NASA CONTRACTOR REPORT

NASA CR-2376

NASA CR-2376

CASE FILE COPY

HANDBOOK OF NOISE RATINGS

by Karl S. Pearsons and Ricarda L. Bennett

Prepared by
BOLT BERANEK AND NEWMAN, INC.
Canoga Park, Calif. 91303
for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • APRIL 1974

1. Report No. NASA CR-2376	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle HANDBOOK OF NOISE RATINGS		5. Report Date April 1974
		6. Performing Organization Code
7. Author(s) Karl S. Pearsons and Ricarda Bennett		8. Performing Organization Report No. 2419
9. Performing Organization Name and Address BOLT BERANEK AND NEWMAN INC. Canoga Park, Calif. 91303		10. Work Unit No. 138-80-01-04
		11. Contract or Grant No. NAS1-11,839 Task 2
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Contractor Report
		14. Sponsoring Agency Code

15. Supplementary Notes

This is the final report on Task 2.

16. Abstract

The Handbook of Noise Ratings has been compiled to provide information in a concise form describing the multitude of noise rating schemes which are in use today. Although most of the information contained herein can be found in other references, it is hoped that by describing the noise rating methods in a single volume the user will have better access to the definitions, application and calculation procedures of the current noise rating methods.

The format used in this Handbook divides the measures into four chapters: I. Direct Ratings of Sound Level, II. Computed Loudness and Annoyance Ratings, III. Communication Interference Ratings, IV. Community Response Ratings. The first page for each noise rating contains the title of the measure, the units used, the definition of the measure, associated standards, geographical usage, and purpose. On the following pages, the additional information on a given noise rating is divided into such headings as: BACKGROUND, CALCULATION METHOD, EXAMPLE, EQUIPMENT AND REFERENCES.

17. Key Words (Suggested by Author(s)) Noise, subjective response to noise, noise ratings, acoustics		18. Distribution Statement Unclassified - Unlimited Cat.23	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 332	22. Price* $7.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

INTRODUCTION

The Handbook of Noise Ratings has been compiled to provide information in a concise form describing the multitude of noise rating schemes which are in use today. Although most of the information contained herein can be found in other references, it is hoped that by describing the noise rating methods in a single volume the user will have better access to the definitions, application and calculation procedures of the current noise rating methods.

The format used in this Handbook divides the measures into four chapters: I. Direct Ratings of Sound Level, II. Computed Loudness and Annoyance Ratings, III. Communication Interference Ratings, IV. Community Response Ratings. The first page for each noise rating contains the title of the measure, the units used, the definition of the measure, associated standards, geographical usage, and purpose. On the following pages, the additional information on a given noise rating is divided into such headings as: BACKGROUND, CALCULATION METHOD, EXAMPLE, EQUIPMENT and REFERENCES.

The TITLE for each measure is given in its most complete form; followed in parenthesis by its commonly referred to abbreviations. The UNITS are listed in preferred form followed by alternative forms in brackets. The official measuring unit for direct ratings is the decibel (dB). A shorthand method of identifying the weighting function that is being used to rate the noise level is by attaching an additional letter to the abbreviation "dB". Thus, dB(A) is often used to denote A-weighted sound level.

Reference levels are included when appropriate for the units. The DEFINITION briefly outlines the scope of the measure and the parameters that it takes into consideration. STANDARDS include both existing standards and proposed standards. In some cases, industrial standards have been used when national or international standards do not exist. The GEOGRAPHICAL USAGE is included to indicate where the measure is most commonly used. If a specified country is listed in this section, it does not necessarily mean that the measure is used exclusively in this country; nor does it mean that this measure is the only one of its type used in this country. The PURPOSE describes the reasons for the noise rating's development and its major uses. The BACKGROUND provides some indication of the development of the noise rating as well as a description of the elements of the calculation procedures for those measures utilizing relatively complicated techniques. Under the CALCULATION METHOD, a step-by-step procedure is outlined to enable the user to ideally calculate the noise rating. The EXAMPLE uses numerical information in an effort to simulate a real-life situation. A list of the equipment necessary for collecting the data, for calculating the noise rating, or for direct measurement of the noise rating is included under the heading of EQUIPMENT. Some of the literature used in writing the measure is listed under REFERENCES.

The appendix entitled ADDITIONAL RATINGS contains a few of the less frequently used measures. The ABBREVIATIONS section consists of a simple cross reference index. A GLOSSARY of acoustical terminology is included for completeness.

The authors are sincerely grateful to all the people who helped bring this work to completion. In particular, we are indebted to Drs. William J. Galloway and David C. Nagel who individually made many valuable and constructive comments on an earlier draft of this book. And we owe a special thanks to Richard Horonjeff who gave much needed advice and encouragement.

Finally, we welcome any comments regarding content, and (if possible) serious omissions. We hope that the Handbook of Noise Ratings will prove to be a useful tool in fostering a better understanding of noise ratings and their implementation.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

CHAPTER I

DIRECT RATINGS OF SOUND LEVEL

TITLE

SOUND PRESSURE LEVEL
(OVERALL SOUND PRESSURE LEVEL) (LINEAR LEVEL)
(SPL) (OASPL) (L) (L_p)

UNIT

dB

Reference pressure: 20 $\mu N/m^2$*

DEFINITION

The sound pressure level of a sound is 20 times the logarithm to the base 10 of the ratio of the measured root-mean-square (RMS) value of the sound pressure to a reference sound pressure*.

$$SPL = 20 \log_{10}(p_{meas.}/p_{ref.}) \qquad [1]$$

*The reference sound pressure for this Handbook is 20 $\mu N/m^2$, but often seen is the reference pressure 20 μ Pascal (Pa). Also commonly used is .0002 microbar. The relationship is that .0002 microbar is equal to .0002 $dyne/cm^2$ is equal to 20 $\mu N/m^2$.

STANDARDS

Overall sound pressure level is not standardized. Related Standards are:

1) American National Standards Institute Specification for Sound Level Meters (S1.4-1971)
2) IEC Recommendation, Publication 179. Precision Sound Level Meters, 1965
3) IEC Recommendation, Publication 123. Recommendation for Sound Level Meter, 1961
4) IEC Recommendation, Publication 225. Octave, half-octave, and third-octave band filters intended for the analysis of Sounds and Vibration, 1966

GEOGRAPHICAL USAGE	International
PURPOSE	Overall sound pressure level is a simple physical measure of sound which gives equal weight to all frequencies. It measures the environmental noise level but gives little information as to the human perception of the noise. It is primarily used by engineers who need a measure which relates to total noise energy.
BACKGROUND	Overall sound pressure level was used as one of the first attempts at measuring the magnitude of noise. Earlier equipment limitations only allowed a narrow frequency band analysis of the sound pressure level of a noise. Today, though no standard exists for the bandwidth of overall sound pressure level, it is generally considered to extend from 20 to 20,000 Hz, a range which corresponds to human hearing. The more recent sound level meter (SLM) equipment encompasses a range from 10 Hz to 40,000 Hz. Sound pressure levels may also be expressed in terms of *fast* or *slow* response. These terms refer to the speed with which the SLM indicator follows fluctuating sound. The averaging times are 0.3 seconds and 1.5 seconds respectively. For more detailed information

on the meaning of the *fast* and *slow* response, refer to one of the above listed standards for sound level meters.

CALCULATION METHOD

Overall sound pressure level can be determined using a sound level meter, or it can be calculated from octave or one-third octave frequency band sound levels. The procedure is to sum the band levels on the basis of their squared pressures, (often referred to as summation on an *energy* basis).

EXAMPLE

An example of OASPL noise calculations for one-third octave band measurements of an aircraft flyover noise spectrum is shown in Table OASPL-I. In order to combine decibels, the band levels are first converted to relative pressure squared by dividing by ten and taking the antilog of the result.

$$\text{Relative Pressure Squared} = \text{antilog}_{10}\,(\text{level}/10) \qquad [2]$$

The relative pressure squared is then summed and converted back to decibels.

$$\text{OASPL} = 10 \log_{10} \sum_{i=1}^{25} \text{Relative Pressure Squared} \qquad [3]$$

For this example, OASPL = 102.3 dB.

TABLE OASPL-I

EXAMPLE OF OVERALL SOUND PRESSURE LEVEL CALCULATION FROM ONE-THIRD OCTAVE BAND MEASUREMENTS OF AIRCRAFT FLYOVER

One-Third Octave Band Center Frequency Hz	Band Level dB	Relative Pressure Squared
50	74.0	2.51 X 10^7
63*	76.0	3.98 " "
80	73.0	1.99 " "
100	66.0	0.39 " "
125*	77.0	5.01 " "
160	80.0	10.00 " "
200	85.0	31.62 " "
250*	83.0	19.95 " "
315	76.0	3.98 " "
400	79.0	7.94 " "
500*	79.0	7.94 " "
630	80.0	10.00 " "
800	80.0	10.00 " "
1000*	82.0	15.84 " "
1250	83.0	19.95 " "
1600	84.0	25.11 " "
2000*	89.0	79.43 " "
2500	101.0	1258.92 " "
3150	90.0	100.00 " "
4000*	84.0	25.11 " "
5000	87.0	50.11 " "
6300	77.0	5.01 " "
8000*	74.0	2.51 " "
10000	61.0	0.12 " "

*Octave Band

TOTAL 1697.505 X 10^7

$$\text{OASPL} = 10 \log (1697.505 \times 10^7) = 102.3 \text{ dB}$$

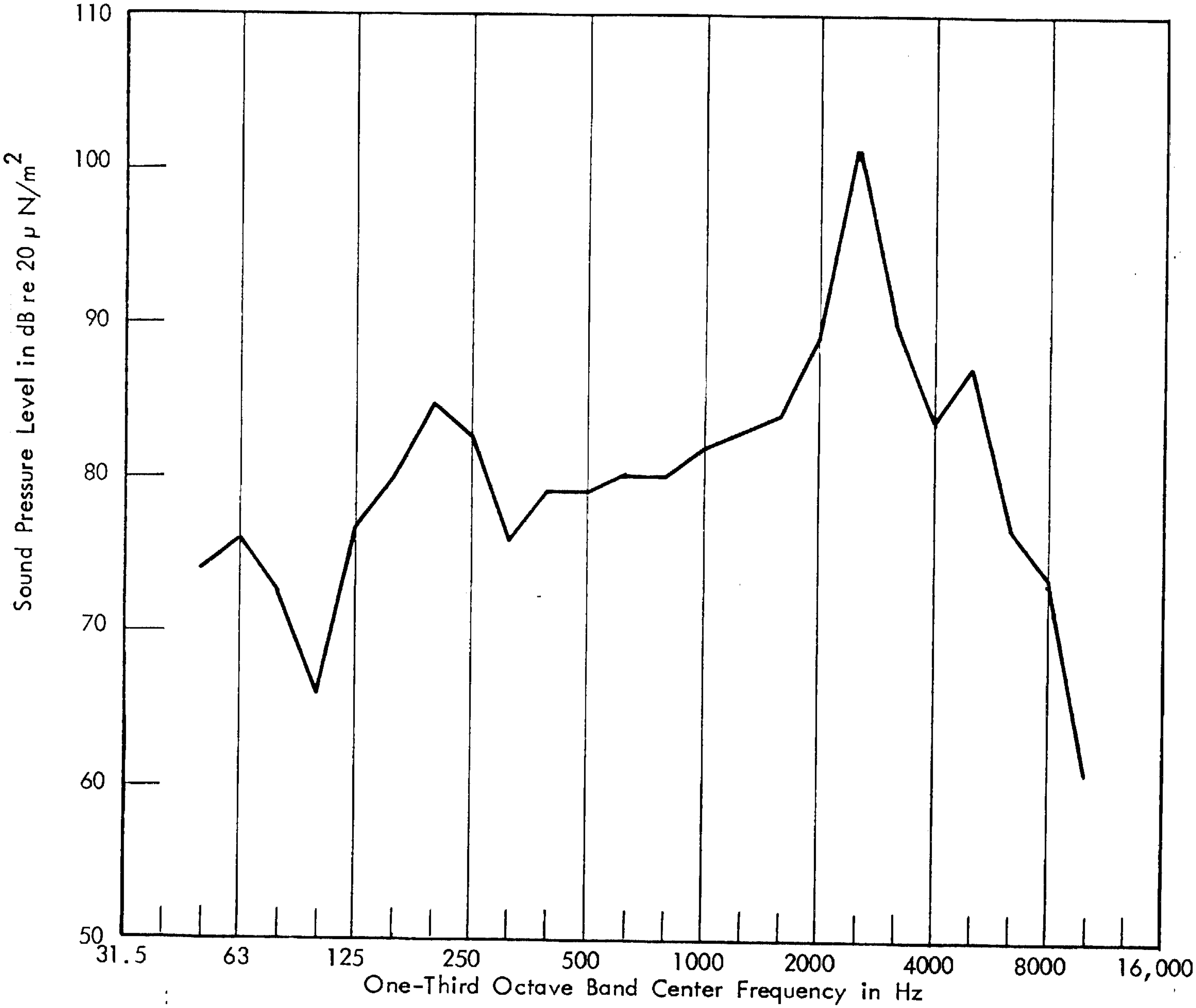


FIGURE 1. TYPICAL FLYOVER NOISE SPECTRUM

EQUIPMENT

1) A sound level meter or equivalent equipment adhering to the above mentioned standards (ANSI, IEC)
2) Or, Equipment for determining octave band or one-third octave band noise measurements.

REFERENCES

1. Beranek, Leo, Acoustic Measurement, John Wiley & Sons, 1949.
2. Harris, Cyril, Handbook of Noise Control, McGraw Hill Co., 1957, New York.

TITLE

A-LEVEL

(SOUND LEVEL-A) (AL) (L_A)

UNIT

dB(A)* (dBA) (dB)

Reference pressure: 20 $\mu N/m^2$

DEFINITION

A-weighted sound pressure level or A-level is sound pressure level which has been filtered or weighted to quantitatively reduce the effect of the low frequency noise. It was designed to approximate the response of the human ear to sound. A-level is measured in decibels with a standard sound level meter which contains the weighting network for "A" shown in Figure AL-1.

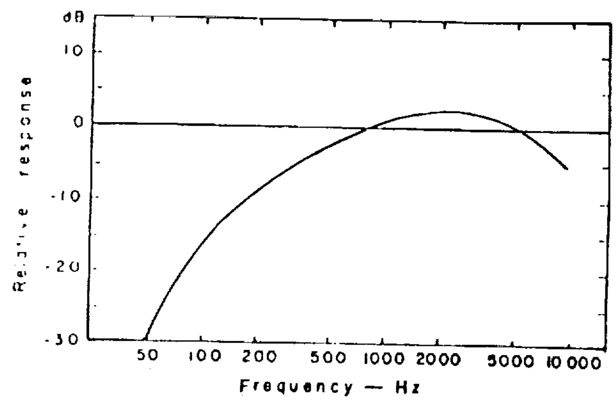


Figure AL-1 A-Weighting

STANDARDS

1) American National Standards Institute Specification for Sound Level Meters (S1.4-1971).
2) IEC Recommendation, Publication 179. Precision Sound Level Meters, 1965.
3) IEC Recommendation, Publication 123. Recommendation for Sound Level Meters, 1961.

*The official unit for all the weighted sound levels is dB, however it is often seen in literature as dB(A), dB(B) etc.

4) IEC Recommendation, Publication 225. Octave, Half-Octave, and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibration, 1966.

GEOGRAPHICAL USAGE International

PURPOSE

A-level provides a simple measure that is found to correlate better than overall or C-level with people's subjective assessment of the loudness or noisiness of many types of sound. A-level is presently used as single number rating for industrial noise, aircraft flyovers and traffic noise levels.

BACKGROUND

Because overall sound pressure level did not correlate well with human assessment of the loudness of sounds, weighting networks were added to sound level meters to attenuate low frequency noise in accordance with equal loudness contours. One of these weighting networks was designated "A" and was originally employed for sounds less than 55 dB in level. Now A-level is used for all levels.

The A-weighting is realized by a simple electrical network which provides the weighting shown in Figure AL-1. A-level has been found to correlate well with people's subjective judgment of the annoyance of many types of noise. Its simplicity and superiority over unweighted SPL in predicting people's responses to noise has made it a widely used measure.

CALCULATION METHOD

A-level can be determined using a sound level meter that contains an electrical network for A-weighting. A-level also may be estimated by applying A-weighting values (Table AL-I, Figure AL-1) to octave or one-third octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an *energy* basis).

TABLE AL-I

A-WEIGHTING CORRECTION FUNCTIONS

One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB	One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB
50	-30.2	1000	0.0*
63	-26.2*	1250	0.6
80	-22.5	1600	1.0
100	-19.1	2000	1.2*
125	-16.1*	2500	1.3
160	-13.4	3150	1.2
200	-10.9	4000	1.0*
250	- 8.6*	5000	0.5
315	- 6.6	6300	-0.1
400	- 4.8	8000	-1.1*
500	- 3.2*	10000	-2.5
630	- 1.9	12500	-4.3
800	- 0.8		

*Octave Band Corrections

EXAMPLE

An example of A-level calculation for one-third octave band measurements of an aircraft flyover noise is shown in Table AL-II. The noise spectrum is first corrected by the A-weighting response functions given in Table AL-I.

In order to combine decibels, the corrected band levels are first converted to relative pressure squared by dividing by ten and taking the antilog of the result.

Relative Pressure Squared =

$$\text{antilog}_{10}\ (\text{corrected level}/10) \qquad [1]$$

The relative pressure squared is then summed and converted back to corresponding decibels.

$$\text{A-level} = 10\ \log_{10} \sum_{i=1}^{25} \text{Relative Pressure Squared} \qquad [2]$$

For this example, A-level = 103.3 dB(A).

EQUIPMENT

1) A sound level meter or equivalent equipment adhering to the above mentioned standards (ANSI, IEC).
2) *OR*, Equipment for determining octave band or one-third octave band noise measurements.

REFERENCES

1. Schultz, Theodore J., "Technical Background for Noise Abatement in HUD's Operating Programs", for U. S. Department of Housing and Urban Development, BBN Report No. 2005, (September 1970).
2. U. S. Environmental Protection Agency, "Fundamentals of Noise: Measurement, Rating Schemes, and Standards", (Dec., 1971), NTID300.15.
3) Young, R. W., "Don't Forget the Simple Sound Level Meter", NOISE CONTROL 4: 42-43 (1958).

TABLE AL-II

EXAMPLE OF A-LEVEL CALCULATION FROM ONE-THIRD OCTAVE BAND MEASUREMENTS OF AIRCRAFT FLYOVER

One-Third Octave Band Center Frequency Hz	Band Level dB	Correction for A-Weighting (from Table AL-I)	Corrected Level dB	Relative Pressure Squared
50	74.0	-30.2	43.8	.023 X 10^6
63	76.0	-26.2	49.8	.095 " "
80	73.0	-22.5	50.5	.112 " "
100	66.0	-19.1	46.9	.049 " "
125	77.0	-16.1	60.9	1.23 " "
160	80.0	-13.4	66.6	4.57 " "
200	85.0	-10.9	74.1	25.70 " "
250	83.0	- 8.6	74.4	27.54 " "
315	76.0	- 6.6	69.4	8.70 " "
400	79.0	- 4.8	74.2	26.30 " "
500	79.0	- 3.2	75.8	38.01 " "
630	80.0	- 1.9	78.1	64.56 " "
800	80.0	- 0.8	79.2	83.18 " "
1000	82.0	0.0	82.0	158.49 " "
1250	83.0	0.6	83.6	229.08 " "
1600	84.0	1.0	85.0	316.22 " "
2000	89.0	1.2	90.2	1047.12 " "
2500	101.0	1.3	102.3	16982.44 " "
3150	90.0	1.2	91.2	1318.25 " "
4000	84.0	1.0	85.0	316.22 " "
5000	87.0	0.5	87.5	562.34 " "
6300	77.0	- 0.1	76.9	48.97 " "
8000	74.0	- 1.1	72.9	19.49 " "
10000	61.0	- 2.5	58.5	0.708 " "

TOTAL 21279.39 X 10^6

$$AL = 10 \log (21279.39 \times 10^6) = 103.3 \text{ dB(A)}$$

N O T E S

TITLE B-LEVEL (BL) (L_B)

UNIT dB(B) (dB)

Reference Pressure: 20 $\mu N/m^2$

DEFINITION B-weighted sound pressure level or B-level is sound pressure level which has been filtered or weighted to quantitatively reduce the effect of the low frequency noise. B-level is measured in decibels with a standard sound level meter which contains the weighting network for "B" shown in Figure BL-1.

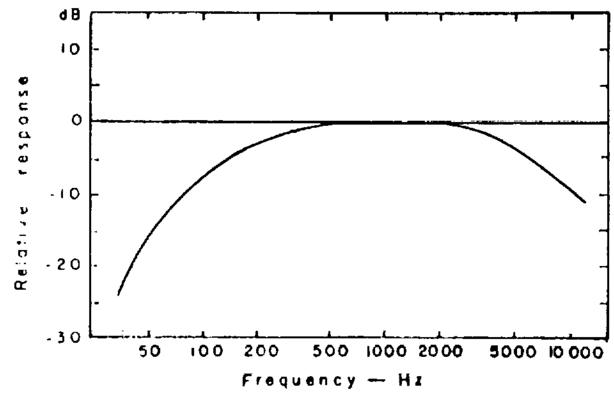


Figure BL-1 B-Weighting

STANDARDS

1) American National Standards Institute Specification for Sound Level Meters (S1.4-1971)
2) IEC Recommendation, Publication 179. Precision Sound Level Meters, 1965
3) IEC Recommendation, Publication 123. Recommendation for Sound Level Meters, 1961
4) IEC Recommendation, Publication 225. Octave, Half Octave, and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibration, 1966

GEOGRAPHICAL USAGE International

PURPOSE

B-level was originally intended to be a measure that would correlate with the loudness of sounds which ranged between 55 and 85 decibels. Currently B-level is *not* widely used.

BACKGROUND

Because overall sound pressure level did not correlate well with human assessment of the loudness of sounds, weighting networks were designed into sound level meters to attenuate low frequency noise in accordance with equal loudness contours. One of these weighting networks was designated "B" and was originally employed for estimation of sounds between 55 and 85 dB in level. The B-weighting is implemented by a simple electrical network which provides the weighting shown in Figure BL-1.

Presently B-level is not widely used because of the popularity of A-level for all levels of sounds.

CALCULATION METHOD

B-level can be determined using a sound level meter that contains an electrical network for B-weighting. B-level also may be estimated by applying B weighting values (Figure BL-1, Table BL-I) to octave or one-third octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an *energy* basis).

TABLE BL-I

B-WEIGHTING CORRECTION FUNCTIONS

One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB	One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB
50	-11.6	1000	0.0*
63	- 9.3*	1250	0.0
80	- 7.4	1600	0.0
100	- 5.6	2000	-0.1*
125	- 4.2*	2500	-0.2
160	- 3.0	3150	-0.4
200	- 2.0	4000	-0.7*
250	- 1.3*	5000	-1.2
315	- 0.8	6300	-1.9
400	- 0.5	8000	-2.9*
500	- 0.3*	10000	-4.3
630	- 0.1	12500	-6.1
800	0.0		

*Octave band corrections

EXAMPLE

Use Table BL-I and follow the procedure in the example for A-level (Table AL-II).

EQUIPMENT

1) A sound level meter or equivalent equipment with a B-weighting network adhering to the above mentioned standards (ANSI, IEC).
2) *OR*, equipment for determining octave band or one-third octave band noise measurements.

REFERENCES

1. Anonymous, "B & K Handbook", Bruel & Kjaer Instruments, Inc. (1971).
2. Peterson, Arnold, and E. E. Gross, Jr., "Handbook of Noise Measurement", General Radio Company, (1972).

NOTES

TITLE C-LEVEL (CL) (L_C)

UNIT dB(C) (dB)

Reference pressure: 20 μN/m^2

DEFINITION

C-weighted sound pressure level or C-level is sound pressure level which has been frequency filtered to approximate overall sound pressure level for the average range of human hearing. C-level is measured in decibels with a standard sound level meter with frequency characteristics which provide a response curve as shown in Figure CL-1.

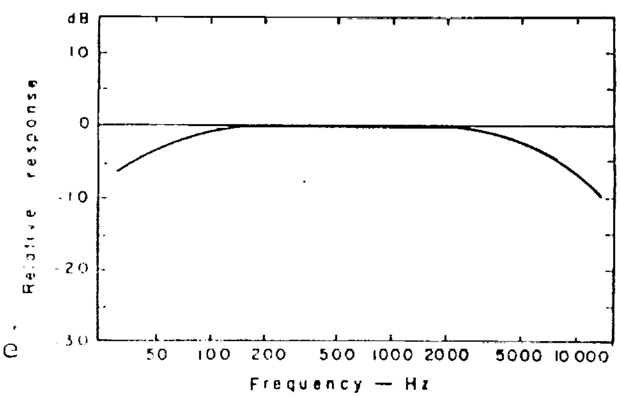


Figure CL-1 C-Weighting

STANDARDS

1) American National Standards Institute Specification for Sound Level Meter (S1.4-1971)
2) IEC Recommendation, Publication 123. Recommendation for Sound Level Meters, 1961
3) IEC Recommendation, Publication 179. Precision Sound Level Meters, 1965
4) IEC Recommendation, Publication 225. Octave, Half-Octave, and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibration, 1966

GEOGRAPHICAL USAGE International

PURPOSE

C-level was originally intended to be a measure that would correlate with the loudness of sounds above 85 decibels. It is now used as an overall measure of any level of noise with equal weighting given to levels at frequencies from 31.5 to 8000 Hz.

BACKGROUND

As initially conceived C-level was a measure of the total sound pressure level of a noise. Even now C-level and overall sound pressure level (SPL) are usually thought of as synonymous. However, C-level does have some weighting factors at the low-and high-frequency ends. This accounts for the small differences in level between applying the C-level curve and the more nearly uniform response curve of OASPL. In spite of this limitation C-level still provides a reasonable approximation of overall sound pressure level for most common sounds.

CALCULATION METHOD

C-level can be determined using a sound level meter whose overall frequency characteristics provide a frequency response as shown in Figure CL-1. C-level also may be estimated by applying the C-weighting values (Figure CL-1, Table CL-I) to octave or one-third octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an *energy* basis). Normally the summation can be made without the weighting C-scale since the corrections are relatively small.

TABLE CL-I

C-WEIGHTING CORRECTION FUNCTIONS

One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB	One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB
50	-1.3	1000	0.0*
63	-0.8*	1250	0.0
80	-0.5	1600	-0.1
100	-0.3	2000	-0.2*
125	-0.2*	2500	-0.3
160	-0.1	3150	-0.5
200	0.0	4000	-0.8*
250	0.0*	5000	-1.3
315	0.0	6300	-2.0
400	0.0	8000	-3.0*
500	0.0*	10000	-4.4
630	0.0	12500	-6.2
800	0.0		

*Octave Band Corrections

EXAMPLE

Use Table CL-I and follow the procedure in the example for A-level (Table AL-II).

EQUIPMENT

1) A sound level meter or equivalent equipment with a C-weighting network adhering to the above mentioned standards (ANSI, IEC).
2) *OR*, Equipment for determining octave band or one-third octave band noise measurements.

REFERENCES

1. Beranek, Leo, Noise Reduction, McGraw-Hill, New York, 1960.
2. Peterson, Arnold, and E. E. Gross, Jr., "Handbook of Noise Measurement", General Radio Company, (1972).

NOTES

TITLE — D-LEVEL (DL) (L_D)

UNIT — dB(D) (dB)

Reference pressure: 20 μN/m²

DEFINITION — D-weighted sound pressure level or D-level is sound pressure level which has been frequency filtered to reduce the effect of the low frequency noise and increase the effect of high frequency noise. D-level is measured in decibels with a standard sound level meter which contains a "D" weighting network with the response curve shown in Figure DL-1.

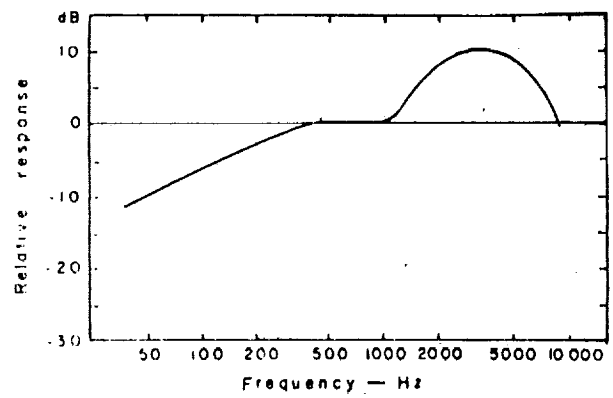


Figure DL-1 D-Weighting

STANDARDS

1) A standardized D-weighting network is being considered for incorporation in: IEC Recommendation, Publication 179. Precision Sound Level Meters

2) SAE Committee: Frequency Weighting Network for Approximation of Perceived Noise Level for Aircraft Flyover Noise. ARP 1080

3) IEC Recommendation, Publication 225. Octave, Half Octave, and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibration, 1966

GEOGRAPHICAL USAGE

International

PURPOSE

D-level was developed as a simple approximation of perceived noise level (PNL) (see p. 76).

BACKGROUND

D-level is similar to A-level in that it attenuates the lower frequencies in a manner approximating the behavior of the human ear. However, D-level was intended to relate to the relative *noisiness* of broadband spectra while A-level was intended to relate to *loudness*. D-level replaced N-weighted sound level (N-level) which was a much earlier measure for estimating PNL.

The D-weighting network provides a frequency response comparable to the inverse 40-noy contour of equal annoyance. This network when incorporated into a sound level meter provides a simple approximation of the judged perceived noise level (PNL) for a variety of sounds. PNL can be estimated from the sound level reading of D-level by this equation:

$$PNL \cong DL + 7 \qquad [1]$$

Kryter (1970) proposes three different D-levels: D_1, D_2 and D_3 as means of estimating PNL. He notes that the D_2 weighting is adjusted to take into account relatively fewer number of critical bands below 355 Hz than above. It is recommended that D-level be used as an estimator for PNL only for those sounds having their energy predominantly above 355 Hz.

CALCULATION METHOD

D-level can be determined using a sound level meter that contains an electrical network for D-weighting. It also may be estimated by applying the D-weighting values (Figure DL-1, Table DL-I) to octave or one-third octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an *energy* basis). If octave or one-third octave measurements are available probably PNL should be calculated instead of D-level inasmuch as D-level is only an approximation of perceived noise level.

TABLE DL-I

D-WEIGHTING CORRECTION FUNCTIONS

One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB	One-Third Octave Band Center Frequency Hz	Octave and One-Third Octave Band Corrections dB
50	-12.8	1000	0.0*
63	-10.9*	1250	2.0
80	- 9.0	1600	4.9
100	- 7.2	2000	7.9*
125	- 5.5*	2500	10.6
160	- 4.0	3150	11.5
200	- 2.6	4000	11.1*
250	- 1.6*	5000	9.6
315	- 0.8	6300	7.6
400	- 0.4	8000	5.5*
500	- 0.3*	10000	3.4
630	- 0.5	12500	-1.4
800	- 0.6		

*Octave Band Corrections

EXAMPLE

Use Table DL-I and follow the procedure in the example for A-level (Table AL-II).

EQUIPMENT

1) A sound level meter or equivalent equipment with a D-weighting network adhering to the above mentioned standards (IEC).
2) *OR*, Equipment for determining octave or one-third octave band noise measurements.

REFERENCES

1. Kryter, Karl D., The Effects of Noise on Man, Academic Press, New York, 1970.
2. Peterson, Arnold, and E. E. Gross, Jr., "Handbook of Noise Measurement", General Radio Company, (1972).

N O T E S

CHAPTER II

COMPUTED LOUDNESS AND ANNOYANCE RATINGS

TITLE	LOUDNESS LEVEL (LL_Z) ZWICKER
UNIT	Phons
DEFINITION	The Loudness Level is a single number rating of the loudness of a sound signal calculated from acoustic measurements made in octave or one-third octave bands.
STANDARDS	International Organization for Standardization, ISO Recommendation R532. Method for Calculating Loudness Level (1966) (Method B)
GEOGRAPHICAL USAGE	International
PURPOSE	Loudness Level was developed in an effort to provide an acoustic measure that would correlate highly with people's assessment of the loudness of a sound.

BACKGROUND

The numerical value of Loudness Level (LL_Z) is intended to represent the sound pressure level (SPL) of a one-third octave band of noise centered at 1000 Hz judged to be equally as loud as the sound being rated. Today, the term *Loudness Level* denotes a calculation procedure rather than results from a judgment test.

The method uses one-third octave band noise data and can be employed for any type spectra including those with pure tones. This is because the Zwicker method more accurately accounts for effects of remote masking than does the simpler Stevens' method (LL_S p. 50). These two methods also differ in other respects and the results do not always agree. Slightly higher results are obtained for the same sounds with the Zwicker method than with the Stevens method. There may be a computed difference in results as great as 5 phons.

CALCULATION METHOD

The Zwicker method uses one-third octave band sound pressure levels to calculate the loudness of steady complex sounds. The Loudness Level (LL_Z) in phons is calculated by means of a formula or from the nomograph of the formula (Figures LL_Z-1 to 10).

The procedure is as follows:

1) Select a graph (Figures LL_Z-1 to 5 for frontal sounds (GF) or Figures LL_Z-6 to 10 for a diffuse field (GD))which is appropriate to the type of sound field involved and which includes the highest one-third octave band level measured (in decibels).

2) For frequency bands *above* 280 Hz, plot the measured band levels on the appropriate graph as horizontal lines so that the cut-off frequencies of the one-third octave bands correspond to the abscissa of the graph and the measured band levels correspond to the numbering of the stepped curves on the graph.

3) For frequency bands *below* 280 Hz, the one-third octave band data are grouped as follows to obtain corresponding band levels L_1, L_2 and L_3 before entering them on the graph.

L_1 Combine all bands with center frequencies up to 80 Hz.

L_2 Combine the bands with center frequencies of 100, 125 and 160 Hz.

L_3 Combine the bands with center frequencies of 200 and 250 Hz.

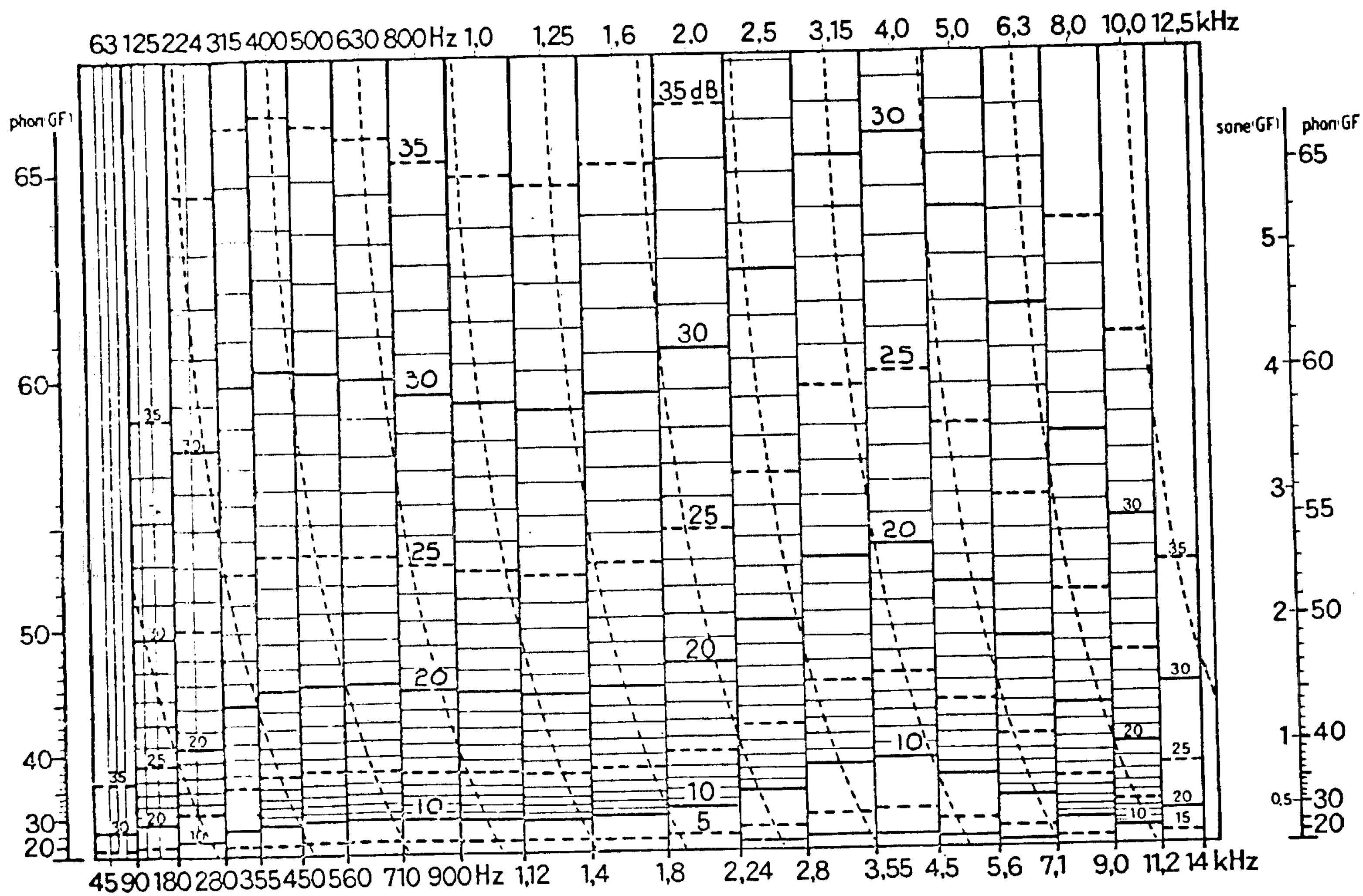


FIGURE LL-1$_Z$. CALCULATION NOMOGRAPH FOR LOUDNESS OF FRONTAL SOUND (GF)

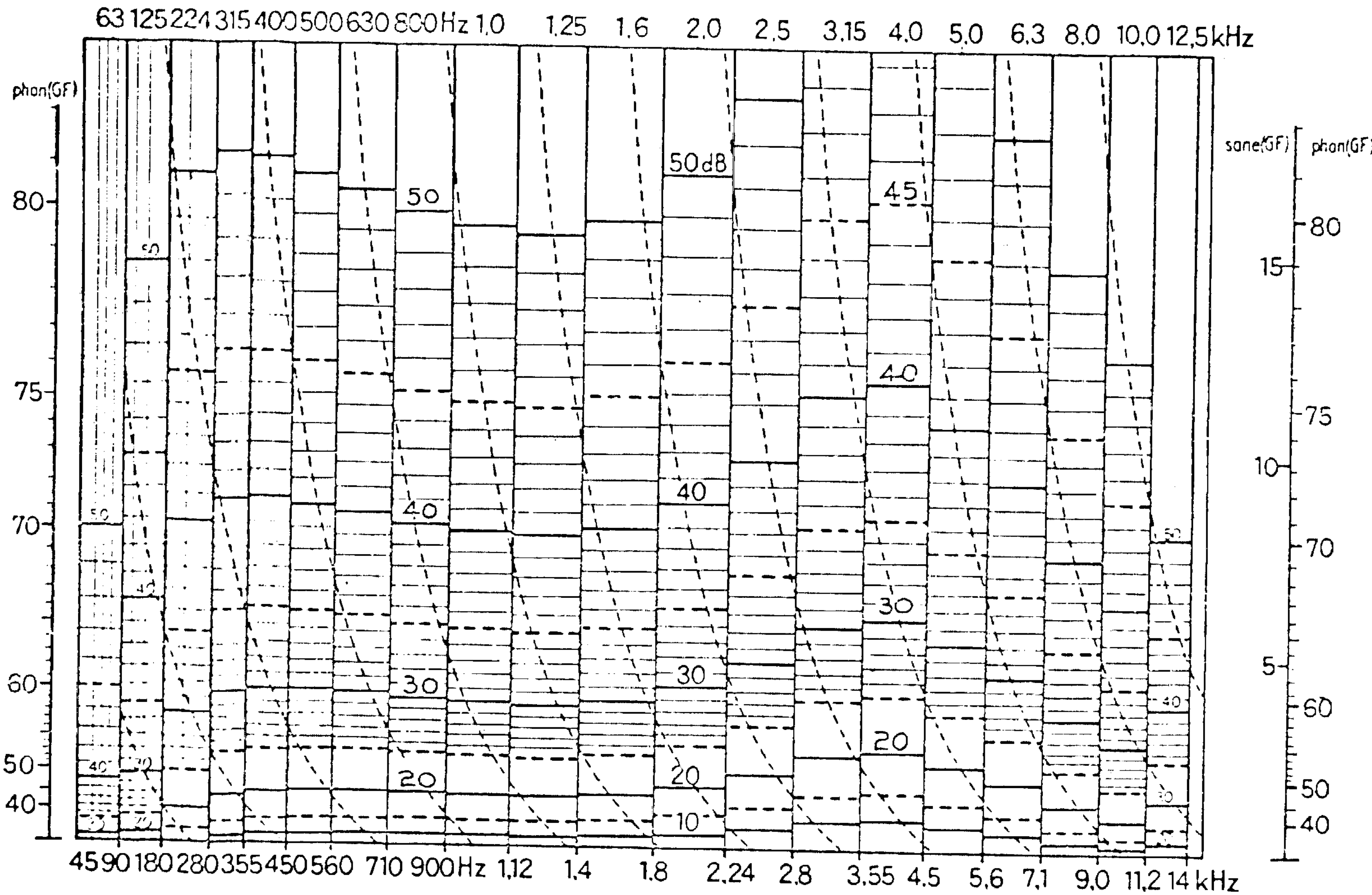


FIGURE LL-2. CALCULATION NOMOGRAPH FOR LOUDNESS OF FRONTAL SOUND (GF)
Z

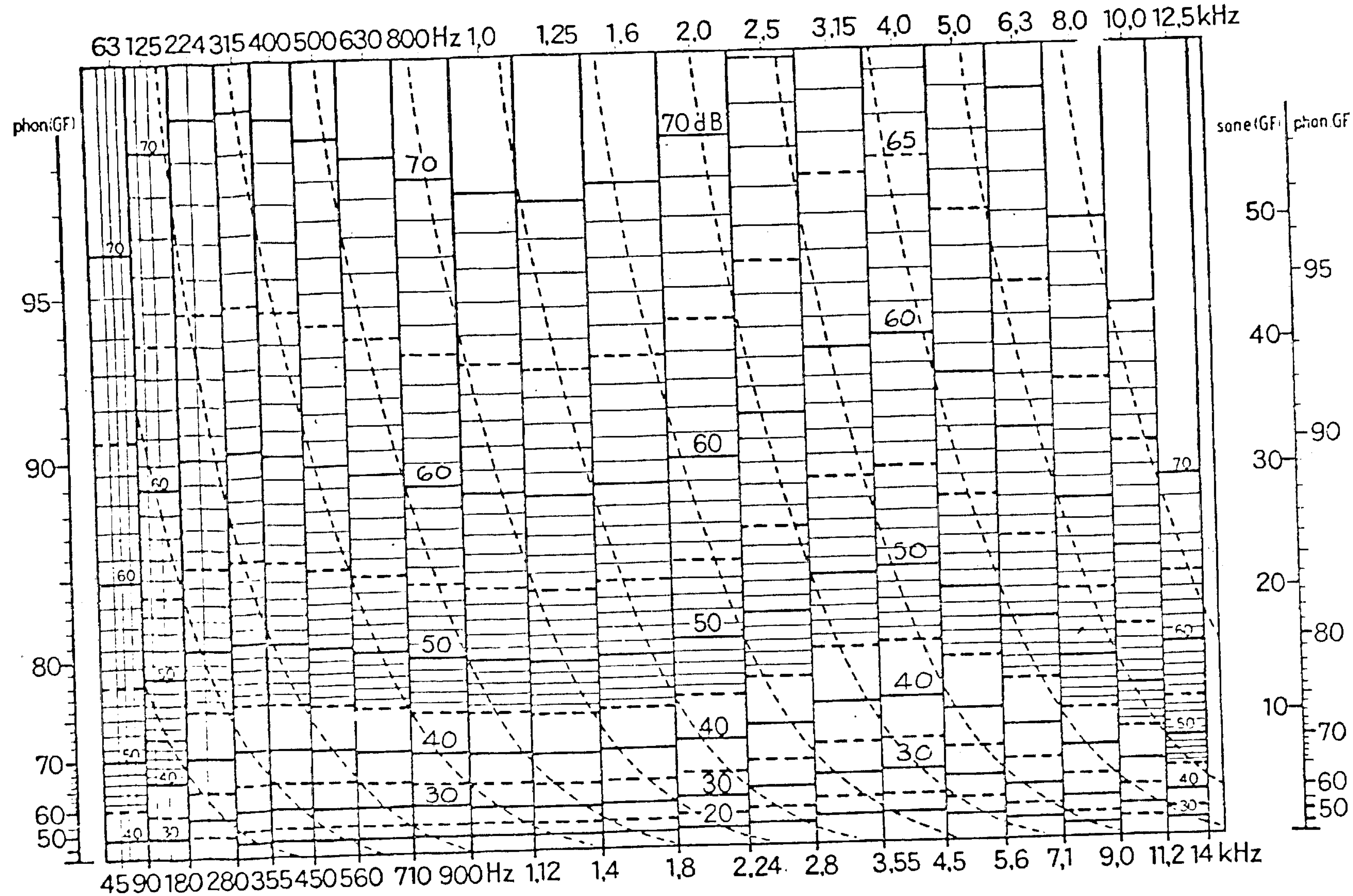


FIGURE LL_Z-3. CALCULATION NOMOGRAPH FOR LOUDNESS OF FRONTAL SOUND (GF)

