TRAFFIC SOUND LEVEL EVALUATION PROCEDURES

4-204 TRAFFIC SOUND LEVEL EVALUATION PROCEDURES

4-204.1 GENERAL

Sounds produced by vehicles on a highway create sound pressure levels. A sound pressure level is the root-mean-square sound pressure (P) as related to a reference pressure. Sound pressure level = $10 \log \frac{P^2}{P_R^2}$

Where P_R is the basic reference pressure equal to 0.6002 microbars. A microbar is approximately one millionth of a normal atmospheric pressure of 14.7 pounds per square inch.

For practical purposes, the sound pressure level in decibels is read directly from a sound level meter.

4-204.2 MEASUREMENT OF SOUND LEVELS

a. For purposes of simplicity, scientists divide the audible sound pressure levels into units called decibels. Although the levels of sound are nearly infinite, the range of audibility for humans usually begins at zero decibels, which is the accepted threshold of hearing, and ranges upward to and beyond one hundred and twenty decibels which is the average threshold of pain. There are three established decibel scales which are used for different sound evaluations.

(1) Decibels on "A" scale

The "A" scale, calibrated in dB(A), approximates the level of sound as detected by the human ear. The human ear registers higher frequencies of sound pressures more emphatically than low frequencies. If a high frequency is registered by the ear at a decibel level which is the same decibel level as that of a low frequency, the ear will record the high frequency at a higher decibel level.

(2) Decibels on "B" scale

The "B" scale was originally established for the same purpose as that of an "A" scale (to measure sound levels as the human ear hears them). It measures sound levels in the range from 55 to 85 decibels. However, since the adoption of the "A" scale as the usual method of measuring sound levels, the "B" scale is seldom used.

(3) Decibels on "C" scale

Of the alphabetic scales, the "C" scale most closely measures sound as it actually exists. It is used primarily in scientific experimentation and research.

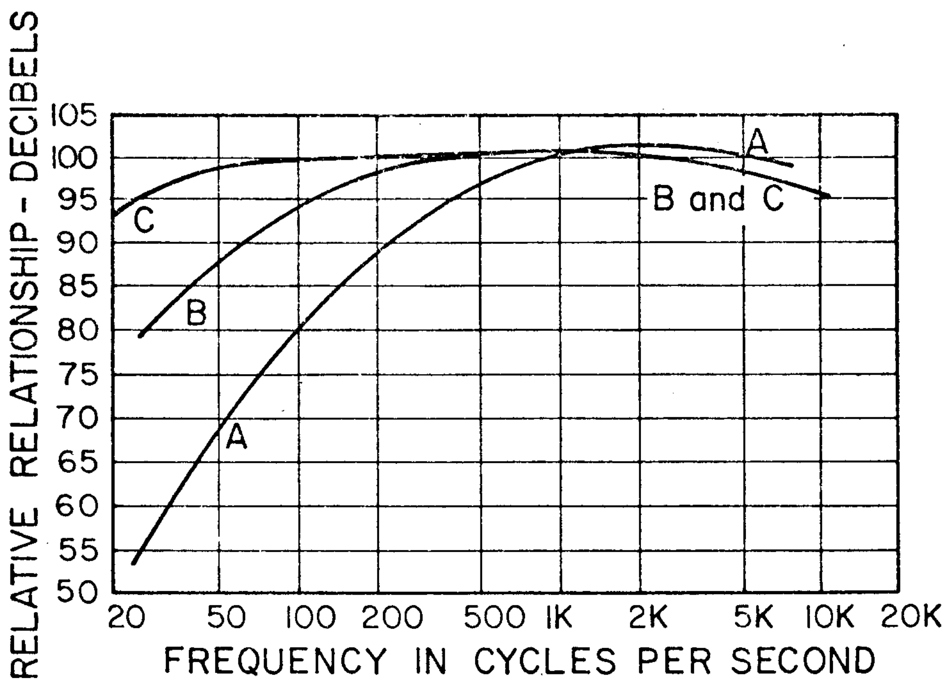
(4) Figure No. 4-204A shows the relationship of the different sound measurement scales of varying frequencies.

b. Sound Frequency Measurement

Sound frequency is defined as the vibrations or cycles occuring each second and is measured in hertz (Hz). If sound pressure levels are of sufficient magnitude, the normal undamaged human ear usually hears frequencies from approximately 20 hertz to 20,000 hertz.

c. Design Sound Level Measurement dB(A)

The "A" scale reading is used in traffic sound evaluation because of the close correlation between the "A" scale and responses of the human ear. All sound evaluation procedures set forth herein are based upon sound levels as measured on the "A" scale.



