given band and the nearest two bands below.

> Note: The value for the two lowest frequency bands, and the two highest bands is based on only the average of available adjacent bands.

Step 2

Mark all bands that exceed this computed value by 3 dB or more. Recompute for all bands a second average value as in Step 1, omitting the marked bands in calculations of the average. (The average may now be based on several non-contiguous bands.) A discrete frequency is said to exist if the SPL in any band exceeds this recomputed average value by 3 dB or more.

Step 3

The difference in dB between the second computer average value and actual SPL in each marked band, is designated as F, and is used to determine the discrete frequency corrections, F_c, from the following equations:

$F_c = 0.3F$	$3 \leq F \leq 20$	for 1/3 octave bands from 500 to 5000 Hz
$F_c = 6.0$	$20 \leq F$	
$F_c = 0.15F$	$3 \leq F \leq 20$	For 1/3 octave bands 100, 125, 160, 200, 250, 315, 400, 6300, 8000, and 10,000 Hz
$F_c = 3.0$	$20 \leq F$	

Thus, a discrete frequency correction is determined for each one-third octave band that exceeds its "average" by 3 dB or more. The correction is added to the perceived noise level calculated for one-half second interval. If a correction is found for more than one frequency, only the largest calculation is used.

Let us call the maximum measure thus calculated the tone corrected perceived noise level. The duration correction is determined from the amout of time the tone corrected perceived noise level is within 10 dB of the maximum level. This duration is then employed to determine the duration correction according to the same formula described above for the Kryter-Pearsons duration correction, that is:

$$\text{duration correction} = 10 \log \frac{\text{duration}}{15}$$

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