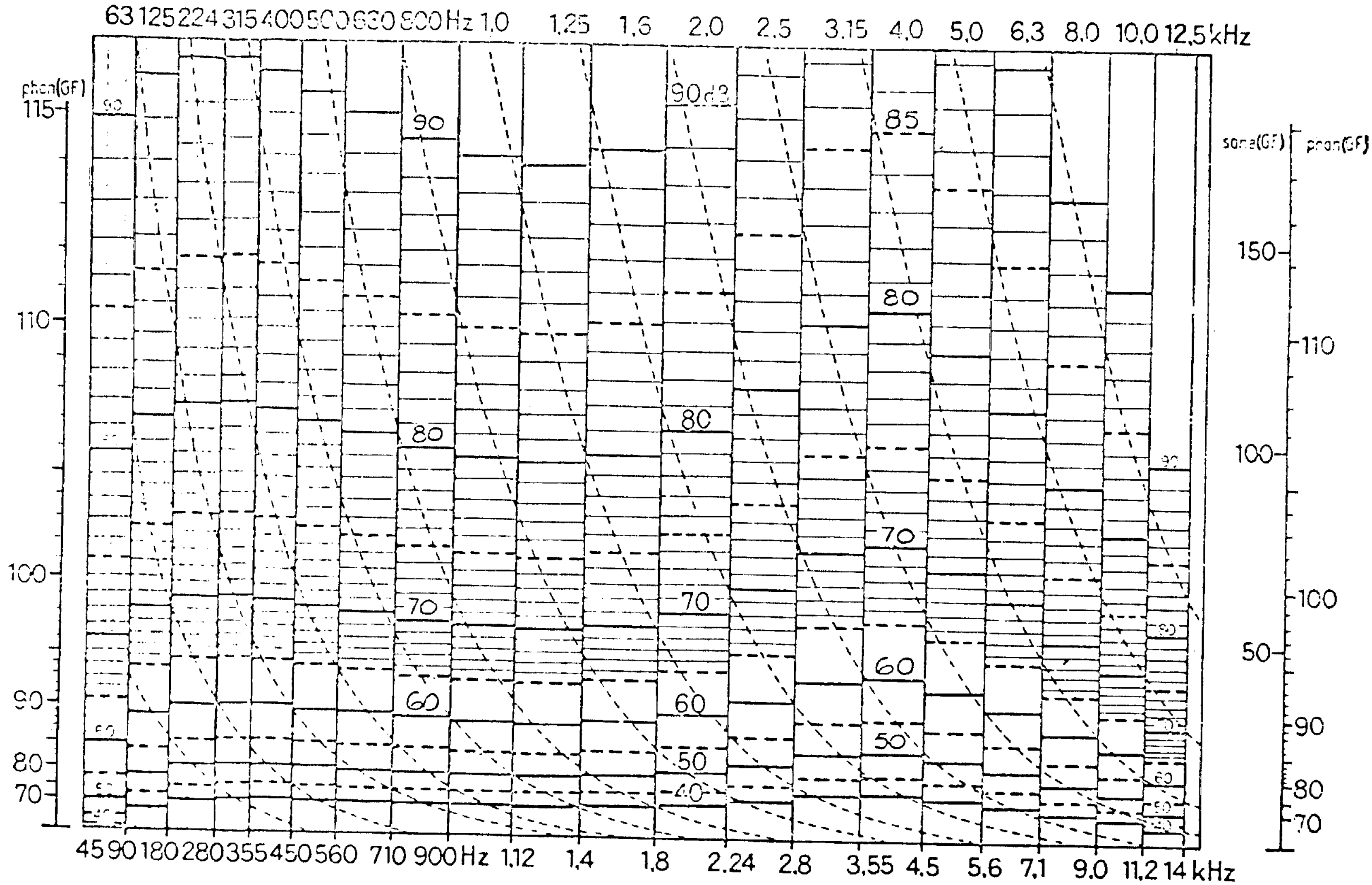


FIGURE LL-4. CALCULATION NOMOGRAPH FOR LOUDNESS OF FRONTAL SOUND (GF)
Z

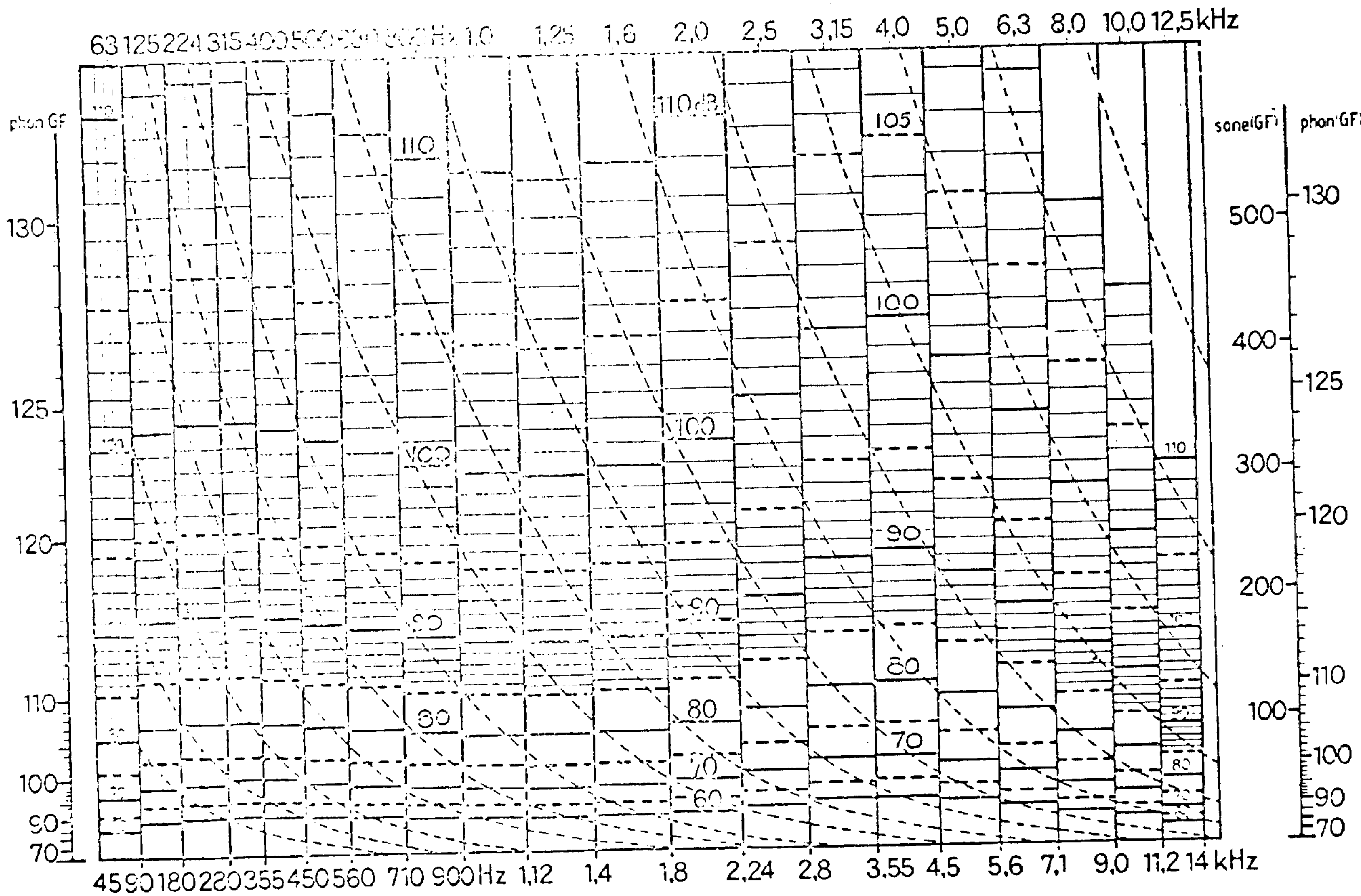


FIGURE LL-5. CALCULATION NOMOGRAPH FOR LOUDNESS OF FRONTAL SOUND (GF)
Z

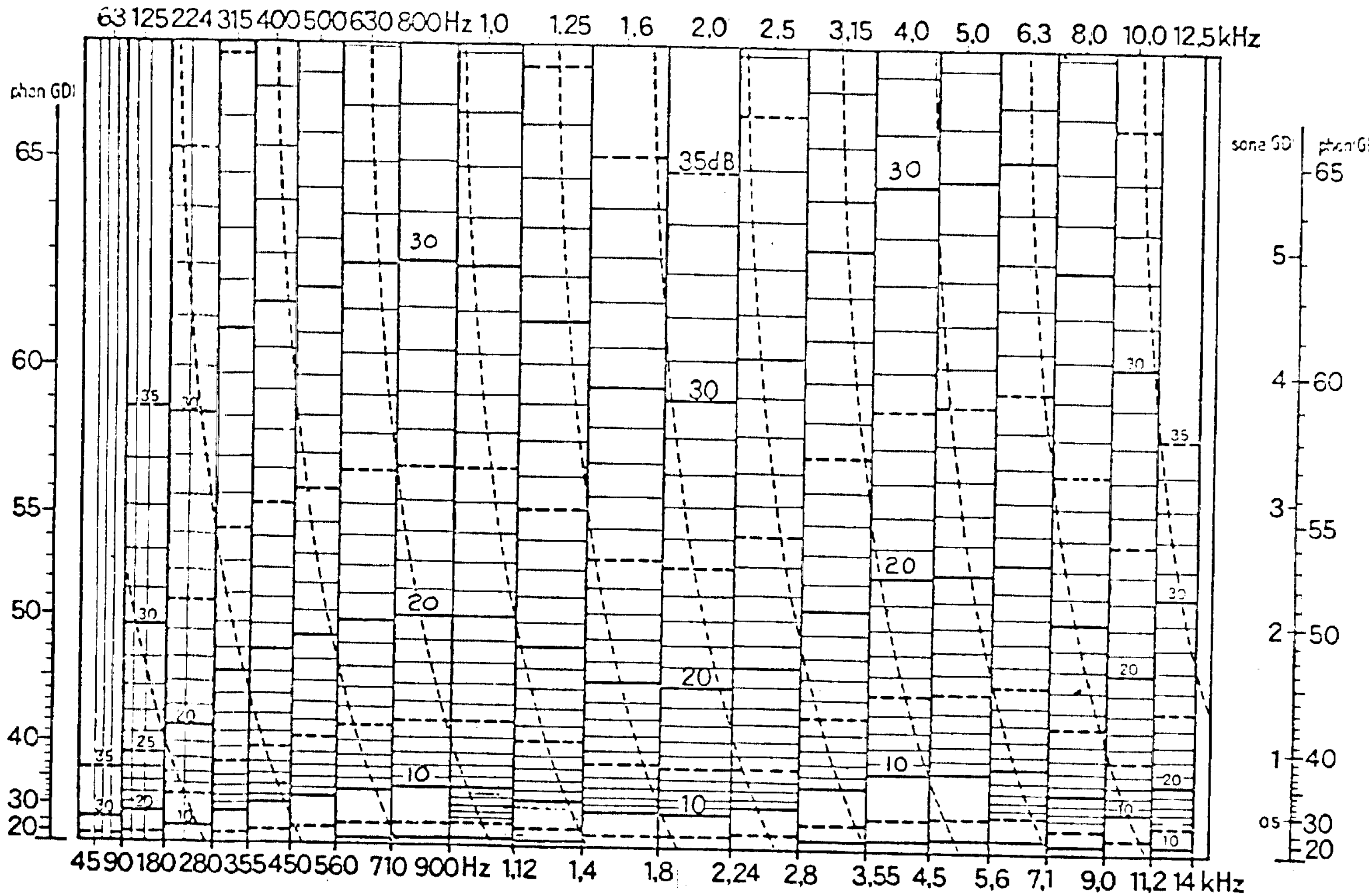


FIGURE LL-6. CALCULATION NOMOGRAPH FOR LOUDNESS OF DIFFUSE SOUND (GD)
Z

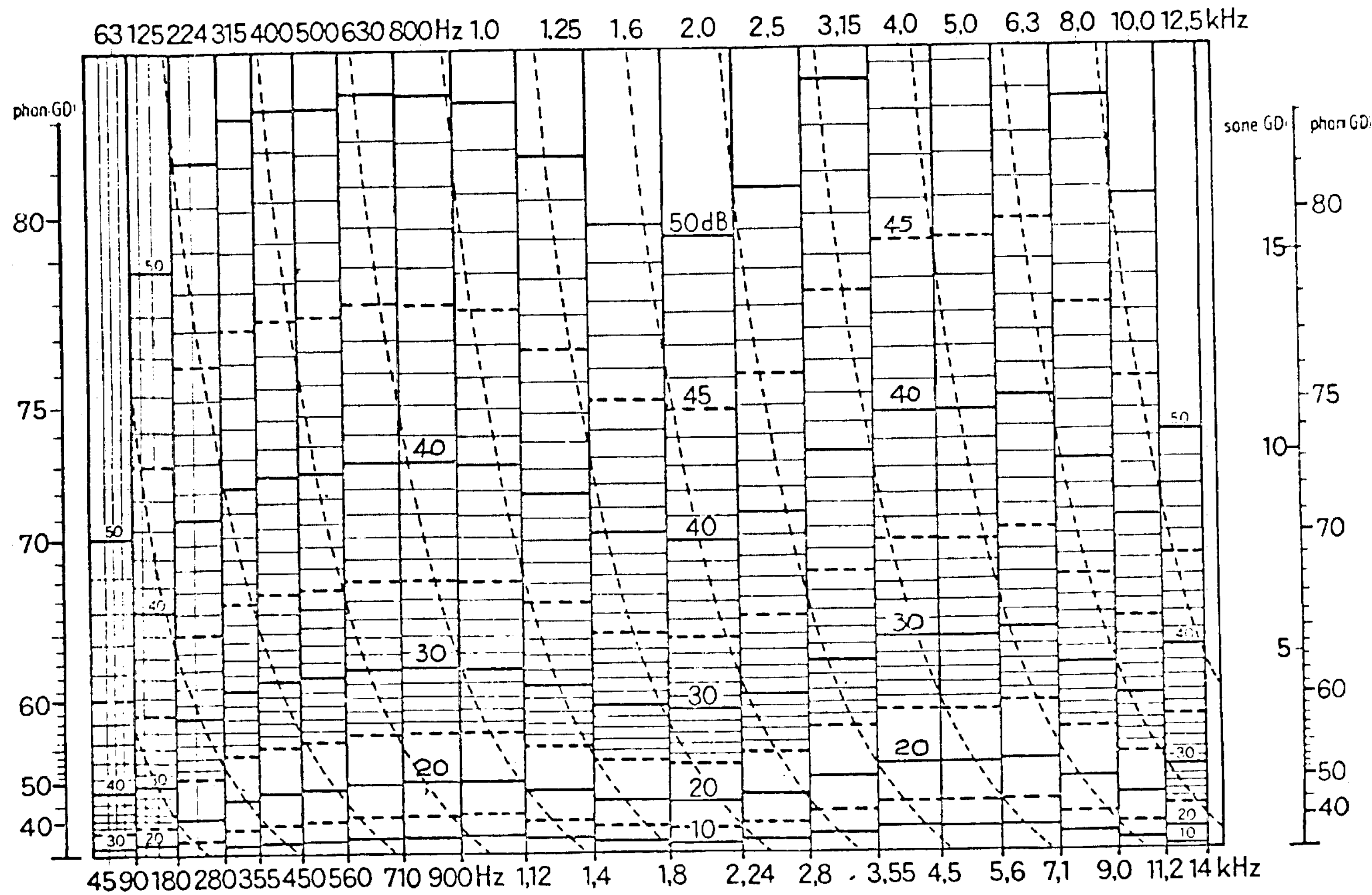


FIGURE LL-7. CALCULATION NOMOGRAPH FOR LOUDNESS OF DIFFUSE SOUND (GD)
Z

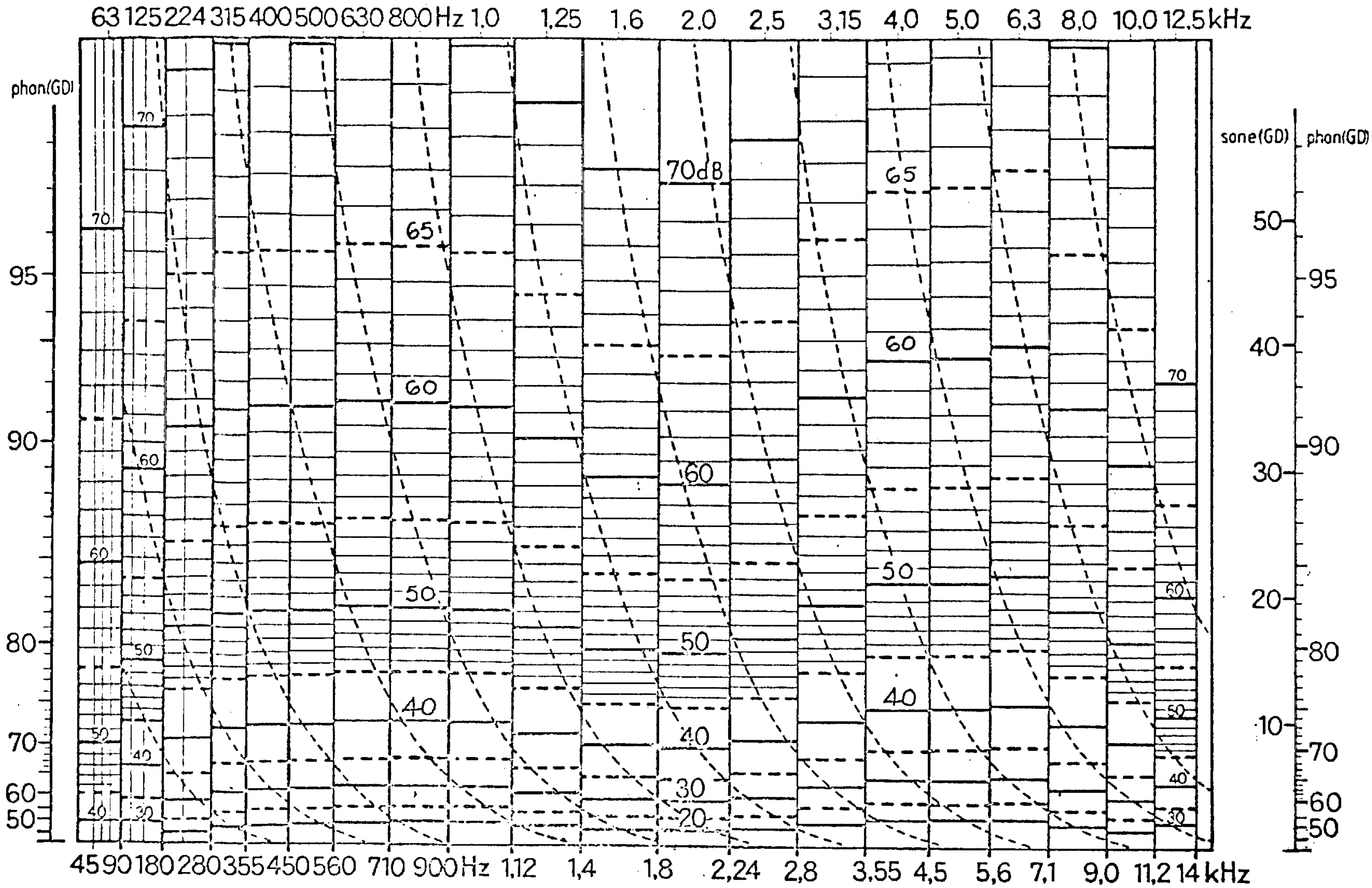


FIGURE LL_z-8. CALCULATION NOMOGRAPH FOR LOUDNESS OF DIFFUSE SOUND (GD)

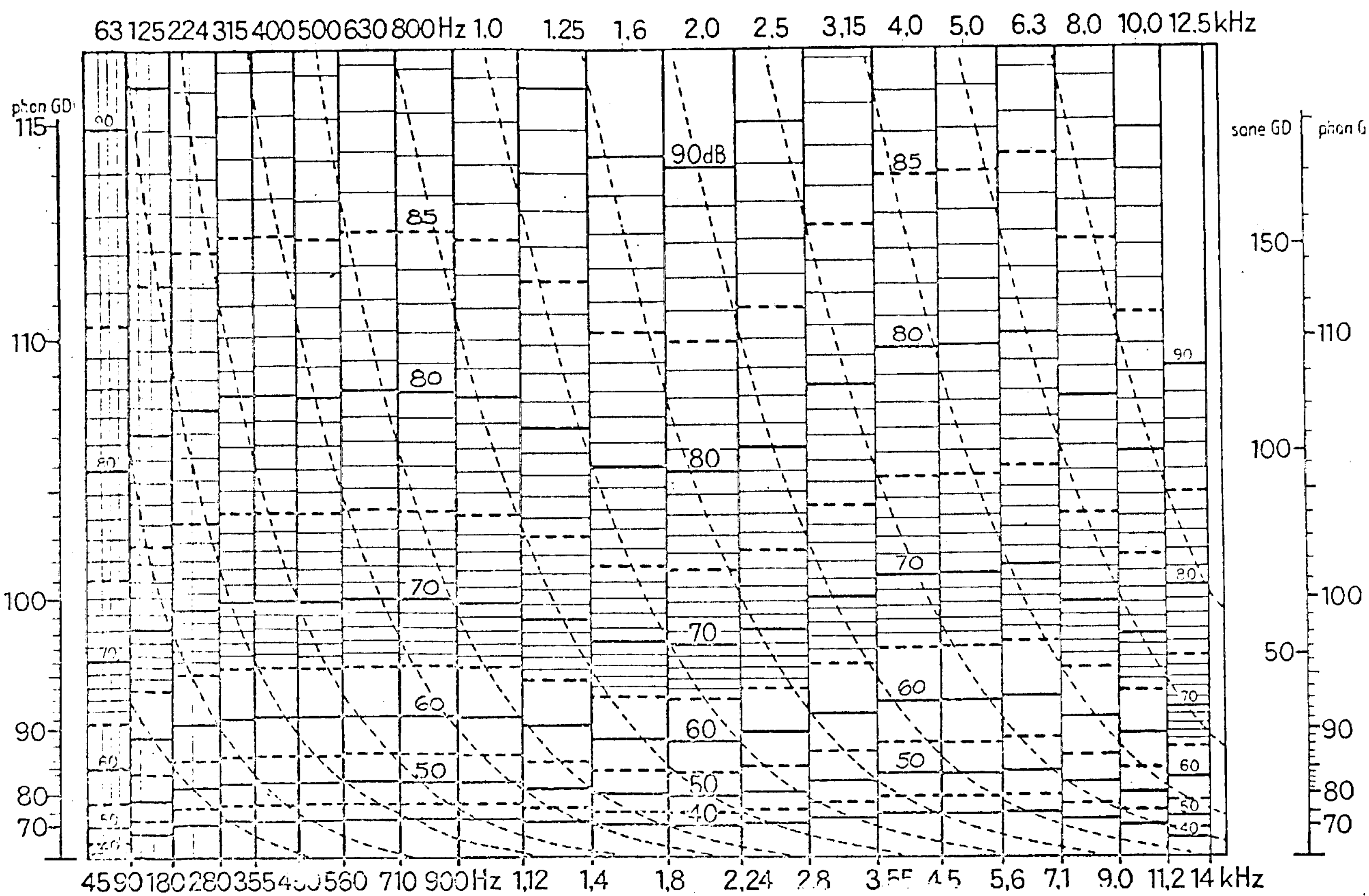


FIGURE LL-9. CALCULATION NOMOGRAPH FOR LOUDNESS OF DIFFUSE SOUND (GD)
z

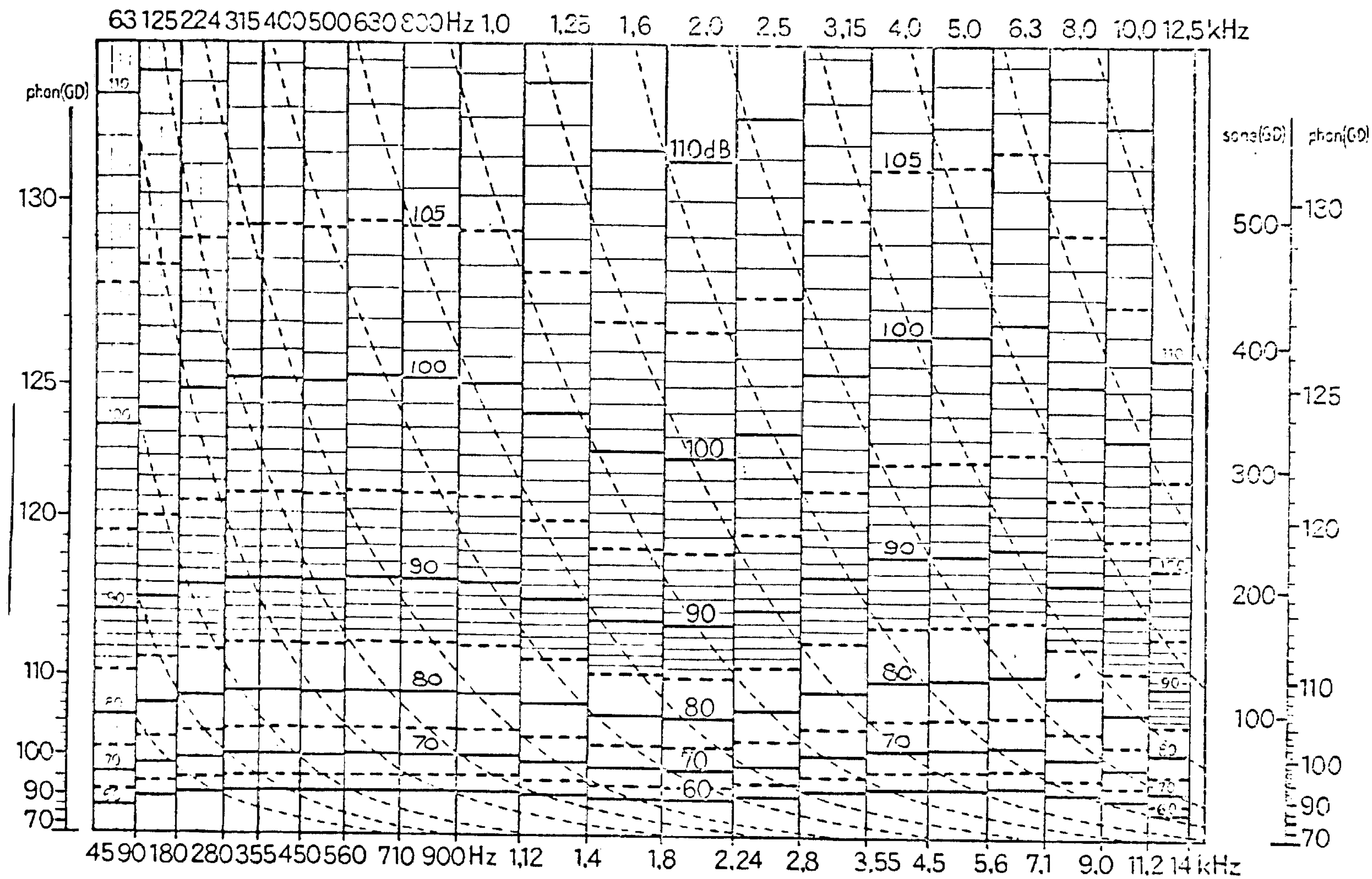


FIGURE LL-10$_Z$. CALCULATION NOMOGRAPH FOR LOUDNESS OF DIFFUSE SOUND (GD)

The rule of combination is illustrated in the following example:

$$L_2 = 10 \log [\text{antilog}(L_{100}/10) + \text{antilog}(L_{125}/10) + \text{antilog}(L_{160}/10)] \quad [1]$$

where:

L_{100} etc.	is the measured one-third octave band sound pressure level for the band with a center frequency of 100 Hz.

Plot each of these combined levels as a horizontal line of the width of the combined band, so that the levels correspond to the numbering of the stepped curves on the graph.

4) Where the steps formed by these horizontal lines are rising with frequency, the adjacent horizontal levels are connected by vertical lines at the frequency separating the two bands. When the level in the next highest frequency band is lower, the fall is drawn as a downward sloping curve interpolated between the dashed curves on the graph, starting from the right-hand end of the horizontal line.

The area enclosed by the whole stepped figure obtained by the previous method corresponds to the total loudness.

5) The total loudness may be converted into Loudness Level in phons by utilizing a planimeter. Transform the enclosed area on the graph into a rectangle with the same area and having a base equal to the abscissa of the graph by means of tracing the area outline with a planimeter.

The computed height of the rectangle gives directly the Loudness Level in phons (GF) or (GD) from the scales on either side of the graph.

6) The sones (GF) or (GD) corresponding to the phons may be read from the second scale on the right *or* computed from the following equation:

$$LL_z = 40 + 10 \log_2 S_t \qquad [2]$$

where:

S_t is the total loudness in sones.

EXAMPLE

An example of the Zwicker Loudness Level (LL_Z) method using an aircraft flyover noise spectrum is shown in Figure LL_Z-11. First the flyover spectrum is plotted on the appropriate graph for frontal sounds (GF) and the connecting lines added according to the calculation procedure.

Next the area under the resulting step curve is determined with the planimeter and related to total phons. In this case the Loudness $Level_Z$ is calculated at 112.3 phons (GF).

The corresponding sones are:

$$112.3 = 40 + 10 \log_2 S_t$$

$$\log_2 S_t = 7.23$$

$$S_t = 150.12 \text{ sones (GF)}$$

EQUIPMENT

1) Tape recorder (necessary for single event
2) Sound level meter (IEC Standard)
3) Octave or 1/3 octave band analyzer
4) Digital computer optional
5) Planimeter

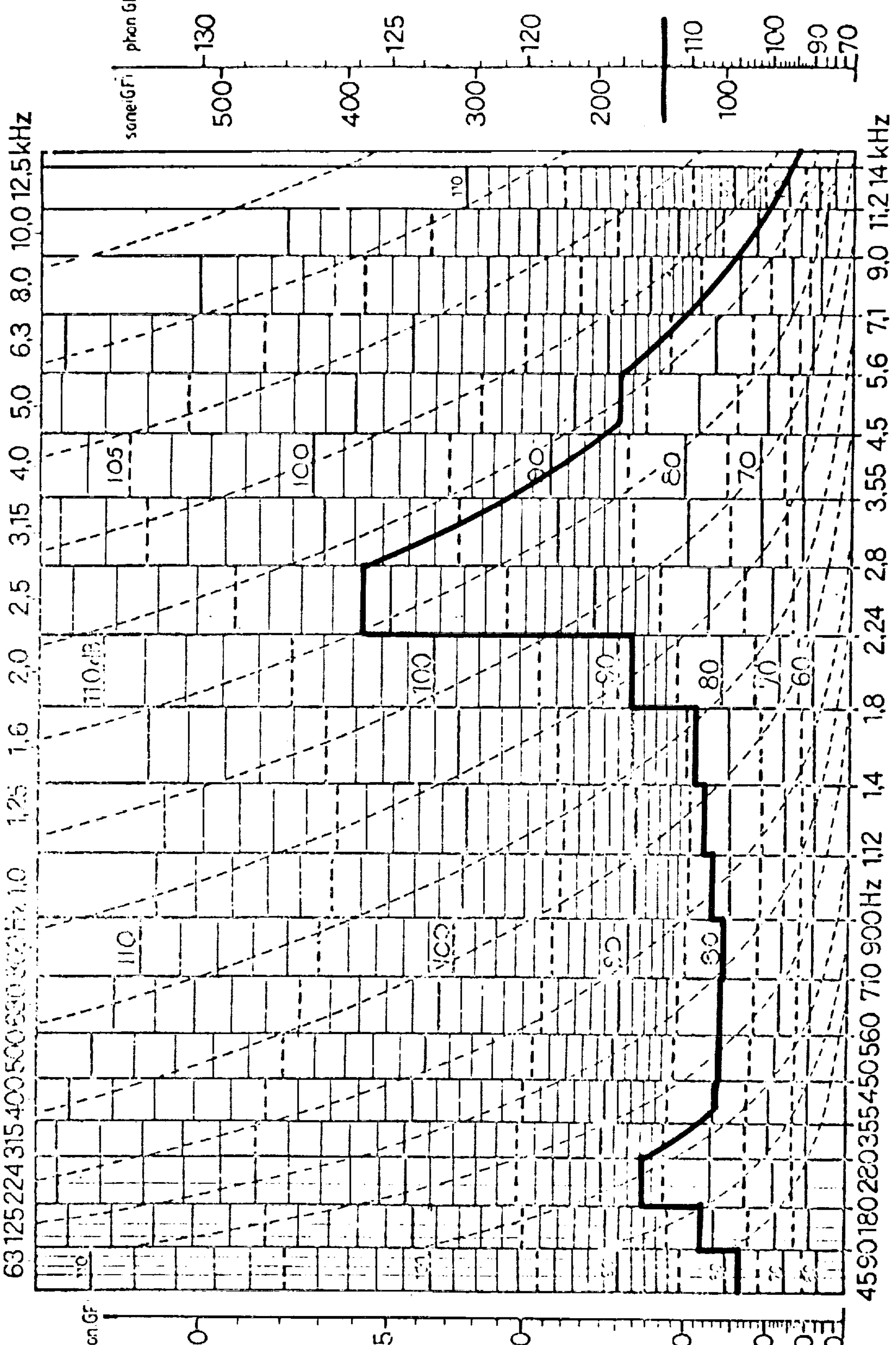


FIGURE LL-11. EXAMPLE OF LOUDNESS CALCULATION USING AIRCRAFT NOISE SPECTRUM

Z

REFERENCES

1. Zwicker, E., "Lautstarkeberechnungsverfahren im Vergleich", ("Comparison of Procedures for Calculations of Loudness"), Acustica 17: 278-284 (1966).
2. Zwicker, E., "Uber psychologische und methodische Grundlagen der Lautheit", ("Concerning the Psychological and Methodical Bases of Loudness"), Acustica 8, Beiheft 1: 237-258 (1958).
3. U. S. Environmental Protection Agency, "Fundamentals of Noise: Measurement, Rating Schemes, and Standards", (December, 1971), NTID300.15.
4. Kryter, Karl D., The Effects of Noise on Man, Academic Press, New York, 1970.

TITLE	LOUDNESS LEVEL (LL_S) STEVENS MARK VI
UNIT	Phons
DEFINITION	The Loudness Level is a single number rating of the loudness of a sound signal calculated from acoustic measurements made in octave or one-third octave bands.
STANDARDS	International Organization for Standardization, ISO Recommendation R532. Method for Calculating Loudness Level (1966) (Method A)
GEOGRAPHICAL USAGE	International
PURPOSE	Loudness Level was developed in an effort to provide an acoustic measure that would correlate highly with people's assessment of the loudness of a sound.

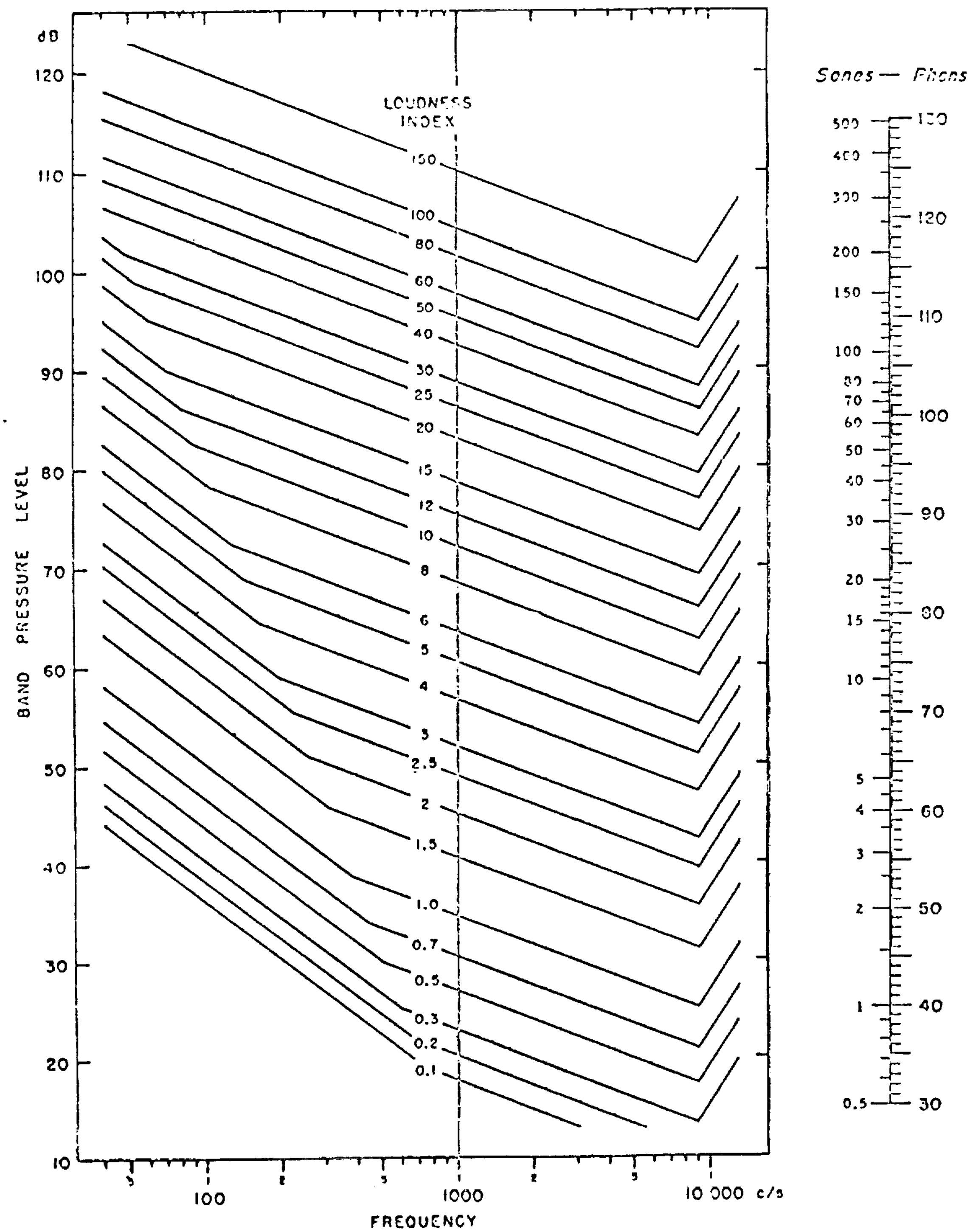
BACKGROUND

The numerical value of Loudness Level in phons was originally intended to represent the sound pressure level (SPL) of a 1000 Hz pure tone judged to be equally as loud as the sound being rated. Today, the term *Loudness Level* denotes a calculation procedure rather than a judgment test.

This method uses octave bands or one-third octave band noise data and should be employed only when the sound spectrum is relatively smooth and contains no pure tones. Further, this method is only applicable to diffuse sound fields. Details in the calculation procedure have been revised over the years although the basic method has remained essentially the same. Briefly, the LL_S method converts band SPL's to loudness in sones (or Loudness Index), sums the results and converts the sum to the logarithimically scaled quantity - phons. In some cases sones are used directly since they are claimed to constitute a ratio scale of loudness (e.g., twice as many sones means twice as much loudness).

CALCULATION METHOD

The calculation procedure for Loudness Level (LL_S) is composed essentially of a graph (Figure LL_S-1) and a formula. For a more accurate estimation of the loudness indices, additional computations may be made in conjunction with Table LL_S-I. The graph or



dB
LOUDNESS INDEX
BAND PRESSURE LEVEL
FREQUENCY
Sones — Phons

FIGURE LL-1.
S

TABLE $LL\text{-}I_S$

Loudness index at 1000 Hz (c/s)

Band pressure level (dB)	Loudness index	Band pressure level (dB)	Loudness index	Band pressure level (dB)	Loudness index
15		50	2.68	85	23.0
16		51	2.84	86	24.7
17		52	3.0	87	26.5
18	0.10	53	3.2	88	28.5
19	0.14	54	3.4	89	30.5
20	0.18	55	3.6	90	33.0
21	0.22	56	3.8	91	35.3
22	0.26	57	4.1	92	38.0
23	0.30	58	4.3	93	41.0
24	0.35	59	4.6	94	44.0
25	0.40	60	4.9	95	48
26	0.45	61	5.2	96	52
27	0.50	62	5.5	97	56
28	0.55	63	5.8	98	61
29	0.61	64	6.2	99	66
30	0.67	65	6.6	100	71
31	0.73	66	7.0	101	77
32	0.80	67	7.4	102	83
33	0.87	68	7.8	103	90
34	0.94	69	8.3	104	97
35	1.02	70	8.8	105	105
36	1.10	71	9.3	106	113
37	1.18	72	9.9	107	121
38	1.27	73	10.5	108	130
39	1.35	74	11.1	109	139
40	1.44	75	11.8	110	149
41	1.54	76	12.6	111	160
42	1.64	77	13.5	112	171
43	1.75	78	14.4	113	184
44	1.87	79	15.3	114	197
45	1.99	80	16.4	115	211
46	2.11	81	17.5	116	226
47	2.24	82	18.7	117	242
48	2.38	83	20.0	118	260
49	2.53	84	21.4	119	278
				120	298

table provides a summation rule for combining the loudness indices in order to compute the total loudness.

The procedure is as follows:

1) From Figure LL_S-1 convert the sound level in each band to the proper Loudness Index in sones.

2) The total loudness in sones is found by the following summation rule:

$$S_t = S_m + F\left(\sum_{i=1}^{24} S - S_m\right) \qquad [1]$$

where:

S_t is the total loudness of a sound (in sones)

S_m is the loudness of the loudest band (maximum Loudness Index)

F is the factor which equals:

0.15 one-third octave band measures

0.20 one-half octave band measures

0.30 octave band measures

S is the Loudness Index for frequency band i

n equals 24 for one-third octave band measures

equals 16 for half-octave band measures

equals 8 for octave band measures

3) The total loudness may be converted into Loudness Level by the following formula:

$$LL_S = 40 + 10 \log_2 S_t \qquad [2]$$

A nomograph giving this relation is included in Figure LL_S-1. The value of LL_S so obtained is expressed in phons.

TABLE OF LOUDNESS INDEX (Table LL_S-I)

In Table LL_S-I values of the Loudness Index are tabulated for the frequency of 1000 Hz. Values at other frequencies can be obtained by means of the following rules. The value of the Loudness Index is constant on the contour having a slope of -3 dB/octave. Above 9000 Hz the contour has a slope of 12 dB/octave. Below a certain frequency the contour has a slope of -6 dB/octave. The frequency at which this change of slope occurs lies on a line having a slope of -21 dB/octave. This line passes through the point determined by 1000 Hz and 10 dB band pressure level.