COMPARISON OF dB(A), dB(B), & dB(C)

FIGURE 4-204 A

4-204.3 TRAFFIC SOUND GENERATION

a. Environmental sound is rarely constant. It changes minute by minute, both in intensity and frequency. Sound levels produced by traffic are proportional to the traffic activity taking place on a facility. Therefore, traffic generated sound is generally greatest during the morning and afternoon peaks.

The effect of sound in the vicinity of residential areas becomes most critical at the beginning of the sleep period from 9:00 PM to 12:00 midnight. This period is identified as the Sound Sensitive Hours (SSH). The analysis of traffic sound generation may require evaluation at peak hours or during the sound sensitive hours.

b. Traffic Variables

(1) Directional Distribution

As discussed in Paragraph 4-201.7, the distribution of traffic on most highways during the design hour is heavier in one direction than in the other. For purposes of sound evaluation, the Directional Distribution (D) should be used in estimating sound levels only on wide median facilities as discussed in Paragraph 4-204.4.

(2) Composition of Traffic

For purposes of sound evaluation, light delivery trucks (such as panels and pickups) take on the operational characteristics of passenger cars and are included as such. Other trucks, truck-trailers and buses (whether diesel or gasoline powered) are referred to as trucks. The percentage of trucks in the traffic stream during the design hour and the Sound Sensitive Hour will be furnished by File D-10 upon request. Truck traffic influences the operating speed (See Paragraph 4-201.9), and the sound level, (See Paragraph 4-204.4).

(3) Design Speed for Sound Sensitive Hours

The operational speed of a highway is influenced by a number of variables. On rural highways, speed is largely influenced by the physical characteristics. In urban areas, the speed tends to be governed by the volume of traffic. The recommended design speeds for various types of highways are shown in Figure No. 4-4. For purposes of evaluating sound levels during Sound Sensitive Hours on all facilities, the use of design speed should be considered. For evaluating sound levels during the design hour, operating speeds which would be experienced for the particular Level of Service on the highway should be used.

c. Geometric Variables

(1) Variables in horizontal alignment generally have little perceptible effect on traffic generated sound.

(2) Vertical Alignment, in certain instances, will have an effect on traffic generated sound levels. The effect of auto traffic on a grade is negligible; however, truck traffic noticeably changes the sound level because of changes in operational characteristics on grades as illustrated by Figure No. 4-204F.

(3) The usual slight variations in cross-section elements have a negligible effect on sound levels unless they present some physical obstruction between adjacent property and highway traffic. Pronounced cross-section variations such as steep slopes, retaining walls, etc., have an effect as discussed in subsequent paragraphs.

d. Design Sound Levels

(1) General

The degree to which sound affects people is dependent upon the individual traits of each person and the activity with which the sound may be interfering. Some persons are more sensitive to sound than others. Some activities depend on a quieter environment than do others. In some instances, the mere screening of the sound source so that it is no longer visible will increase a person's tolerance without materially reducing sound levels. In other instances, sound levels may be great enough to interfere with sleep, study, speech or other sound sensitive functions.

(2) Recommended Maximum Mean Sound levels

Recommended sound levels for different land uses are shown in Figure No. 4-204B. Maximum peak sound levels are not considered appropriate for design purposes. Instead, research has indicated that two levels of sound generation, identified as L_{10} and L_{50} are appropriate. (See TTI Research Report #166-1, "Threshold Noise Levels").

a. L_{50} Sound Level

The L_{50} sound level is the fiftieth percentile measure of sound or the average sound generated by a facility. It is used to identify maximum mean sound levels which occur during the design hours of traffic operation (usually the morning and evening peaks.) Figure No. 4-204C shows the relationship between volume,

SOUND LEVELS FOR VARIOUS LAND USES

Land Use Activity	Time of Day	Recommended Maximum Mean Sound Pressure Level (dBA)	
		Outside a Structure	Inside a Structure
Residential (Single and multiple family)	Day	70	65
	Night	65	55
Business-Commercial Industrial	All	75	65
Educational Institutions	All	70	60
Hospitals & Rest Homes	Day	60	55
	Night	50	45
Public Parks	All	70	55

FIGURE 4-204 B

speed, distance from effective lane and the L_{50} sound level of automobile traffic. A straight line drawn between a particular volume at its indicated speed to a point on the distance column will pass through the sound level column at the related value of L_{50} in dB(A).