EXAMPLE

An example of the Stevens Loudness Level (LL_S) method using an aircraft flyover noise spectrum is shown in Table LL_S-II. Here the one-third octave band levels are tabulated and converted Loudness Index (in sones). Calculated, S_m = 105 sones and F = 0.15, then from equation [1] it follows that:

$$S_t = 105 + 0.15\ (509.6 - 105)$$

$$= 165.69 \text{ sones}$$

The total loudness is converted to Loudness Level in phons by:

$$LL_S = 40 + 10 \log\ (165.69)$$

$$= 113.72 \text{ phons}$$

EQUIPMENT

1) Tape recorder (necessary for single sample)
2) Sound Level Meter (IEC Standard)
3) Octave or 1/3 octave band analyzer
4) Digital computer optional

TABLE LL_S-II

EXAMPLE OF LL_S CALCULATIONS FROM ONE-THIRD OCTAVE BAND MEASUREMENTS OF AIRCRAFT FLYOVER

Band Center Frequency Hz	Band Level dB	Loudness Index sones
50	74	3.7
63	76	5.0
80	73	4.7
100	66	3.2
125	77	7.8
160	80	9.9
200	85	14.4
250	83	13.5
315	76	9.3
400	79	11.8
500	79	12.6
630	80	14.4
800	80	15.3
1000	82	18.7
1250	83	21.4
1600	84	24.7
2000	89	38.0
2500	101	105.0
3150	90	48.0
4000	84	33.0
5000	87	44.0
6300	77	23.0
8000	74	20.0
10000	61	8.2

$$\Sigma S = 509.6$$

$$\begin{aligned} S_t &= 105 + 0.15\ (509.6 - 105) \\ &= 165.69 \text{ sones} \\ LL_S &= 40 + 10 \log_2 (165.69) \\ &= 113.72 \text{ phons} \end{aligned}$$

REFERENCES

1. Stevens, S. S., "Calculation of the Loudness of Complex Noise", J. Acoust. Soc. Am. 28: 807-832 (1956) (Mark I).
2. Stevens, S. S., "Procedure for Calculating Loudness: Mark VI", J. Acoust. Soc. Am. 33: 1577-1585 (1961).
3) U. S. Environmental Protection Agency, "Fundamentals of Noise: Measurement, Rating Schemes, and Standards", (December, 1971), NTID300.15.

N O T E S

TITLE	PERCEIVED LEVEL (PL) MARK VII
UNIT	PLdB
DEFINITION	The Perceived Level is a rating of the loudness or noisiness of a noise signal calculated from acoustic measurements made in octave or one-third octave bands.
STANDARDS	(None)
GEOGRAPHICAL USAGE	Limited
PURPOSE	Perceived Level (PL) was developed as a measure of the loudness or noisiness of sounds to provide a compromise between Perceived Noise Level (see p. 76) and Stevens' Loudness Level (see p. 50).

BACKGROUND

Perceived Level (PL), known also as Mark VII, is a 1972 revision of the Loudness Level (Mark VI) developed by S. S. Stevens to incorporate research done both on loudness and noisiness. The main changes include:

1) The reference sound is a one-third band of noise centered at 3150 Hz instead of a 1000 Hz tone, and this sound at a level of 32 dB, re 20 $\mu N/m^2$, is assigned a perceived magnitude of 1 sone. This new reference standard results in a decrease in Perceived Level in decibels (PLdB) of 8 dB as compared to the phon values of Mark VI.

2) The equal loudness and noisiness contours are changed to incorporate new data of loudness and noisiness research.

3) Doubling the perceived magnitude (loudness/noisiness) in sones is now accomplished by raising the signal level by 9 dB instead of the previously used 10 dB.

4) The masking factor, F, in the calculation procedure now varies with level instead of remaining constant.

CALCULATION METHOD

The calculation procedure for Perceived Level assumes that the noise signal has been measured in one-third or octave bands. Summarily, the levels in each band are converted into a perceived value in sones and then totaled according to a summation rule. The total is then converted into a calculated Perceived Level in decibels (PLdB) by means of the power function relating perceived magnitude to sound pressure.

The calculation procedure for PL is the following:

1) From Figure PL-1 or Table PL-I convert the sound level in each band to the proper perceived magnitude (loudness or noisiness) in sones.

2) Using the maximum perceived magnitude, S_m, find the factor, F, from Table PL-II. If octave bands are used, subtract 4.9 dB from the level of the loudest band. Then find the corresponding sone value which will be used for obtaining the factor F (Table PL-II); double this factor and use it as F.

3) The total perceived magnitude in sones is found by the following summation rule:

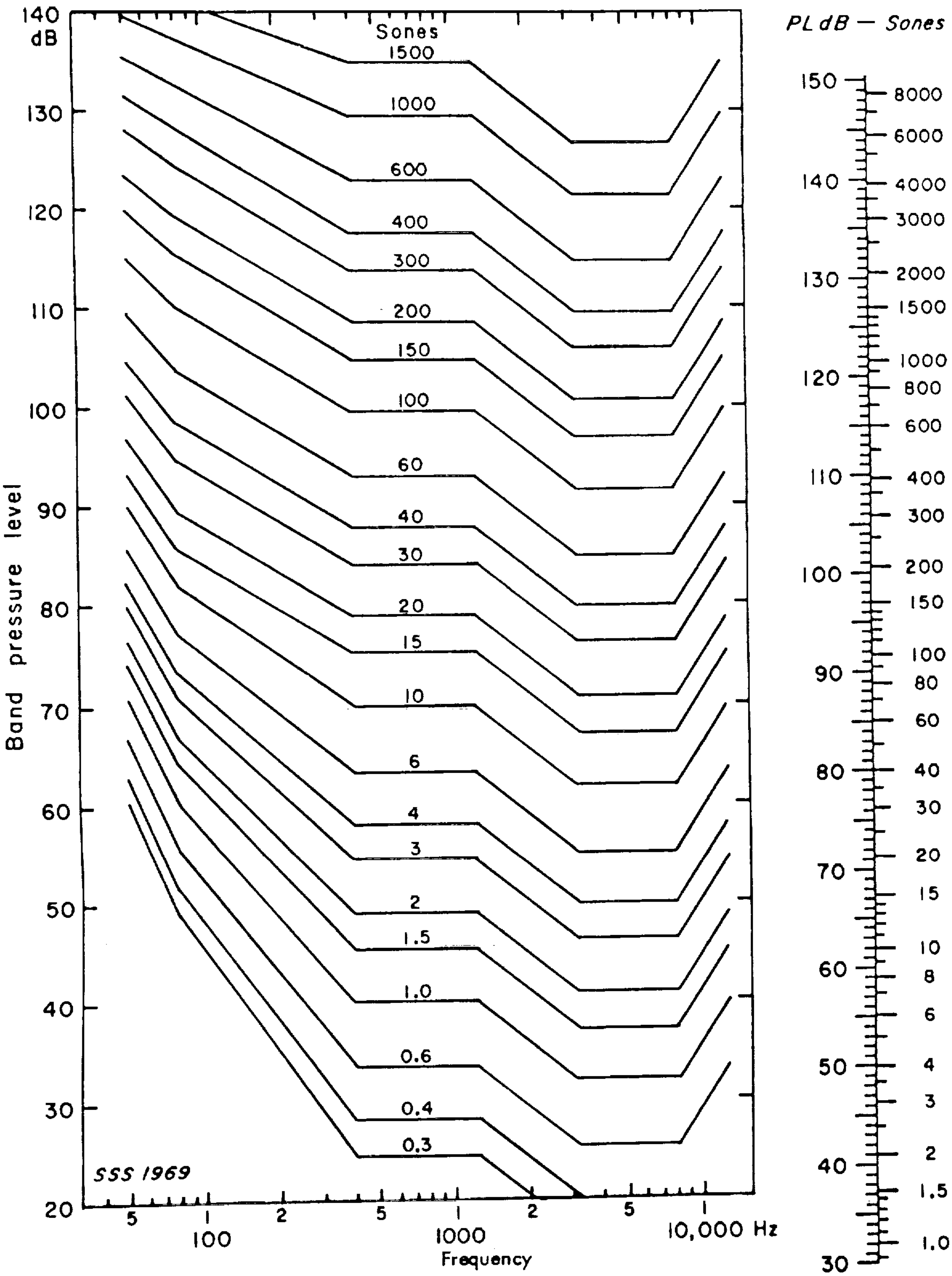


FIGURE PL-1. CONTOURS OF EQUAL PERCEIVED MAGNITUDE IN SONES AND A NOMOGRAM RELATING SONES TO PERCEIVED LEVEL IN PLdB

TABLE PL-I Perceived magnitude in sones as a function of band pressure level.

Band	17	18	19	20	21	22	23	24	25	26–31	32	33	34	35–39	40	41
Freq	50	63	80	100	125	160	200	250	315	400–1250	1600	2000	2500	3150–8000	10,000	12,500
1 dB														.078		
2														.087		
3													.078	.097		
4													.087	.107		
5												.078	.097	.118	.078	
6												.087	.107	.129	.087	
7											.078	.097	.118	.141	.097	
8											.087	.107	.129	.153	.107	
9										.078	.097	.118	.141	.166	.118	.078
10										.087	.107	.129	.153	.181	.129	.087
11										.097	.118	.141	.166	.196	.141	.097
12										.107	.129	.153	.181	.212	.153	.107
13									.077	.118	.141	.166	.196	.230	.166	.118
14									.087	.129	.153	.181	.212	.248	.181	.129
15									.097	.141	.166	.196	.230	.269	.196	.141
16									.107	.153	.181	.212	.248	.290	.212	.153
17								.076	.119	.166	.196	.230	.269	.314	.230	.166
18								.086	.130	.181	.212	.248	.290	.339	.248	.181
19								.097	.143	.196	.230	.269	.314	.367	.269	.196
20								.108	.156	.212	.248	.290	.339	.396	.290	.212
21							.075	.120	.169	.230	.269	.314	.367	.428	.314	.230
22							.086	.131	.185	.248	.290	.339	.396	.463	.339	.248
23							.097	.144	.201	.269	.314	.367	.428	.500	.367	.269
24							.108	.158	.219	.290	.339	.396	.463	.540	.396	.290
25						.074	.121	.173	.237	.314	.367	.428	.500	.483	.428	.314
26						.085	.134	.190	.256	.339	.396	.463	.540	.630	.463	.339
27						.097	.147	.207	.279	.367	.428	.500	.583	.680	.500	.367
28						.110	.162	.224	.302	.396	.463	.540	.630	.735	.540	.396
29					.073	.122	.178	.244	.329	.428	.500	.583	.680	.794	.583	.428
30					.085	.136	.194	.267	.356	.463	.540	.630	.735	.857	.630	.463
31					.097	.149	.212	.290	.384	.500	.583	.680	.794	.926	.680	.500
32					.110	.165	.233	.316	.418	.540	.630	.735	.857	1.00	.735	.540
33				.072	.123	.182	.254	.345	.452	.583	.680	.794	.926	1.08	.794	.583
34				.084	.137	.201	.277	.375	.490	.630	.735	.857	1.00	1.17	.857	.630
35				.097	.153	.221	.304	.406	.531	.680	.794	.926	1.08	1.26	.926	.680
36				.111	.169	.241	.332	.442	.576	.735	.857	1.00	1.17	1.36	1.00	.735
37			.070	.125	.187	.264	.361	.481	.624	.794	.926	1.08	1.26	1.47	1.08	.794
38			.084	.140	.207	.290	.396	.523	.676	.857	1.00	1.17	1.37	1.59	1.17	.857
39			.097	.156	.228	.319	.431	.570	.732	.926	1.08	1.26	1.47	1.72	1.26	.926
40			.112	.173	.250	.350	.470	.620	.794	1.00	1.17	1.36	1.59	1.85	1.36	1.00

TABLE PL -I (continue)
Perceived magnitude in sones as a function of band pressure level.

Band	17	18	19	20	21	22	23	24	25	26–31	32	33	34	35–39	40	41
Freq	50	63	80	100	125	160	200	250	315	400–1250	1600	2000	2500	3150–8000	10,000	12,500
40 dB			.112	.173	.250	.350	.470	.618	.794	1.00	1.17	1.36	1.59	1.85	1.36	1.00
41			.126	.193	.277	.381	.511	.672	.860	1.08	1.26	1.47	1.71	2.00	1.47	1.08
42			.142	.214	.304	.418	.561	.729	.933	1.17	1.36	1.59	1.85	2.16	1.59	1.17
43			.160	.237	.337	.459	.611	.794	1.01	1.26	1.47	1.71	2.00	2.33	1.71	1.26
44		.079	.178	.262	.370	.504	.665	.864	1.10	1.36	1.59	1.85	2.16	2.52	1.85	1.36
45		.092	.199	.290	.406	.552	.727	.938	1.18	1.47	1.71	2.00	2.33	2.72	2.00	1.47
46		.107	.222	.321	.448	.606	.794	1.02	1.28	1.59	1.85	2.16	2.52	2.94	2.16	1.59
47		.121	.246	.356	.492	.660	.866	1.10	1.39	1.71	2.00	2.33	2.72	3.18	2.33	1.71
48		.138	.275	.393	.540	.724	.945	1.20	1.50	1.85	2.16	2.52	2.94	3.43	2.52	1.85
49		.156	.307	.435	.597	.794	1.03	1.31	1.64	2.00	2.33	2.72	3.18	3.70	2.72	2.00
50	.072	.176	.341	.481	.655	.871	1.12	1.42	1.77	2.16	2.52	2.94	3.43	4.00	2.94	2.16
51	.086	.197	.378	.531	.724	.955	1.23	1.55	1.91	2.33	2.72	3.18	3.70	4.32	3.18	2.33
52	.101	.222	.422	.588	.794	1.04	1.34	1.69	2.08	2.52	2.94	3.43	4.00	4.67	3.43	2.52
53	.117	.250	.468	.649	.871	1.14	1.46	1.82	2.26	2.72	3.18	3.70	4.32	5.04	3.70	2.72
54	.134	.279	.519	.718	.962	1.25	1.59	1.98	2.44	2.94	3.43	4.00	4.67	5.44	4.00	2.94
55	.152	.314	.579	.794	1.06	1.37	1.74	2.16	2.64	3.18	3.70	4.32	5.04	5.88	4.32	3.18
56	.175	.347	.643	.877	1.17	1.50	1.90	2.35	2.85	3.43	4.00	4.67	5.44	6.35	4.67	3.43
57	.197	.390	.714	.970	1.28	1.65	2.06	2.56	3.10	3.70	4.32	5.04	5.88	6.86	5.04	3.70
58	.222	.435	.794	1.07	1.40	1.80	2.26	2.78	3.35	4.00	4.67	5.44	6.35	7.41	5.44	4.00
59	.250	.488	.882	1.18	1.55	1.97	2.46	3.01	3.65	4.32	5.04	5.88	6.86	8.00	5.88	4.32
60	.282	.544	.977	1.31	1.70	2.16	2.68	3.27	3.94	4.67	5.44	6.35	7.41	8.64	6.35	4.67
61	.319	.611	1.09	1.45	1.87	2.37	2.94	3.56	4.27	5.04	5.88	6.86	8.00	9.33	6.86	5.04
62	.358	.686	1.21	1.60	2.06	2.60	3.20	3.88	4.63	5.44	6.35	7.41	8.64	10.1	7.41	5.44
63	.402	.762	1.34	1.77	2.26	2.83	3.48	4.22	5.00	5.88	6.86	8.00	9.33	10.9	8.00	5.88
64	.454	.851	1.49	1.95	2.50	3.10	3.79	4.58	5.44	6.35	7.41	8.64	10.1	11.8	8.64	6.35
65	.511	.952	1.66	2.16	2.74	3.40	4.16	4.98	5.88	6.86	8.00	9.33	10.9	12.7	9.33	6.86
66	.574	1.06	1.84	2.39	3.01	3.73	4.52	5.40	6.37	7.41	8.64	10.1	11.8	13.7	10.1	7.41
67	.649	1.18	2.05	2.64	3.32	4.09	4.94	5.88	6.91	8.00	9.33	10.9	12.7	14.8	10.9	8.00
68	.729	1.33	2.28	2.92	3.65	4.47	5.40	6.40	7.48	8.64	10.1	11.8	13.7	16.0	11.8	8.64
69	.818	1.48	2.54	3.22	4.02	4.89	5.88	6.96	8.10	9.33	10.9	12.7	14.8	17.3	12.7	9.33
70	.921	1.66	2.81	3.56	4.42	5.36	6.40	7.55	8.78	10.1	11.8	13.7	16.0	18.7	13.7	10.1
71	1.03	1.87	3.13	3.94	4.85	5.88	7.00	8.21	9.51	10.9	12.7	14.8	17.3	20.2	14.8	10.9
72	1.16	2.08	3.48	4.35	5.34	6.45	7.64	8.91	10.3	11.8	13.7	16.0	18.7	21.8	16.0	11.8
73	1.32	2.33	3.85	4.81	5.88	7.07	8.33	9.70	11.1	12.7	14.8	17.3	20.2	23.5	17.3	12.7
74	1.48	2.58	4.29	5.32	6.47	7.70	9.09	10.6	12.1	13.7	16.0	18.7	21.8	25.4	18.7	13.7
75	1.66	2.90	4.76	5.88	7.13	8.46	9.92	11.5	13.1	14.8	17.3	20.2	23.5	27.4	20.2	14.8
76	1.87	3.24	5.28	6.50	7.82	9.26	10.8	12.5	14.1	16.0	18.7	21.8	25.4	29.6	21.8	16.0
77	2.10	3.62	5.88	7.18	8.61	10.2	11.8	13.5	15.4	17.3	20.2	23.5	27.4	32.0	23.5	17.3
78	2.37	4.03	6.53	7.94	9.48	11.1	12.9	14.7	16.6	18.7	21.8	25.4	29.6	34.6	25.4	18.7
79	2.66	4.52	7.26	8.78	10.4	12.2	14.0	16.0	18.0	20.2	23.5	27.4	32.0	37.3	27.4	20.2
80	2.99	5.05	8.06	9.70	11.5	13.3	15.3	17.3	19.4	21.8	25.4	29.6	34.6	40.3	29.6	21.8
81	3.35	5.64	8.95	10.7	12.6	14.6	16.6	18.7	21.0	23.5	27.4	32.0	37.3	43.5	32.0	23.5
82	3.79	6.31	9.96	11.8	13.8	16.0	18.0	20.2	22.6	25.4	29.6	34.6	40.3	47.0	34.6	25.4
83	4.25	7.05	11.1	13.1	15.3	17.3	19.4	21.8	24.4	27.4	32.0	37.3	43.5	50.8	37.3	27.4
84	4.79	7.88	12.3	14.5	16.6	18.7	21.0	23.5	26.4	29.6	34.6	40.3	47.0	54.9	40.3	29.6
85	5.40	8.81	13.7	16.0	18.0	20.2	22.6	25.4	28.5	32.0	37.3	43.5	50.8	59.3	43.5	32.0
86	6.06	9.85	15.2	17.3	19.4	21.8	24.4	27.4	30.8	34.6	40.3	47.0	54.9	64.0	47.0	34.6
87	6.82	11.0	16.6	18.7	21.0	23.5	26.4	29.6	33.3	37.3	43.5	5018	59.3	69.1	50.8	37.3
88	7.68	12.3	18.0	20.2	22.6	25.4	28.5	32.0	35.9	40.3	47.0	54.9	64.0	74.7	54.9	40.3
89	8.64	13.8	19.4	21.8	24.4	27.4	30.8	34.6	38.8	43.5	50.8	59.3	69.1	80.6	59.3	43.5
90	9.71	15.4	21.0	23.5	26.4	29.6	33.3	37.3	41.9	47.0	54.9	64.0	74.7	87.1	64.0	47.0

TABLE PL-I (continue)

Perceived magnitude in sones as a function of band pressure level.

Band	17	18	19	20	21	22	23	24	25	26-31	32	33	34	35-39	40	41
Freq	50	63	80	100	125	160	200	250	315	400-1250	1600	2000	2500	3150-8000	10,000	12,500
90 dB	9.71	15.4	21.0	23.5	26.4	29.6	33.3	37.3	41.9	47.0	54.9	64.0	74.7	87.1	64.0	47.0
91	10.9	16.8	22.6	25.4	28.5	32.0	35.9	40.3	45.2	50.8	59.3	69.1	80.6	94.1	69.1	50.8
92	12.3	18.3	24.4	27.4	30.8	34.6	38.8	43.5	48.0	54.9	64.0	74.7	87.1	102	74.7	54.9
93	13.8	19.8	26.4	29.6	33.3	37.3	41.9	47.0	52.8	59.3	69.1	80.6	94.1	110	80.6	59.3
94	15.6	21.5	28.5	32.0	35.9	40.3	45.2	50.8	57.1	64.0	74.7	87.1	102	119	87.1	64.0
95	17.1	23.3	30.8	34.6	38.8	43.5	48.9	54.9	61.6	69.1	80.6	94.1	110	128	94.1	69.1
96	18.6	25.3	33.3	37.3	41.9	47.0	52.8	59.3	66.6	74.7	87.1	102	119	138	102	74.7
97	20.3	27.4	35.9	40.3	45.3	50.8	57.1	64.0	71.9	80.6	94.1	110	128	149	110	80.6
98	22.1	29.8	38.8	43.5	48.9	54.9	61.6	69.1	77.6	87.1	102	119	138	161	119	87.1
99	24.1	32.3	41.9	47.0	52.8	59.3	66.6	74.7	83.8	94.1	110	128	149	174	128	94.1
100	26.3	35.1	45.3	50.8	57.1	64.0	71.9	80.6	90.6	102	119	138	161	188	138	102
101	28.6	38.0	48.9	54.9	61.6	69.1	77.6	87.1	98.0	110	128	149	174	203	149	110
102	31.2	41.2	52.8	59.3	66.6	74.7	83.8	94.1	106	119	138	161	188	219	161	119
103	34.0	44.7	57.0	64.0	71.9	80.6	90.6	102	114	128	149	174	203	237	174	128
104	37.0	48.5	61.6	69.1	77.6	87.1	98.0	110	124	138	161	188	219	256	188	138
105	40.4	52.4	66.5	74.7	83.8	94.1	106	119	133	149	174	203	237	276	203	149
106	44.0	57.0	71.8	80.6	90.6	102	114	128	144	161	188	219	256	299	219	161
107	48.0	61.8	77.6	87.1	98.0	110	124	138	155	174	203	237	276	323	237	174
108	52.3	67.1	83.8	94.1	106	119	133	149	168	188	219	256	299	348	256	188
109	57.0	72.8	90.5	102	114	128	144	161	181	203	237	276	323	376	276	203
110	62.1	78.9	97.8	110	124	138	155	174	196	219	256	299	348	406	299	219
111	67.5	85.6	106	119	133	149	168	188	211	237	276	323	376	439	323	237
112	73.8	92.9	114	128	144	161	181	203	228	256	299	348	406	474	348	256
113	80.5	101	123	138	155	174	196	219	246	276	323	376	439	512	376	276
114	87.7	109	133	149	168	188	211	237	266	299	348	406	474	553	406	299
115	95.6	119	144	161	181	203	228	256	288	323	376	439	512	597	439	323
116	104	129	155	174	196	219	246	276	311	348	406	474	553	645	474	348
117	114	139	168	188	211	237	266	299	336	376	439	512	597	697	512	376
118	124	152	181	203	228	256	288	323	362	406	474	553	645	752	553	406
119	135	164	196	219	246	276	311	348	391	439	512	597	697	813	597	439
120	147	178	211	237	266	299	336	376	422	474	553	645	752	878	645	474
121	160	193	228	256	288	323	362	406	456	512	597	697	813	948	697	512
122	175	209	246	276	311	348	391	439	493	553	645	752	878	1024	752	553
123	190	227	266	299	336	376	422	474	532	597	697	813	948	1106	813	597
124	207	246	287	323	362	406	456	512	575	645	752	878	1024	1194	878	645
125	226	267	310	348	391	439	493	557	625	697	813	948	1106	1290	948	697
126	246	290	335	376	422	474	579	606	676	752	878	1024	1194	1393	1024	752
127	268	314	362	406	456	512	584	660	735	813	948	1106	1290	1505	1106	813
128	293	341	391	439	493	562	635	713	794	878	1024	1194	1393	1625	1194	878
129	319	370	422	474	536	616	697	776	864	948	1106	1290	1505	1756	1290	948
130	348	401	456	512	593	670	758	845	934	1024	1194	1393	1625	1896	1393	1024
131	379	435	493	566	650	735	825	919	1008	1106	1290	1505	1756	2048	1505	1106
132	413	472	540	625	713	806	905	1001	1097	1194	1393	1625	1896	2212	1625	1194
133	450	512	600	691	788	885	985	1089	1185	1290	1505	1756	2048	2389	1756	1290
134	490	572	666	764	864	970	1072	1176	1290	1393	1625	1896	2212	2580	1896	1393
135	543	640	740	845	948	1064	1167	1280	1393	1505	1756	2048	2389	2787	2048	1505
136	611	715	823	934	1048	1158	1280	1393	1505	1625	1896	2212	2580	3010	2212	1625
137	687	799	914	1032	1149	1270	1393	1516	1638	1756	2048	2389	2787	3251	2389	1756
138	773	893	1016	1140	1270	1393	1517	1651	1769	1896	2212	2580	3010	3511	2580	1896
139	870	998	1129	1261	1393	1528	1663	1797	1925	2048	2389	2787	3251	3792	2787	2048
140	979	1115	1254	1393	1528	1676	1810	1940	2080	2212	2580	3010	3511	4096	3010	2212

TABLE PL-II The factor F as a function of the number of sones in the 1/3 octave band that is maximally loud or noisy. The separation between successive sone values corresponds to 1.0 dB. The value of F remains constant above 219 sones.

Sones	F	Sones	F	Sones	F	Sones	F
.181	.10	1.85	.314	18.7	.194	188	.225
.196	.122	2.00	.311	20.2	.193	203	.226
.212	.140	2.16	.308	21.8	.192	219	.227
.230	.158	2.33	.304	23.5	.191	237	.227
.248	.174	2.52	.300	25.4	.190	256	.227
.269	.187	2.72	.296	27.4	.190		.
.290	.200	2.74	.292	29.6	.190		.
.314	.212	3.18	.288	32.0	.190		.
.339	.222	3.43	.284	34.6	.190		.
.367	.232	3.70	.279	37.3	.190		.
.396	.241	4.00	.275	40.3	.191		
.428	.250	4.32	.270	43.5	.191		
.463	.259	4.67	.266	47.0	.192		
.500	.267	5.04	.262	50.8	.193		
.540	.274	5.44	.258	54.9	.194		
.583	.281	5.88	.253	59.3	.195		
.630	.287	6.35	.248	64.0	.197		
.680	.293	6.86	.244	69.1	.199		
.735	.298	7.41	.240	74.7	.201		
.794	.303	8.00	.235	80.6	.203		
.857	.308	8.64	.230	87.1	.205		
.926	.312	9.33	.226	94.1	.208		
1.00	.316	10.1	.222	102	.210		
1.08	.319	10.9	.217	110	.212		
1.17	.320	11.8	.212	119	.215		
1.26	.322	12.7	.208	128	.217		
1.36	.322	13.7	.204	138	.219		
1.47	.320	14.8	.200	149	.221		
1.59	.319	16.0	.197	161	.223		
1.72	.317	17.3	.195	174	.224		

TABLE PL-III Relation between perceived level in PLdB and perceived magnitude in sones.

dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-3	.000	.012	.024	.028	.031	.033	.036	.038	.040	.041
-2	.043	.045	.046	.047	.049	.050	.052	.053	.054	.055
-1	.056	.058	.059	.060	.061	.062	.063	.064	.065	.066
0	.067	.068	.069	.070	.072	.073	.074	.075	.076	.077
1	.078	.079	.080	.080	.081	.082	.083	.084	.085	.086
2	.087	.088	.089	.090	.091	.092	.093	.094	.095	.096
3	.097	.098	.099	.100	.101	.102	.103	.104	.105	.106
4	.107	.108	.110	.111	.112	.113	.114	.115	.116	.117
5	.118	.119	.120	.121	.122	.123	.125	.126	.127	.128
6	.129	.130	.131	.133	.134	.135	.136	.137	.138	.140
7	.141	.142	.143	.144	.146	.147	.148	.149	.151	.152
8	.153	.154	.156	.157	.158	.160	.161	.162	.164	.165
9	.166	.168	.169	.171	.172	.173	.175	.176	.178	.179
10	.181	.182	.184	.185	.187	.188	.190	.191	.193	.194
11	.196	.197	.199	.201	.202	.204	.205	.207	.209	.210
12	.212	.214	.215	.217	.219	.221	.222	.224	.226	.228
13	.230	.231	.233	.235	.237	.239	.241	.243	.244	.246
14	.248	.250	.252	.254	.256	.258	.260	.262	.264	.267
15	.269	.271	.273	.275	.277	.279	.282	.284	.286	.288
16	.290	.293	.295	.297	.300	.302	.304	.307	.309	.312
17	.314	.316	.319	.321	.324	.326	.329	.332	.334	.337
18	.339	.342	.345	.347	.350	.353	.356	.358	.361	.364
19	.367	.370	.372	.375	.378	.381	.384	.387	.390	.393
20	.396	.399	.402	.406	.409	.412	.415	.418	.422	.425
21	.428	.431	.435	.438	.442	.445	.448	.452	.455	.459
22	.463	.466	.470	.473	.477	.481	.484	.488	.492	.496
23	.500	.504	.507	.511	.515	.518	.523	.527	.531	.536
24	.540	.544	.548	.552	.557	.561	.565	.570	.574	.579
25	.583	.588	.592	.597	.601	.606	.611	.615	.620	.625
26	.630	.635	.640	.645	.649	.655	.660	.665	.670	.675
27	.680	.686	.691	.696	.702	.707	.712	.718	.724	.729
28	.735	.740	.746	.752	.758	.764	.770	.775	.781	.788
29	.794	.800	.806	.812	.818	.825	.831	.838	.844	.851
30	.857	.864	.871	.877	.884	.891	.898	.905	.912	.919
31	.926	.933	.940	.947	.955	.962	.970	.977	.985	.992
32	1.00	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.06	1.07
33	1.08	1.09	1.10	1.10	1.11	1.12	1.13	1.14	1.15	1.16
34	1.17	1.18	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25
35	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35
36	1.36	1.37	1.38	1.39	1.40	1.41	1.42	1.44	1.45	1.46
37	1.47	1.48	1.49	1.50	1.52	1.53	1.54	1.55	1.56	1.58
38	1.59	1.60	1.61	1.62	1.64	1.65	1.66	1.68	1.69	1.70
39	1.72	1.73	1.74	1.76	1.77	1.78	1.80	1.81	1.82	1.84
40	1.85	1.87	1.88	1.90	1.91	1.92	1.94	1.95	1.97	1.98
41	2.00	2.02	2.03	2.05	2.06	2.08	2.10	2.11	2.13	2.14
42	2.16	2.18	2.19	2.21	2.23	2.24	2.26	2.28	2.30	2.32
43	2.33	2.35	2.37	2.39	2.41	2.42	2.44	2.46	2.48	2.50
44	2.52	2.54	2.56	2.58	2.60	2.62	2.64	2.66	2.68	2.70
45	2.72	2.74	2.76	2.78	2.81	2.83	2.85	2.87	2.90	2.92
46	2.94	2.96	2.98	3.01	3.03	3.06	3.08	3.10	3.13	3.15
47	3.18	3.20	3.22	3.25	3.27	3.30	3.32	3.35	3.38	3.40
48	3.43	3.46	3.48	3.51	3.54	3.56	3.59	3.62	3.65	3.68
49	3.70	3.73	3.76	3.79	3.82	3.85	3.88	3.91	3.94	3.97
50	4.00	4.03	4.06	4.09	4.12	4.16	4.19	4.22	4.25	4.29

TABLE PL-III (continue)

Relation between perceived level in PLdB and perceived magnitude in sones.

dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
50	4.00	4.03	4.06	4.09	4.12	4.16	4.19	4.22	4.25	4.29
51	4.32	4.35	4.39	4.42	4.46	4.49	4.52	4.56	4.60	4.63
52	4.67	4.70	4.74	4.78	4.81	4.85	4.89	4.92	4.96	5.00
53	5.04	5.08	5.12	5.16	5.20	5.24	5.28	5.32	5.36	5.40
54	5.44	5.49	5.53	5.57	5.61	5.66	5.70	5.74	5.79	5.83
55	5.88	5.92	5.97	6.02	6.06	6.11	6.16	6.20	6.25	6.30
56	6.35	6.40	6.45	6.50	6.55	6.60	6.65	6.70	6.75	6.81
57	6.86	6.91	6.96	7.02	7.07	7.13	7.18	7.24	7.29	7.35
58	7.41	7.46	7.52	7.58	7.64	7.70	7.76	7.81	7.88	7.94
59	8.00	8.06	8.12	8.19	8.25	8.32	8.38	8.44	8.51	8.58
60	8.64	8.71	8.78	8.84	8.91	8.98	9.05	9.12	9.19	9.26
61	9.33	9.40	9.48	9.55	9.62	9.70	9.77	9.85	9.93	10.0
62	10.1	10.2	10.2	10.3	10.4	10.5	10.6	10.6	10.7	10.8
63	10.9	11.0	11.1	11.1	11.2	11.3	11.4	11.5	11.6	11.7
64	11.8	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6
65	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6
66	13.7	13.8	13.9	14.0	14.1	14.3	14.4	14.5	14.6	14.7
67	14.8	14.9	15.0	15.2	15.3	15.4	15.5	15.6	15.8	15.9
68	16.0	16.1	16.2	16.4	16.5	16.6	16.8	16.9	17.0	17.1
69	17.3	17.4	17.6	17.7	17.8	18.0	18.1	18.2	18.4	18.5
70	18.7	18.8	19.0	19.1	19.2	19.4	19.5	19.7	19.9	20.0
71	20.2	20.3	20.5	20.6	20.8	21.0	21.1	21.3	21.4	21.6
72	21.8	21.9	22.1	22.3	22.5	22.6	22.8	23.0	23.2	23.3
73	23.5	23.7	23.9	24.1	24.3	24.4	24.6	24.8	25.0	25.2
74	25.4	25.6	25.8	26.0	26.2	26.4	26.6	26.8	27.0	27.2
75	27.4	27.7	27.9	28.1	28.3	28.5	28.7	29.0	29.2	29.4
76	29.6	29.9	30.1	30.3	30.6	30.8	31.0	31.3	31.5	31.8
77	32.0	32.2	32.5	32.7	33.0	33.3	33.5	33.8	34.0	34.3
78	34.6	34.8	35.1	35.4	35.6	35.9	36.2	36.5	36.8	37.0
79	37.3	37.6	37.9	38.2	38.5	38.8	39.1	39.4	39.7	40.0
80	40.3	40.6	40.9	41.3	41.6	41.9	42.2	42.6	42.9	43.2
81	43.5	43.9	44.2	44.6	44.9	45.3	45.6	46.0	46.3	46.7
82	47.0	47.4	47.8	48.1	48.5	48.9	49.3	49.6	50.0	50.4
83	50.8	51.2	51.6	52.0	52.4	52.8	53.2	53.6	54.0	54.4
84	54.9	55.3	55.7	56.1	56.6	57.0	57.5	57.9	58.4	58.8
85	59.3	59.7	60.2	60.6	61.1	61.6	62.1	62.5	63.0	63.5
86	64.0	64.5	65.0	65.5	66.0	66.5	67.0	67.5	68.1	68.6
87	69.1	69.7	70.2	70.7	71.3	71.8	72.4	73.0	73.5	74.1
88	74.7	75.2	75.8	76.4	77.0	77.6	78.2	78.8	79.4	80.0
89	80.6	81.3	81.9	82.5	83.2	83.8	84.4	85.1	85.8	86.4
90	87.1	87.8	88.4	89.1	89.8	90.5	91.2	91.9	92.6	93.3
91	94.1	94.8	95.5	96.3	97.0	97.8	98.5	99.3	100	101
92	102	102	103	104	105	106	106	107	108	109
93	110	111	111	112	113	114	115	116	117	118
94	119	119	120	121	122	123	124	125	126	127
95	128	129	130	131	132	133	134	135	136	137
96	138	139	140	141	143	144	145	146	147	148
97	149	150	152	153	154	155	156	158	159	160
98	161	163	164	165	166	168	169	170	172	173
99	174	176	177	179	180	181	182	184	185	187
100	188	190	191	193	194	196	197	199	200	202

TABLE PL-III (continue)

Relation between perceived level in PLdB and perceived magnitude in sones.

dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
100	188	190	191	193	194	196	197	199	200	202
101	203	205	206	208	210	211	213	214	216	215
102	219	221	223	225	226	228	230	232	233	235
103	237	239	241	243	244	246	248	250	252	254
104	256	258	260	262	264	266	268	270	272	274
105	276	279	281	283	285	287	290	292	294	296
106	299	301	303	306	308	310	313	315	318	320
107	323	325	328	330	333	335	338	340	343	346
108	348	351	354	356	359	362	365	368	370	373
109	376	379	382	385	388	391	394	397	400	403
110	406	409	413	416	419	422	426	429	432	436
111	439	442	446	449	453	456	460	463	467	470
112	474	478	481	485	489	493	496	500	504	508
113	512	516	520	524	528	532	536	540	545	549
114	553	557	562	566	570	575	579	584	588	593
115	597	602	606	611	616	621	625	630	635	640
116	645	650	655	660	665	670	676	681	686	691
117	697	702	707	713	718	724	730	735	741	747
118	752	758	764	770	776	782	788	794	800	806
119	813	819	825	832	838	845	851	858	864	871
120	878	885	891	898	905	912	919	926	934	941
121	948	955	963	970	978	985	993	1001	1008	1016
122	1024	1032	1040	1048	1056	1064	1072	1081	1089	1097
123	1106	1114	1123	1132	1140	1149	1158	1167	1176	1185
124	1194	1204	1213	1222	1232	1241	1251	1261	1270	1280
125	1290	1300	1310	1320	1330	1341	1351	1362	1372	1383
126	1393	1404	1415	1426	1437	1448	1459	1471	1482	1493
127	1505	1517	1528	1540	1552	1564	1576	1588	1601	1613
128	1625	1638	1651	1663	1676	1689	1702	1715	1729	1742
129	1755	1769	1783	1797	1810	1824	1838	1853	1867	1881
130	1896	1911	1925	1940	1955	1970	1986	2001	2017	2032
131	2048	2064	2080	2096	2112	2128	2145	2161	2178	2195
132	2212	2229	2246	2263	2281	2299	2316	2334	2352	2370
133	2389	2407	2426	2445	2464	2483	2502	2521	2541	2560
134	2580	2600	2620	2640	2661	2681	2702	2723	2744	2765
135	2787	2808	2830	2852	2874	2896	2918	2941	2964	2987
136	3010	3033	3056	3080	3104	3128	3152	3176	3201	3226
137	3251	3276	3301	3327	3352	3378	3404	3431	3457	3484
138	3511	3538	3565	3593	3621	3649	3677	3705	3734	3763
139	3792	3821	3851	3881	3911	3941	3971	4002	4033	4064
140	4095	4127	4159	4191	4224	4256	4289	4322	4356	4389
141	4423	4458	4492	4527	4562	4597	4633	4668	4704	4741
142	4777	4814	4852	4889	4927	4965	5003	5042	5081	5120
143	5160	5200	5240	5281	5321	5363	5404	5446	5488	5530
144	5573	5616	5660	5703	5747	5792	5837	5882	5927	5973
145	6019	6066	6113	6160	6208	6256	6304	6353	6402	6451
146	6501	6551	6602	6653	6704	6756	6809	6861	6914	6968
147	7022	7076	7131	7186	7241	7297	7354	7410	7468	7525
148	7584	7642	7701	7761	7821	7881	7942	8004	8066	8128
149	8191	8254	8318	8382	8447	8512	8578	8644	8711	8779

$$S_t = S_m + F \left(\sum_{i=1}^{n} S - S_m \right) \qquad [1]$$

where:

S_t is the total loudness of a sound (in sones)

S_m is the loudness of the loudest band (maximum perceived magnitude)

F is the factor which varies by level of S_m

S is the perceived magnitude of frequency band i

n equals 24 for one-third octave band measures

equals 8 for octave band measures

4) The total perceived magnitude may be converted into Perceived Level (PLdB) by finding the S_t (in sones) in the body of Table PL-1II and relating it to the corresponding band pressure level (in dB) in the column on the extreme left.

For S_t levels *above* 20 dB, Perceived Level may be calculated from this equation:

$$PL = 32 + 9 \log_2 S_t \qquad [2]$$

EXAMPLE

An example of the Perceived Level (PL) method using an aircraft flyover noise spectrum is shown in Table PL-IV. Here the one-third octave band levels are tabulated and converted to perceived magnitude (in sones). Computed, $S_m = 174$ sones and $F = 0.224$, then from equation [1] it follows that:

$$S_t = 174 + 0.224\ (771.43 - 174)$$

$$= 307.82 \text{ sones}$$

A) Then from Table PL-III the S_t is converted to Perceived Level in PLdB of 106.4 PLdB.

B) *Or*, By equation [2] Perceived Level equals:

$$PL = 32 + 9 \log_2 (307.82)$$

$$= 106.4 \text{ PLdB}$$

EQUIPMENT

1) Tape recorder (necessary for single event)
2) Sound Level Meter (IEC Standard)
3) Octave band or 1/3 octave band analyzer
4) Digital computer optional

TABLE PL-IV

EXAMPLE OF PL CALCULATIONS FROM ONE-THIRD OCTAVE BAND MEASUREMENTS OF AIRCRAFT FLYOVER

One-Third Octave Band Center Frequency Hz	Band Level dB	Perceived Magnitude sones
50	74	1.48
63	76	3.24
80	73	3.85
100	66	2.39
125	77	8.61
160	80	13.30
200	85	22.60
250	83	21.80
315	76	14.10
400	79	20.20
500	79	20.20
630	80	21.80
800	80	21.80
1000	82	25.40
1250	83	27.40
1600	84	34.60
2000	89	59.30
2500	101	174.00
3150	90	87.10
4000	84	54.90
5000	87	69.10
6300	77	32.00
8000	74	25.40
10000	61	6.86

$\Sigma S = 771.43$

$$S_t = 174 + 0.224\ (771.43 - 174)$$
$$= 307.82 \text{ sones}$$
$$PL = 32 + 9 \log_2 (307.82)$$
$$= 106.4 \text{ PLdB}$$

REFERENCES

1. Stevens, S. S., "Perceived Level of Noise by Mark VII and Decibels (E)", J. Acoust. Soc. Am., 51, No. 2(2), (February 1972), p. 575-593.
2. Peterson, Arnold, and E. E. Gross, Jr., "Handbook of Noise Measurement", General Radio Company, (1972).

NOTES

TITLE	PERCEIVED NOISE LEVEL (PNL) (L_{PN})
UNIT	PNdB
DEFINITION	Perceived Noise Level (PNL) is rating of the noisiness of a sound signal calculated from acoustic measurements. PNL is computed from sound pressure levels measured in octave or one-third octave frequency bands. This rating is most accurate in estimating the perceived noisiness of broadband sounds of similar time duration which do not contain strong discrete frequency components.
STANDARDS	1) Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP 1071 issue June 1972 2) International Organization for Standardization, ISO R 507 issue June 1970 3) Federal Aviation Administration (FAA) Certification Procedure FAR Part 36
GEOGRAPHICAL USAGE	International
PURPOSE	PNL was developed as a measure of the noisiness of sounds of widely differing character. Currently it is used mainly for assessing the disturbance likely to be caused by aircraft flyovers.

BACKGROUND

PNL is patterned after Loudness Level except that equal noisiness curves are employed instead of equal loudness curves. Discrete frequency or impulsive type sounds are not within the scope of PNL. The numerical value of PNL was intended to represent the sound pressure level of an octave band of noise at 1000 Hz which would be judged to be equally as noisy as the sound to be rated. Equally noisy is intended to mean that in a comparison of sounds one would just as soon have or not have one noise as the other at his home during the day or night. Perceived noise level is measured in units of PNdB. These units are the translation of the subjective Noy scale to a dB-type scale; an increase of 10 PNdB in a sound is equivalent to a doubling of its noy value.

CALCULATION METHOD

Two methods are available for determining PNL. One uses Noy tables and is suitable for hand calculation; the other uses equations and is adapted for computer calculations.

I. PNL FROM NOY TABLES

1) The sound pressure level in each one-third (or full) octave band from 50 to 10,000 Hz is converted to a noy value (abbreviated N) by reference to Table I. One finds the proper value of Noys, corresponding to each of the measured levels in the various one-third octave bands, by entering the table at the appropriate band center frequency.

2) These noy values are summed in the following manner:

OCTAVE BANDS

$$N_{TOT} = n_{max} + 0.3 \left[\sum_{i=1}^{k} n - n_{max} \right] \qquad [1]$$

ONE-THIRD OCTAVE BANDS

$$N_{TOT} = n_{max} + 0.15 \left[\sum_{i=1}^{k} n - n_{max} \right] \qquad [2]$$

where:

n_{max} is the number of noys in the band having the greatest noy value

Σn is the sum of the noy values in all bands

k equals 24 for one-third octave bands

equals 8 for octave bands

3) Perceived Noise Level (PNL) in PNdB is then calculated from the formula:

$$PNL = 40 + 33.22 \log N_{TOT} \qquad [3]$$

For N_{TOT} values of 1.0 or greater, the PNL can also be found from Table I by treating the quantity in the 1000 Hz column as the noy value and reading SPL as PNL.

TABLE I - NOYS AS A FUNCTION OF SOUND PRESSURE LEVEL

SPL	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
4																			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	0.19	0.16	0.10		
11																	0.13	0.19	0.22	0.21	0.19	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	0.25		
17										0.11	0.11	0.11	0.11	0.11	0.13	0.19	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	0.15	0.16	0.16	0.16	0.16	0.20	0.27	0.35	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	0.15	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	0.35	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	0.45	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	0.59	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	0.35	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	0.65	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	0.15	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	0.35	0.45	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	1.48	1.00
42			0.15	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	1.97	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	1.97
49	0.10	0.22	0.43	0.65	0.82	1.09	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	2.15

TABLE I CONTINUED

SPL	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	.12	[illegible]	.49	.72	.90	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]	.55	[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]	.34	.62	[illegible]	1.09	1.36	1.58	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	.25	.45	.79	1.09	1.29	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	.30	.51	.89	1.19	1.39	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	.34	.59	1.00	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	2.89	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]	1.19	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	.51	[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	2.25	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	.87	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	1.00	1.45	1.97	2.54	2.88	3.41	3.98	4.38	4.73	5.28	5.28	5.28	5.28	5.28	6.05	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	5.65	5.65	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	3.98	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	7.45	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	7.45	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	10.5	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	22.6	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 I CONTINUED

PNL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
	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	1664									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										

II. PNL FROM EQUATIONS

The procedure for determining PNL with equations is the same as that used with noy tables except noy values are determined by equation as follows:

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

$$N = A \left[10^{M_j (L-L_k)} \right] \qquad [4]$$

For:

$N \leq 0.1$

$L \geq 150$

Where:

$\left.\begin{array}{l} M_j \\ L_k \\ A \end{array}\right\}$ depend upon the band center frequency

L its magnitude is shown in Table II

For $L_1 \leq L < L_2$

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

TABLE II

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

For $L_2 \leq L < L_3$ $\quad N = 10^{M_2 (L - L_3)} \quad 0.3 \leq N \leq 1.0$

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

For $L_c \leq L \leq 150$ $\quad N = 10^{M_4 (L - L_4)}$

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 II.

EXAMPLE

PNL from noy tables

An example of PNL calculations using an aircraft flyover noise spectrum is shown in Table PNL-III. Here the one-third octave band levels are tabulated and converted to noy values. Using equation [2] the total noy value is determined by:

$$N_{TOT} = 134 + 0.15\ (604.63 - 134)$$

$$= 204.59$$

Then the total noy value is converted to Perceived Noise Level in PNdB:

$$PNL = 40 + 10 \log (204.59)$$

$$= 116.8 \text{ PNdB}$$

TABLE PNL-III

EXAMPLE OF PNL CALCULATIONS FROM ONE-THIRD OCTAVE BAND FREQUENCY FOR AIRCRAFT FLYOVER

One-Third Octave Band Center Frequency Hz	Band Level dB	Noy	One-Third Octave Band Center Frequency Hz	Band Level dB	Noy
50			1000	82	18.40
63	76	4.46	1250	83	22.60
80	73	4.23	1600	84	31.50
100	66	3.01	2000	89	51.00
125	77	8.29	2500	101	134.00
160	80	11.30	3150	90	67.20
200	85	18.40	4000	84	44.40
250	83	17.10	5000	87	51.00
315	76	11.00	6300	77	23.90
400	79	14.90	8000	74	15.80
500	79	14.90	10000	61	5.24
630	80	16.00			
800	80	16.00			
				TOTAL	604.63

$$N_{TOT} = 134 + 0.15\ (604.63-134)$$
$$= 204.59$$
$$PNL = 40 + 10 \log\ (204.59)$$
$$= 116.8 \text{ PNdB}$$

EQUIPMENT

1) Tape recorder (necessary for single events)
2) Sound level meter (IEC Standard)
3) Octave or 1/3 octave band analyzer
4) Digital computer optional

REFERENCES

1. Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP 1071 issue June 1972.
2. International Organization for Standardization, ISO R 507 issue June 1970.
3. Federal Aviation Administration (FAA) Certification Procedure FAR Part 36.

TITLE	TONE CORRECTED PERCEIVED NOISE LEVEL (PNLT)
UNIT	PNdB
DEFINITION	Tone corrected Perceived Noise Level is Perceived Noise Level (PNL) corrected for those one-third octave bands which contain discrete frequency components. Perceived noisiness of sounds which are of equal duration but which have pure tone characteristics can be compared using PNLT.
STANDARDS	1) Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP 1071 issue June 1972 2) International Organization for Standardization, ISO R 507 issue June 1970 3) Federal Aviation Administration (FAA) Certification Procedure FAR Part 36
GEOGRAPHICAL USAGE	International
PURPOSE	PNLT was developed to aid in prediction of perceived noisiness for aircraft flyovers or vehicle noise which contain pure tones, or have pronounced irregularities in their spectrum.

BACKGROUND

PNLT was developed in order to assess the added noisiness of discrete frequency components. An adjustment feature was added to PNL that increased its value when tones were present in the noise signal. The various methods used to compute PNLT all apply the tone correction to the perceived noise level in PNdB units. The method adopted by the FAA calculates the PNL of a sound and then adds a tone correction based on the tonal frequency and the amount that the tone exceeds the noise in the adjacent one-third octave bands.

Another method that was developed before the FAA method but is not in widespread use at this time, adds the tone correction to the sound pressure level of the one-third octave band containing the prominent tone prior to the perceived noise level calculation. This method takes into consideration multiple tones rather than just the largest tone.

CALCULATION METHOD

In the FAA method the PNL of a sound is calculated in the usual manner. The band spectra of the sound are examined to determine the presence of any pure tone components, which are specified in terms of a tone-to-background noise ratio. If this ratio exceeds a certain level, a correction, in dB, is added to the PNL for the sound. The magnitudes of the correction are a function of the tone-to-noise ratio and frequency of tone. Only one tone correction is added to the PNL of that sound, even though more than one pure-tone might be present.

The following is a step by step procedure for calculating PNLT:

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:

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

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 L_i, set $L_i' = L_i$

B. For encircled values L_i set L_i' equal to the aritnmetic 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 $\overline{L_i}$ equal to L_i'. Determine all other values of $\overline{L_j}$ by adding $\overline{D}_{ji}$ to $\overline{L}_i$.

Step 8

Determine F_i where:

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

*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 9

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

$$\left.\begin{array}{ll} C = 0 & F<3 \\ C = F/3 & 3 \leq F<20 \\ C = 6.7 & 20 \leq F \end{array}\right) \quad \text{For one-third octave bands between 500 and 5000 Hz.}$$

$$\left.\begin{array}{ll} C = 0 & F<3 \\ C = F/6 & 3 \leq F<20 \\ C = 3.3 & 20 \leq F \end{array}\right) \quad \text{For all other one-third octave bands in the frequency range 100 Hz up to 10,000 Hz.}$$

Step 10

The maximum value of C determined in Step 9 defines the discrete frequency correction which should be added to the value for PNL to obtain PNLT.

EXAMPLE

An example of PNLT calculation for an aircraft flyover noise with a PNL of 104.6 PNdB is illustrated in Table PNLT-I. The numbers heading each column correspond to the step numbers in the calculation procedure. Tone correction is added to PNL which is calculated in the normal manner to determine PNLT. Thus PNLT = 104.6 + 2 = 106.6 PNdB.

EQUIPMENT

1) Tape recorder (necessary for single events)
2) Sound Level Meter (IEC Standard)
3) Octave or 1/3 octave band analyzer
4) Digital computer optional

REFERENCES

1. Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP 1071 issue June 1972.
2. International Organization for Standardization, ISO R 507 issue June 1970.
3. Federal Aviation Administration (FAA) Certification Procedure FAR Part 36.

TABLE PNLT-I

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

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

Thus

PNLT = 104.6 + 2 = 106.2 PNdB

NOTES

TITLE	EFFECTIVE PERCEIVED NOISE LEVEL (EPNL) (L_{EPN})
UNIT	EPNdB (PNdB)
DEFINITION	Effective Perceived Noise Level is a single number measure of complex aircraft flyover noise which approximates laboratory annoyance responses. It is derived from PNL, but it includes correction terms for the duration of an aircraft flyover and for the presence of audible pure tones or discrete frequencies (such as the whine of a jet aircraft) in the noise signal.
STANDARDS	1) Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP 1071 issue June 1972 2) International Organization for Standardization, ISO R 507 issue June 1970 3) Federal Aviation Administration (FAA) Certification Procedure FAR Part 36
GEOGRAPHICAL USAGE	International
PURPOSE	Effective Perceived Noise Level (EPNL) takes into account both the duration and the tonal components of the spectra for varying types of non-sonic boom aircraft flyover signals. This measure is used by the Federal Aviation Administration in aircraft certification.

BACKGROUND

Although there are several methods of determining EPNL all include both duration and tone corrections (References). The tone correction factor increases the magnitude of PNL to account for the increased noisiness of audible discrete frequency components such as are found in aircraft flyover noise. The duration correction increases the magnitude of PNL in an attempt to account for the increased noisiness of sounds of long versus short duration. Effective Perceived Noise Level, in EPNdB units, is usually obtained by first determining a time sequence of tone-corrected Perceived Noise Levels (PNLT) from one-third octave band noise spectra. EPNL is then determined by summing (on an *energy* basis) the tone corrected EPNL in 0.5-second time segments.

CALCULATION METHOD

Effective Perceived Noise Level (EPNL) expressed in EPNdB is determined as follows:

1) The sound pressure level (SPL) for each of the 24 one-third octave bands having a center frequency from 50 to 10,000 Hz is measured for a continuous sequence of 0.5 second time intervals (i in the subscript designates the sequence number of the .5 second interval) throughout the time period of the flyover noise.

2) The Perceived Noise Level (PNL) is computed for every one-third octave band calculated at each 0.5 second (or i^{th}) time segment defined within the duration interval (see PNL p. 50).

3) Audible discrete frequencies are detected and tone-corrections are determined for these frequencies (see PNLT p. 86).

4) PNLT (tone corrected Perceived Noise Level) is calculated by adding tone-corrections (T) determined in Step 3 to the perceived noise level at .5 second (or i^{th}) interval (Step 2). Thus:

$$PNLT_i = PNL_i + T_i \qquad [1]$$

5) The computation formula for Effective Perceived Noise Level, in EPNdB is:

$$EPNL = 10 \log \left[\sum_{i=0}^{d} \text{antilog} \left(\frac{PNLT_i}{10} \right) \right] - 13 \qquad [2]$$

Remember that PNLT is computed from one-third octave band sound pressure levels determined at discrete .5 second (or i^{th}) intervals. The summation process noted in the formula extends over the duration (d) of the noise which is defined as the seconds between the first and last values of tone-corrected PNL which are a minimum of 10 dB down from maximum PNLT (see PNLT p. 86).

EXAMPLE

Table EPNL-I shows an example of the EPNL calculation procedure, given PNLT as a function of time, for an aircraft flyover.

$$EPNL = 10 \log (167768.34 \times 10^6) - 13$$

$$= 99.2 \text{ EPNdB}$$

EQUIPMENT

1) Tape recorder (necessary for single events)
2) Sound Level Meter (IEC Standard)
3) One-third octave band real time analyzer
4) *Or*, One-third octave band analyzer plus graphic level recorder

REFERENCES

1. a) Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP 1071 issue June 1972.
   b) International Organization for Standardization, ISO R 507 issue June 1970.
   c) Federal Aviation Administration (FAA) Certification Procedure FAR Part 36.
2. Pearsons, K. S., and R. L. Bennett, "The Effects of Temporal and Spectral Combinations on the Judged Noisiness of Aircraft Sounds", DOT-FAA Office of Noise Abatement, BBN No. FAA-NO-69-3, (June 1969).
3. U. S. Environmental Protection Agency, "Fundamentals of Noise: Measurement, Rating Schemes, and Standards," (December 31, 1971) NTID 300.15.

TABLE EPNL-I

EXAMPLE OF EPNL CALCULATION FOR AIRCRAFT FLYOVER NOISE

Time (Sec)	PNLT	Antilog $(\frac{PNLT}{10})$
6.0	82.8	
6.5	82.9	
7.0	83.1	
7.5	84.9	
8.0	86.9	
8.5	87.6	
9.0	87.7	
9.5	89.6	
10.0	88.9	
10.5	90.3	
11.0	93.0	1995.26 x 10^6
11.5	94.8	3019.95 "
12.0	97.3	5370.32 "
12.5	100.8	12022.64 "
13.0	101.9	15488.17 "
13.5	103.0	19952.62 "
14.0	103.2	20892.96 "
14.5	103.8	23988.32 "
15.0	102.7	18620.87 "
15.5	101.5	14125.38 "
16.0	100.2	10471.29 "
16.5	98.2	6606.93 "
17.0	97.4	5495.41 "
17.5	96.4	4365.16 "
18.0	95.2	3311.31 "
18.5	93.1	2041.74 "
19.0	92.9	
19.5	91.6	
20.0	90.3	
	Total:	167768.34 x 10^6

EPNL = 10 Log (167768.34 x 10^6) - 13

EPNL = 99.2 PNdB

N O T E S

TITLE	EQUIVALENT SOUND LEVEL (L_{eq}) (SLAQ)
UNIT	dB
DEFINITION	Equivalent Sound Level (L_{eq}) is the average (i.e., the average on an energy basis) noise level (usually A-level) integrated over some specified amount of time.
STANDARDS	(None)
GEOGRAPHICAL USAGE	International
PURPOSE	The purpose of L_{eq} is to provide a single number measure of time-varying noise for a predetermined time period.

BACKGROUND

The early noise assessment measures estimated the level of a noise for an instant in time. Some of the measurement schemes that were developed later allowed for ratings of fluctuating sounds over a longer period of time. One of these measures was an equivalent sound pressure level. *Equivalent* signifies that the numerical value of the fluctuating sound is equivalent in level to a steady state sound with the same amount of total energy. The specified time integration period may be for varying durations (i.e., 2 minutes, 2 hours or 24 hours, etc.). L_{eq} differs from Hourly Noise Level (HNL) in that no provision is made for a minimum sampling threshold. If not stipulated, the level of the noise is taken in A-level, although other types of weighted frequency spectra could be employed (i.e., B-level, D-level, C-level).

CALCULATION METHOD

L_{eq} can be determined by two different methods.

1) CONTINUOUS INTEGRATION

For continuous time integration of A-weighted sound level for a specified time period, the formula is:

$$L_{eq} = 10 \log \frac{\int_{o}^{T} \text{antilog } (AL)[t]/10) \ dt}{T} \quad [1]$$

where:

$AL[t]$ is instantaneous A-level at time t

dt is Δt as it approaches 0

T is the specified time period over which the time integration process takes place

NOTE: Equivalent Sound Level (L_{eq}) is time averaged *exposure level* (1/T).

2) TEMPORAL SAMPLING

For discrete sampling of A-weighted sound level for a specified time period, the formula is:

$$L_{eq} = 10 \log \frac{\sum_{i=1}^{n} \text{antilog } (AL_i/10)}{n} \quad [2]$$

where:

AL_i is the instantaneous A-level for sample i

n is the number of samples of AL in a specified time period

EXAMPLE

The following example illustrates one method of determining L_{eq}. Normally more than three samples would be taken within a time period.

A) TEMPORAL SAMPLING
(for a 45 minute time period)

Given:

$$AL_1 = 67 \text{ dB}$$

$$AL_2 = 74 \text{ dB}$$

$$AL_3 = 76 \text{ dB}$$

Then:

$$L_{eq} = 10 \log \left[\frac{\text{antilog } \frac{67}{10} + \text{antilog } \frac{74}{10} + \text{antilog } \frac{76}{10}}{3} \right]$$

$$= 10 \log \left[\frac{(5.01 + 25.12 + 39.81)}{3} \times 10^6 \right]$$

$$= 73.7 \text{ dB}$$

EQUIPMENT

1. Continuous Sampling:
   a) Special monitoring equipment capable of integrating sound levels for long periods of time
2. Temporal Sampling:
   a) Sound Level Meter (IEC Standards)
   b) Tape recorder

REFERENCES

1. Von Gierke, Henning, "Impact Characterization of Noise Including Implications of Identifying and Achieving Levels of Cumulative Noise Exposure", EPA Aircraft/ Airport Noise Report Study, June, 1973, Task Group 3.

TITLE	SINGLE EVENT NOISE EXPOSURE LEVEL (SENEL) (SOUND EXPOSURE LEVEL) (SEL)
UNIT	dB
DEFINITION	SENEL is time integrated A-level of a single aircraft flyover (which exceeds a threshold noise level) which is expressed by the level of an equivalent 1 second duration reference signal.
STANDARDS	1) California Department of Aeronautics, "Noise Standards," California Administrative Code, Chapter 9, Title 4, (Register 70, No. 48, November 28, 1970). 2) SENEL has been renamed by the Environmental Protection Agency (EPA) to Sound Exposure Level (SEL).
GEOGRAPHICAL USAGE	State of California
PURPOSE	SENEL provides a measure which quantifies the effect of duration and magnitude for a single event measured above a specified threshold. Normally it is used in computing Community Noise Equivalent Level (CNEL).

BACKGROUND

SENEL was developed at the same time as Community Noise Equivalent Level (CNEL) and is used in the CNEL formula for estimating effects of aircraft flyovers on airport communities. SENEL is an A-weighted measure of an individual flyover which time integrates the level accumulated during this event with reference to a duration of one second. Because of this integration process, SENEL takes into consideration both the duration as well as the magnitude of the noise signal.

SENEL is a special case of SEL in that the computation is made for those noise signals which exceed a certain level.

CALCULATION METHOD

The Single Event Noise Exposure Level (SENEL) may be determined by the two following methods. (SEL may be computed by the same methods by disregarding the sampling threshold limitations.)

1) Continuous Integration

For continuous time integration of A-weighted sound level above a specified threshold, the formula is:

$$\text{SENEL} = 10 \log \left[\frac{\int_{t_1}^{t_2} \text{antilog } (AL[t]/10)\ dt}{1 \text{ second}} \right] \quad [1]$$

where:

t is time in seconds

dt is Δt as it approaches 0

$AL[t]$ is instantaneous A-level in excess of a specified threshold at time t

$\int_{t_1}^{t_2}$ brackets the time during which the noise signal is within a <u>minimum</u> of 10 dB(A) down from its maximum value

2) Temporal Sampling

For discrete sampling of A-weighted sound level above a specified threshold, the formula is:

$$SENEL = 10 \log \left[\sum_{i=1}^{n} \text{antilog } (AL_i/10)\Delta t \right] \qquad [2]$$

where:

AL_i is the instantaneous A-level in excess of a specified threshold as for sample i

Δt is the time interval between samples in seconds

n is the number of samples for which the noise is within a <u>minimum</u> of 10 dB(A) down from its maximum AL_i

SENEL is a measure of the noise exposure of a single event which is in excess of a specified threshold, and as such the time limits of the integration process must be selected to encompass the greater portion of the sound energy from the source in question. From a practical standpoint, the noise samples must be taken during the time the signal is within a minimum of 10 dB(A) down from its maximum value.

SENEL is currently used as a criterion for identifying excessively noisy aircraft operations at California airports. According to California Administrative Code Title 4, no event shall exceed the limits recommended for takeoff and landings (Figures SENEL-1 and SENEL-2). These maximum limit values plotted in the figures correspond to the noisiest aircraft class utilizing the airport on a recurrent basis. A minimum threshold is approximated by subtracting 30 dB from the respective maximum values. The noise samples for the sound energy are taken above this threshold.

Curve	Aircraft Class
A	4 Engine Turbojet Turbofan (e.g., 707, 720, DC-8)
B	4 Engine "Jumbo" Turbofan* (e.g., 747)
C	3 Engine Turbofan and Airbus* (e.g., 727, DC-10, L-1011)
D	2 Engine Turbofan (e.g., DC-9, 737)
E	2 Engine Business Jet
E + 3 dB	4 Engine Business Jet
	* High Bypass Ratio Engine

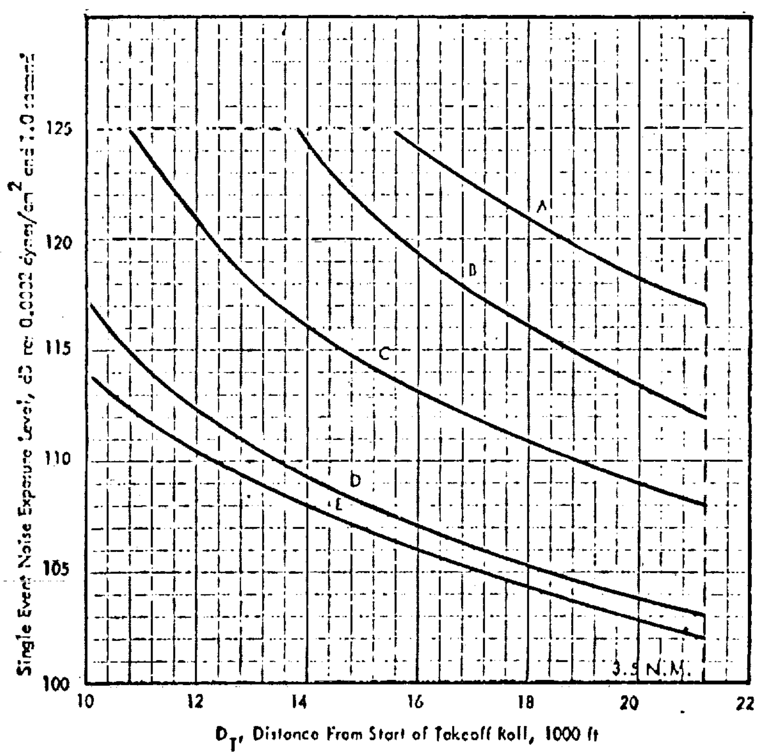
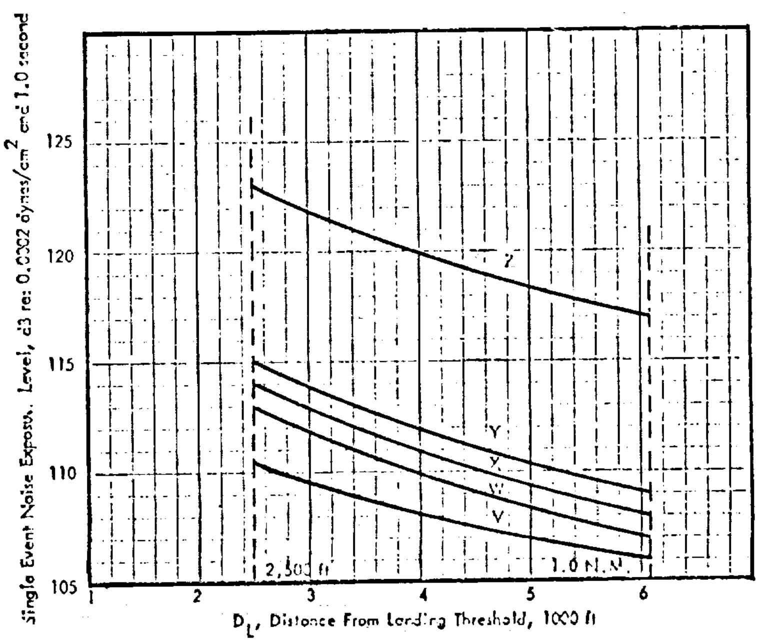


FIGURE SENEL-1. MAXIMUM LIMITS FOR SINGLE EVENT NOISE EXPOSURE LEVEL (SENEL)

AIRCRAFT TAKEOFF

Curve	Aircraft Class
Z	4 Engine Turbojet and Turbofan (e.g., 707, 720, DC-8)
Y	2, 3 Engine Turbofan (e.g., 727, 737, DC-9)
X	4 Engine "Jumbo" Turbofan* (e.g., 747)
W	3 Engine Airbus Turbofan* (e.g., DC-10, L-1011)
V	2 Engine Business Jet
V + 3 dB	4 Engine Business Jet
	* High Bypass Ratio Engine



b) Landing

FIGURE SENEL-2. MAXIMUM LIMITS FOR SINGLE EVENT NOISE EXPOSURE LEVEL (SENEL)

AIRCRAFT LANDING

EXAMPLE

An example of SENEL for a two engine business jet (Aircraft class V, Figure SENEL-2) landing at 1 nautical mile from the landing threshold is shown in Table SENEL-I. From Figure SENEL-2 it is determined that the recommended maximum single event noise exposure level is 106 dB. According to the calculation method, 30 dB is subtracted from the maximum single event noise exposure level yielding a threshold of 76 dB.

In the SENEL example, the sampling interval was every 0.5 second, and the noise signal above threshold was measured within 10 dB(A) down from its maximum value. The resulting SENEL for the two engine jet aircraft landing is 97.4 dB which is within the recommended limits.

EQUIPMENT

1) Continuous Integration
    a) Special monitoring equipment capable of integrating sound levels for a specified duration.
2) Temporal Sampling
    a) If the noise level of the signal is continuous with very little variation, a sound level meter (IEC Standards) may be used.
    b) Tape recorder
    c) Graphic level recorder or digital computer with sampling capability.

TABLE SENEL-I

EXAMPLE OF SENEL CALCULATIONS FOR AIRCRAFT FLYOVER NOISE

Time (Sec.)	A-Level	Antilog	Δt (Sec.)
6.0	66.1		
6.5	66.7		
7.0	67.5		
7.5	70.3		
8.0	73.5		
8.5	74.5		
9.0	74.3		
9.5	77.2	5.24×10^7	0.5
10.0	76.3	4.26 " "	"
10.5	77.9	6.16 " "	"
11.0	81.5	14.12 " "	"
11.5	84.1	25.70 " "	"
12.0	86.4	43.65 " "	"
12.5	88.7	74.13 " "	"
13.0	90.0	100.00 " "	"
13.5	91.4	138.03 " "	"
14.0	91.7	147.91 " "	"
14.5	91.6	144.54 " "	"
15.0	90.7	117.48 " "	"
15.5	89.0	79.43 " "	"
16.0	87.7	58.88 " "	"
16.5	86.4	43.65 " "	"
17.0	84.8	30.19 " "	"
17.5	83.2	20.89 " "	"
18.0	82.0	15.84 " "	"
18.5	80.2	10.47 " "	"
19.0	79.8	9.54 " "	"
19.5	78.6	7.24 " "	"
20.0	76.6	4.57 " "	"

TOTAL = 10 log $(1102.05 \times 10^7) \times 0.5$

= 10 log (551.02×10^7)

SENEL = 97.41 dB

REFERENCES

1. Von Gierke, Henning, "Impact Characterization of Noise Including Implications of Identifying and Achieving Levels of Cumulative Noise Exposure", EPA Aircraft/Airport Noise Report Study, June, 1973, Task Group 3.
2. California Department of Aeronautics, "Noise Standards," California Administrative Code, Chapter 9, Title 4, (Register 70, No. 48, November 28, 1970).

N O T E S

TITLE	HOURLY NOISE LEVEL (HNL) (Hourly Level) (HL) (L_H)
UNIT	dB
DEFINITION	Hourly Noise Level (HNL) is the average (i.e., the average on an energy basis) A-level which exceeds a threshold noise level and is integrated over a time period of one hour.
STANDARDS	California Department of Aeronautics, "Noise Standards," California Administrative Code, Chapter 9, Title 4 (Register 70, No. 48, November 28, 1970).
GEOGRAPHICAL USAGE	State of California
PURPOSE	The purpose of HNL is to provide a single number measure of time varying noise for one hour intervals exceeding a threshold value.

BACKGROUND

HNL was developed at the same time that Community Noise Equivalent Level (CNEL see p.198) was conceived in order to establish measures of noise impact for the State of California.

HNL is implemented by sampling, in A-level, above a predetermined threshold noise level. This threshold, according to the California Administrative Code Title 4, is a noise level which is 10 dB below the numerical value of the appropriate criterion CNEL. The CNEL criterion for airport noise for both existing and proposed civilian airports is effectively 65 dB (for detailed airport noise criteria see California Code Title 4).

HNL is a special case of Equivalent Sound Level (L_{eq}) for an hourly period. It is also a subset of <u>Hourly Level</u> (HL) (L_H). The difference being that HNL is computed from samples over a specified threshold. The difference in results between HNL and HL becomes negligible when there are three or four samples whose levels are more than 10 decibels above the threshold because then these samples become the controlling factor.

CALCULATION METHOD

HNL can be determined by three different methods. (HL can be computed by the same methods by disregarding the sampling threshold limitations.)

1) CONTINUOUS INTEGRATION

For continuous time integration of A-weighted sound level above a specified threshold over one hour, the formula is:

$$HNL = 10 \log \left[\frac{\int_{o}^{3600} \text{antilog } (AL[t]/10) \ dt}{3600 \text{ seconds}} \right] \quad [1]$$

where:

AL[t] is instantaneous A-level in excess of a specified threshold at time t

dt is Δt as it approaches 0

3600 is the number of seconds in one hour

2) TEMPORAL SAMPLING

For discrete sampling of A-weighted sound level above a specified threshold over one hour, the formula is:

$$HNL = 10 \log \left[\frac{\sum_{i=1}^{n} \text{antilog } (AL_i/10)}{n} \right] \quad [2]$$

where:

n is the number of samples of AL in an hour

AL_i is the instantaneous A-level above a specified threshold for sample i

3) EVENT SAMPLING

For measurement of single events, the formula is:

$$HNL = 10 \log \left[\frac{\sum_{i=1}^{n} \text{antilog } (SENEL_i/10)}{3600} \right] \quad [3]$$

where:

n is the number of samples of SENEL events in an hour

SENEL is the integrated level of each event

3600 is the number of seconds in one hour

EXAMPLE

The following examples illustrate only the last two methods of determining HNL. Normally more than three samples would be taken within a one hour period.

A) TEMPORAL SAMPLING

(For a threshold of 65 dB and a one hour period)

Given:

AL_1 = 67 dB

AL_2 = 74 dB

AL_3 = 76 dB

Then:

$$HNL = 10 \log \left[\frac{\text{antilog } \frac{67}{10} + \text{antilog } \frac{74}{10} + \text{antilog } \frac{76}{10}}{3} \right]$$

$$= 10 \log \left[\left(\frac{5.01 + 25.12 + 39.81}{3} \right) \times 10^6 \right]$$

$$= 73.7 \text{ dB}$$

B) EVENT SAMPLING

(A one hour period)

Given:

$SENEL_1 = 79$ dB

$SENEL_2 = 86$ dB

$SENEL_3 = 88$ dB

Then:

$$HNL = 10 \log \left[\frac{\text{antilog } \frac{79}{10} + \text{antilog } \frac{86}{10} + \text{antilog } \frac{88}{10}}{3600} \right]$$

$$= 10 \log \left[\left(\frac{7.94 + 39.81 + 63.09}{3600} \right) \times 10^7 \right]$$

$$= 54.8 \text{ dB}$$

EQUIPMENT

1) Continuous Integration and Temporal Sampling
   a) special monitoring equipment capable of integrating sound levels for one hour
2) Temporal Sampling
   a) for temporal sampling a sound level meter (IEC Standards) may be used if the noise level is continuous with very little variation
3) Event and Temporal Sampling
   a) Sound Level Meter (IEC Standards)
   b) Tape recorder

REFERENCES

1. Von Gierke, Henning, "Impact Characterization of Noise Including Implications of Identifying and Achieving Levels of Cumulative Noise Exposure", EPA Aircraft/ Airport Noise Report Study, June, 1973, Task Group 3.

2. California Department of Aeronautics, "Noise Standards," California Administrative Code, Chapter 9, Title 4 (Register 70, No. 48, November 28, 1970).

NOTES

CHAPTER III

COMMUNICATION INTERFERENCE RATINGS

TITLE	ARTICULATION INDEX (AI)
UNIT	(None)
DEFINITION	The Articulation Index is a numerically calculated measure for predicting speech intelligibility and is based on the proportion of normal speech signal that is available to a listener. The magnitude of the index ranges from 0 to 1.0.
STANDARDS	American National Standards Institute ANSI S3.5-1969 (January 1969).
GEOGRAPHICAL USAGE	United States
PURPOSE	The Articulation Index is used to rate noise environments or communication systems for their effect on speech intelligibility.
BACKGROUND	The Articulation Index is based on the fact that noise masks speech; the more noise present during speech, the lower the speech intelligibility. A signal-to-noise ratio, representing a given speech channel and noise condition, is the basis for determining the normal speech signal that is available to a listener for conveying speech intelligibility. The Articulation

Index has been tested and validated principally against speech intelligibility studies using male speakers, therefore, the same results cannot be assumed for female or children speakers.

There are two methods for computing the Articulation Index which have been standardized. The 20 Band Method (AI-20 band), developed by French and Steinberg, is based upon the signal-to-noise ratio of speech and noise present in each of 20 contiguous frequency bands ranging from 200 to 6100 Hz. These bands (Table AI-I) were specifically chosen so that in the absence of noise the speech components within each band contribute equally to speech intelligibility. Briefly, the value of AI is determined by the corrected sum (in decibels) of the difference between peak speech levels and the noise spectra in each of the 20 corresponding bands. For the exact 20 Band Method note the Standard listed above.

AI can also be computed from the One-third Octave Band (AI-1/3 octave band) and the Octave Band (AI-octave band) Method. These methods differ from the AI - 20 Band Method by requiring that appropriate weighting factors be applied to each one-third or octave band to account for the relative contribution of each band to speech intelligibility. These methods are less accurate than the original AI-20 Band Method but more commonly used as an estimate of speech intelligibility.

TABLE AI - I

20 Frequency Bands of Equal Contribution to Speech Intelligibility

Band No.	Limits (Hz)	Mid-Frequency (Hz)
1	200-330	270
2	330-430	380
3	430-560	490
4	560-700	630
5	700-840	770
6	840-1000	920
7	1000-1150	1070
8	1150-1310	1230
9	1310-1480	1400
10	1480-1660	1570
11	1660-1830	1740
12	1830-2020	1920
13	2020-2240	2130
14	2240-2500	2370
15	2500-2820	2660
16	2820-3200	3000
17	3200-3650	3400
18	3650-4250	3950
19	4250-5050	4650
20	5050-6100	5600

CALCULATION METHOD

The calculation procedure for One-third Octave Bands and Octave Band Methods are outlined in this section. These methods should be adequate for estimating speech intelligibility in most cases except the following:

1) Those instances where the difference between the level of the noise and the threshold of audibility, i.e., sensation level, for an octave or one-third octave band exceeds 84 dB.
2) Sounds which have narrow band components, i.e., tones.
3) Spectra with discrete frequency components or prominent peaks which cause an upward or downward spread in masking (ANSI S3.5).

For these exceptions refer to the ANSI S3.5 Standards for the 20 Band Method.

THE OCTAVE BAND METHOD AND THE ONE-THIRD OCTAVE BAND METHOD

Step 1. Plot on the appropriate work sheets (Fig. AI-1, or AI-2 depending on the filters used) the band pressure levels of the speech peaks reaching the listener's ear. (Figs. AI-1 and AI-2 utilize the preferred frequencies.) The band pressure levels of the speech peaks may be approximated by adding algebraically the frequency response

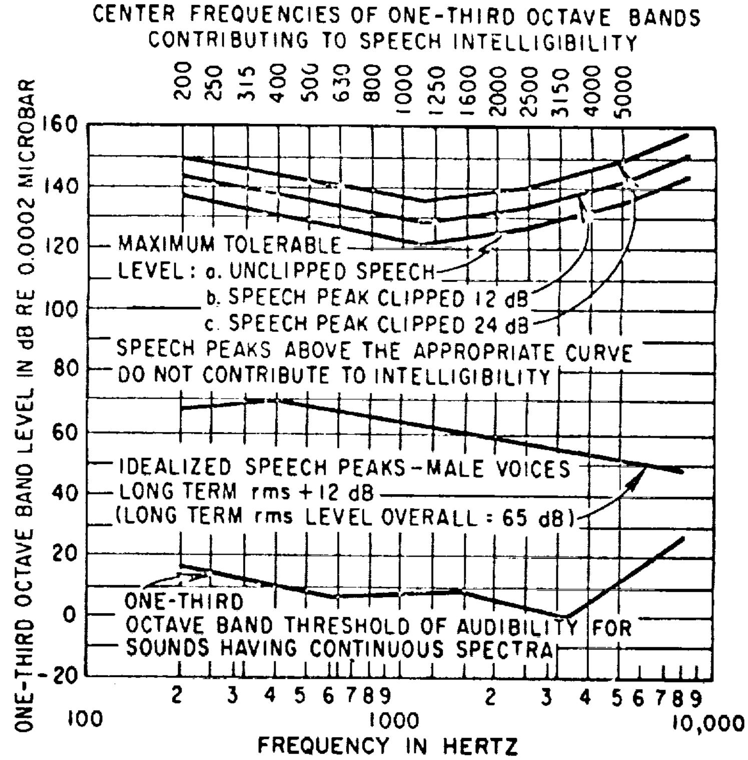
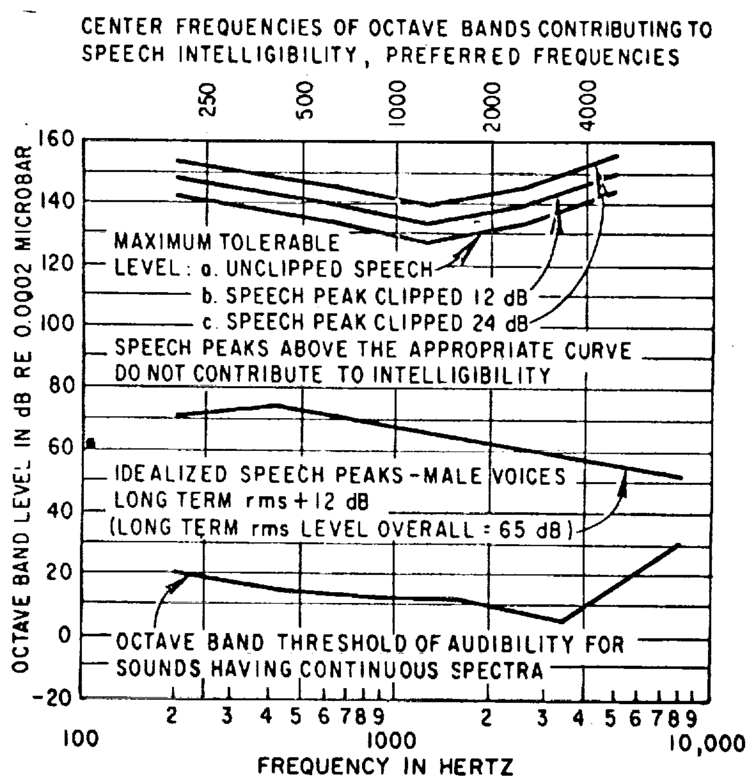


FIGURE AI - 1.
Work Sheet for AI, One-Third Octave Band Method

FIGURE AI - 2.
Work Sheet for AI, Octave Band Method, Preferred Frequencies



characteristics (in decibels) of the system to be evaluated and the idealized spectrum found on the work sheets (Fig. AI-1, or AI-2, or Table V).

The frequency response at each center frequency is the difference in decibels (at that frequency) between the band sound pressure level at the listener's ear and the band sound pressure level at the microphone of the talker. Care should be exercised to ensure that the frequency response properly reflects characteristics of the transmitting and receiving transducer elements of the overall system.

The idealized speech spectrum found on the work sheets (Fig. AI-1, or AI-2, or Table V) should be raised by an amount equal to the difference between the overall long-term rms for speech as measured or estimated and 65 dB, which is the overall long-term rms sound pressure level of the idealized speech spectrum of Fig. AI-1 or AI-2.

In the case of loudspeaker presentation of speech in a non-free-field or non-anechoic room, the speech level should be lowered by the number of decibels indicated in Table AI-II. It should be noted that the correction given in Table AI-II is not to be used for speech presented to listeners via earphones or by a loudspeaker operating in a free field.

TABLE AI - II

Correction for Level of Speech Presented by Loudspeaker in a Reverberant or Semireverberant Room

Overall Level of Speech (dB)	Amount to be Subtracted from Speech Level (dB)
85	0
90	2
95	4
100	7
105	11
110	15
115	19
120	23
125	27
130	30

CALCULATION OF THE ARTICULATION INDEX

TABLE AI - III

Articulation Index Calculation Form for One-Third Octave Bands

Col 1		Col 2	Col 3	Col 4
One-Third Octave Band (Hz)	Center Frequency (Hz)	Speech Peak-to-Noise Difference in dB	Weight	Col 2 x Col 3
180-224	200	______	0.0004	______
224-280	250	______	0.0010	______
280-355	315	______	0.0010	______
355-450	400	______	0.0014	______
450-560	500	______	0.0014	______
560-710	630	______	0.0020	______
710-900	800	______	0.0020	______
900-1120	1000	______	0.0024	______
1120-1400	1250	______	0.0030	______
1400-1800	1600	______	0.0037	______
1800-2240	2000	______	0.0038	______
2240-2800	2500	______	0.0034	______
2800-3550	3150	______	0.0034	______
3550-4500	4000	______	0.0024	______
4500-5600	5000	______	0.0020	______
			AI =	______

NOTE: The idealized spectrum in Figs. AI-1, AI-2, and Table V applies strictly at one meter from the lips of an ideal talker in an essentially non-reverberant, noise-free environment. The shape of the spectrum is reasonably accurate for speech measured from a point one inch to one meter in front of the talker's lips.

Step 2. Plot on the work sheet (Fig. AI-1 or AI-2) the band levels of the steady-state noise reaching the ear of the listener. The rms sound pressures of the noises from several sources, for example, ambient noise in the listener's environment and noise, if any, reaching the listener via the speech transmission system, should be added together.

Step 3. Determine at the center frequency of each of the bands indicated on the work sheet (Fig. AI-1 or AI-2) the difference in decibels between the band pressure level of the speech peaks and the band pressure level of the noise. Whenever the difference is zero or less, assign a value of zero to that difference; whenever the band pressure level of the speech exceeds the band pressure level of the noise by 30 or more decibels, assign a value of 30 to that difference. Write this speech peak-to-noise difference in Column 2 of Table AI-III or AI-IV.