b. L_{10} Sound Level

The L_{10} sound level represents the ninetieth percentile of sound generation. At high volume conditions, the L_{10} level is substantially the same as the L_{50} level but the difference becomes more pronounced as volumes decrease and speeds increase. As it represents a measure of a condition which approaches a point source generation, its use, where possible, is more appropriate for measurement of sound during Sound Sensitive Hours than is the L_{50} level. As volumes are generally greatly reduced during late evening hours (SSH) a three and three tenths percentage (3.3%) of average daily traffic (ADT) should be used in determining SSHV rather than the usual K factor for DHV.

c. Selection of L_{10} or L_{50}

Where traffic sound is generated primarily by the passing of individual vehicles and during SSH, L_{10} should be used instead of L_{50} when possible. To determine the dB(A) value of L_{10} and the circumstances of speed(s), volume (V), and distance (d) which justify its use, the following procedure applies:

1. Find L_{50} from Figure 4-204C

NOMOGRAPH FOR BASIC SOUND LEVEL DETERMINATION (AUTOMOBILES)

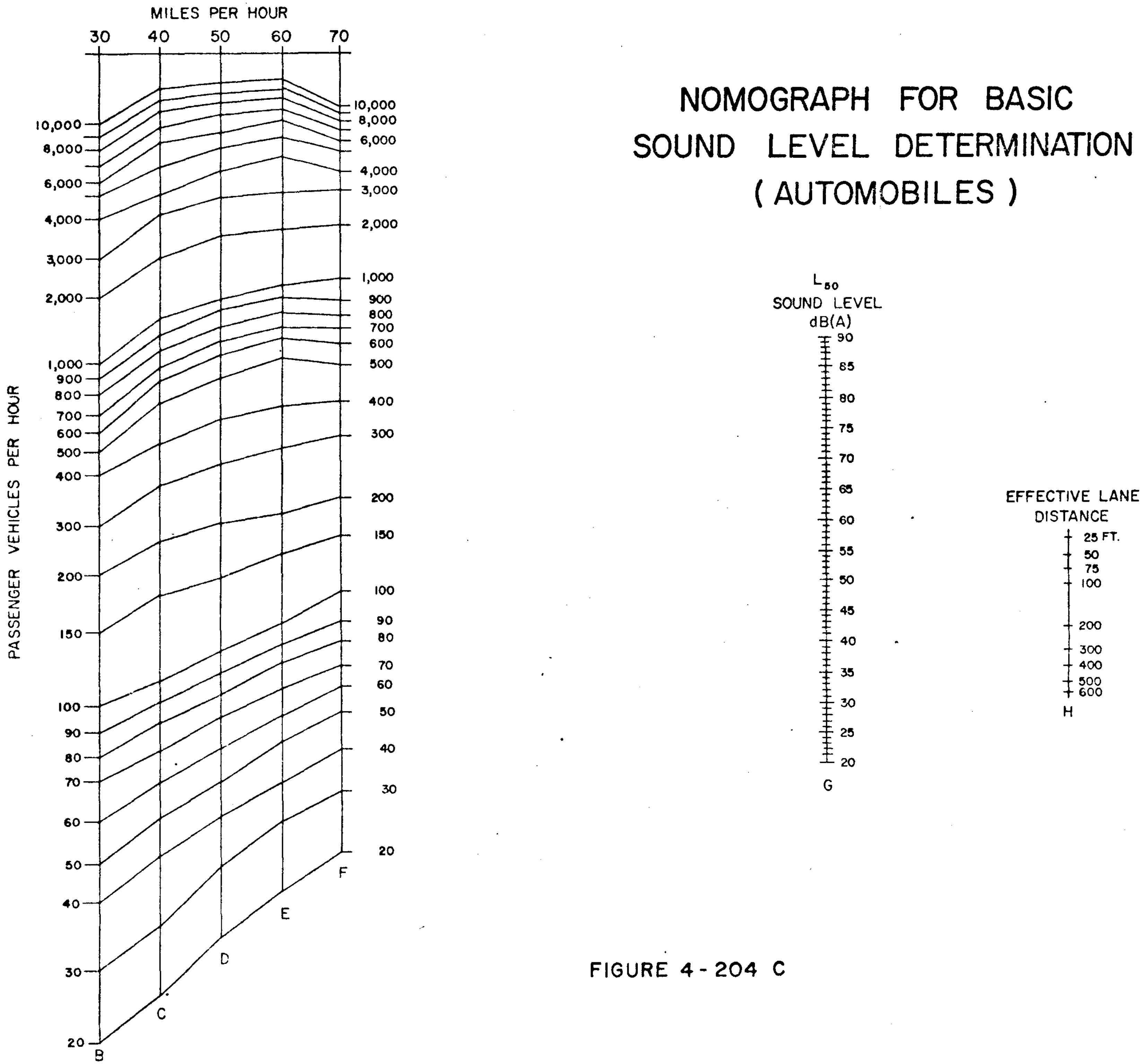


FIGURE 4-204 C

Assumed Source of Sound Emission

Location of Effective Lane Line

$$D_E = \sqrt{D_N D_F}$$

where :