TABLE AI - IV

Articulation Index Calculation Form for Octave Bands—Preferred Frequencies

Col 1		Col 2	Col 3	Col 4
Octave Band (Hz)	Center Frequency (Hz)	Speech Peak-to-Noise Difference in dB	Weight	Col 2 x Col 3
180-355	250	______	0.0024	______
355-710	500	______	0.0048	______
710-1400	1000	______	0.0074	______
1400-2800	2000	______	0.0109	______
2800-5600	4000	______	0.0078	______
			AI =	______

TABLE AI - V

Idealized Speech Spectrum +12 dB (Col a), Spectrum of Effective Threshold of Audibility (Col b), and Maximum Tolerable Level for Unclipped Speech for Sound Having Continuous Spectra (Col c)

(See Fig. AI - 1 and AI - 2)

	Spectrum Level at Mid Frequency of 20 Bands Contributing Equally to Speech Intelligibility with Male Voices				Band Pressure Level at Mid-Frequency of 1/3 Octave Bands				Band Pressure Level at Mid-Frequency of Octave Bands, Non-Preferred Frequencies				Band Pressure Level at Mid-Frequency of Octave Bands, Preferred Frequencies			
	Mid-Frequency (Hz)	a (dB)	b (dB)	c (dB)	Mid-Frequency (Hz)	a (dB)	b (dB)	c (dB)	Mid-Frequency (Hz)	a (dB)	b (dB)	c (dB)	Mid-Frequency (Hz)	a (dB)	b (dB)	c (dB)
1	270	50	−7.0	114	200	67.0	16.0	138	212	71.0	20.0	142	250	72.5	19.0	140
2	330	50.0	−11.0	110	250	68.0	14.0	135	425	75.0	15.0	138	500	74.0	14.0	136
3	490	48.5	−14.0	108	315	69.0	12.0	132	850	69.0	12.0	130	1000	68.0	12.0	129
4	630	45.5	−16.0	105	400	70.0	10.0	131	1700	63.0	11.0	130	2000	62.0	10.0	131
5	770	42.5	−16.0	103	500	68.5	9.0	129	3400	57.0	5.0	138	4000	57.0	10.0	140
6	920	40.0	−16.0	101	630	66.5	7.0	127	6800	52.0	25.0	—	—	—	—	—
7	1070	37.5	−16.0	100	800	65.0	8.0	124	—	—	—	—	—	—	—	—
8	1230	35.0	−17.5	99	1000	64.0	8.5	122	—	—	—	—	—	—	—	—
9	1400	33.0	−19.0	99	1250	62.0	8.5	122	—	—	—	—	—	—	—	—
10	1570	31.5	−20.0	99	1600	60.5	8.5	123	—	—	—	—	—	—	—	—
11	1740	30.5	−22.0	99	2000	59.5	5.5	125	—	—	—	—	—	—	—	—
12	1920	28.5	−23.5	99	2500	58.0	3.0	128	—	—	—	—	—	—	—	—
13	2130	27.0	−25.5	99	3150	56.0	1.0	130	—	—	—	—	—	—	—	—
14	2370	26.0	−27.5	99	4000	53.0	5.0	132	—	—	—	—	—	—	—	—
15	2660	24.5	−29.0	99	5000	51.0	12.0	135	—	—	—	—	—	—	—	—
16	3000	23.0	−30.0	99	—	—	—	—	—	—	—	—	—	—	—	—
17	3400	21.5	−30.0	100	—	—	—	—	—	—	—	—	—	—	—	—
18	3950	20.0	−29.0	101	—	—	—	—	—	—	—	—	—	—	—	—
19	4650	19.0	−24.0	103	—	—	—	—	—	—	—	—	—	—	—	—
20	5600	18.0	−21.0	105	—	—	—	—	—	—	—	—	—	—	—	—

NOTES: (1) The threshold of audibility curve, in Figs. AI-1 and AI-2, or Table V is to be considered as the minimum equivalent noise band level wherever the threshold curve exceeds the noise band level.
(2) Wherever the speech peak curve exceeds the appropriate maximum tolerable level (specified in Figs. AI-1 and AI-2, or Table V), the speech peaks should be considered to be at the maximum tolerable level.

Step 4. Multiply the values for the respective bands found in Step 3, according to weighting factors in Column 3 of Table AI-III or AI-IV.

Step 5. Sum Column 4 on Table AI-III or AI-IV. The resulting number is the AI for that particular speech system operating under the noise conditions and for the speech level specified.

EXAMPLE

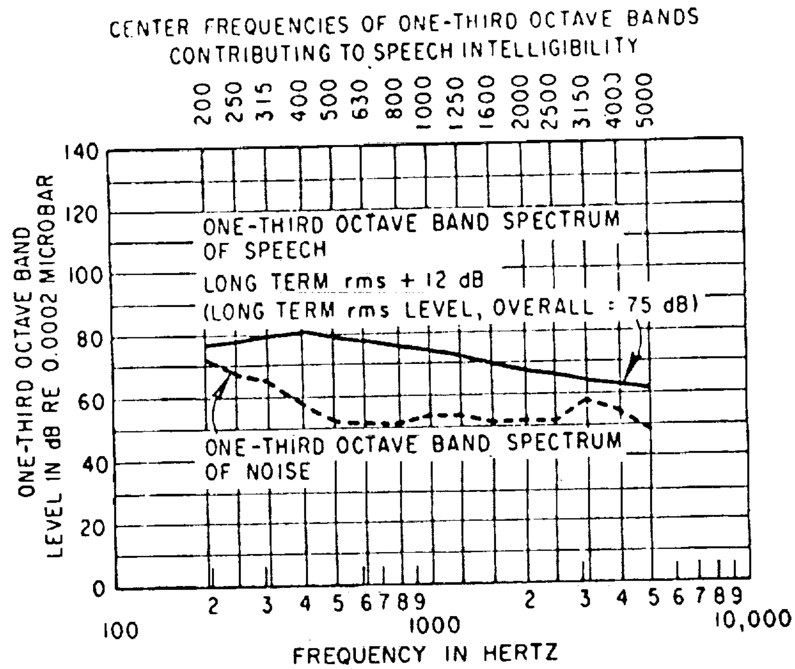
Examples of the calculation of an AI by the One-Third Octave and Octave Band Methods are given in Figs. AI-3 and AI-4. The AI by the One-Third Octave Band Method is 0.53, and the AI by the Octave Band Method is 0.54 (from ANSI S3.5).

EQUIPMENT

1) Tape recorder (necessary for single events)
2) Sound level meter (IEC Standard)
3) Octave or 1/3 Octave band analyzer
4) Digital computer (optional)
5) Adjustable variable band pass filter (AI - 20 Band Method)

FIGURE AI - 3.

Example of the Calculation of an AI by the One-Third Octave Band Method



BAND cf	SPEECH PEAKS MINUS NOISE-dB	WEIGHT	CL 2 x 3
200	4	0.0004	0.0016
250	10	0.0010	0.0100
315	13	0.0010	0.0130
400	24	0.0014	0.0336
500	26	0.0014	0.0364
630	26	0.0020	0.0520
800	24	0.0020	0.0480
1000	21	0.0024	0.0504
1250	18	0.0030	0.0540
1600	18	0.0037	0.0666
2000	15	0.0037	0.0555
2500	15	0.0034	0.0510
3150	6	0.0034	0.0204
4000	8	0.0024	0.0192
5000	12	0.0020	0.0240
		AI = 0.5357	

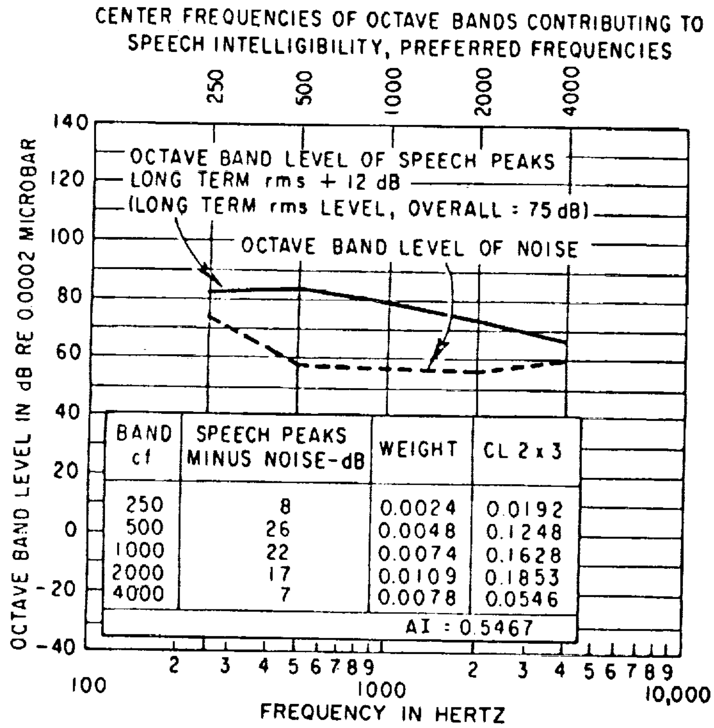


FIGURE AI - 4.

Example of the Calculation of an AI by the Octave Band Method, Preferred Frequencies

REFERENCES

1. Acoustical Society of America, "American National Standard Methods for the Calculation of the Articulation Index", Am. Nat. Stds. Instit. S3.5-1969, January 1969.
2. French, N. R., and J. C. Steinberg, "Factors Governing the Intelligibility of Speech Sounds", J. Acoust. Soc. Am. 19: 90-119 (1957).
3. Kryter, Karl D., The Effects of Noise on Man, Academic Press, New York, 1970.

TITLE	SPEECH INTERFERENCE LEVEL (SIL)
UNIT	dB
DEFINITION	The Speech Interference Level is a simplified method of quantifying noise in terms of its interfering effect on speech communication. It is calculated from the arithmetic average of the sound pressure levels of specified octave bands within the speech frequency range.
STANDARDS	[Both ANSI and ISO are in the process of writing standards for an approved form of SIL]
GEOGRAPHICAL USAGE	International
PURPOSE	SIL was developed as a simplified substitute for the Articulation Index (AI) for which certain voice levels were assumed. It was developed initially to evaluate the effects of aircraft noise on passenger communication during flight.

BACKGROUND

SIL essentially measures only the noise background and estimates from a table (Table SIL-I) or figure the noise level which will effect communication. The principal variables that are taken into consideration for speech intelligibility are the general voice level and distance between communicators.

SIL is an arithmetic average of octave bands in the speech frequency range. It initially included octave bands 600-1200 Hz., 1200-2400 Hz. and 2400-4800 Hz. With the advent of preferred frequencies for octave bands, the old octave bands were estimated from plots of new frequency band data. Later, *preferred* speech interference level (PSIL) was introduced which used 500, 1000, and 2000 Hz. octave bands. Currently proposed standards for SIL include 500, 1000, 2000, and 4000 Hz. octave bands (4 Band Method). To interpret SIL scores, graphs or tables (Table SIL-I) are used to indicate conversing distance over which speech is satisfactorily intelligible (AI=0.4).

The SIL scale gives a reasonably accurate estimate of the relative ranking of steady state noises with respect to their speech-interfering qualities. The SIL procedure is not very appropriate however for evaluating the speech-interfering quality of noise with considerably more energy at high frequencies

TABLE SIL-I

RELATIONS AMONG SIL, VOICE EFFORT, AND BACKGROUND NOISE*

Distance between talker and listener, ft (m)	Speaker's Voice Effort			
	Normal	Raised	Very loud	Shouting
	SIL, dB	SIL, dB	SIL, dB	SIL, dB
0.5 (0.15)	73	79	85	91
1 (0.3)	67	73	79	85
2 (0.6)	61	67	73	79
4 (1.2)	55	61	67	73
6 (1.8)	51	57	63	69
12 (3.7)	45	51	57	63

*Corresponding to an articulation index of about 0.40.

than at low frequencies. It is also of limited usefulness under any of the following conditions: 1) the noise is not relatively steady state in its characteristics; 2) the frequency spectrum of the noise is not smooth; and 3) the speech and noise are subject to perceptible echo or reverberation.

CALCULATION METHOD

The SIL is the arithmetic average of the sound pressure levels of the noise in the four octave bands (4 Band Method) with center frequencies lying between 500 and 4000 Hz.

EXAMPLE

Table SIL-II shows an example of SIL calculation for octave band background noise data.

TABLE SIL-II

EXAMPLE OF CALCULATIONS OF SIL FROM OCTAVE BAND LEVELS (4 BAND METHOD)

Octave Band Center Frequency Hz	Background Noise (dB)	Background Noise for Speech Frequency Band (dB)
63	63	
125	61	
250	60	
500	62	62
1000	60	60
2000	55	55
4000	45	45
8000	40	
		TOTAL = 222

$$SIL = \frac{222}{4} = 55.5 \text{ dB}$$

The resulting SIL value of 55.5 dB allows speech communication at a normal voice level for a distance of approximately 4 feet (from Table SIL-I).

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Octave band analyzer

REFERENCES

1. Beranek, Leo, and H. W. Rudmose, "Sound Control in Airplanes", Jr. of the Acoustical Society of America, March, 1947, v. 19, no. 2, 357-364.
2. Beranek, Leo, Noise and Vibration Control, McGraw-Hill Co., New York, 1971.
3. Burns, William, Noise and Man, J. B. Lippincot Co., Phil., 1968.
4. Webster, J. C., "Effects of Noise on Speech Intelligibility", from "Noise as a Public Health Hazard", Proceedings of Conference, American Speech and Hearing Assoc., Washington, D. C., February, 1969.

N O T E S

TITLE	NOISE CRITERION CURVES (NC)
UNIT	(None) [dB like scale]
DEFINITION	Noise Criterion Curves are sets of octave band levels (as shown in Figure NC-1; Table NC-I) which were established to provide a single number rating for octave band spectra.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United States
PURPOSE	NC-curves are used in setting specifications of acceptable ambient noise levels in various indoor environments. It is commonly used for rating noise in offices, auditoriums, sound studios, and restaurants. Table NC-II lists some suggested noise criteria for different types of activity areas.

BACKGROUND

The Noise Criterion rating method was developed from extensive interviews and noise measurements of various office environments. Initially the NC curves were known as *speech communication* (SC) criterion. The NC measure has been primarily used since its introduction in 1957 in architectural acoustics. This measure specifies a single number rating number (i.e., NC-50) which is assigned to a curve of octave-band sound pressure levels. When the noise level in a given architectural space is measured in the required octave bands of frequency, the sound levels should not exceed the NC rating curve recommended for a communication environment (Table NC-II and NC-III).

The NC method is based both on the Speech Interference Level (SIL) and the Loudness Level (LL) measures. The NC curves are drawn (Figure NC-1) such that computed LL for each curve is 22 dB (phons) higher than the SIL. The NC number (e.g., NC-30) which is assigned to each curve reflects the SIL value which is obtained from an average of the levels in the appropriate octave bands.

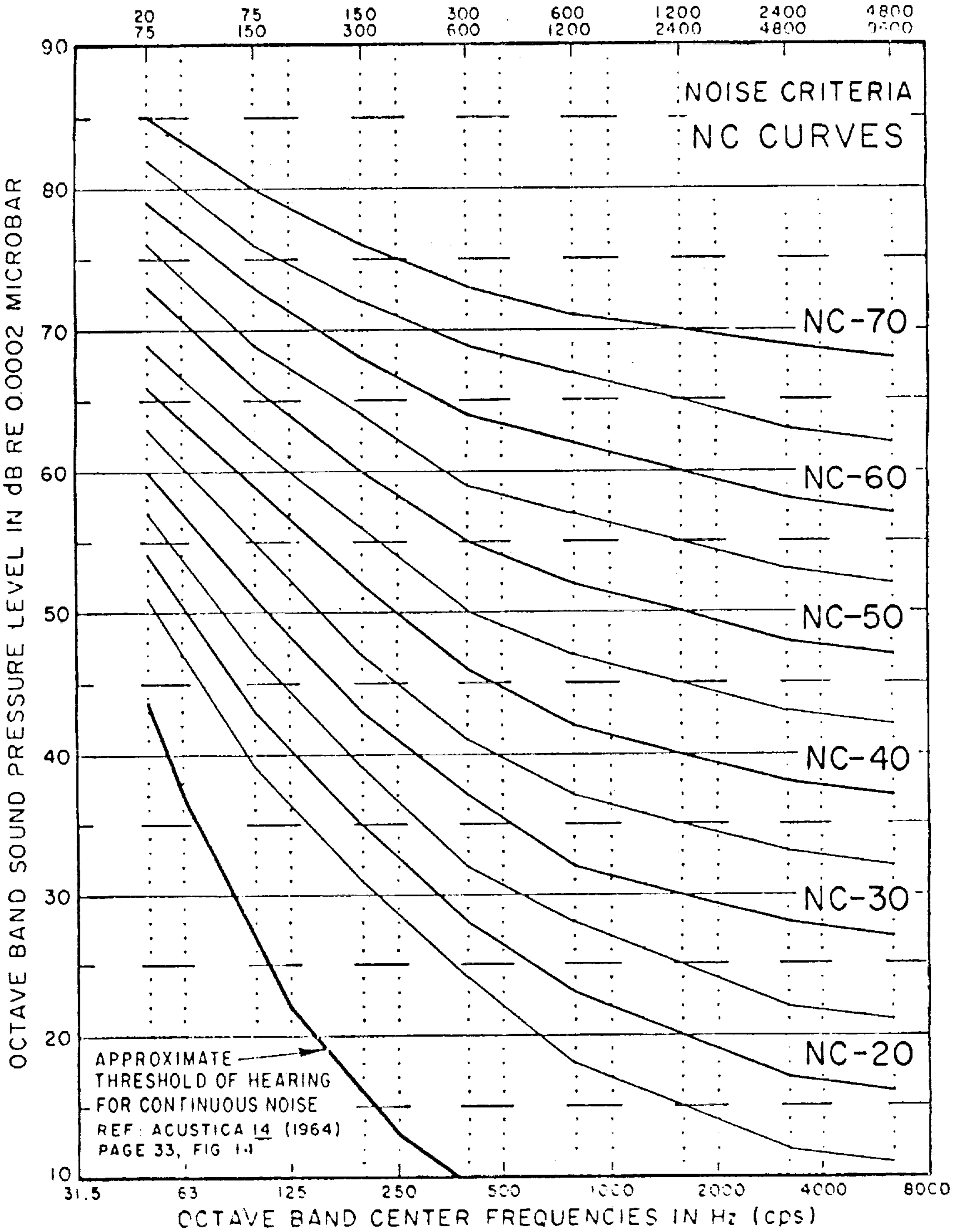


FIGURE NC-1 NOISE CRITERIA CURVES

TABLE NC-I

OCTAVE-BAND SOUND-PRESSURE LEVELS ASSOCIATED WITH THE 1957 NOISE CRITERION (NC) CURVES OF FIG. NC-1*

1957 noise criterion curves	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz
NC-15	47	36	29	22	17	14	12	11
NC-20	51	40	33	26	22	19	17	16
NC-25	54	44	37	31	27	24	22	21
NC-30	57	48	41	35	31	29	28	27
NC-35	60	52	45	40	36	34	33	32
NC-40	64	56	50	45	41	39	38	37
NC-45	67	60	54	49	46	44	43	42
NC-50	71	64	58	54	51	49	48	47
NC-55	74	67	62	58	56	54	53	52
NC-60	77	71	67	63	61	59	58	57
NC-65	80	75	71	68	66	64	63	62

*Beranek (1971)

TABLE NC-II

RECOMMENDED NOISE CRITERION FOR OFFICES*

NC Curve NC units	Communication Environment	Typical Applications
20-30	Very quiet office—telephone use satisfactory—suitable for large conferences	Executive offices and conference rooms for 50 people
30-35	"Quiet" office; satisfactory for conferences at a 15-ft table; normal voice 10 to 30 ft; telephone use satisfactory	Private or semiprivate offices, reception rooms and small conference rooms for 20 people
35-40	Satisfactory for conferences at a 6- to 8-ft table; telephone use satisfactory; normal voice 6 to 12 ft	Medium-sized offices and industrial business offices
40-50	Satisfactory for conferences at a 4- to 5-ft table; telephone use occasionally slightly difficult; normal voice 3 to 6 ft; raised voice 6 to 12 ft	Large engineering and drafting rooms, etc.
50-55	Unsatisfactory for conferences of more than two or three people; telephone use slightly difficult; normal voice 1 to 2 ft; raised voice 3 to 6 ft	Secretarial areas (typing) accounting areas (business machines), blueprint rooms, etc.
Above 55	"Very noisy"; office environment unsatisfactory; telephone use difficult	Not recommended for any type of office

*Beranek (1960)

TABLE NC-III

RECOMMENDED NOISE CRITERION FOR ROOMS*

Type of Space	Recommended NC Curve NC units	Computed Equivalent SLM Readings Weighting Scale A
Broadcast studios	15–20	25–30
Concert halls	15–20	25–30
Legitimate theaters (500 seats, no amplification)	20–25	30–35
Musicrooms	25	35
Schoolrooms (no amplification)	25	35
Television studios	25	35
Apartments and hotels	25–30	35–40
Assembly halls (amplification)	25–35	35–40
Homes (sleeping areas)	25–35†	35–45†
Motion-picture theaters	30	40
Hospitals	30	40
Churches (no amplification)	25	35
Courtrooms (no amplification)	25	30–35
Libraries	30	40–45
Restaurants	45	55
Coliseums for sports only (amplification)	50	60

*Beranek (1960)

Approximate A-levels are given in Table NC-III which are computed from the appropriate NC curves. This listing is for comparison purposes only. It is not recommended that dB(A) readings be substituted for the NC ratings in determining specifications for a noise situation. However, if A-level should be used to estimate the noise environment suggested by an NC rating, the A-level reading from Table NC-III should be reduced by about 5 dB.

NOISE CRITERION ALTERNATE (NCA) CURVES

When estimation of the levels of the acoustical environment and the effects of the low-frequency noise is less critical (i.e., a storage room versus an auditorium), NCA ratings are often used. They are applied in situations which dictate a compromise between the quality of the acoustical environment and economical considerations.

Like the NC curves, the NCA measure takes into account the SIL and the LL. For the NCA curves (Figure NC-2), the LL-SIL difference is limited to 30 dB (phons) above the NCA value. This means there might be complaints whenever the LL-SIL difference

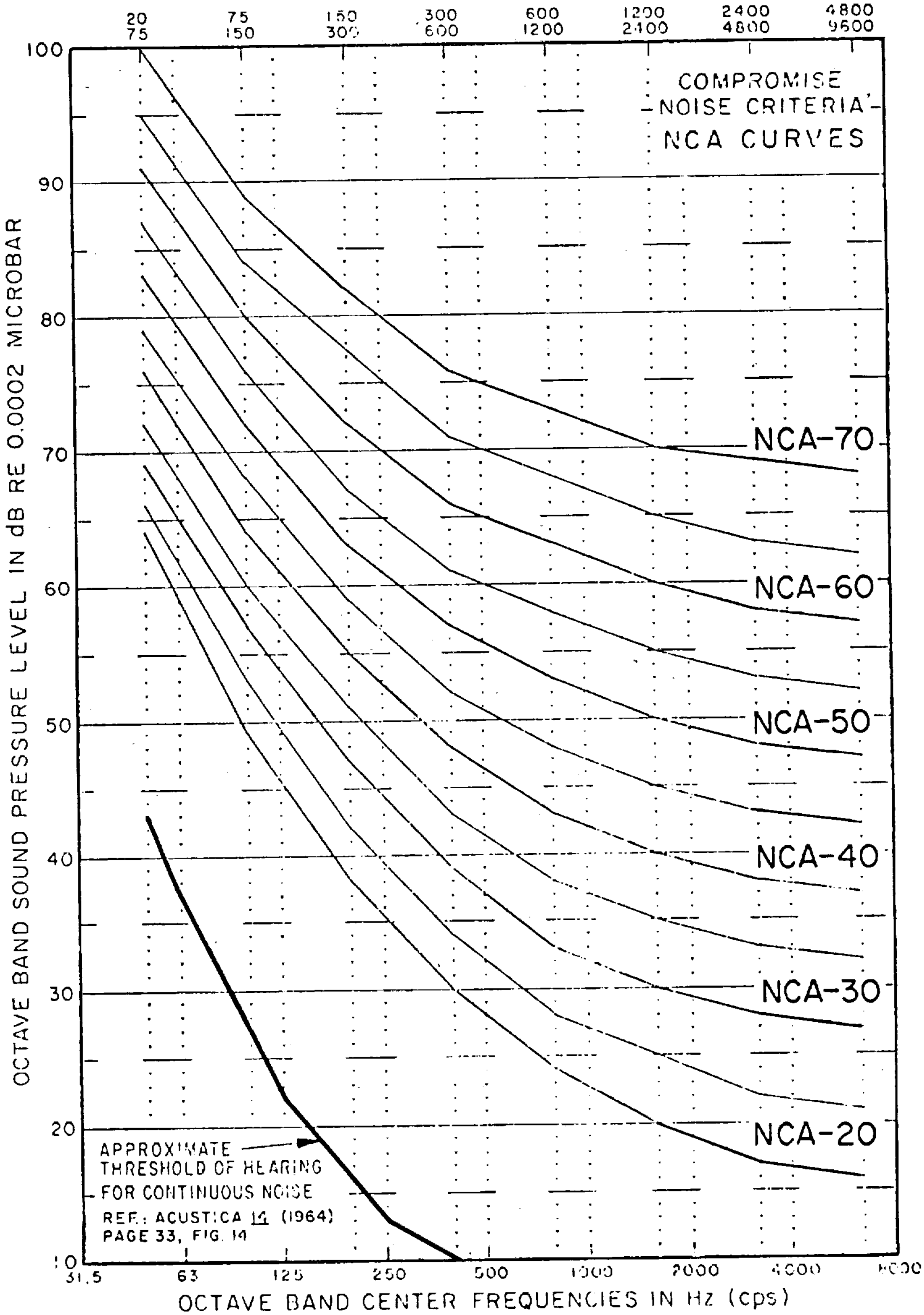


FIGURE NC-2. NOISE CRITERIA A (NCA) CURVES exceeds 30 dB (phons). In some office noise situations there are objections when the low frequency levels of a noise exceed the value given by the NCA curves, even though the recommended SIL is low enough to allow for satisfactory speech communication. Substantial objections also arise whenever there are low-frequency noise fluctuations or beats between the low frequency components. It is therefore recommended that the NCA curves only be applied in an industrial noise situation.

CALCULATION METHOD

Noise Criterion (NC) curves as shown in Figure NC-1 and the equivalent numbers in Table NC-I are applied to steady state noises to enable the architect to specify the maximum noise levels permitted in each octave band for a specified NC curve. A NC value is assigned to the spectrum of noise to be evaluated corresponding to the highest NC curve to which the spectrum is anywhere tangent. Thus, the NC rating is almost always determined by the sound pressure level at a single octave band frequency.

EXAMPLE

In order to determine the NC rating of a given noise, it is necessary to measure the sound pressure level in each octave band for a given spectrum. Table NC-IV contains the example numerical values.

TABLE NC-IV

NC RATING FROM OCTAVE BAND LEVELS

Band Center Frequency Hz	Background Noise (dB)
63	63
125	61
250	60
500	62
1000	60
2000	55
4000	45
8000	40

Given the octave band values shown in Table NC-IV and plotted in Figure NC-3, the NC rating is NC-59. This can be determined by the level in the fourth band (500 Hz) which is 1 dB less than the NC-60 curve.

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Octave Band Analyzer

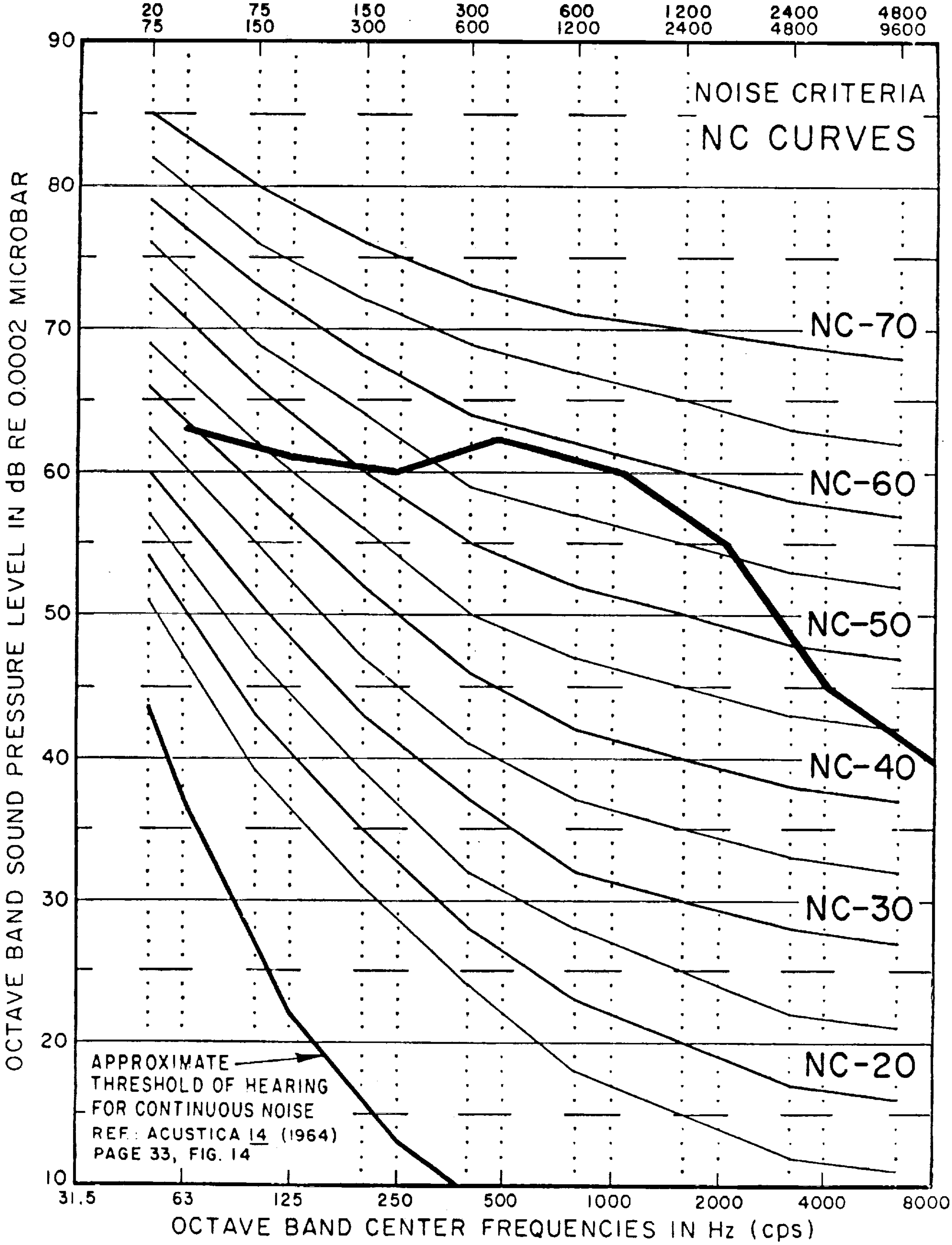


FIGURE NC-3. NOISE CRITERIA CURVES (NC) WITH NOISE SPECTRUM EXAMPLE

REFERENCES

1. Beranek, Leo L., Noise Reduction, McGraw-Hill Publisher, New York, 1960.
2. Beranek, Leo L., "Noise and Vibration Control", McGraw-Hill, (1971).
3. Peterson, Arnold, and E. E. Gross, Jr. "Handbook of Noise Measurement", General Radio Company, (1972).

TITLE	PREFERRED NOISE CRITERION (PNC)
UNIT	(None) [dB like scale]
DEFINITION	Preferred Noise Criterion (PNC) curves are sets of octave band levels (as shown in Figure PNC-1, Table PNC-I) which were established to provide a single number rating for octave band spectra.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United States
PURPOSE	PNC-curves are revisions of NC-curves and are used for similar situations in rating the noise environments for offices, auditoriums, sound studios, and restaurants. Table PNC-II lists some suggested noise criteria for different types of activity areas.

BACKGROUND

After years of practical experience with the Noise Criterion (NC) method, certain improvements were desired. The 1971 Preferred Noise Criterion (PNC) curves were developed in answer to the many objections made about the adequacy of the NC curves. Four of the most notable criticisms were:

1) The NC curves were not properly adapted from the old octave-frequency bands (where the low is 20-75 Hz) to the new preferred frequencies (which centered on 31.5 and 63 Hz).

2) Preferred Speech Interference Level (PSIL) was introduced and was based on the levels in new preferred bands centered at 500, 1000, and 2000 Hz.

3) The NC curves did not conform well to the more recent data on the threshold of hearing for a continuous noise.

4) The shape of the 1957 NC curves did not adequately compensate for tone reproduction in an architectural space.

In order to improve upon this method for evaluating tonal quality in a noise situation, the PNC curves were changed in the low and high frequencies. This effectively eliminated the "hissy" and "rumbly" sound associated with a shaped noise spectrum equal in octave-band levels to a particular

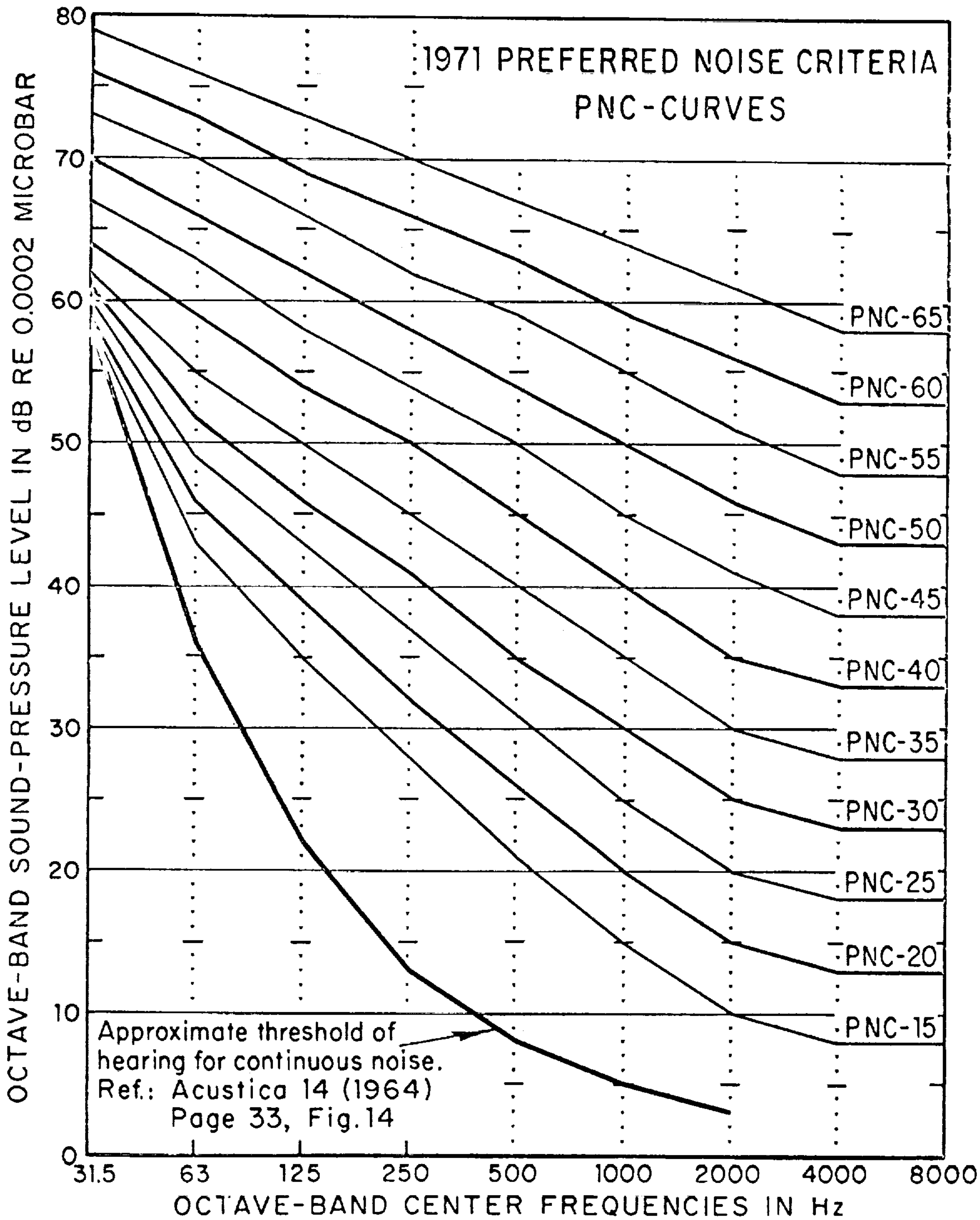


FIGURE PNC-1. PREFERRED NOISE CRITERIA CURVES (1971)

TABLE PNC-I

PNC OCTAVE-BAND SOUND-PRESSURE-LEVEL VALUES ASSOCIATED WITH THE 1971 PREFERRED NOISE CRITERION (PNC) CURVES OF FIG. PNC-1*

Preferred noise criterion curves	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz
PNC-15	58	43	35	28	21	15	10	8	8
PNC-20	59	46	39	32	26	20	15	13	13
PNC-25	60	49	43	37	31	25	20	18	18
PNC-30	61	52	46	41	35	30	25	23	23
PNC-35	62	55	50	45	40	35	30	28	28
PNC-40	64	59	54	50	45	40	36	33	33
PNC-45	67	63	58	54	50	45	41	38	38
PNC-50	70	66	62	58	54	50	46	43	43
PNC-55	73	70	66	62	59	55	51	48	48
PNC-60	76	73	69	66	63	59	56	53	53
PNC-65	79	76	73	70	67	64	61	58	58

*Beranek (1971)

TABLE PNC-II

PNC NOISE CRITERIA

RECOMMENDED CATEGORY CLASSIFICATION AND SUGGESTED NOISE CRITERIA RANGE FOR STEADY BACKGROUND NOISE AS HEARD IN VARIOUS INDOOR FUNCTIONAL ACTIVITY AREAS*

Type of space (and acoustical requirements)	PNC curve	Approximate L_A, dBA
Concert halls, opera houses, and recital halls (for listening to faint musical sounds)	10 to 20	21 to 30
Broadcast and recording studios (distant microphone pick-up used)	10 to 20	21 to 30
Large auditoriums, large drama theaters, and churches (for excellent listening conditions)	Not to exceed 20	Not to exceed 30
Broadcast, television, and recording studios (close microphone pickup only)	Not to exceed 25	Not to exceed 34
Small auditoriums, small theaters, small churches, music rehearsal rooms, large meeting and conference rooms (for good listening), or executive offices and conference rooms for 50 people (no amplification)	Not to exceed 35	Not to exceed 42
Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels, etc. (for sleeping, resting, relaxing)	25 to 40	34 to 47
Private or semiprivate offices, small conference rooms, classrooms, libraries, etc. (for good listening conditions)	30 to 40	38 to 47
Living rooms and similar spaces in dwellings (for conversing or listening to radio and TV)	30 to 40	38 to 47
Large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc. (for moderately good listening conditions)	35 to 45	42 to 52
Lobbies, laboratory work spaces, drafting and engineering rooms, general secretarial areas (for fair listening conditions)	40 to 50	47 to 56
Light maintenance shops, office and computer equipment rooms, kitchens, and laundries (for moderately fair listening conditions)	45 to 55	52 to 61
Shops, garages, power-plant control rooms, etc. (for just acceptable speech and telephone communication). Levels above PNC-60 are not recommended for any office or communication situation	50 to 60	56 to 66
For work spaces where speech or telephone communication is not required, but where there must be no risk of hearing damage	60 to 75	66 to 80

*Beranek (Ref. 2)

NC curve. The PNC values were made about 1 dB lower than the NC curves in the four octave bands at 125, 250, 500 and 1000 Hz for the same curve rating numbers. In the 63 Hz band the levels were 4 or 5 dB lower and there was a reduction in level in the highest three bands of 4 or 5 dB. Because of the steep slope of the PNC curves, the levels in the highest three frequency bands were much lower than at the midfrequencies.

The PNC method takes into consideration both the Preferred Speech Interference Level (PSIL) and Loudness Level (LL). The curve number (i.e., PNC-30) reflects the PSIL value for the sound pressure levels at the 500, 1000 and 2000 Hz octave bands. The PNC curves at the two frequency bands 4000, and 8000 Hz were flattened off to conform with the latest equal-loudness contour data.

Approximate A-levels are given (Table PNC-II) which are computed from the appropriate PNC curves. This listing is for comparison purposes only. It is not recommended that dB(A) readings be substituted for the PNC ratings in determining specifications for a noise situation. The same A-level reading may be obtained for a wide variety of shapes of spectra. Furthermore, it is important that the engineer or architect know the levels in the eight octave bands in order to make the necessary noise control design recommendations. However, if A-level should be used to estimate the noise environment suggested by a PNC rating, the A-level reading from Table PNC-II should be reduced by about 3 to 5 dB.

CALCULATION METHOD

The Preferred Noise Criterion (PNC) curves are applied in the same manner as the NC curves. Table PNC-I has the number equivalents corresponding to the PNC curves in Figure PNC-1. A spectrum level of a room, for example, is assigned a PNC rating depending on its tangential relationship to the highest PNC curve. Thus, the PNC rating may be determined by the sound pressure level at a single octave band frequency.

EXAMPLE

The first step in determining the PNC rating for a given noise is to measure the noise levels in each octave band for the noise spectrum. Table PNC-III contains the necessary numerical values.

TABLE PNC-III

OCTAVE BAND LEVELS USED IN CALCULATING PNC RATING

Band Center Frequency Hz	Background Noise (dB)
63	63
125	61
250	60
500	62
1000	60
2000	55
4000	45
8000	40

In Figure PNC-2 a plot of the noise spectrum on the family of PNC curves, shows that for this noise the PNC rating is PNC-61. This can be determined by the level in the fifth band (1000 Hz) which is 1 dB more than the NC-60 curve.

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Octave Band Analyzer

REFERENCES

1. Beranek, Leo L., "Noise and Vibration Control", McGraw-Hill, (1971).
2. Beranek, Leo L., Warren E. Blazier, and J. Jacek Figwer, "Preferred Noise Criterion (PNC) Curves and Their Application to Rooms," Jr. of Acoust. Society of America, v. 50, no. 5 (part 1, Nov. 1971, p. 1223.

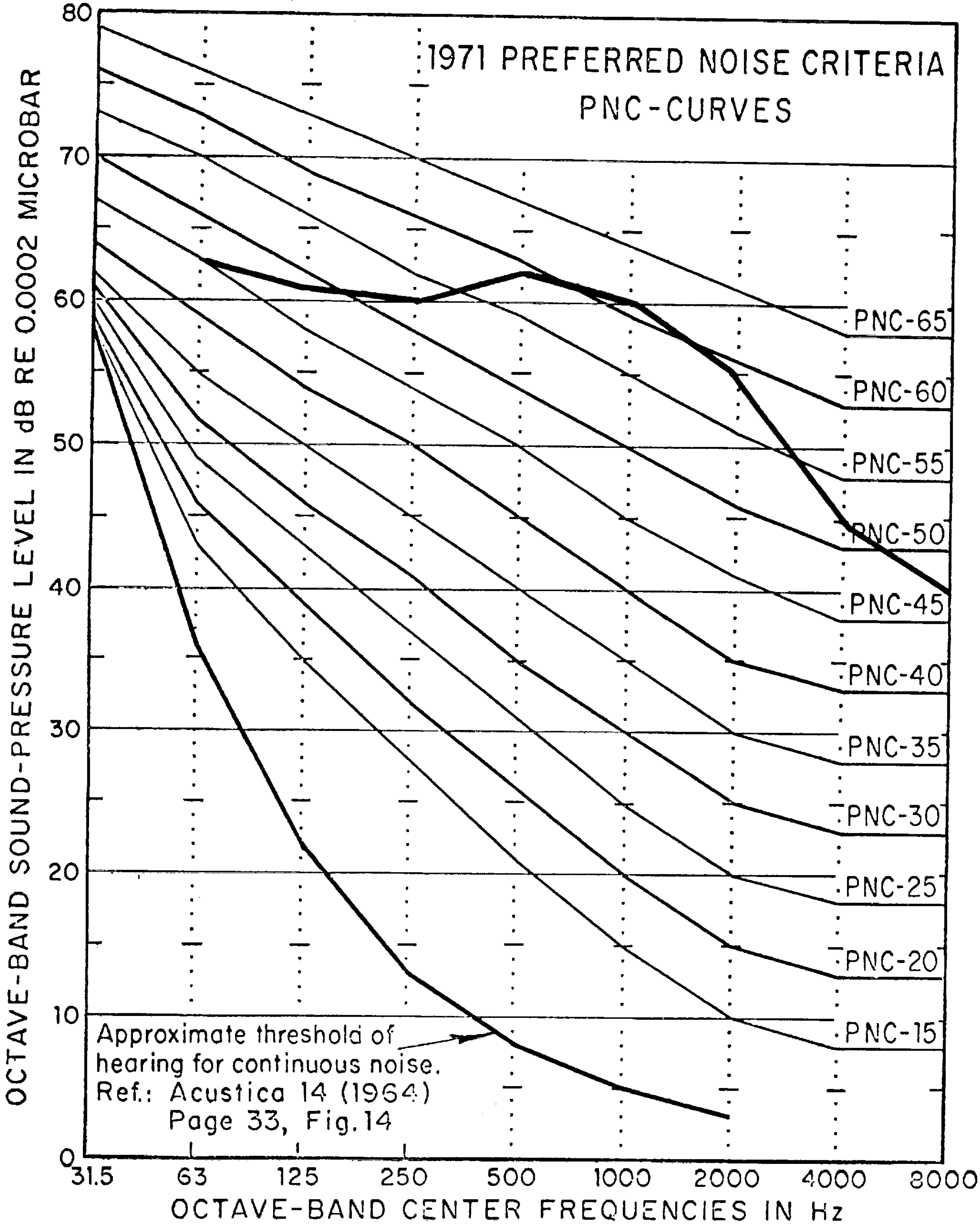


FIGURE PNC-2. PNC CURVES WITH NOISE SPECTRUM EXAMPLE

N O T E S

CHAPTER IV

COMMUNITY RESPONSE RATINGS

NOTES

TITLE	COMPOSITE NOISE RATING (CNR_C) For Community Noise
UNIT	(None) [quantity is expressed by a "letter" in 5 dB increments]
DEFINITION	The Composite Noise Rating is a measure which uses octave band sound pressure level data with appropriate corrections for spectral characteristics, background noise interference, and time of day.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United States
PURPOSE	CNR_C is used to assess the influence of various noise sources such as traffic, industrial noise, as well as aircraft noise on the community.

BACKGROUND

The Composite Noise Rating (CNR_C) was the first attempt at evaluating community reaction to noise (1952). In the determination of community response it is assumed that the spectra of the noise are given as sound pressure levels in octave bands of frequency, and that these values are obtained by averaging (on an *energy* basis) over a reasonable time interval and over a reasonable number of locations in the community.

Figure CNR_C-1 shows a family of curves that define the *noise level rank*. The ranks are designated by the letter *a* to *m* in ascending order. Each rank denotes the *zone* between two neighboring curves, i.e., *c* - zone, *d* - zone, etc.

To determine the level rank of a noise the measured or calculated octave band spectrum would be superimposed onto Figure CNR_C-1. The noise level rank for the community noise is given by the highest zone into which the spectrum protrudes.

The final CNR_C is the level rank modified by six correction factors for: 1) discrete frequency components, 2) impulsive nature of the sound, 3) repetitiveness of the sound, 4) background noise level in the community, 5) effect of the time of day, and 6) previous community exposure to the noise.

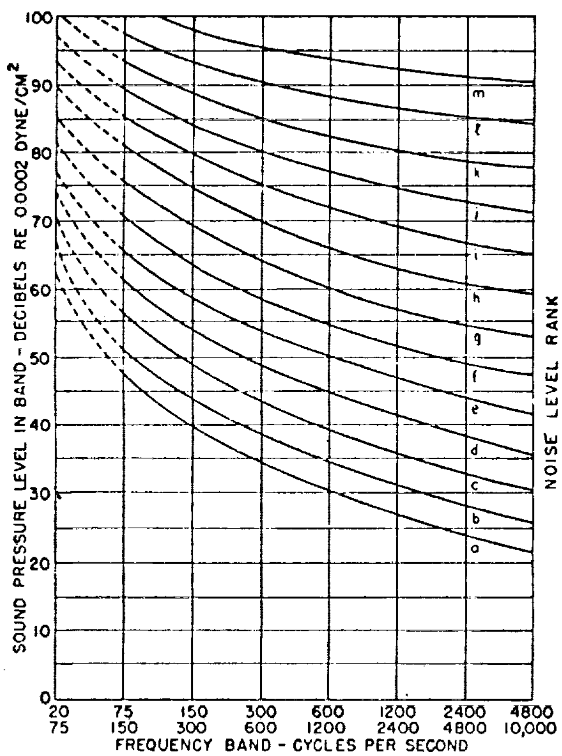


FIGURE CNR$_C$-1. Family of curves used to determine the noise level rank.

Predicting community reaction to a noise source originally depended upon each of the following six categories corresponding to the CNR_C rating. These six descriptors are: 1) no annoyance, 2) mild annoyance, 3) mild complaints, 4) strong complaints, 5) threats of legal action, and 6) vigorous legal action. They were originally derived from extensive previous experience with community noise response and a series of eleven case histories in which measures of noise level and its operation were correlated with the community reaction.

Stevens, Rosenblith, and Bolt later developed a modification of the 1952 CNR (Ref. 3). The changes were in the extension of the range of consideration for background noise levels to encompass a range of +10 to -15 dB; the correction for repetitiveness from the number of 20-30 second events to the percentage of time a noise source operated in an 8-hour period; and an adjustment was made for seasonal influence on noise. For example, if the source operated only in the wintertime a reduction of -5 dB in the effective noise stimulus was permitted.

The most notable distinction between the two schemes was a change in the description of community response. In the earlier study six descriptors with the words *annoyance* and *legal action* were used. In this publication the scale of response was reduced to the following five descriptors: 1) no observed reaction, 2) sporadic complaints, 3) widespread complaints, 4) threats of community reaction, and 5) vigorous community reaction.

CALCULATION METHOD

In order to calculate CNR_C, the octave band sound pressure levels of the intruding noise source are determined from measurements or estimation. These levels may be plotted on Figure CNR_C-1 to derive a level rank letter. This level rank is adjusted according to the community information and the procedure outlined in Table CNR_C-I (Table CNR_C-II, Figure CNR_C-2, 3).

To illustrate, for a level rank of letter *f* a -2 adjustment would decrease the level rank to *d* which conveniently changes to capital *D* as the descriptor of CNR_C. Community response for this illustration is estimated by the CNR_C value of *D* which when read from the graph in Figure CNR_C-4 would lead to expected responses from a community somewhere in the range of "sporadic" and "widespread" complaints.

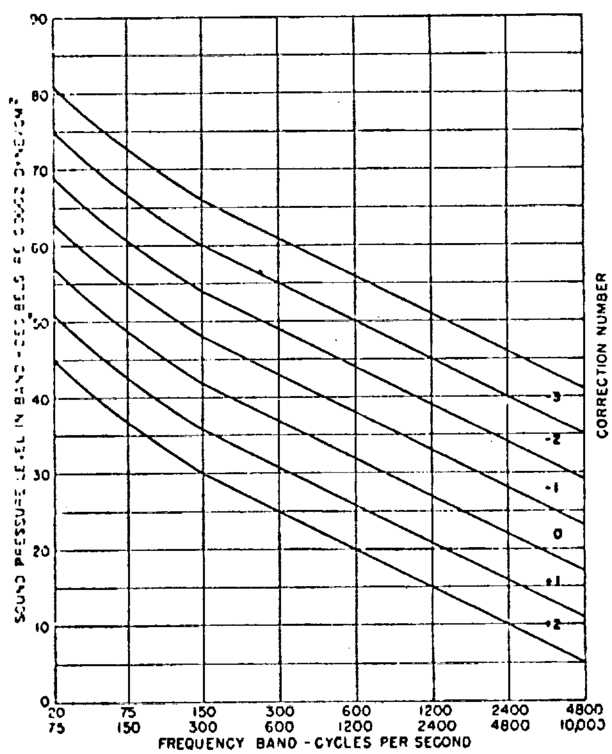


FIGURE CNR$_C$-2. Family of curves used to determine the correction number for background noise.

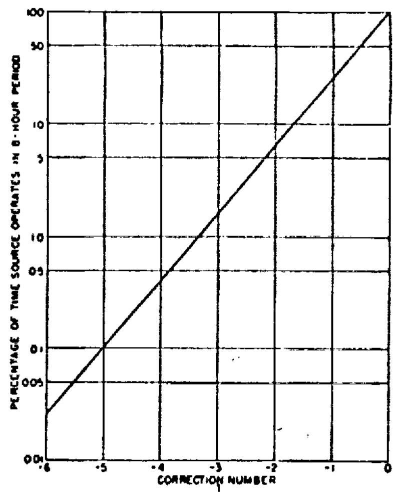


FIGURE CNR$_C$-3. Proposed correction numbers for repetitiveness of the noise when the source operates on a reasonably regular daily schedule.

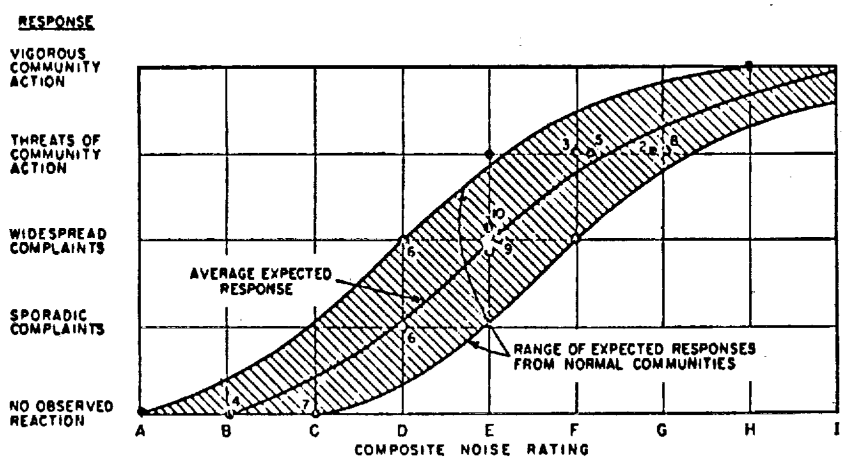


FIGURE CNR_C-4. The wide curve shows the range of responses that can be expected from communities exposed to noises of increasing severity.

TABLE CNR_C-I

LIST OF CORRECTION NUMBERS TO BE APPLIED TO NOISE LEVEL RANK TO GIVE CNR_C

Influencing Factor	Correction Number
1. Background noise (see Fig. CNR-2 on Table CNR-II)	+2 to -3
2. Temporal and seasonal factors	
a. Daytime only	-1
Nighttime	0
b. Repetitiveness (see Fig. CNR-3)	0 to -6
c. Winter	-1
Summer	0
3. Detailed description of the noise	
a. Continuous spectrum	0
Pure-tone components	+1
b. Smooth time character	0
Impulsive	+1
4. Previous Exposure	
None	0
Some	-1

TABLE CNR_C-II

CORRECTIONS FOR BACKGROUND NOISE

Neighborhood	Correction Number
Very quiet suburban	+1
Suburban	0
Residential urban	-1
Urban near some industry	-2
Area of heavy industry	-3

EXAMPLE

Table CNR_C-III provides octave band noise levels in a suburban community resulting from a factory that plans to operate continuously at night from 8:00 p.m. to 10:00 p.m. Also shown are background levels without the factory operating. Time of year is summer. The noise is impulsive and contains a whine (pure tone).

TABLE CNR_C-III

Octave Frequency Band Hz	Factory Noise dB	Background Noise dB
20-75	45	40
75-150	50	42
150-300	45	39
300-600	41	33
600-1200	33	27
1200-2400	34	20
2400-4800	27	15
4800-10000	22	10

By superimposing the factory noise spectrum on the level rank curves as shown in Figure CNR_C-5, the level rank is determined to be *c*. Table CNR_C-IV gives the corrections for the noise and environmental characteristics that will adjust the level rank *c* up two letters (+2) to level rank *e*.

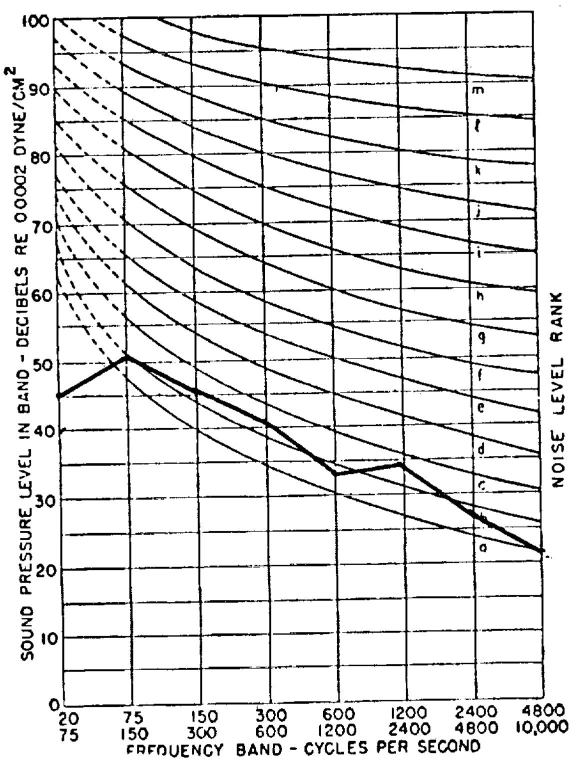


FIGURE CNR$_C$-5. Example showing determination of level rank (C) for factory noise.

TABLE CNR_C-IV

EXAMPLE OF CORRECTION NUMBERS TO BE APPLIED TO NOISE LEVEL RANK TO GIVE COMPOSITE NOISE RATING.

Influencing Factor	Correction Number
1. Background noise (see Fig. CNR_C-6)	+1
2. Temporal and seasonal factors	
Nighttime	0
Repetitiveness (see Fig. CNR_C-3)	-1
Summer	0
3. Detailed description of the noise	
Pure-tone components	+1
Impulsive	+1
4. Previous exposure	
None	0

Total Correction = +2

Thus the level rank with the applied corrections becomes a CNR_C of *E*. This CNR_C of *E* read on the response curve in Figure CNR_C-4 would predict the response of "widespread complaints" with possibilities of "threats of community action". If CNR_C is used as a guide in estimating community response, the factory would do well to adopt an alternate operation schedule or apply some noise control procedure.

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Tape Recorder (optional)
3) Octave Band Analyzer

REFERENCES

1. Harris, Cyril, Handbook of Noise Control, McGraw-Hill Book Co., New York, 1957.
2. Rosenblith, W. A., K. N. Stevens and the Staff of Bolt Beranek and Newman Inc., Handbook of Acoustic Noise Control, Vol. 2 Noise and Man. WADC TR 52-204, Wright-Patterson Air Force Base, Ohio: Wright Air Development Center (1953).
3. Stevens, K. N., W. A. Rosenblith and R. H. Bolt, "A Community's Reaction to Noise: Can It Be Forecast?", Noise Control 1: 63-71 (1955).

TITLE	COMPOSITE NOISE RATING (CNR_A) For Aircraft
UNIT	(None) [dB like scale]
DEFINITION	The Composite Noise Rating is a measure for aircraft noise which uses Perceived Noise Level (PNL) with appropriate corrections for frequency of operations, time of day and seasons of the year.
STANDARDS	(None) Related Documents: BBN Technical Report, "Land Use Planning Relating to Aircraft Noise," FAA, October 1964, including Appendix A, May 1965. Also published by the Department of Defense as AFM 86-5, TM 5-365, NAVDOCKS P-98, "Land Use Planning with Respect to Aircraft Noise."
PURPOSE	Composite Noise Rating is used to determine the relative impact of aircraft noise near an airport. It is employed as a guide to land use planning in areas adjacent to airports.

BACKGROUND

The Composite Noise Rating (CNR_A) of 1964 placed more emphasis on the influence of aircraft noise in the community environment than its predecessor - CNR_C (1955) (see CNR_C p.170). This improved CNR_A evolved from an Air Force sponsored noise survey which explored both community reactions and the physical noise levels of the surrounding areas. Instead of measuring the noise from a single source, the objective was to predict the effect of a large number of separate operations, and to develop a single noise rating number scale which could be related to community response.

The original CNR went through a series of modifications. The most noteworthy change was the replacement of the letter descriptors (*a* thru *m*) for the noise level rank curves with a numerical equivalent defined by the level of the curve at the 300-600 Hz frequency band (Figure CNR_A-1).

Other changes were made which eliminated the necessity to make adjustments for the discrete frequencies and the impulsive characteristics of the noise. These two factors were discarded because they were not predominantly present in the military aircraft used at that time.

The correction for duration (repetitiveness) was modified to apply directly to the

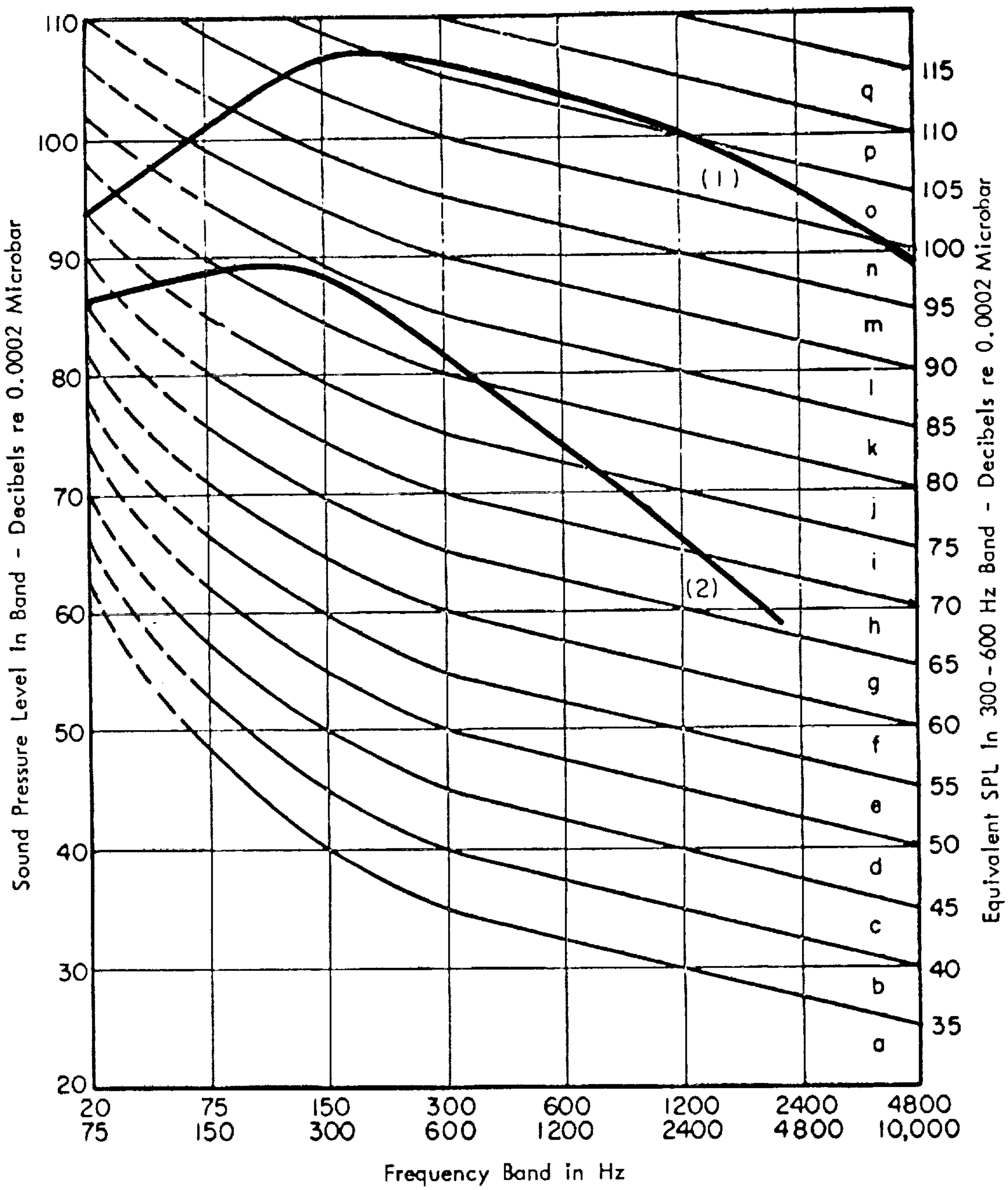


FIGURE CNR-1. DETERMINATION OF EQUIVALENT SPL IN 300-600 Hz BAND FOR TWO TYPICAL SPECTRA. VALUES ARE 105 dB FOR SPECTRUM (1) AND 80 dB FOR SPECTRUM (2) TO THE NEAREST 5 dB. (From WADC TN 57-10) level of the spectrum for summation on an energy basis rather than the previously used graphical estimation method. The averaging of the time-varying signals from the aircraft flyovers yields the *equivalent continuous sound pressure level* (L_{eq}) for the maximum sound pressure level in the 300 to 600 Hz band.

Additional environmental corrections were added to L_{eq}. One correction factor was for the seasonal variations of the year, and the other weighted the three segments (0600-1800 daytime, 1800-2300 evening, and 2300-0600 nighttime) of a 24 hour period.

The background (ambient) noise correction followed the same pattern as used previously. This adjustment ranged from +5 dB for quiet suburban areas to -10 dB for noisy urban communities.

In this updated version of CNR, an attempt was made to quantify more specifically the adjustments for community attitudes and previous exposure to aircraft operations. This procedure provided the following descriptions:

Community has had some previous exposure to noise from air base operations, but little effort is made to foster good public relations; correction may also be applied in a situation where the community has not been exposed to noise from air base operation previously, but some effort has been made to foster good public relations. -5 dB

Community has had considerable previous exposure to noise from air base operations, and air base-community relations are good. -10 dB

With good public relations, the correction can be applied for an operation of limited duration: it cannot be applied for an indefinite period. -15 dB

The value of CNR_A obtained from the adjusted L_{eq} was translated into descriptions of estimated community response by Table CNR_A-I.

TABLE CNR_A-I

Description of Community Response	Equivalent Continuous SPL in 300-600 Hz Octave, Plus Corrections
Essentially no complaints are reported: the noise may, however, interfere occasionally with activities of the residents.	Less than 45 dB
Some residents in the community may complain, perhaps vigorously. Concerted group action is probably not brought against the authorities, but the possibility of such action exists.	45 to 55 dB
Concerted group action is brought against the authorities. The community action may vary from strong threats to vigorous action.	Greater than 55 dB

The major innovation at this stage in the development of CNR was the conceptio of a technique which would allow the user to proceed directly from a series of operational characteristics of aircraft to derive a noise rating and expected community response. This technique was a preliminary step toward facilitating the description of the total operations of an airbase by CNR_A contours.

Several developments took place in 1963 which lead to further changes in CNR. The most significant factor being the substitution of PNL calculation for the counterpart noise level rank of L_{eq}. Fourteen sets of PNL contours were developed for a variety of aircraft. These contours coupled with additional changes in corrections for environmental conditions simplify the application procedure for the average user. The number of measurement corrections for PNL were reduced to three: 1) weighting for time of day (daytime 0700-2200, and nighttime 2200-0700); 2) seasonal adjustment; 3) the number of aircraft operations (with average duration assumed).

CALCULATION METHOD

CNR_A is determined from PNL_{max} for aircraft and the appropriate correction according to the formula:

$$CNR_A = PNL_{max} + C \quad [1]$$

where:

PNL_{max} is obtained from measurements or from graphs for various aircraft types (see Standard).

C is the sum of the corrections listed in Tables CNR_A-II and III.

Aircraft operations are divided into take-off, landing and ground run-up groups. The CNR_A for each aircraft type within each group is computed separately with the appropriate corrections applied. The maximum CNR_A value for each group is selected and taken as the descriptor for take-off or landing operations unless three or more of the CNR_A's are within 3 units of this maximum value. In the latter case, the maximum CNR_A is increased by 5 units. The descriptor CNR_A's for the landing and take-off operations are compared and the larger of the two selected to represent CNR_A for the combined set of operations.

CNR_A for ground run-up operations are treated in a similar manner, but evaluated separately in determining community response.

The value of CNR for these groups of aircraft operation just determined may be translated from Table CNR_A-IV to obtain an estimate of community response.

TABLE CNR_A-II

OPERATIONAL CORRECTIONS TO APPLY TO PERCEIVED NOISE LEVELS FOR TAKEOFFS AND LANDINGS

FREQUENCY OF OPERATIONS

Number of Takeoffs or Landings Per Period		Correction
Day (0700-2200)	Night (2200-0700)	
Less than 10	Less than 5	-5
10-30	5-15	0
31-100	16-50	+5
More than 100	More than 50	+10

TIME OF DAY

Time of Day	Correction
0700-2200	0
2200-0700	+10

SEASON OF YEAR

Season	Correction
All year	0
Winter only	-5

Note: For the special situation where the area in question is an on-base military housing installation, an additional correction of -5 is suggested.

TABLE CNR_A-III

OPERATIONAL CORRECTIONS TO APPLY TO PERCEIVED NOISE LEVELS FROM RUNUP OPERATIONS

NUMBER OF RUNUPS

Number of Runups Per Period		Correction
Day (0700-2200)	Night (2200-0700)	
5 or less	3 or less	0
More than 5	More than 3	+5

DURATION OF RUNUP

Duration in Minutes	Correction
Less than 1	-5
1 to 5	0
More than 5	+5

TIME OF DAY

Time of Day	Correction
0700-2200	0
2200-0700	+10

TABLE CNR_A-IV

CHART FOR ESTIMATING COMMUNITY RESPONSE FROM COMPOSITE NOISE RATING

Composite Noise Rating		Description of Community Response
Takeoffs and Landings	Runups	
Less than 100	Less than 80	Essentially no complaints would be expected. The noise may, however, interfere occasionally with certain activities of the residents.
100 to 115	80 to 95	Residents in the community may complain, perhaps vigorously. Concerted group action is possible.
Greater than 115	Greater than 95	Individual reactions would likely include repeated, vigorous complaints and recourse to legal action. Concerted group action would be expected.

EXAMPLE

An example of CNR_A at a particular location in the summertime for flight operations and ground runups is shown in Tables CNR_A-V, VI and CNR_A-VII, respectively.

TABLE CNR_A-V
EXAMPLE OF CNR_A CALCULATIONS FOR TAKEOFFS

Aircraft	Time of Day	No.**	PNL	Corrections No.**	Corrections Time	Corrections Season	CNR
Civil Turbojet* > 2000 miles	0700-2200	20	108.	0	0	0	108.
Civil Turbojet < 2000 miles	"	15	106.	0	0	0	106.
Civil Turbofan > 2000 miles	"	35	103.	+5	0	0	108.
Civil Turbofan < 2000 miles	"	18	101.	0	0	0	101.
Civil Turbofan < 2000 miles	2200-0700	3	101.	-5	10	0	106.

*The flight range for this type of aircraft in the example is greater than 2000 miles. The PNL values for this aircraft are given in previously mentioned Standard. It is recommended that PNL be used to the nearest dB.

**Frequency of operations per time period.

The maximum CNR_A for this group of aircraft measured during take-off is 108. There are three other CNR_A values which are within 3 units of this maximum. Thus maximum CNR_A is increased by 5 units to equal 113 as the CNR_A descriptor for take-off operations.

TABLE CNR_A-VI
EXAMPLE OF CNR_A CALCULATIONS FOR LANDINGS

Aircraft	Time of Day	No.	PNL	Corrections			CNR
				No.	Time	Season	
Civil Turbojets and Turbofans	0700-2200	81	91	5	0	0	96
Civil Turbojets and Turbofans	2200-0700	10	91	0	10	0	101

CNR_A is computed as 101 for landing operations at this point in the community.

Since the CNR_A of 113 for take-off operations is greater than the CNR_A of 101 for landing operations, the CNR_A of 113 is the Composite Noise Rating for the combined flight operations.

Table CNR_A-VII examines the effect of aircraft ground run-up operations on the community.

TABLE CNR_A-VII

EXAMPLE OF CNR_A CALCULATIONS FOR GROUND RUN-UP OPERATIONS

Aircraft	Time of Day	No.	Duration of Run-up Min.	PNL (PNdB)	Correction			CNR
					No.	Dur.	Time	
Civil Turbofan	0700-2200	3	.5	79	0	-5	0	74
Civil Turbojet	0700-2200	6	4	73	5	0	0	78

Thus the CNR_A for aircraft ground run-ups is 78.

Using the values of CNR_A determined in this example in conjunction with Table CNR_A-IV, the reaction of the community would be estimated as follows:

For Flight Operations

CNR_A = 113 Individuals may complain, perhaps vigorously. Concerted group action is possible.

For Ground Run-ups

CNR_A = 78 Essentially no complaints would be expected. The noise may, however, interfere occasionally with certain activities of the resident.

Thus reactions of the community would be expected for the flight operations, but not for ground run-ups.

EQUIPMENT

With Field Noise Measurements

1) Tape recorder (necessary for single events)
2) Sound Level Meter (IEC Standard)
3) One-third octave band real time analyzer
4) *Or*, One-third octave band analyzer plus graphic level recorder

Without Field Noise Measurements

a. No equipment is necessary. CNR_A contours can be drawn using PNL levels for different classes of aircraft along with proposed volume of operations.
b. In the interest of economizing time and money, use of a high speed digital computer is recommended.

REFERENCES

1. Department of Defense, AFM 86-5, TM 5-365, NAVDOCKS p-98, "Land Use Planning with Respect to Aircraft Noise".
2. Stevens, K.N.,Adone Pietrasanta, "Procedures for Estimating Noise Exposure and Resulting Community Reaction From Air Base Operations" WADC Technical Note 57-10, April 1957

TITLE	COMMUNITY NOISE EQUIVALENT LEVEL (CNEL)
UNIT	dB
DEFINITION	The Community Noise Equivalent Level (CNEL) is the average (i.e., average on an energy basis) noise level measured in A-level for a 24 hour period with different weighting factors for the noise levels occurring during the day, evening and nighttime periods.
STANDARDS	California Department of Aeronautics, "Noise Standards," California Administrative Code, Chapter 9, Title 4 (Register 70, No. 48, November 28, 1970).
GEOGRAPHICAL USAGE	State of California
PURPOSE	CNEL is used in the assessment of noise impact areas around airports. It was developed for noise surveillance in land use planning.

BACKGROUND

CNEL was developed to provide a measure of noise impact for the State of California airports using a simple weighting network to account for spectral distribution of the noise. The A-weighting was chosen because of its wide spread acceptance and international standardization.

Evening (1900-2200) and nighttime (2200-0700) events are increased in level by 5 and 10 dB respectively to account for the lower tolerance of people to noise during those time periods.

CALCULATION METHOD

CNEL may be determined using either of the following two calculation procedures.

I. Calculations <u>With</u> Field Noise Measurements

1) CNEL using Hourly Noise Level (HNL)

$$CNEL = 10 \log \left[\frac{\sum_{i=1}^{24} w_i \cdot \text{antilog } (HNL_i/10)}{24} \right] \quad [1]$$

where:

w_i is the time of day weighting factor

weighting	time
1	0700-1900
3*	1900-2200
10	2200-0700

*the exact weighting is 3.16

24 is the twenty-four hours in a full day

2) CNEL using Single Event Noise Exposure Level (SENEL)

$$CNEL = 10 \log \left[\frac{\sum_{i=1}^{n} w_i \cdot \text{antilog } (SENEL_n/10)}{86400} \right] \quad [2]$$

where:

w_i is the time of day weighting factor

weighting	time
1	0700-1900
3*	1900-2200
10	2200-0700

*the exact weighting is 3.16

n is the number of events measured in SENEL

86400 is the number of seconds in a day

II. Calculations <u>Without</u> Field Noise Measurements

The Community Noise Equivalent Level for a given period is weighted depending upon the number of aircraft flyovers and the time of occurrence.

$$CNEL = SENEL + 10 \log (N_D + 3N_E + 10N_N) - 49.4$$

where:

SENEL is the average on an energy basis

N_D is the number of flights during the day (0700-1900)

N_E is the number of flights during the evening (1900-2200)

N_N is the number of flights during the night (2200-0700)

EXAMPLE

I. Calculations <u>With</u> Field Noise Measurements

1) CNEL using Hourly Noise Level (HNL)

Table CNEL-I gives the HNL values for a 24 hour period. The weighting factor for time of day has been applied and the CNEL is calculated at 80.3 dB.

2) CNEL using Single Event Noise Exposure Level (SENEL)

Given (Table CNEL-II) the SENEL events and the approximate time of occurrence during the day, CNEL for seven events is 64.4 dB.

II. Calculations <u>Without</u> Field Noise Measurements

For the seven SENEL events given in Table CNEL-III, the average SENEL is equal to 99.0 dB.

TABLE CNEL-I

EXAMPLE OF CALCULATION FOR CNEL USING HNL

Time	HNL dB	Antilog	Weighting Factor W
0000	71.3	13.48×10^6	10
0100	41.0	0.012 "	"
0200	42.2	0.016 "	"
0300	71.9	15.48 "	"
0400	44.0	0.02 "	"
0500	40.7	0.011 "	"
0600	75.8	38.01 "	"
0700	79.1	81.28 "	1
0800	80.3	107.15 "	"
0900	78.0	63.09 "	"
1000	74.6	28.84 "	"
1100	78.2	66.06 "	"
1200	79.5	89.12 "	"
1300	83.0	199.52 "	"
1400	75.5	35.48 "	"
1500	77.6	57.54 "	"
1600	70.5	11.22 "	"
1700	70.0	10.00 "	"
1800	73.4	21.87 "	"
1900	79.0	79.43 "	3
2000	77.9	61.65 "	"
2100	81.3	134.89 "	"
2200	73.5	22.38 "	10
2300	67.8	6.02 "	"

$$\text{TOTAL} = 10 \log \left(\frac{253.0 \times 10^6}{24}\right)$$

$$= 10 \log (106.41 \times 10^6)$$

CNEL = 80.3 dB

TABLE CNEL-II

EXAMPLE OF CALCULATION FOR CNEL USING SENEL

TIME	EVENT n	SENEL dB	ANTILOG	WEIGHTING FACTOR w
0700-1900	1	90.0	10.00×10^8	1
	2	92.0	15.84 "	1
	3	89.0	7.94 "	1
1900-2200	4	105.0	316.22 "	3
	5	100.0	100.00 "	3
2200-0700	6	95.0	31.62 "	10
	7	99.0	79.43 "	10

$$\text{TOTAL} = 10 \log \left(\frac{2393.03}{86400} \times 10^8\right)$$

$$= 10 \log (276.97 \times 10^4)$$

CNEL = 64.4 dB

TABLE CNEL-III EXAMPLE OF CALCULATION FOR CNEL WITHOUT FIELD NOISE MEASUREMENTS	
SENEL dB	ANTILOG
90.0	10.00×10^8
92.0	15.84 " "
89.0	7.94 " "
105.0	316.22 " "
100.0	100.00 " "
95.0	31.62 " "
99.0	79.43 " "

$$\text{TOTAL} = 10 \log \left(\frac{561.07}{7} \times 10^8\right)$$

Average (on an energy basis)
SENEL = 99.0 dB

The number of flyovers occurring during the three major divisions of the day are:

N_D = 3 flyovers

N_E = 2 flyovers

N_N = 2 flyovers

Then:

$$\text{CNEL} = 99.0 + 10 \log [3 + 3(2) + 10\ (2)] - 49.4$$

$$= 64.2 \text{ dB}$$

EQUIPMENT

With Field Noise Measurements

1) Tape recorder (necessary for single events)
2) Sound Level Meter (IEC Standard)

Without Field Noise Measurements

1) No equipment *per se* is necessary. CNEL contours can be drawn using SENEL levels for different classes of aircraft along with proposed volume of operations.
2) In the interest of time and money economics, a high speed digital computer is recommended.

REFERENCES

1. California Department of Aeronautics, "Noise Standards," California Administrative Code, Chapter 9, Title 4 (Register 70, No. 48, November 28, 1970).

TITLE | NOISE EXPOSURE FORECAST (NEF)

UNIT | (dB like scale)

DEFINITION

Noise Exposure Forecast (NEF) is the total summation (on an *energy* basis) over a 24 hour period (weighted for the time of day) of Effective Perceived Noise Level (EPNL) minus the constant 88 dB. An illustrated approximation of NEF contours for runways at a major airport is shown in Figure NEF-1.

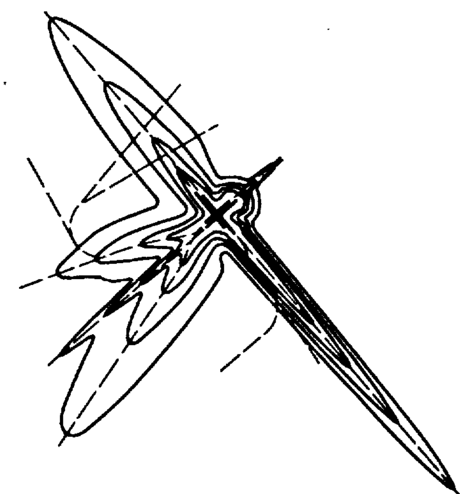


Figure NEF-1 NEF Contours

STANDARDS | (None)

GEOGRAPHICAL USAGE | United States

PURPOSE

NEF is used to determine the relative noise impact of aircraft noise near an airport. It serves as a land use planning tool for areas near airports to estimate the effect of various airplane types and operations on the community.

BACKGROUND

The noise exposure forecast uses EPNL as its basic noise measure for aircraft flyovers. EPNL together with the number of operations during the daytime (0700 to 2200) and nighttime (2200 to 0700) provide the information necessary to determine NEF at some specified location. As the number of events increases NEF becomes larger.

Because of the added disturbance of night-time versus the daytime operations, the noise of each night event effectively increases in the calculation procedure by 10 dB. That is, for the same average number of aircraft operations per hour during the daytime and nighttime periods, the NEF value for nighttime operation would be 10 dB higher than for daytime operations. For ease in determining NEF for known aircraft types, tables and graphs showing EPNL versus distance are available (Ref. 1).

The Noise Exposure Forecasts around a given airport are lowered in absolute value by subtraction of a constant (88) to avoid confusion with CNR, CNEL, etc. An example of NEF contours for a typical airport configuration is shown in Figure NEF-1.

CALCULATION METHOD

Calculations With Field Noise Measurements

When using field noise measurements with EPNL calculated for each of the noise events, the Noise Exposure Forecast can be found with the following equation:

$$NEF = 10 \log \left[\underbrace{\sum_{i=1}^{n} \text{antilog } (EPNL_i/10)}_{\text{Daytime Events}} + 16.67 \underbrace{\sum_{i=1}^{n} \text{antilog } (EPNL_i/10)}_{\text{Nighttime Events}} \right] - 88 \qquad [1]$$

where:

$EPNL_i$ is the Effective Perceived Noise Level of event i

n is the number of events

Calculations Without Field Noise Measurements

A) The total noise exposure at a given point is viewed as composed of noise produced by different aircraft flying different flight paths. For a specific class of aircraft, "i", on flight path, "j", the NEF_{ij} can be expressed:

$$NEF_{ij} = EPNL_{ij} + 10 \log \left[N_{D_{ij}} + 16.67 \, (N_{N_{ij}}) \right] - 88 \qquad [2]$$

where:

i is aircraft class

j is flight path

$N_{D_{ij}}$ is number of daytime (0700-2200) events for aircraft class i, flight path j

$N_{N_{ij}}$ is number of nighttime (2200-0700) events for aircraft class i, flight path j

B) The <u>total</u> NEF at a given ground position is determined by summation of all the individual NEF_{ij} values on an *energy* basis.

$$NEF = 10 \log \Sigma_i \Sigma_j \text{antilog} (NEF_{ij}/10) \qquad [3]$$

EXAMPLE

Calculations <u>Without</u> Field Noise Measurements

A) An example for one NEF_{ij} point using equation [2] is:

Given:

$EPNL_{ij}$ = 90 EPNdB

$N_{D_{ij}}$ = 30

$N_{N_{ij}}$ = 4

Then:

$$NEF_{ij} = 90 + 10 \log [30 + 16.67 (4)] - 88$$

$$= 21.85$$

B) Computations showing the calculations involving the total NEF value using equation [3] (i.e., a sum of NEF_{ij} values) is:

Given:

$NEF_1 = 21.85$

$NEF_2 = 19.71$

$NEF_3 = 23.36$

$$NEF\ (total) = 10 \log \left(\text{antilog}\ \frac{21.85}{10} + \text{antilog}\ \frac{19.71}{10} + \text{antilog}\ \frac{23.36}{10}\right)$$

$$NEF\ (total) = 10 \log (153.1 + 93.5 + 216.8)$$

$$= 10 \log (463.4)$$

$$= 26.7$$

EQUIPMENT

With Field Noise Measurements

1) Tape recorder (necessary for single events)
2) Sound Level Meter (IEC Standard)
3) One-third octave band real-time analyzer
4) *Or*, One-third octave band analyzer plus graphic level recorder

Without Field Noise Measurements

a. No equipment is necessary. NEF contours can be drawn using EPNL levels for different classes of aircraft along with proposed volume of operations.
b. In the interest of economizing time and money a high speed digital computer is recommended.

REFERENCES

1. Bishop, Dwight, and Myles A. Simpson, "Noise Exposure Forecast Contours for 1967, 1970 and 1975 Operations at Selected Airports", DOT/FAA Office of Noise Abatement, FA68WA-1900, September 1970, BBN Report No. 1863.
2. Bishop, D. E., Richard Horonjeff, "Noise Exposure Forecast Contour Interpretations of Aircraft Noise Tradeoff Studies", DOT/FAA Office of Noise Abatement, BBN Report No. 1714, (May 1969).

TITLE	WEIGHTED EQUIVALENT CONTINUOUS PERCEIVED NOISE LEVEL (WECPNL)
UNIT	PNdB
DEFINITION	Weighted Equivalent Continuous Perceived Noise Level is the average (on an *energy* basis) noise level for a 24 hour period. Appropriate weightings are included for time of day and night and season of the year.
STANDARDS	International Civil Aviation Organization, "Aircraft Noise", Annex 16; First Edition, August 1971.
GEOGRAPHICAL USAGE	Limited
PURPOSE	WECPNL is used to determine the relative noise impact of aircraft noise near an airport.

BACKGROUND

WECPNL was adopted by the International Civil Aviation Organization (ICAO) as a reference unit for total noise exposure from aircraft noise. WECPNL uses Effective Perceived Noise Level (EPNL) as its basic noise measure for aircraft flyovers. EPNL for each of the operations during the daytime (0700 to 2200) and nighttime (2200 to 0700) plus monthly temperature values provide the information necessary to determine WECPNL. As the number of events increases WECPNL becomes larger. Because of the added disturbance of nighttime versus the daytime operations, the nighttime portion of the noise is increased by 10 dB.

A seasonal weighting factor based on temperature values is also included to adjust for *open* windows or *closed* windows.

CALCULATION METHOD

In order to calculate WECPNL, first determine Total Noise Exposure Level (TNEL) and then Equivalent Continuous Perceived Noise Level (ECPNL) for the day and nighttime periods.

TOTAL NOISE EXPOSURE LEVEL (TNEL)

$$TNEL = 10 \log \left[\sum_{i=1}^{n} \text{antilog } (EPNL_i/10) \right] + 10 \log \left(T_o/t_o \right) \quad [1]$$

where:

$EPNL_i$ is the Effective Perceived Noise Level of event i

n is the number of events

T_o is 10 seconds

t_o is one second

EQUIVALENT CONTINUOUS PERCEIVED NOISE LEVEL (ECPNL)

$$ECPNL = TNEL - 10 \log (T/t_o) \quad [2]$$

where:

T is a specified time period, i.e., day, month, or year (usually total time under consideration in seconds)

t_o is one second

WEIGHTED EQUIVALENT CONTINUOUS PERCEIVED NOISE LEVEL (WECPNL)

$$WECPNL = 10 \log \left[\frac{5}{8} \text{antilog } (ECPNL_D/10) + \frac{3}{8} \text{antilog } (ECPNL_N + 10)/10) \right] + S \qquad [3]$$

where:

$ECPNL_D$	is the ECPNL during the daytime hours 0700-2200
$ECPNL_N$	is the ECPNL during the nighttime hours 2200-0700
S	is seasonal variations

TABLE WECPNL-I

Seasonal Weighting Factor, S dB	
Condition	S
Less than 100 hours per month at or above 20°C (68°F)	-5
More than 100 hours per month at or above 20°C and less than 100 hours at or above 25.6°C (78°F)	0
More than 100 hours per month at or above 25.6°C	+5

EXAMPLE

An example of the WECPNL calculation procedure for five flyovers per day during the summer.

Given: $EPNL_1 = 85$ PNdB Daytime

$EPNL_2 = 90$ PNdB Daytime

$EPNL_3 = 95$ PNdB Daytime

$EPNL_4 = 85$ PNdB Nighttime

$EPNL_5 = 90$ PNdB Nighttime

Temperature 80°F for more than 100 hours per month

Then:

$$TNEL_{Day} = 10 \log \left[\text{antilog} \frac{85}{10} + \text{antilog} \frac{90}{10} + \text{antilog} \frac{95}{10}\right] + 10 \log \frac{10}{1}$$

$$= 10 \log (3.162 \times 10^8 + 10.0 \times 10^8 + 31.62 \times 10^8) + 10$$

$$= 106.5$$

$$TNEL_{Night} = 10 \log \left[\text{antilog} \frac{85}{10} + \text{antilog} \frac{90}{10}\right] + 10 \log \frac{10}{1}$$

$$= 10 \log (3.162 \times 10^8 + 10.0 \times 10^8) + 10$$

$$= 101.2$$

$$ECPNL_D = 106.5 - 10 \log \left[\frac{15 \times 60 \times 60}{1}\right]$$

$$= 59.2$$

$$ECPNL_N = 101.2 - 10 \log \left[\frac{9 \times 60 \times 60}{1}\right]$$

$$= 56.1$$

$$WECPNL = 10 \log \left[\frac{5}{8} \text{ antilog } \frac{59.2}{10} + \frac{3}{8} \text{ antilog } \frac{56.1 + 10}{10}\right] + 5$$

$$= 10 \log (5.199 + 1.528 \times 10^5) + 5$$

$$= 63.3$$

Thus WECPNL for the 5 flyovers per day during the summer is 63.3 PNdB.

EQUIPMENT

1) Tape recorder (necessary for single event)
2) Sound Level Meter (IEC Standard)
3) One-third octave band real time analyzer
4) *Or*, One-third octave band analyzer plus graphic level recorder

REFERENCES

International Civil Aviation Organization, "Aircraft Noise", Annex 16; First Edition, August 1971.

TITLE	NOISE POLLUTION LEVEL (NPL) (L_{NP})
UNIT	(None) [dB like units]
DEFINITION	Noise Pollution Level (NPL) is a noise rating which takes into account the equivalent continuous noise level and the effect of the magnitude of the time variation of the noise level.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United Kingdom and United States
PURPOSE	NPL was developed in an effort to improve upon the other single number noise rating systems (in particular Equivalent Sound Level, L_{eq}) which had previously considered only noise intensity. NPL attempts to account for the increased annoyance due to the effect of fluctuations of the environmental noise level.

BACKGROUND

NPL was introduced by Robinson (Reference 1 and 2) in a further effort to combine results from studies on community reaction and noise level. NPL is essentially derived from two terms, the first one is based on the intensity in level of the intruding noise while the second term is influenced by the level or fluctuation in the background noise. Thus, even though two noise sources have the same equivalent sound level, the less steady the level of a noise the greater its disturbing and annoying quality and the greater the NPL.

NPL is measured upon some scale like A-level or Perceived Noise Level which has been related to subjective evaluations of noisiness. Results from studies using NPL measures have been found to correlate well with existing survey data (Ref. 3). However, additional investigation is recommended to validate the effectiveness of NPL when used directly in a community survey.

CALCULATION METHOD

The basic definition of NPL is given by the following equation:

1) Continuous Integration

$$NPL = L_{eq} + k\sigma \qquad [1]$$

where:

L_{eq} is Equivalent Continuous Sound Level in A-Level (AL) over a specified period of time (see L_{eq} p.100)

k is a constant assuming the value of 2.56, since this value leads to the best fit with currently available studies of subjective response to noise

σ is the standard deviation of the time varying sound level over a specified period of time

2) Temporal Sampling

$$NPL = L_{eq} + k\sigma \qquad [2]$$

where:

L_{eq} is equivalent continuous sound level sampled in instantaneous level (i.e., AL_i) over a specified period of time (see L_{eq} p.100)

k is a constant assuming the value of 2.56

σ is the standard deviation of the instantaneous level (i.e., AL_i) considered as a statistical time series over a specified period of time

$$\sigma = \sqrt{\frac{\Sigma\ (\bar{L} - L)^2}{N}} = \sqrt{\frac{N\ \Sigma\ L^2 - (\Sigma\ L)^2}{N^2}}$$

L is instantaneous level for sample i

3) An alternate expression for NPL is:

$$NPL' = L_{50} + d + (d^2/60) \qquad [3]$$

where:

d is $(L_{10} - L_{90})$

L_{10}, L_{50}, L_{90} are the decile noise levels exceeded respectively 10%, 50% and 90% of the time during the observation period

EXAMPLE

NPL using the approximation method of temporal sampling in equation [2] is as follows:

Given:

$AL_1 = 67$ dB(A)

$AL_2 = 74$ dB(A)

$AL_3 = 76$ dB(A)

Then:

$$L_{eq} = 10 \log \left[\frac{\text{antilog } \frac{67}{10} + \text{antilog } \frac{74}{10} + \text{antilog } \frac{76}{10}}{3} \right]$$

$$= 10 \log \left[\frac{5.01 + 25.12 + 39.81}{3} \right]$$

$$= 73.7$$

$$\overline{L} = \frac{67 + 74 + 76}{3} = 72.33$$

$$\sigma = \sqrt{\frac{(72.33-67)^2 + (72.33-74)^2 + (72.33-76)^2}{3}}$$

$$= 3.86$$

$$NPL = 73.7 + 2.56\ (3.86)$$

$$= 83.6$$

Thus NPL for the three sound level samples in time is 83.6.

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Continuous Integration: special monitoring equipment capable of integrating sound levels for specified duration
3) Digital computer with sampling capabilities (optional)
4) Statistical distribution analyzer may be employed which contains approximate formulas listed under the calculation method

REFERENCES

1. Robinson, D. W., "The Concept of Noise Pollution Level", NPL Aero Report Ac38, National Physical Laboratory, Aerodynamics Division, March 1969.
2. Robinson, D. W., "An Outline Guide to Criteria for the Limitation of Urban Noise", NPL Aero Report Ac39, March 1969, National Physical Laboratory, Aerodynamics Division, Teddington, England.
3. Robinson, D. W., Towards a Unified System of Noise Assessment, J. Sound Vibration 14, 279-98 (1971).

TITLE	DAY-NIGHT LEVEL (L_{dn})
UNIT	dB
DEFINITION	Day-Night Level (L_{dn}) is the average (i.e., on an *energy* basis) A-weighted noise level integrated over a 24 hour period. Appropriate weightings are applied for the noise levels occurring in the daytime and nighttime periods.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United States
PURPOSE	The purpose of L_{dn} is to provide a single number measure of time-varying noise for a specified time period. It was developed for noise exposure surveillance and as an aid in land use planning.

BACKGROUND

Day-Night Level (L_{dn}) was developed as a single number measure of community noise exposure. It was designed to improve upon Equivalent Sound Level (L_{eq}) by adding a correction for nighttime noise intrusions. A 10 dB correction is applied to nighttime (2200-0700) sound levels to account for the increased annoyance to noise during the night hours. L_{dn} uses the same *energy equivalent* concept as L_{eq}, which is defined as representing a fluctuating noise level in terms of a steady state noise having the same energy content. The specified time integration period is for 24 hours. Again, like L_{eq} there is no stipulation of a minimum noise sampling threshold.

The noise level is measured in A-weighted sound pressure level. However, other weighting functions may be better for evaluating the effects of noise on human annoyance (i.e., D-level).

L_{dn} was not designed as a single source measure, and therefore it does not account adequately for tonal components or impulse noise. It is recommended that this measure not be used in determining source standards or for certification of product noise. Essentially, Day-Night Level was introduced as a simple method for predicting the effects on a population of the average long term exposure to environmental noise.

Recommended L_{dn} levels of 55 to 60 dB are projected as the long range goal for maximum permissible average sound level with respect to health and welfare. Results from test data indicated that an outdoor L_{dn} of approximately 60 dB or less is required in order that no more than 23% of the population exposed to noise would be highly annoyed.

CALCULATION METHOD

L_{dn} can be determined by two different methods.

1) CONTINUOUS INTEGRATION

For continuous time integration of A-weighted sound level for a 24 hour period (86400 seconds), the formula is:

$$L_{dn} = 10 \log \left[\frac{\int_0^{86400} w\,[t] \cdot \text{antilog}\,(AL[t]/10)\, dt}{86400} \right] \quad [1]$$

where:

w is the time of day weighting factor

WEIGHTING	TIME
1	0700 - 2200
10	2200 - 0700

t	is time in seconds
$AL[t]$	is instantaneous A-level at time t
dt	is Δt as it approaches 0
86400	is the number of seconds in a day

2) TEMPORAL SAMPLING

For discrete sampling of A-weighted sound level for a 24 hour time period, the formula is:

$$L_{dn} = 10 \log \left[\frac{\sum_{i=1}^{n} w_i \cdot \text{antilog } (AL_i/10)}{n} \right] \qquad [2]$$

where:

w_i	is the time of day weighting factor (see equation [1]) for sample i
AL_i	is the A-level for sample i (for sounds with time varying fluctuations use L_{eq})
n	is the number of samples of AL in a 24 hour period (or L_{eq} for specified periods of time within 24 hours)

EXAMPLE

The following example illustrates one method of determining L_{dn}. These three samples are Equivalent Sound Level (L_{eq}) over specified time periods.

TEMPORAL SAMPLING
(for 24 hours)

TABLE L_{dn}-I

EXAMPLE OF CALCULATION FOR L_{dn}

TIME	n	L_{eq} (dB)	ANTILOG	WEIGHTING FACTOR w
0700-1000	1	71	12.0×10^6	1
1000-1300	2	75	31.0 " "	"
1300-1600	3	70	10.0 " "	"
1600-1900	4	73	20.0 " "	"
1900-2200	5	70	10.0 " "	"
2200-0100	6	70	10.0 " "	10
0100-0400	7	65	3.2 " "	"
0400-0700	8	68	6.3 " "	"

Table L_{dn}-I gives the measured L_{eq} for eight 3-hour samples during a 24 hour period. The weighting factors for time of day and night have been applied and the Day-Night Sound Level is:

$$\text{TOTAL} = 10 \log \left[\frac{278.0 \times 10^6}{8} \right]$$

$$= 10 \log (34.75 \times 10^6)$$

$$L_{dn} = 75.4 \text{ dB}$$

EQUIPMENT

Continuous Sampling:

Special monitoring equipment capable of integrating sound levels for long periods of time

Temporal Sampling

a. Sound Level Meter (IEÇ Standard)
b. Graphic level recorder
c. Tape recorder
d. Statistical distribution analyzer

REFERENCES

1. von Gierke, Henning, Draft Report on Impact Characterization of Noise Inducing Implications of Identifying and Achieving Levels of Cumulative Noise Exposure, Environmental Protection Agency (EPA), Aircraft/Airport Noise Report Study, June 1, 1973, Task Group 3.

TITLE	ISOPSOPHIC INDEX (*N*)
UNIT	PNdB
DEFINITION	The Isopsophic Index (*N*) is an aircraft noise rating measure based upon the average (on an *energy* basis) maximum Perceived Noise Level ($\overline{PNL}_{max}$) of a flyover. It takes into account the number of events and appropriate weightings for time of day, evening or night. Another French measure, termed the Classification Index, R, is identical in all respects to *N*. It is also used in land use planning and in attempts to predict people's annoyance with noise exposure.
STANDARDS	(None)
GEOGRAPHICAL USAGE	France
PURPOSE	*N* is used to determine the relative noise impact of aircraft noise near an airport. It serves as a land use planning tool for areas near airports.

BACKGROUND

The French conducted an extensive social survey in the community areas around their four major airports. The results from the survey were used to derive two attitude scales, one a nuisance scale related to aircraft noise, and the other a general satisfaction scale related to the district of residence. The correlation between the rating of the nuisance scale and the degree of noise exposure as a function of N was 0.93.

When night operations are considered in the Isopsophic Index the nighttime hours are divided into two periods (2000-0200) and (0200-0600) with weighting factors applied to each period much like CNEL. The first night period is viewed as 3 times more significant than the second nighttime period. The 10 log summation is no longer used, the term being replaced by 6 log $(3n_1+n_2)-1$ where n_1 and n_2 are the number of operations in the two nighttime periods. However, a direct 10 log summation process can be used when $3n_1+n_2<64$. There is a simple linear translation of N to Composite Noise Rating (CNR) where $N \simeq$ CNR-18.

As a result of their work with Isopsophic Index, the French have established areas for land use on the basis of the noise exposure.

Land Planning Zones

AREA A $N>96$ $(\mathrm{CNR}>114)$	All buildings prohibited except those corresponding to activities associated with the vicinity of the airport.
AREA B $89<N<96$ $(107<\mathrm{CNR}<114)$	Development of existing communities to be restricted to areas located within the smallest possible perimeters. Construction for residential purposes will be authorized subject to adequate soundproofing. Density limitations (number of inhabitants to the hectare) will also be established for this type of residential area. Erection of public buildings (i.e., schools, hospitals, etc.) and residential buildings should be avoided. Should the erection of such public buildings be considered essential, soundproofing should conform to at least a certain given value and each case should be studied specifically.
AREA C $84<N<89$ $(102<\mathrm{CNR}<107)$	New residential developments to be avoided. Density limitations (number of inhabitants per hectare) will be established for all residential buildings and it will be recommended that such residential buildings as well as public building be provided with adequate soundproofing, each case being studied specifically.
AREA D $N<84$ $(\mathrm{CNR}<102)$	No building restrictions.

CALCULATION METHOD

The Isopsophic Index can be computed from the following equations:

<u>FOR DAYTIME OPERATIONS</u> (0600-2200)

$$N_{day} = \overline{PNL}_{max} + 10 \log N - 30 \qquad [1]$$

where:

$\overline{PNL}_{max}$ is the average (on an *energy* basis) of maximum PNL's

N is the number of events during the daytime (0600-2200)

<u>FOR NIGHTTIME OPERATIONS</u> (2200-0600)

$$N_{night} = \overline{PNL}_{max} + 6 \log (3n_1 + n_2) - 31 \qquad [2]$$

where:

$\overline{PNL}_{max}$ is the average (on an *energy* basis) of maximum PNL's

n_1 is the number of events during early night (2200-0200)

n_2 is the number of events during late night (0200-0600)

FOR THE 24 HOUR PERIOD

$$N = 10 \log [\text{antilog } (N_{day}/10) + \text{antilog } (N_{night}/10)] \quad [3]$$

EXAMPLE

Given:

PNL_{max_1} = 85 Daytime (0600-2200)

PNL_{max_2} = 90 " "

PNL_{max_3} = 95 " "

PNL_{max_4} = 90 Nighttime (2200-0200)

PNL_{max_5} = 95 " "

PNL_{max_6} = 85 " (0200-0600)

PNL_{max_7} = 90 " "

Thus for Daytime:

$$\overline{PNL}_{max} = 10 \log \left[\frac{\text{antilog } \frac{85}{10} + \text{antilog } \frac{90}{10} + \text{antilog } \frac{95}{10}}{3}\right]$$

$$= 91.7 = \left[\frac{3.162 \times 10^8 + 10 \times 10^8 + 31.62 \times 10^8}{3}\right]$$

$$N_{day} = 91.7 + 10 \log 3 - 30$$

$$= 91.7 + 4.8 - 30$$

$$= 66.5$$

For <u>Nighttime</u>:

$$\overline{PNL}_{max} = 10 \log \left[\frac{\text{antilog } \frac{90}{10} + \text{antilog } \frac{95}{10} + \text{antilog } \frac{85}{10} + \text{antilog } \frac{90}{10}}{4}\right]$$

$$= 91.4 = \left[\frac{10 \times 10^8 + 31.62 \times 10^8 + 3.162 \times 10^8 + 10 \times 10^8}{4}\right]$$

$$N_{night} = 91.4 + 6 \log (3 \times 2 + 2) - 31$$

$$= 91.4 + 5.41 - 31$$

$$= 65.8$$

For <u>24 Hour Period</u>

$$N = 10 \log \left[\text{antilog } (\frac{66.5}{10}) + \text{antilog } (\frac{65.8}{10}\right]$$

$$= 69.2 \text{ PNdB}$$

EQUIPMENT

1) Tape recorder (necessary for single event)
2) Sound Level Meter (IEC Standard)
3) One-third octave band real time analyzer
4) *Or*, One-third octave band analyzer plus graphic level recorder

REFERENCES

1. Galloway, William J., Dwight Bishop, "Noise Exposure Forecasts: Evolution, Evaluation, Extensions and Land Use Interpretations", DOT-FAA Office of Noise Abatement, BBN Report No. 1862, (August 1970).
2. ICAO Special Meeting, "Correlation of Surveys with the Determination of Noise Areas Around Aerodromes," Presentation by France, Meeting on Aircraft Noise in the Vicinity of Aerodromes, Noise 1969-WP/15, Item 2, Paper No. 2, 6 August 1969.

TITLE	MEAN ANNOYANCE LEVEL ($\overline{Q}$)
UNIT	dB
DEFINITION	The Mean Annoyance Level ($\overline{Q}$) is the average (on an *energy* basis) noise level measured in A-level for a specified time period.
GEOGRAPHICAL USAGE	Germany and Austria
PURPOSE	The $\overline{Q}$ index as a rating of noise impact is used in Germany to define four zones of aircraft noise exposure for land use. The Austrians adapted the $\overline{Q}$ index to measure noise fluctuations in homes and office buildings.

BACKGROUND

Germany

The Mean Annoyance Level ($\bar{Q}$) in Germany was developed for assessing aircraft noise and land use around airports. The four zones around an airport which define land use for occupants are based on a *critical* value of $\bar{Q}$ equal to the noise level of 82 PNdB.

Land Planning Zones

Zone I	$\bar{Q}>82$	Nonresidential building, uninhabitable.
Zone II	$77<\bar{Q}<82$	Residential building only in urgent cases (i.e., for airport personnel). Strong sound suppression measures are required.
Zone III	$72<\bar{Q}<77$	Not recommended for residences. Sound suppression measures required if dwellings must be built here.
Zone IV	$\bar{Q}<72$	No restrictions, but no new hospitals, rest homes, homes for the aged, schools, churches, or scientific institutions may be built in the vicinity of the boundary to Zone III.

Austria

The $\bar{Q}$ index value adapted by the Austrians is based upon the *percentage* of time the noise is at a certain level. The concern here is with the habitability of dwellings, office buildings and educational institutions in areas where there is influence from traffic noise.

CALCULATION METHOD

Germany

The Mean Annoyance Level ($\overline{Q}$) used in Germany is the summation of various noise level samples multiplied by their respective durations (τ), then averaged over a specified time (T), with the result being multiplied by a constant. The constant in this case is 13.3 which corresponds to 4 dB increase per doubling of duration.

The expression for computing $\overline{Q}$ is as follows:

$$\overline{Q} = 13.3 \log \left[\frac{\sum_{i=1}^{n} \text{antilog } (AL_i/13.3)}{T} \cdot \tau_i \right] \quad [1]$$

where:

- AL_i is the sound level for each sample i (or PNdB may be used)
- τ_i is the duration at that level for sample i
- T is the specified time which may be 1 hour, 12 hours, etc.
- n is the number of samples

Austria

The $\overline{Q}$ index as used in Austria is the summation of sampled A-level, multiplied by the percentage of time that level is maintained within a total specified time period. A constant is used (13.3) which corresponds to 4 dB increase per doubling of duration.

The expression for computing the $\overline{Q}$ index is as follows:

$$\overline{Q} = 13.3 \log \left[\frac{\sum_{k=1}^{n} \text{antilog } (AL_k/13.3)}{100} \cdot f_k \right] \quad [2]$$

where:

AL_k	is the sound level in dB(A) defining each class (k) in the statistical distribution of observed noise levels
f_k	is the percentage of time the noise level is in class k
n	is the number of classes

EXAMPLE

Germany

For the example given in Table $\overline{Q}$-I, A-level has been sampled at one hour intervals for a total period of 12 hours. However, for areas which have a great many aircraft flyovers the sampling interval τ would be much shorter (i.e., approximately 1 second).

Thus for five samples of varying durations the $\overline{Q}$ index is 76.9 dB. This indicates a Zone III recommendation for land usage.

Austria

Table $\overline{Q}$-II gives an example for the Austrian $\overline{Q}$ index. The sampled A-level is divided into class intervals with the respective percentage of time the level is maintained in each of the five intervals.

The $\overline{Q}$ index for this method is 76.9 dB, the same as the measurement procedure from Germany.

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Tape Recorder (optional)
3) Digital Computer (preferably)
   Or, Graphic Level Recorder

TABLE $\bar{Q}$-I

EXAMPLE OF CALCULATION FOR MEAN ANNOYANCE LEVEL ($\bar{Q}$) (FOR A 12 HOUR PERIOD)

GERMANY

Sample	A-Level dB	τ Duration Hours	Antilog
1	70.0	4	7.33×10^5
2	75.0	2	8.71 "
3	80.0	3	31.05 "
4	85.0	1	24.60 "
5	65.0	2	1.54 "
		12 Hrs.	

$$\text{TOTAL} = 13.3 \log \left(\frac{73.24 \times 10^5}{12}\right)$$

$$= 13.3\ (5.78)$$

$$\bar{Q} = 76.9 \text{ dB}$$

TABLE $\overline{Q}$-II

EXAMPLES OF CALCULATIONS FOR MEAN ANNOYANCE LEVEL ($\overline{Q}$) (FOR A 12 HOUR PERIOD)

AUSTRIA

Sample	Hours Sampled	Percent Time %	Class Interval dB (A)	Antilog
1	4	33	70.0	6.04×10^6
2	2	17	75.0	7.40 "
3	3	25	80.0	25.88 "
4	1	8	85.0	19.68 "
5	2	17	65.0	1.31 "
	12 Hr.	100%		

$$\text{TOTAL} = 13.3 \text{ LOG } \left(\frac{60.32 \times 10^6}{100}\right)$$

$$= 13.3\ (5.78)$$

$$\overline{Q} = 76.9 \text{ dB}$$

REFERENCES

1. Bruckmayer, F., "Beurteilung von Larmbelastigung durch Bezug auf den Storpegel", (Judgment of Noise Annoyance by Comparison with the 'Background Noise Level') Osterreichische Ingenieur-Zeitschrift, Jg. 1963, p. 315. Also Paper L-16 in IVth International Congress on Acoustics, Copenhagen, August 21-28, 1962.
2. Bruckmayer, F., and J. Lang, "Storung durch Verkehslarm in Unterrichtsraumen" (Disturbance Due to Traffic Noise in Schoolrooms), Osterreichische Ingenieur-Zeitschrift, II (3): 73-77 (1968).
3. Koppe, E. W., K. R. Matschat and E. A. Muller, "Abstract of a Procedure for the Description and Assessment of Aircraft Noise in the Vicinity of an Airport", Acustica 16: 251-253 (1965/66).
4. Lang, Judith, "Verkehrslarm - Messung and Darstellung" ("Measurement and Presentation of Traffic Noise"), Fifth International Congress on Acoustics, Liege, (7-14 September 1965), paper F-35.

TITLE	NOISINESS INDEX ($\overline{NI}$)
UNIT	(dB like scale)
DEFINITION	The Noisiness Index, $\overline{NI}$, is the average (on an *energy* basis) noise level based upon a tone corrected A-level for a 24 hour period. Appropriate corrections are applied for time of day, or night, and season of the year.
STANDARDS	(None)
GEOGRAPHICAL USAGE	South Africa
PURPOSE	The $\overline{NI}$ rating scheme is another measure used to relate community response to aircraft noise exposure.

BACKGROUND

Van Niekerk and Muller studied the noise exposure from aircraft flyovers in South Africa and developed the Noisiness Index ($\overline{NI}$). The Noisiness Index is the integrated tone corrected A-level with effective duration of that level for a twenty-four hour period. Because of this integration process, $\overline{NI}$ takes into consideration both the duration as well as the magnitude of the noise signal. Additional corrections were introduced to adjust for day, evening, or night hours, or for various seasons of the year.

Measurement and analysis of the noise is done in one-third octave band frequencies. The tone corrections are added to the third-octave band data before calculating A-level. The actual tone correction procedure is taken from the techniques employed for Effective Perceived Noise Level (EPNL) or tone corrected Perceived Noise Level (PNLT). The *effective duration* is the duration of an equivalent energy sample with the same maximum level.

The National Institute for Personnel Research of the South African Council for Scientific and Industrial Research conducted a social survey to relate community response to aircraft noise exposure. The results indicated that about 13% of the people were disturbed by aircraft noise at an $\overline{NI}$ value of 60, about 18% at $\overline{NI}$ of 65, and about 45% were disturbed at an $\overline{NI}$ of 70. The $\overline{NI}$ range between 65 and 70 is thus regarded as the upper limits in setting noise criteria for a residential development.

CALCULATION METHOD

$\overline{NI}$ may be determined using the following formula:

$$\overline{NI} = 10 \log \sum_{i=1}^{n} \text{antilog} \left[\frac{AL_T + 10 \log (t/t_o) + C + S}{10} \right] \quad [1]$$

where:

- AL_T is tone corrected A-level from one-third octave band data. The procedure for determining tone corrected A-level to the same as that for tone corrected Perceived Noise Level (PNLT see p. 86).
- t is effective duration in seconds
- t_o is total time in seconds
- C is the time of day correction
- S is the seasonal correction

EFFECTIVE DURATION (t)

1) Continuous Integration

$$t = \left[\frac{1}{\text{antilog } (AL_{max}/10)} \right] \int_{t_1}^{t_2} \text{antilog } (AL(t)/10)\, dt \quad [2]$$

where:

AL_{max} is maximum A-level

$\int_{t_1}^{t_2}$ brackets the time during which the noise signal is within a minimum of 10 dB(A) down from the maximum value (AL_{max})

dt is Δt as it approaches 0

$AL(t)$ is A-level as a function of time

2) Temporal Sampling

$$t \simeq \sum_{i=1}^{n} \left[\text{antilog } (AL_i/10)\ \Delta t/\text{antilog } (AL_{max}/10)\right] \qquad [3]$$

where:

AL_i is the instantaneous A-level for sample i

Δt is the time interval between samples in seconds

n is the number of samples for which the noise is within a <u>minimum</u> of 10 dB(A) down from its <u>maximum</u> AL_i

EXAMPLE

An example of the $\overline{NI}$ calculation procedure is as follows for a 24 hour time period (86400 seconds) during a season where the temperature is 80°F for more than 100 hours per month.

TABLE $\overline{\text{NI}}$-I

SUGGESTED VALUES FOR THE DIURNAL WEIGHTING FACTOR C (IN dB)

Time of day (hours)	C_2	C_3
0700 - 2200	0	
2200 - 0700	10	
0700 - 1900		0
1900 - 2200		5
2200 - 0700		10

Note: $C = C_2$ if the day is divided into two periods, and $C = C_3$ if the day is divided into three periods.

TABLE $\overline{\text{NI}}$-II

SUGGESTED VALUES FOR THE SEASONAL WEIGHTING FACTOR S (IN dB)

Seasonal Condition	S
Less than 100 hours per month at or above 20°C	-5
More than 100 hours per month at or above 20°C and less than 100 hours at or above 25.6°C	0
More than 100 hours per month at or above 25.6°C	+5

AL_T (Tone corrected A-level)

The appropriate tone corrections have been applied to the spectrum listed in Table $\overline{NI}$-III according to the procedure outlined in the measure for PNLT (see p. 86). Thus, AL_T equals 91.6 dB.

t (effective duration)

Approximate effective duration has been calculated in Table $\overline{NI}$-IV. Thus, for a .5 second interval sampling of the spectrum given in Table $\overline{NI}$-III the effective duration is t = 3.7 seconds.

$\overline{NI}$ (Noisiness Index)

Using the answers calculated for AL_T and t from above, along with the respective information for some additional samples the Noisiness Index is determined as follows:

TABLE $\overline{\text{NI}}$-III

EXAMPLE OF CALCULATIONS FOR TONE CORRECTED A-LEVEL (AL_T)

OA	Flyover* Spectrum (dB)	Tone* Correction	Tone Corrected Spectrum	Correction For A-weighting	Corrected Level dB	Antilog
80	70.0		70.0	-22.5	47.5	0.05 X 10^6
100	62.0		62.0	-19.1	42.9	0.02 "
125	70.0		70.0	-16.1	53.9	0.25 "
160	80.0		80.0	-13.4	66.6	4.57 "
200	82.0		82.0	-10.9	71.1	12.88 "
250	83.0	0.7	83.7	- 8.6	75.1	32.36 "
315	76.0		76.0	- 6.6	69.4	8.71 "
400	80.0		80.0	- 4.8	75.2	33.11 "
500	80.0		80.0	- 3.2	76.8	47.86 "
630	79.0		79.0	- 1.9	77.1	51.29 "
800	78.0		78.0	- 0.8	77.2	52.48 "
1000	80.0		80.0	0.0	80.0	100.00 "
1250	78.0		78.0	0.6	78.6	72.44 "
1600	76.0		76.0	1.0	77.0	50.12 "
2000	79.0		79.0	1.2	80.2	104.71 "
2500	85.0	2.0	87.0	1.3	88.3	676.08 "
3150	79.0		79.0	1.2	80.2	104.71 "
4000	78.0		78.0	1.0	79.0	79.43 "
5000	71.0		71.0	0.5	71.5	14.13 "
6300	60.0		60.0	-0.1	59.9	0.98 "
8000	54.0		54.0	-1.1	52.9	0.19 "
10000	45.0		45.0	-2.5	42.5	0.02 "

*From example on Page PNLT-7

TOTAL = 10 LOG (1446.41 X 10^6)
= 10 (9.16)
AL_T = 91.6 dB
AL = 90.8

TABLE $\overline{\text{NI}}$-IV

EXAMPLE OF CALCULATIONS FOR EFFECTIVE DURATION (t)

Time (Sec.)	A-level dB(A)	Antilog
9.5	76.3	4.27×10^7
10.0	75.4	3.47 "
10.5	77.0	5.01 "
11.0	80.6	11.48 "
11.5	83.2	20.89 "
12.0	85.5	35.48 "
12.5	87.8	60.26 "
13.0	89.1	81.28 "
13.5	90.5	112.20 "
14.0	90.8	120.23 "
14.5	90.7	117.49 "
15.0	89.8	95.50 "
15.5	88.1	64.57 "
16.0	86.8	47.86 "
16.5	85.5	35.48 "
17.0	83.9	24.55 "
17.5	82.3	16.98 "
18.0	81.1	12.88 "
18.5	79.3	8.51 "
19.0	78.9	7.76 "
19.5	77.7	5.89 "
20.0	75.7	3.72 "

$$\text{TOTAL} = \frac{(895.76 \times 10^7) \times 0.5}{120.23 \times 10^7}$$

$$t = 3.7 \text{ sec.}$$

Given:

$AL_{T_1} = 90.6^*$ $t = 3.7^*$ sec. Daytime

$AL_{T_2} = 95.7$ $t = 5.2$ sec. Daytime

$AL_{T_3} = 87.9$ $t = 2.8$ sec. Evening

$AL_{T_4} = 93.3$ $t = 4.3$ sec. Night

$AL_{T_5} = 85.4$ $t = 2.2$ sec. Night

*From calculations above

Then:

$$\overline{NI} = 10 \log \left[\text{antilog } \frac{90.6 + 10 \log (3.7/86400) + 0 + 5}{10} + \text{antilog } \frac{95.7 + 10 \log (5.2/86400) + 0 + 5}{10} + \text{antilog } \frac{87.9 + 10 \log (2.8/86400) + 5 + 5}{10} + \text{antilog } \frac{93.3 + 10 \log (4.3/86400) + 10 + 5}{10} + \text{antilog } \frac{85.4 + 10 \log (2.2/86400) + 10 + 5}{10} \right]$$

$$= 10 \log [(1.55 + 7.08 + 2.00 + 38.02 + 2.82) \times 10^5]$$

$$= 10 \log (51.46 \times 10^5)$$

$$\overline{NI} = 67.1$$

Thus, the Noisiness Index ($\overline{NI}$) for five flyovers during the summer is $\overline{NI} = 67.1$, which puts it in the marginal region for residential acceptability.

EQUIPMENT

1) Tape recorder
2) Sound level meter (IEC Standard)
3) One-third octave band real time analyzer
4) *Or*, Graphic level recorder
5) Digital computer with sampling capability (optional)
6) Continuous Integration
   Special monitoring equipment capable of integrating sound levels for a specified duration

REFERENCES

1. Galloway, William J., Dwight Bishop, "Noise Exposure Forecasts: Evolution, Evaluation, Extensions and Land Use Interpretations", DOT-FAA Office of Noise Abatement, BBN Report No. 1862, (August 1970).
2. van Niekerk, C. G., and Muller, J. L., "Assessment of Aircraft Noise Disturbance," J. R. Ae. Soc. 73, 383-396 (1969).

N O T E S

TITLE	TOTAL NOISE LOAD (B)
UNIT	(None)
DEFINITION	The Total Noise Load (B) is the average (on an *energy* basis) noise level measured in A-level. Appropriate corrections are made for number of aircraft flyovers and for the time of day. B is numerically equal to the "mean relative nuisance" percentage.
STANDARDS	(None)
GEOGRAPHICAL USAGE	Netherlands
PURPOSE	Total Noise Load is used to determine the relative noise impact of aircraft noise near an airport.

BACKGROUND

Total Noise Load was developed following an extensive study done by the Committee on Noise Nuisance of the Netherlands. One thousand interviews were done in the communities surrounding the airport in Amsterdam resulting in a "mean relative nuisance" scale. Physical measurements of noise produced by about 1000 aircraft flyovers were also obtained to establish the noise exposure in the communities.

The Dutch scientists then developed a concept which combined the number of events with the respective A-levels. The resulting expression places a different emphasis on the effect of the variations in level or number of aircraft as compared to the other community measures.

The Total Noise Load is the number equal to the percentage of "mean relative nuisance" obtained in the Dutch social survey. The Dutch authorities have chosen a B rating of 45 as the "limit of admissibility" which is equal to a 45% "mean relative nuisance" score.

CALCULATION METHOD

The equation for the Total Noise Load is as follows:

$$B = 20 \log \left[\sum_{i=1}^{n} w \cdot \text{antilog } (AL_i/15) \right] - C \quad [1]$$

where:

C is 157 for noise measurements made for 1 year

is 106 for noise measurements made for 1 day

AL_i is the A-level for event i

w is the time of day weighting factor

n is the number of events

TABLE B-I

HOURLY WEIGHTING FACTOR

Time	Weighting Factor w
0000-0600	10
0600-0700	8
0700-0800	4
0800-1800	1
1800-1900	2
1900-2000	3
2000-2100	4
2100-2200	6
2200-2300	8
2300-2400	10

EXAMPLE

The example of calculations for the Total Noise Load (B) for eight flyovers during the time period of one day is shown in Table B-II. A B of 50.6 for the flyovers is equivalent to the 50% "mean relative nuisance" score.

EQUIPMENT

1) Sound Level Meter (IEC Standard)
2) Tape recorder (optional)
3) Digital computer
   Or, Graphic level recorder

REFERENCES

1. Bitter, C., "La Gene due au Bruit des Avions" ("Disturbance Due to Airplane Noise"), presented at a Colloquium on the Definition of Human Requirements with Regard to Noise, 18 & 19 November 1968, Paris; published in Revue d'Acoustique, 3 (10): 88-96 (1970).
2. Schultz, Theodore J., "Technical Background for Noise Abatement in HUD's Operating Programs", for U. S. Department of Housing and Urban Development, BBN Report No. 2005, (September 1970).

TABLE B-II

EXAMPLE OF CALCULATION FOR TOTAL NOISE LOAD FOR 1 DAY

Time	Events (in AL_{max})	Antilog	Weighting Factor
0000-0100	None		10
0100-0200	"		"
0200-0300	"		"
0300-0400	"		"
0400-0500	"		"
0500-0600	80.0	2.15×10^5	"
	95.0	21.54 "	"
	98.0	34.14 "	"
0600-0700	None		8
0700-0800	"		4
0800-0900	"		1
0900-1000	"		"
1000-1100	"		"
1100-1200	85.0	4.64×10^5	"
1200-1300	93.0	15.84 "	"
1300-1400	None		"
1400-1500	"		"
1500-1600	"		"
1600-1700	95.0	21.54×10^5	"
	99.0	39.81 "	"
1700-1800	None		"
1800-1900	"		2
1900-2000	"		3
2000-2100	85.0	4.64×10^5	4
2100-2200	None		6
2200-2300	"		8
2300-2400	"		10

$$\text{TOTAL} = 20 \text{ LOG } (67.88 \times 10^6) - 106.0$$
$$= 156.63 - 106.0$$
$$B = 50.6$$

N O T E S

TITLE	RATING SOUND LEVEL (L_r)
UNIT	dB
DEFINITION	Rating Sound Level (L_r) is a procedure that provides a numerical value for sounds of different spectral and temporal parameters using corrected A-level or equivalent A-weighted sound level (L_{eq}). The assessed L_r for the intruding noise is compared with a Noise Criterion which takes various environmental features into account.
STANDARDS	International Organization of Standardization. Draft ISO Recommendation No. 1996 - Noise Assessment with Respect to Community Response (Document ISO/TC 43 (Secretariat - 452) 529 E).
GEOGRAPHICAL USAGE	United Kingdom
PURPOSE	L_r is always used in conjunction with a Noise Criterion as specified in ISO 1996. Together they provide a means of assessing the impact of noise on a community.

BACKGROUND

The Rating Sound Level (L_r) and the Noise Criterion are used together in an effort to refine predictions of community response to an intruding sound. L_r uses A-level or L_{eq} depending on the fluctuating characteristics of the sound. A correction term is added to these measures to account for impulse noise, tonal content, and duration of the noise. (Table L_r-I).

Noise Rating (NR) curves (see p.271) or Composite Noise Rating (CNR) (see p.184) methods are employed when the sound pressure levels are measured in one-third or octave band frequencies instead of A-level.

The Noise Criterion is used with L_r as a means of describing projected community response. The basic noise criteria itself is related to the pre-existing background level which should be established according to the living habits of the people of the community in question. It has been suggested for residential areas that a suitable background criteria is in the 35-45 dB(A) range. Correction terms for time of day (Table L_r-II) and for different zoning specifications (Table L_r-III) are applied to the basic noise criteria.

The community reaction to a noise source is approximated by the amount that the Rating Sound Level (L_r) exceeds the Noise Criterion.

TABLE L_r-I

CORRECTIONS TO THE MEASURED SOUND LEVEL IN dB(A)

Characteristic features of the noise		Correction dB(A)
Peak factor	Impulsive noise (e.g. from hammering)	+ 5
Spectrum character	Audible tone components (e.g. whine) present	+ 5
Duration of the noise with sound level L_A as a percentage of the relevant time period	Between : 100 and 56 56 and 18 18 and 6 6 and 1.8 1.8 and 0.6 0.6 and 0.2 Less than 0.2	 0 − 5 − 10 − 15 − 20 − 25 − 30

TABLE L_r-II

CORRECTIONS TO BASIC CRITERION FOR DIFFERENT TIMES OF DAY

Time of day	Correction to basic criterion dB(A)
Daytime	0
Evening	-5
Nighttime	-10 to -15

TABLE L_r-III

CORRECTIONS TO BASIC CRITERION FOR RESIDENTIAL PREMISES IN DIFFERENT ZONES

Type of district	Correction to basic criterion dB(A)
Rural residential, zones of hospitals, recreation	0
Suburban residential, little road traffic	+ 5
Urban residential	+ 10
Residential urban with some workshops or with business or with main roads	+ 15
City (business, trade, administration)	+ 20
Predominantly industrial area (heavy industry)	+ 25

CALCULATION METHOD

Rating Sound Level

The Rating Sound Level (L_r) for most types of sounds can be determined from the following formulas:

a) Impulsive Noise or Tones
$L_r = L_A$ + correction*

b) Noises of Fluctuating Level
$L_r = L_{eq}$ + correction*

*Refer to Table L_r-I

Noise Criteria Procedure

After choosing the basic Noise Criterion according to the zoning definition for a specified community (i.e., 35-45 dB(A) for a residential area), the corrections for time of day and type of district (Table L_r-II and III respectively) are applied.

Community Response

Community response to the intruding noise is then categorically estimated in Table L_r-IV by the amount that the Rating Sound Level exceeds the Noise Criterion.

TABLE L_r-IV

ESTIMATED COMMUNITY RESPONSE TO NOISE

Amount in dB(A) by which the rating sound level L_r exceeds the noise criterion	Estimated community response.	
	Category	Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very strong	Vigorous community action

EXAMPLE

The Rating Sound Level measure (L_r) and the Noise Criterion are used together to assess estimated community reaction during the evening hours for the following model urban residential district with these specified noise sources:

Noise Source	dB	Description
Transformer	45 dB(A)	Continuous steady state with tonal components
Industrial	60 dB(A)	Includes both impulsive and audible tone components occurring about 10% of the time
Traffic	45 dB(A)	Fluctuating noise measured in L_{eq}

<u>Evaluate L_r</u>

Transformer Noise

(audible tone + steady state)*

$$L_r = 45 + 5$$
$$= 50 \text{ dB(A)}$$

Industrial Noise

(tone + impulsive + duration)*

$$L_r = 60 + 5 + 5 - 10$$
$$= 60 \text{ dB(A)}$$

Traffic Noise

(fluctuating noise)*

$$L_r = 45 + 0$$
$$= 45 \text{ dB(A)}$$

*Refer to Table L_r-I

The Noise Criterion

The basic noise criteria for the urban residential zone is ideally 40 dB(A). Now look to Table L_r-II for the correction as to time of day; and to Table L_r-III for the zoning correction.

$$\text{Noise Criterion} = 40 - 5 + 10$$
$$= 45 \text{ dB(A)}$$

Community Response

The projected response of the community to the evaluated noise sources is determined by the amount that the L_r exceeds the Noise Criterion (Table L_r-IV). Thus, for the transformer noise which is 5 dB(A) greater than the criteria there might be "sporadic complaints". The industrial noise will probably elicit the most reaction with "threats of community action" due to the excess of 15 dB(A) over the criteria. Whereas the traffic noise is merely part of the background noise.

EQUIPMENT

For Steady State Sounds

Sound Level Meter (IEC Standard)

For Fluctuating Sounds

Special monitoring equipment capable of integrating sound levels for long periods of time (usually 1 hour or 1 day)

REFERENCES

1. International Organization of Standardization. Draft ISO Recommendation No. 1996 - Noise Assessment with Respect to Community Response (Document ISO/TC 43 (Secretariat - 452) 529 E).

TITLE	NOISE RATING CURVES (NR)
UNIT	(None) [dB like scale]
DEFINITION	The Noise Rating Curves are sets of octave band levels (as shown in Figure NR-1, Table NR-I) which were established to provide ratings for octave band levels of community noise.
STANDARDS	International Organization of Standardization. Draft ISO Recommendation No. 1996 - Noise Assessment with Respect to Community Response (Document ISO/TC 43 (Secretariat - 452) 529 E).
GEOGRAPHICAL USAGE	United Kingdom
PURPOSE	NR curves are used in conjunction with a Noise Criterion as specified in ISO 1996. Together they provide a means of assessing the impact of noise on a community.

BACKGROUND

Noise Rating Curves (NR) are used in conjunction with a Noise Criterion in an effort to improve predictions of community response to an intruding sound. For this method the noise from the sound source is measured in octave bands and the spectrum is compared to the noise rating curves.

It may be advisable to determine the Equivalent Sound Level (L_{eq} see p.100) for sounds with time-varying characteristics. A correction term is added to the octave band levels to account for impulse noise, tonal content and duration of the noise (Table NR-II).

Rating Sound Level (L_r) differs from the Noise Rating Curves only in the initial measurement of an intruding sound. L_r measures the noise in A-weighted sound pressure level instead of octave band frequency analysis (NR).

A Noise Criterion is used with NR as a means of describing projected community response. The basic noise criteria itself is related to the pre-existing background level which should be established according to the living habits of the people of the community in question. It has been suggested for residential areas

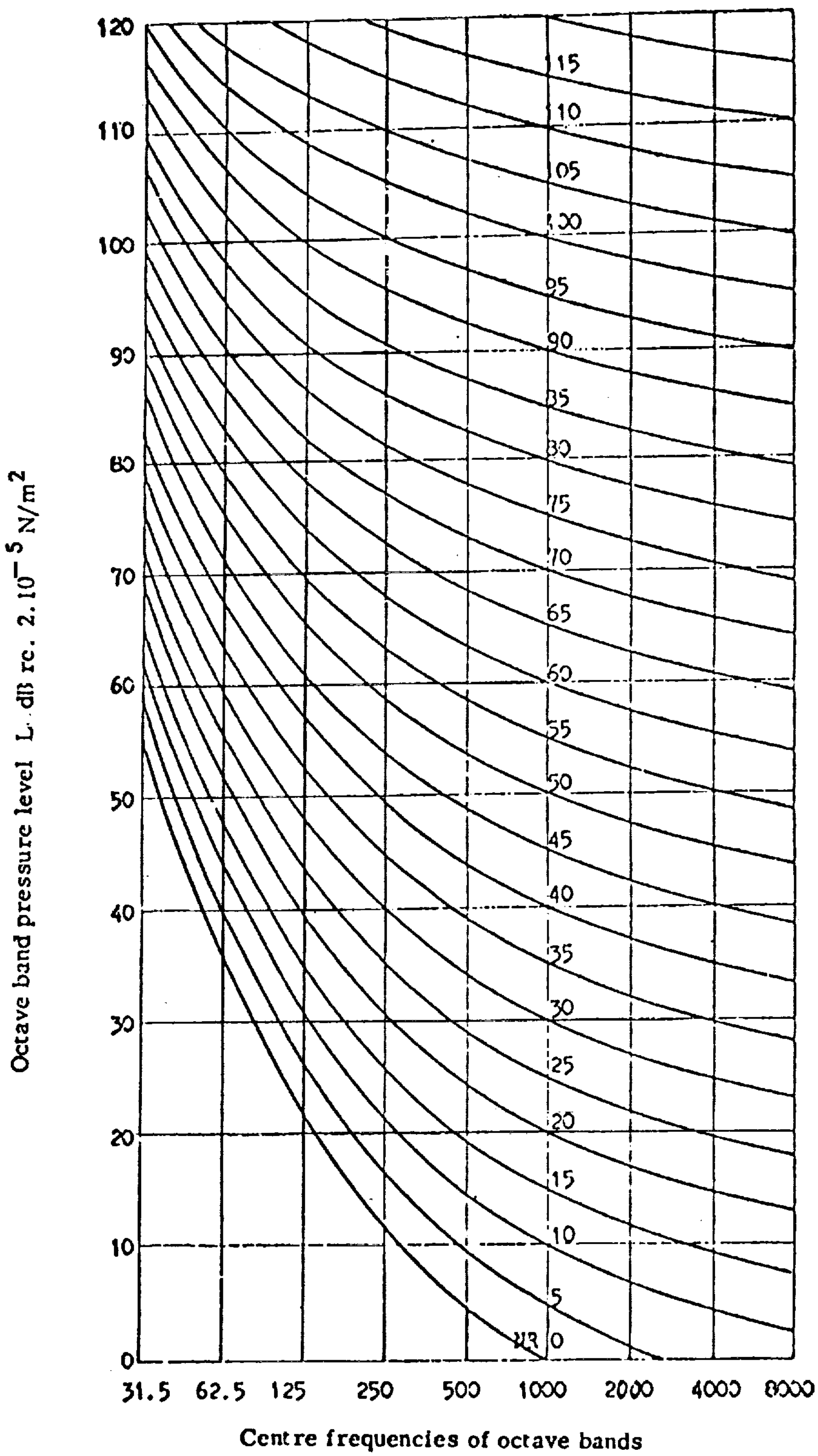


FIGURE NR-1. NOISE RATING CURVES

TABLE NR-I

OCTAVE BAND PRESSURE LEVELS

CORRESPONDING TO NOISE RATING NUMBER NR

NR	Octave band sound pressure level (dB) for centre-frequencies (Hz)								
	31.5	63	125	250	500	1000	2000	4000	8000
0	55.4	35.5	22.0	12.0	4.8	0	-3.5	-6.1	-8.0
5	58.8	39.4	26.3	16.6	9.7	5	+1.6	-1.0	-2.8
10	62.2	43.4	30.7	21.3	14.5	10	6.6	+4.2	+2.3
15	65.6	47.3	35.0	25.9	19.4	15	11.7	9.3	7.4
20	69.0	51.3	39.4	30.6	24.3	20	16.8	14.4	12.6
25	72.4	55.2	43.7	35.2	29.2	25	21.9	19.5	17.7
30	75.8	59.2	48.1	39.9	34.0	30	26.9	24.7	22.9
35	79.2	63.1	52.4	44.5	38.9	35	32.0	29.8	28.0
40	82.6	67.1	56.8	49.2	43.8	40	37.1	34.9	33.2
45	86.0	71.0	61.1	53.6	48.6	45	42.2	40.0	38.3
50	89.4	75.0	65.5	58.5	53.5	50	47.2	45.2	43.5
55	92.9	78.9	69.8	63.1	58.4	55	52.3	50.3	48.6
60	96.3	82.9	74.2	67.8	63.2	60	57.4	55.4	53.8
65	99.7	86.8	78.5	72.4	68.1	65	62.5	60.5	58.9
70	103.1	90.8	82.9	77.1	73.0	70	67.5	65.7	64.1
75	106.5	94.7	87.2	81.7	77.9	75	72.6	70.8	69.2
80	109.9	98.7	91.6	86.4	82.7	80	77.7	75.9	74.4
85	113.3	102.6	95.9	91.0	87.6	85	82.8	81.0	79.5
90	116.7	106.6	100.3	95.7	92.5	90	87.8	86.2	84.7
95	120.1	110.5	104.6	100.3	97.3	95	92.9	91.3	89.8
100	123.5	114.5	109.0	105.0	102.2	100	98.0	96.4	95.0
105	126.9	118.4	113.3	109.6	107.1	105	103.1	101.5	100.1
110	130.3	122.4	117.7	114.3	111.9	110	108.1	106.7	105.3
115	133.7	126.3	122.0	118.9	116.8	115	113.2	111.8	110.4
120	137.1	130.3	126.4	123.6	121.7	120	118.3	116.9	115.6
125	140.5	134.2	130.7	128.2	126.6	125	123.4	122.0	120.7
130	143.9	138.2	135.1	132.9	131.4	130	128.4	127.2	125.9

TABLE NR-II

CORRECTIONS TO THE MEASURED SOUND LEVEL IN OCTAVE BANDS

Characteristic features of the noise		Correction dB(A)
Peak factor	Impulsive noise (e.g. from hammering)	+ 5
Spectrum character	Audible tone components (e.g. whine) present	+ 5
Duration of the noise with sound level as a percentage of the relevant time period	Between :	
	100 and 56	0
	56 and 18	− 5
	18 and 6	− 10
	6 and 1.8	− 15
	1.8 and 0.6	− 20
	0.6 and 0.2	− 25
	Less than 0.2	− 30

that a suitable background criterion is in the 30-40 dB(A) range. Correction terms for time of day (Table NR-III and for different zoning specifications (Table NR-IV) are applied to the basic noise criteria.

The community reaction to a noise source is approximated by the amount that the Noise Rating exceeds the Noise Criterion.

CALCULATION METHOD

NR

The Noise Rating, NR, for most types of sounds can be determined for corrected octave band levels using Figure NR-1. The formulas for correcting the octave band levels are as follows:

a) Noises of Constant Level
   Corrected octave band levels =
   Octave band level + correction*

b) Noise of Fluctuating Level
   Corrected octave band levels =
   L_{eq} for octave band level + correction*

*Refer to Table NR-II

TABLE NR-III

CORRECTIONS TO BASIC CRITERION FOR DIFFERENT TIMES OF DAY

Time of day	Correction to basic criterion
Day time	0
Evening	−5
Night time	−10 to −15

TABLE NR-IV

CORRECTIONS TO BASIC CRITERION FOR RESIDENTIAL PREMISES IN DIFFERENT ZONES

Type of district	Correction to basic criterion
Rural residential, zones of hospitals, recreation	0
Suburban residential, little road traffic	+ 5
Urban residential	+ 10
Residential urban with some workshops or with business or with main roads	+ 15
City (business, trade, administration)	+ 20
Predominantly industrial area (heavy industry)	+ 25

Noise Criteria Procedure

After choosing the basic Noise Criterion according to the zoning definition for a specified community (i.e., 30-40 dB(A) for a residential area), the corrections for time of day and type of district (Table NR-III and IV respectively) are applied.

Community Response

Community response to the intruding noise is then categorically estimated in Table NR-V by the amount that the Noise Rating exceeds the Noise Criterion.

EXAMPLE

Evaluating NR

The Noise Rating (NR) and the Noise Criterion are used together to assess estimated community reaction during the evening hours for the following model urban residential district with the industrial sound as the intruding noise source.

The industrial noise includes both impulsive and audible tone components, and occurs about 10% of the time. The corrections for these parameters are in Table NR-II. The total correction to be applied to *each* octave band is as follows:

Total Correction = tone + impulsive + duration

$$= 5 + 5 - 10$$

$$= 0$$

The corrected octave bands are in Table NR-VI and plotted on Figure NR-2. The highest NR value is 55 which occurs in the 2000 Hz octave band.

$$NR = 55$$

The Noise Criterion

The basic noise criteria for the urban residential zone is ideally 35 dB(A). Now look to Table NR-III for the correction as to time of day; and to Table NR-IV for the zoning correction.

Noise Criterion = 35 - 5 + 10

= 40 dB(A)

The Community Response

The projected response of the community to the evaluated industrial noise source is determined by the amount that NR exceeds the Noise Criterion (Table NR-V). In this case the industrial noise will probably elicit the response of "threats of community action" due to the excess of 15 dB(A) over the criterion.

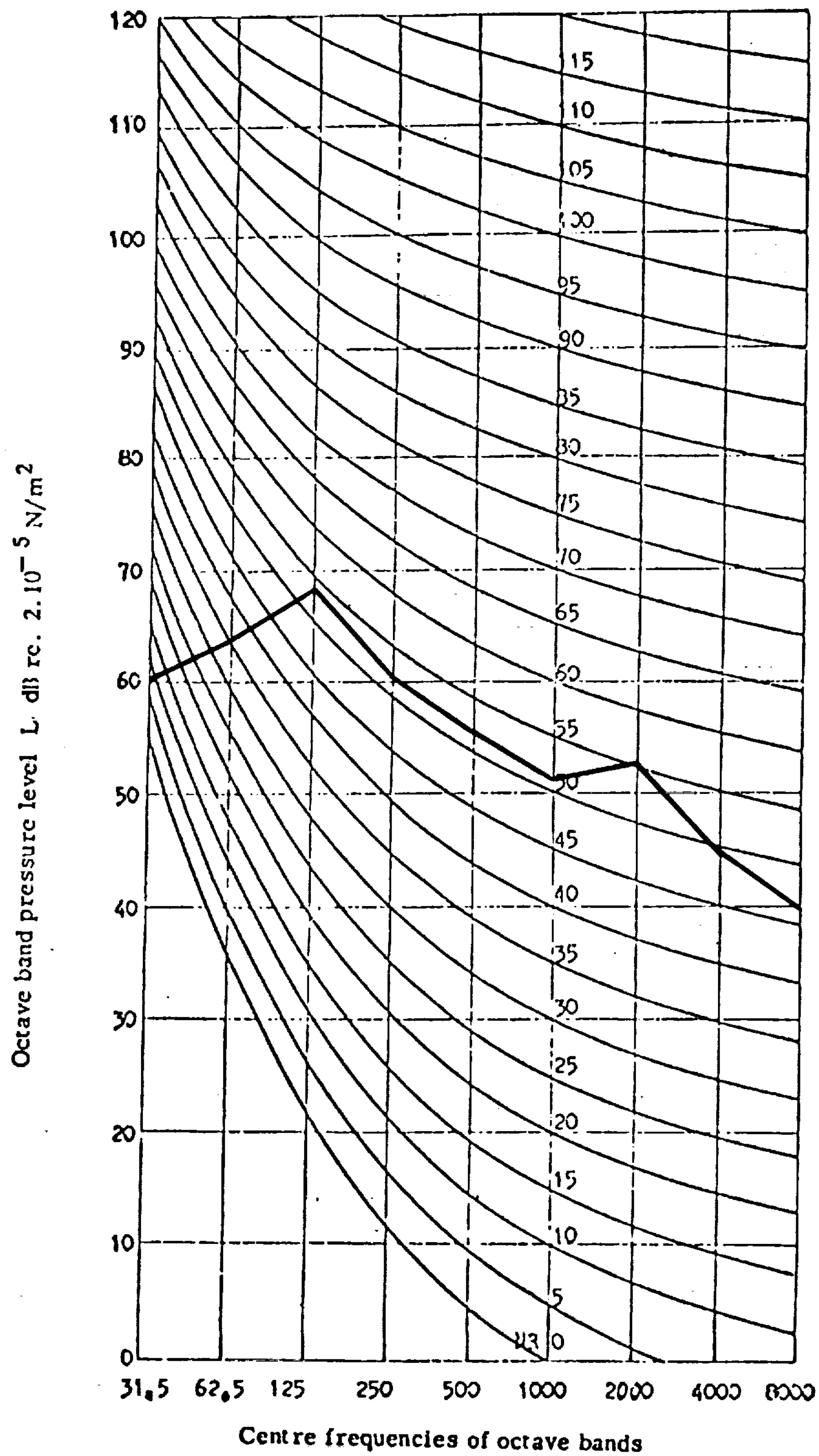


FIGURE NR-2. EXAMPLE OF INDUSTRIAL NOISE SPECTRUM PLOTTED ON NOISE RATING CURVES

TABLE NR-V

ESTIMATED COMMUNITY RESPONSE TO NOISE

Amount by which the NR exceeds the noise criterion	Estimated community response	
	Category	Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very strong	Vigorous community action

TABLE NR-VI

EXAMPLE OF CALCULATIONS FOR CORRECTED OCTAVE BANDS*

Octave Frequency Bands Hz	Factory Noise dB	Total Correction	Corrected Octave Bands dB
31.5	60.0	0	60.0
60.5	63.0	"	63.0
125	68.0	"	68.0
250	61.0	"	61.0
500	55.0	"	55.0
1000	51.0	"	51.0
2000	52.0	"	52.0
4000	45.0	"	45.0
8000	40.0	"	40.0

*Plotted on Figure NR-2

EQUIPMENT

For Steady State Sounds

1) Sound Level Meter (IEC Standard)
2) Octave band analyzer (IEC Standard 225)

For Fluctuating Sounds

1) Special monitoring equipment capable of integrating sound levels for long periods of time (usually 1 hour or 1 day)
2) Octave band analyzer (IEC Standard 225)

REFERENCES

1. International Organization of Standardization. Draft ISO Recommendation No. 1996 - Noise Assessment with Respect to Community Response (Document ISO/TC 43 (Secretariat - 452) 529 E).

TITLE	NOISE AND NUMBER INDEX (NNI)
UNIT	(dB like scale)
DEFINITION	NNI is a composite measure which uses average (i.e., on an *energy* basis) Perceived Noise Level in combination with the number of aircraft heard within a specified period.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United Kingdom
PURPOSE	NNI is used to determine the relative noise impact of aircraft on the surrounding community.

BACKGROUND

NNI was derived from an extensive interview and physical measurement program within the area of London's Heathrow Airport. Aircraft flyover noise was measured at 85 locations within 10 miles of the airport and approximately 2000 people living in the same area were interviewed concerning their general satisfaction or dissatisfaction with their living environment.

The outcome of this study revealed 14 variables related to the noise environment and 58 socio-psychological variables. These were then intercorrelated and found to be reducible to two parameters: 1) the average (i.e., on an *energy* basis) maximum Perceived Noise Level, and 2) the number of aircraft heard during the day or night.

The term 15 log N in the formula for calculating NNI was derived from the estimate that doubling the number of events was equivalent to raising the noise levels by 4.5 dB. The constant of 80 was subtracted from the total noise exposure figures on the basis that the derived annoyance scale was zero at about 80 PNdB.

A survey of NNI levels shows that a level of 50 to 60 NNI is unreasonable during daytime and an NNI of 30 to 45 is intolerable during the nighttime.

CALCULATION METHOD

NNI is determined by the following formula:

$$NNI = \overline{PNL}_{max} + 15 \log N - 80 \qquad [1]$$

where:

N is the number of aircraft heard in the specified time period, i.e., 1 day or 1 night

$$\overline{PNL}_{max} = 10 \log \left[\sum_{i=1}^{n} \text{antilog } (PNL_{max_i}/10)/N \right] \qquad [2]$$

where:

PNL is the peak noise level in PNdB occurring during the passage of each aircraft

EXAMPLE

NNI is calculated for three aircraft flyovers.

Given:

PNL_{max_1} = 99 PNdB

PNL_{max_2} = 105 PNdB

PNL_{max_3} = 107 PNdB

N = 30 per day

$$\overline{PNL}_{max} = 10 \log \left[\frac{\text{antilog } \frac{99}{10} + \text{antilog } \frac{105}{10} + \text{antilog } \frac{107}{10}}{3} \right]$$

$$= 10 \log \left[\frac{(0.794 + 3.162 + 5.012)}{3} \times 10^{10} \right]$$

$$= 104.8 \text{ PNdB}$$

Then:

$$NNI = 104.8 + 15 \log 30 - 80$$

$$= 104.8 + 22.2 - 80$$

$$= 47$$

EQUIPMENT

1) Tape recorder (necessary for single sample)
2) Sound Level Meter (IEC Standard)
3) Octave or one-third octave band analyzer

REFERENCES

1. Galloway, William J., Dwight Bishop, "Noise Exposure Forecasts: Evolution, Evaluation, Extensions and Land Use Interpretations", DOT-FAA Office of Noise Abatement, BBN Report No. 1862, (August 1970).
2. "Noise", Final Report of the Committee on the Problem of Noise, Cmdn. 2056, H. M. Stationary Office, London, (1963).

TITLE	TRAFFIC NOISE INDEX (TNI)
UNIT	(None)
DEFINITION	Traffic Noise Index (TNI) is a noise rating which takes into account the amount of level variability in A-weighted sound pressure level.
STANDARDS	(None)
GEOGRAPHICAL USAGE	United Kingdom
PURPOSE	TNI is used predominantly in evaluating the impact of traffic noise on the community.

BACKGROUND

The Traffic Noise Index was developed to take into consideration the variability of noise levels in an effort to improve the correlation between the noise level measurements and subjective questionnaire data. TNI rates noise measured outdoors in A-weighted sound pressure level. It is based upon the cumulative distribution of noise levels measured over a specified period of time. Two sound levels, L_{10} and L_{90}, are determined from the cumulative function. These represent the levels which were exceeded 10% and 90% of the time. Thus, the 10% level is an average "peak" level while the 90% level is an average "background" level.

CALCULATION METHOD

The TNI is a weighted comparison of L_{10} and L_{90} and is defined as:

$$TNI = 4\ (L_{10} - L_{90}) + L_{90} - 30 \qquad [1]$$

The first term expresses the range of the noise environment (i.e., sound levels exceeded 10 and 90 per cent of the time) and describes the "variability" of the noise. The second term represents the background noise level; the third term is a constant used in an effort to yield more convenient numbers.

EXAMPLE

An example for TNI calculation is:

Given:

$$L_{10} = 80$$

$$L_{90} = 70$$

Then:

$$TNI = 4\ (80 - 70) + 70 - 30$$

$$= 80$$

EQUIPMENT

1) Tape recorder (necessary for single events)
2) Sound level meter (IEC Standard)
3) Distribution analyzer
4) Digital computer optional

REFERENCES

1. Griffiths, I. D., and F. J. Langdon, "Subjective Response to Road Traffic Noise", J. Sound and Vibration <u>8</u> (1): 16-32 (1968).
2. "Noise", Final Report of the Committee on the Problem of Noise, Cmdn. 2056, H. M. Stationary Office, London, (1963).

N O T E S

N O T E S

APPENDIX I

ADDITIONAL RATINGS

TITLE	ANNOYANCE NOISE LEVEL (ANL)
UNIT	dB
DEFINITION	The Annoyance Noise Level is a single-number rating of the annoyance of a noise signal calculated from acoustic measurements in one-third octave bands.
STANDARDS	No direct standard. Related standard: Air-Conditioning and Refrigeration Institute, ARI 275-69
GEOGRAPHICAL USAGE	United States
PURPOSE	ANL was developed in the hope of improving upon the existing measures such as Loudness Level and Perceived Noise Level in the prediction of the annoyance of sounds.

BACKGROUND

ANL was developed by Wells (1969) in an effort to improve the perceived noise level (PNL) rating scheme especially for sounds containing pure tones. ANL uses equal "annoyance" curves which are similar to the curves used in calculating PNL. The calculation procedure is basically that used in PNL or Loudness Level except that a correction is made for the bandwidth of noise. ANL results for most sounds are approximately equal in magnitude to those obtained with PNL or Loudness Level.

CALCULATION METHOD

ANL methodology is very similar to that of PNL (see p. 76). First the Rating Indices are determined for the one-third octave band levels of a given spectrum using the following formula and the method provided in Table ANL-I.

$$\text{Rating Index (RI)} = \text{antilog}_{10}\, m\,(L-L_o) \qquad [1]$$

where:

L is the one-third octave band sound pressure level for each frequency of a given noise spectrum; and m and L_o are given in Table ANL-I.

(Because the methods for determining the tone correction and combining the rating indices are currently under revision they are omitted at this time.)

TABLE ANL-I

COEFFICIENTS m AND L_o FOR COMPUTATION OF RATING INDICES

Band Center Frequency (Hertz)	Lower Segment L < tab. values	Lower Segment m	Lower Segment L_o	Upper Segment L ≥ tab. values	Upper Segment m	Upper Segment L_o
50	91	0.04348	64	91	0.03010	52
63	85	0.04057	60	85	0.03010	50.8
80	85	0.03683	56	85	0.03010	48.8
100	79	0.03683	53	79	0.03010	47
125	79	0.03534	51	79	0.03010	45.8
160	75	0.03333	48	75	0.03010	44.8
200	73	0.03333	46	73	0.03010	43
250	74	0.03205	44	74	0.03010	41.8
315	94	0.03068	42	94	0.03010	40.8
		Full Range of L				
400					0.03010	40
500					0.03010	40
630					0.03010	40
800					0.03010	40
1000					0.03010	39.8
1250					0.03010	38.9
1600					0.02996	37.6
2000					0.02996	35.7
2500					0.02996	32.9
3150					0.02996	30.6
4000					0.02996	29.1
5000					0.02996	29.8
6300					0.02996	31.6
		Lower Segment			Upper Segment	
8000	47	0.04229	38	47	0.02996	33.8
10000	50	0.04229	41	50	0.02996	36.8
12500	61	0.04013	46	61	0.03010	40.6

EXAMPLE

(Omitted for reasons given in Calculation Method).

EQUIPMENT

1) Tape Recorder (necessary for single events)
2) Sound Level Meter (IEC Standard)
3) Octave or 1/3 octave band analyzer
4) Digital Computer (optional)

REFERENCES

1. Wells, R. J., "A New Method for Computing the Annoyance of Steady State Noise Versus Perceived Noise Level and Other Subjective Measures", 77th meeting of the Acoustical Society of America, Phil., (April, 1969).

TITLE E-LEVEL (EL) (L_E)

UNIT dB(E) (dB)

Reference pressure: 20 $\mu N/m^2$

DEFINITION E-weighted (Ear) sound pressure level or E-level is sound pressure level which has been frequency filtered to reduce the effect of the low frequency noise and increase the effect of high frequency noise. An approximation of the "E" weighted response curve is shown in Figure EL-1.

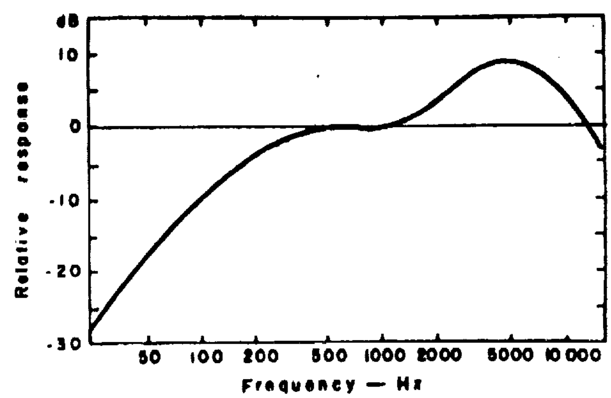


Figure EL-1 E-Weighting

STANDARDS (None)

GEOGRAPHICAL USAGE (None)

PURPOSE E-level is suggested as a simple approximation of perceived level (PL) (see page 60).

BACKGROUND

E-level is similar to D-level in that it attenuates the lower frequencies in a manner approximating the behavior of the human ear. However, E-level was intended to relate to the loudness curve rather than the noy contour. Conceived by Stevens, the E-scale is approximately the inverse of the 20 sone contour of the perceived level calculation method. At this time the E-weighting scale has *not* been standardized and is *not* available in any sound level meter.

CALCULATION METHOD

E-level may be estimated by applying the E-weighting curve (Figure EL-1), to octave or one-third octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an *energy* basis). If octave or one-third octave measures are available, it is suggested that perceived level be calculated instead of E-level since E-level is only an approximation of PL.

EXAMPLE

The exact E-level correction spectrum is *not* available at this time.

EQUIPMENT

Equipment for determining octave or one-third octave band noise measurements.

N O T E S

APPENDIX II

ABBREVIATIONS

ABBREVIATIONS

AI	Articulation Index
AL	A-weighted sound pressure level (see L_A)
ANL	Annoyance Noise Level
ANSI	American National Standards Institute
B	Total Noise Load
BL	B-weighted sound pressure level (see L_B)
CL	C-weighted sound pressure level (see L_C)
CNEL	Community Noise Equivalent Level
CNR_A	Composite Noise Rating for Aircraft
CNR_C	Composite Noise Rating for Community Noise
dB	Decibel. The decibel is one-tenth of the bel.
DL	D-weighted sound pressure level (see L_D)
ECPNL	Equivalent Continuous Perceived Noise Level (see WECPNL)
EL	E-weighted sound pressure level (see L_E)
EPNL	Effective Perceived Noise Level
HL	Hourly Level (see HNL)
HNL	Hourly Noise Level (see HL, L_H)
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
L	Sound Pressure Level (see OASPL, SPL, L_P)
L_A	A-weighted sound pressure level (see AL)
L_B	B-weighted sound pressure level (see B-level) (BL)

L_C	C-weighted sound pressure level (see CL)
L_D	D-weighted sound pressure level (see DL)
L_{dn}	Day-Night Level
L_E	E-weighted sound pressure level (see EL)
L_{EPN}	Effective Perceived Noise Level (see EPNL)
L_{eq}	Equivalent Sound Level (SLAQ)
L_H	Hourly Level (see HNL)
LL	Loudness Level
LL_S	Loudness Level - Stevens
LL_Z	Loudness Level - Zwicker
L_{NP}	Noise Pollution Level (see NPL)
L_P	Sound Pressure Level (see OASPL, SPL, L)
L_{PN}	Perceived Noise Level (see PNL)
L_r	Rating Sound Level
N	Isopsophic Index
NC	Noise Criterion Curves
NCA	Noise Criteria A-curves (see NC)
NEF	Noise Exposure Forecast
$\overline{NI}$	Noisiness Index
NL	N-weighted sound pressure level (see D-level)
NNI	Noise and Number Index
NPL	Noise Pollution Level
NR	Noise Rating Curves
OASPL	Overall Sound Pressure Level
PL	Perceived Level according to Stevens Mark VII, PLdB

PNC	Preferred Noise Criteria Curves
PNL	Perceived Noise Level (see L_{pn})
PNLT	Tone Corrected Perceived Noise Level (PNL + T)
$\overline{PNLT}_{max}$	Maximum Tone Corrected Perceived Level
PSIL	Preferred Speech Interference Level (see SIL)
$\overline{Q}$	Mean Annoyance Level
R	Classification Index (see N)
RMS	Root-Mean-Square
SEL	Sound Exposure Level (see SENEL)
SENEL	Single Event Noise Exposure Level
SIL	Speech Interference Level
SLAQ	Equivalent sound level A-weighted (see L_{eq})
SLM	Sound Level Meter
SPL	Sound Pressure Level
TNEL	Total Noise Exposure Level (see WECPNL)
TNI	Traffic Noise Index
WECPNL	Weighted Equivalent Continuous Perceived Noise Level

N O T E S

APPENDIX III

GLOSSARY

GLOSSARY

ACOUSTICS -- Acoustics is the science of sound, including its production, its transmission and any effect that it may cause.

AMBIENT NOISE -- Ambient noise is the all-encompassing noise as associated with a given environment, usually comprising sounds from many sources near and far.

ANSI -- American National Standards Institute.

BACKGROUND NOISE -- The total of all noise in a system or situation, independent of the presence of the desired signal.

BAND CENTER FREQUENCY -- The designated (geometric) mean frequency of a band of noise or other signal. For example, 1000 Hz is the band center frequency for the octave band that extends from 707 Hz to 1414 Hz, or for the third-octave band that extends from 891 Hz to 1123 Hz.

BAND PRESSURE (OR POWER) LEVEL -- The pressure (or power) level for the sound contained within a specified frequency band. The band may be specified either by its lower and upper cut-off frequencies, or by its geometric center frequency. The width of the band is often indicated by a modifier (e.g., octave band, third-octave band, 10 Hz band).

CYCLES PER SECOND -- See Frequency.

DAMAGE-RISK CRITERION (HEARING-CONSERVATION CRITERION) -- Recommended maximum noise levels not to be exceeded for a given exposure time in order to minimize the risk of hearing damage to persons exposed to the noise.

DECIBEL -- The decibel (abbreviated "dB") is a measure, on a logarithmic scale, of the magnitude of a particular quantity (such as sound pressure, sound power, intensity, etc.) with respect to a standardized reference quantity.

ENERGY BASIS -- This is familiar terminology that is used when referring to the procedure of summing or averaging sound pressure levels on the basis of their aquared pressures. This method involves the conversion of decibels to pressures, then performing the necessary arithmetic calculations, and finally changing the pressures back to decibels. This procedure is also referred to as *energy summation*, *average energy*, or *energy averaging*.

EQUIVALENT LEVEL -- Equivalent level is *averaged* sound pressure level over the total integration time.

EXPOSURE LEVEL -- Exposure level is the *summation* of sound pressure level over any length of time divided by a constant reference time (e.g., 1 sec., or 1 hour). This is differentiated from equivalent level which is *averaged* sound pressure level over the total integration time. See EQUIVALENT LEVEL.

FREQUENCY -- The number of oscillations per second (a) of a periodic wave sound, and (b) of a vibrating solid object; now expressed in Hertz (abbreviation Hz), formerly in cycles per second (abbreviation cps).

HERTZ -- See FREQUENCY.

IEC -- International Electrotechnical Commission. One of the international bodies that provides specification for use by manufacturers of noise measuring instruments.

IMPULSE NOISE -- Impulse noise is noise of a transient nature due to a sudden impulse of pressure like that created by a gunshot, or a balloon bursting.

ISO -- International Organization for Standardization. One of the international bodies that provides specifications for use by manufacturers of noise measuring instruments.

LEVEL -- In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same *kind*. The base of the logarithm is commonly 10. The reference quantity and the kind of level must be specified. The unit is generally the decibel.

LOUDNESS -- Loudness is the intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from *soft* to *loud*. Loudness depends primarily upon the sound pressure of the stimulus, but is also depends upon the frequency and wave form of the stimulus. The unit of loudness is the sone.

MASKING -- 1) Masking is the process by which the *threshold* of audibility for one sound is raised by the presence of another (masking) sound. 2) Masking is the amount by which the threshold of audibility of a sound is raised by the presence of another sound. The unit customarily used is the dB.

NOISE -- Noise is any undesired signal. In acoustics, noise is any undesired sound.

NOY -- Noy is a unit used in the calculation of Perceived Noise Level. It is the noisiness of a noise for which the perceived noise level is 40 PNdB. The noisiness of a noise that is judged by a subject to be n times that of a 1-noy noise is n noys.

OCTAVE BAND -- An octave band is a frequency band with lower and upper cut-off frequencies having a basic ratio of two. The cut-off frequencies of 707 Hz and 1414 Hz define an octave band in common use. See also BAND CENTER FREQUENCY.

OCTAVE BAND SOUND PRESSURE LEVEL -- Octave band sound pressure level is sound pressure level of the noise contained in an octave band. See SOUND PRESSURE LEVEL.

PEAK SOUND PRESSURE -- The peak sound pressure for any specified time interval is the maximum absolute value of the instantaneous sound pressure in that interval.

PHON -- The unit of measurement for Loudness Level.

PURE TONE -- A pure tone is a sound wave whose waveform is a simple sinusoidal function of the time. It is also described as a sound sensation characterized by its singleness of pitch.

SONE -- Sone is a unit to measure loudness. It is (1) equal to 40 phons, or (2) one sone is equal to a 1000 Hz tone at 40 dB. The loudness of any sound that is judged by a listener to be n times that of a 1-sone tone equals n sones.

SONIC BOOM -- The sonic boom is the pressure transient produced at an observing point by a vehicle that is moving past (or over) it faster than the speed of sound.

SOUND -- Sound is an oscillation in pressure, stress, particle velocity, etc., in an elastic medium, or the superposition (combination) of such oscillations. By extension, sound has also come to be associated with the auditory sensation evoked by this type of oscillation.

SOUND LEVEL -- Sound level is a weighted sound pressure level obtained by use of a sound level meter having standard frequency-filters (weightings of A, B, or C, ANSI S1.4-1971) for attenuating part of the sound spectrum.

SOUND LEVEL METER -- A sound level meter is an instrument comprised of a microphone, an amplifier, an output meter, and frequency weighting network used for the measurement of noise and sound levels. Weighting networks usually include "A", "B" and "C" weightings.

SOUND PRESSURE LEVEL -- 1) The sound pressure level of a sound is 20 times the logarithm to the base 10 of the ratio of the measured root-mean-square (RMS) value of the sound pressure to a reference sound pressure. 2) The reference sound pressure for this Handbook is 20 $\mu N/m^2$, but often seen is the reference pressure 20 Pascal (Pa).

SPECTRUM -- The spectrum of a sound wave is a description of its resolution into components, each of different frequency and usually different amplitude and phase.

SPECTRUM LEVEL -- The spectrum level of a specified signal at a particular frequency is the level of that part of the signal contained within a band 1 Hz wide centered at the particular frequency.

STEADY-STATE SOUNDS -- These are sounds whose average characteristics remain constant in time. Possible examples of steady-state sounds are an aircraft ground run-up, a stationary car engine, and electric blender.

THIRD-OCTAVE BAND -- A frequency band whose cut-off frequencies have a ratio of 2 1/3, which is approximately 1.26. The cut-off frequencies of 891 Hz and 1123 Hz define a third-octave band in common use (1000 Hz center frequency). Refer to BAND CENTER FREQUENCY.

THRESHOLD OF AUDIBILITY (THRESHOLD OF DETECTABILITY) -- The threshold of audibility for a specified signal is the minimum effective sound pressure level of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials.

THRESHOLD SHIFT -- Threshold shift is an increase in a hearing threshold level.

TRANSDUCER -- A transducer is a device capable of being actuated by waves from one or more transmission systems or media and supplying related waves to one or more other transmission systems or media. Examples are microphones, accelerometers, and loudspeakers.

TRANSIENT SOUNDS -- Transient sounds are those whose averave properties do not remain constant in time. Examples are an aircraft flyover, a passing train, and a sonic boom.

WAVELENGTH -- Wavelength for a periodic wave (such as sound in air), is the perpendicular distance between analogous points on any two successive waves. The wavelength of sound in air or in water is inversely proportional to the frequency of the sound. Thus the lower the frequency, the longer the wavelength.

WHITE NOISE -- White noise is noise that is uniform in power-per-hertz-bandwidth over a very wide frequency range (equal energy in every cycle). The slope of the pressure spectrum level of white noise is zero dB per octave.

N O T E S

APPENDIX IV

NOISE RATINGS COMPARISONS

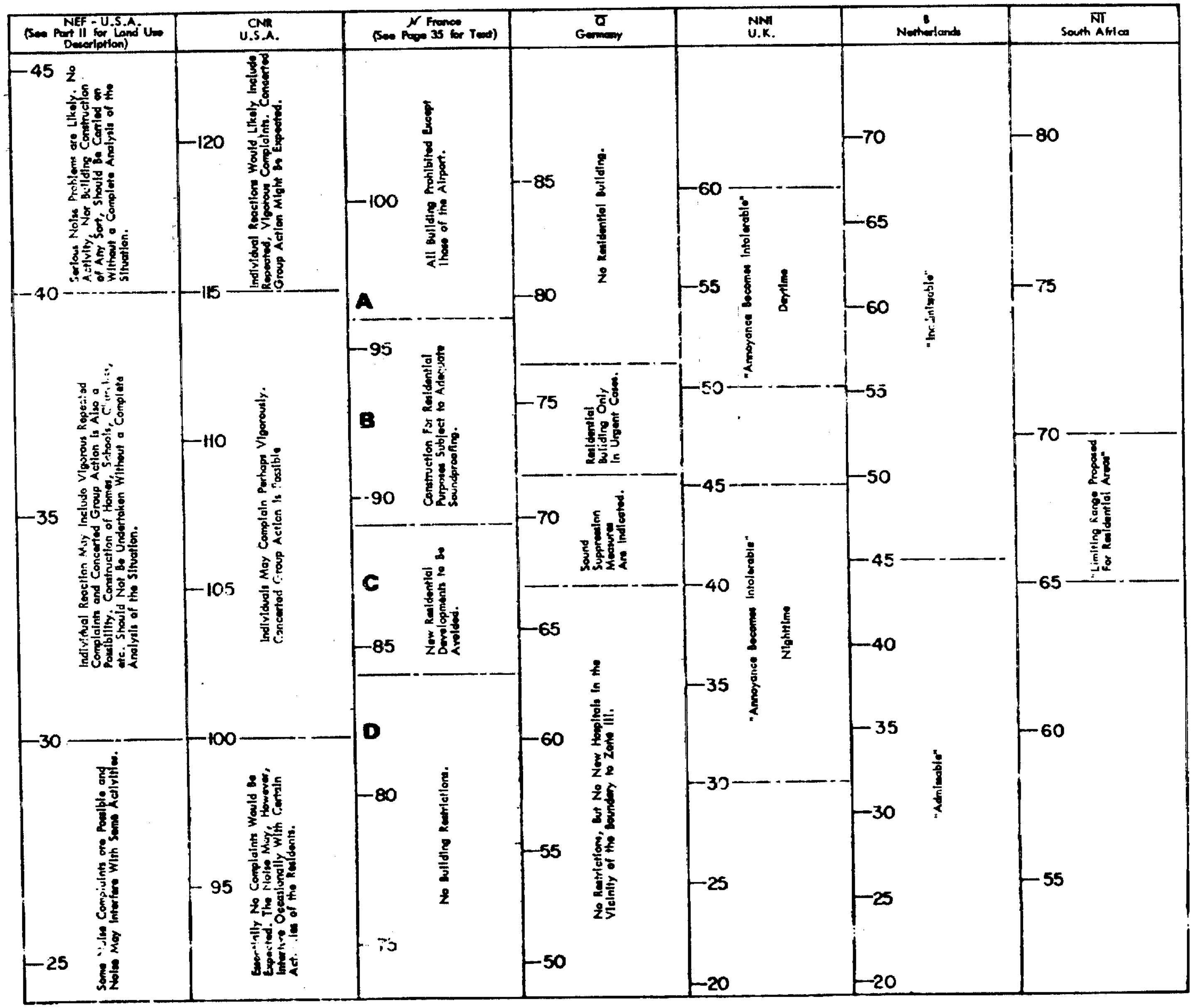


FIGURE A APPROXIMATE EQUIVALENCES BETWEEN NOISE EXPOSURE INDICES AND RESPONSE OR LAND USE DESCRIPTIONS

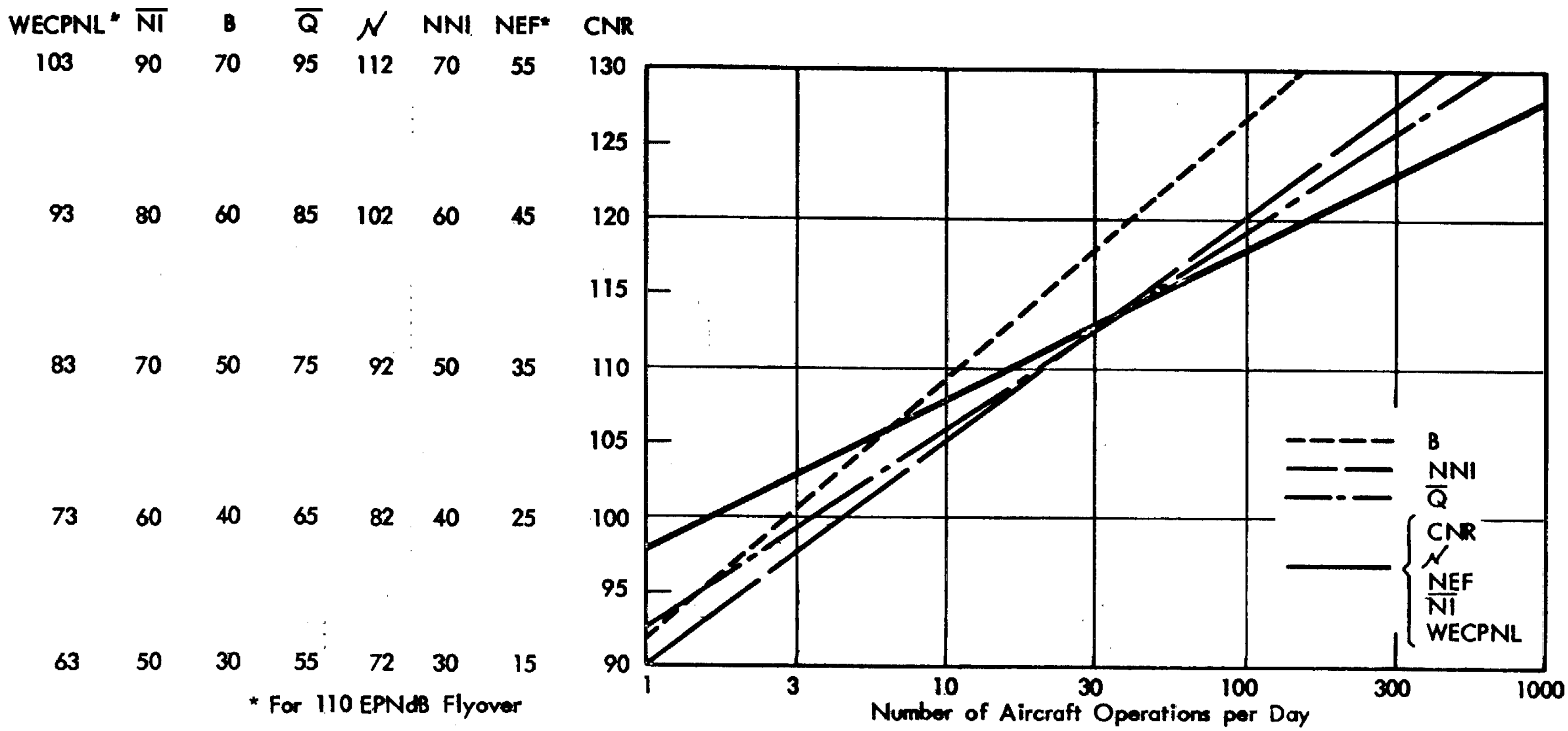


FIGURE B COMPARISON OF VARIOUS NOISE EXPOSURE INDICES FOR A FLYOVER NOISE LEVEL OF 110 PNdB, EFFECTIVE DURATION OF 10 SECONDS, AND VARIABLE NUMBER OF OPERATIONS

REFERENCES

1. Galloway, William J., D. E. Bishop, "Noise Exposure Forecasts" Evolution, Evaluation, Extensions and Land Use Interpretations", DOT-FAA Office of Noise Abatement, BBN Report No. 1862, August 1970.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1974—739-159/107