D_E = Distance from observer to Effective Lane Line

D_N = Distance from observer to ℄ near lane

D_F = Distance from observer to ℄ far lane

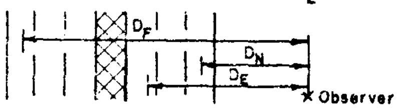


Figure 4-204D

Adjustment for Trucks on Gradients

GRADIENT (%)	ADJUSTMENT (dB)
≤ 2	+ 0
3 to 4	+ 2
5 to 6	+ 3
≥ 7	+ 5

Figure 4-204 F

Addition of Decibels

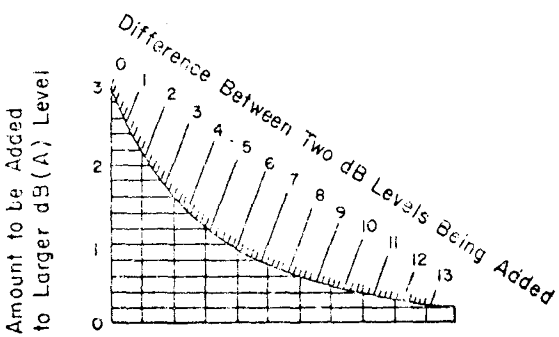


Figure 4-204 H

Adjustment for % Trucks

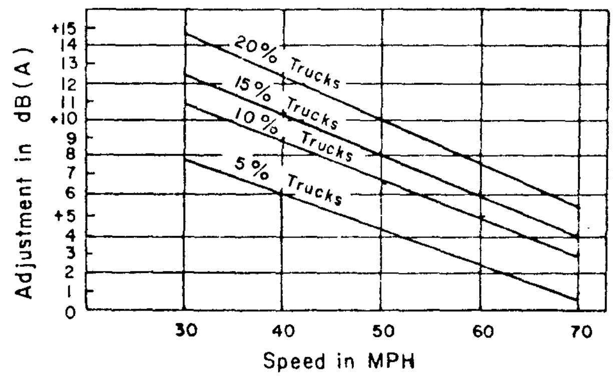


Figure 4-204 E

Level Adjustments for Interrupted Flow

Vehicle Type	Adjustment in dBA	
	L_{50}	L_{10}
Autos	0	+2
Trucks	0	+4

Figure 4-204 G

Adjustments for Pavement Types

Surface Type	Description	dB(A) Adjustment
Smooth	Hot Mix ACP or Concrete Pavement in good Condition.	-5
Normal	Moderately Smooth Asphalt or Concrete Surfacing	0
Rough	Rough Cold Mix ACP with ½" Voids or larger in dia., swept or dragged Concrete, or 1 and 2 Course Surf. Tre.	+5

Figure 4 - 204 I

2. If the product of volume and distance is equal to or less than 75,000, L_{10} should be used. If greater than 75,000, L_{50} should be used. (Example: 20,000 VPH @ 40 feet from equivalent lane = 20,000 x 40 = 800,000 $>$ 75,000, therefore use L_{50}.

3. From Figure 4-204J determine the number of dB(A) units which must be added to L_{50} to obtain L_{10}.

4. If the difference between L_{10} and L_{50} is less than 6 dB(A), L_{10} is assumed to be equal to L_{50}.

d. Reduction of sound levels to acceptable limits.

Reduction of sound levels to acceptable limits is accomplished by modifying the highway geometry. Grades can be reduced in critical areas, roadways may be changed to elevated or depressed configurations or barriers may be incorporated in the cross-section. Specific methods for accomplishing noise abatement are outlined in Paragraph 4-204.4.

4-204.4 SOUND LEVEL EVALUATION PROCEDURES

The sound level evaluation procedures for traffic facilities contained herein are based on various research studies and data now available. The procedures recommended are based on actual traffic operations on existing facilities. It is recognized that the results obtained by use of the following procedures will not, in all instances, correspond with those obtained by other evaluation methods; but, they should be in reasonable agreement. It is expected that these procedures will be revised periodically as additional data and experience in sound analysis becomes available.

a. Design Characteristics as Related to Sound Level Determination

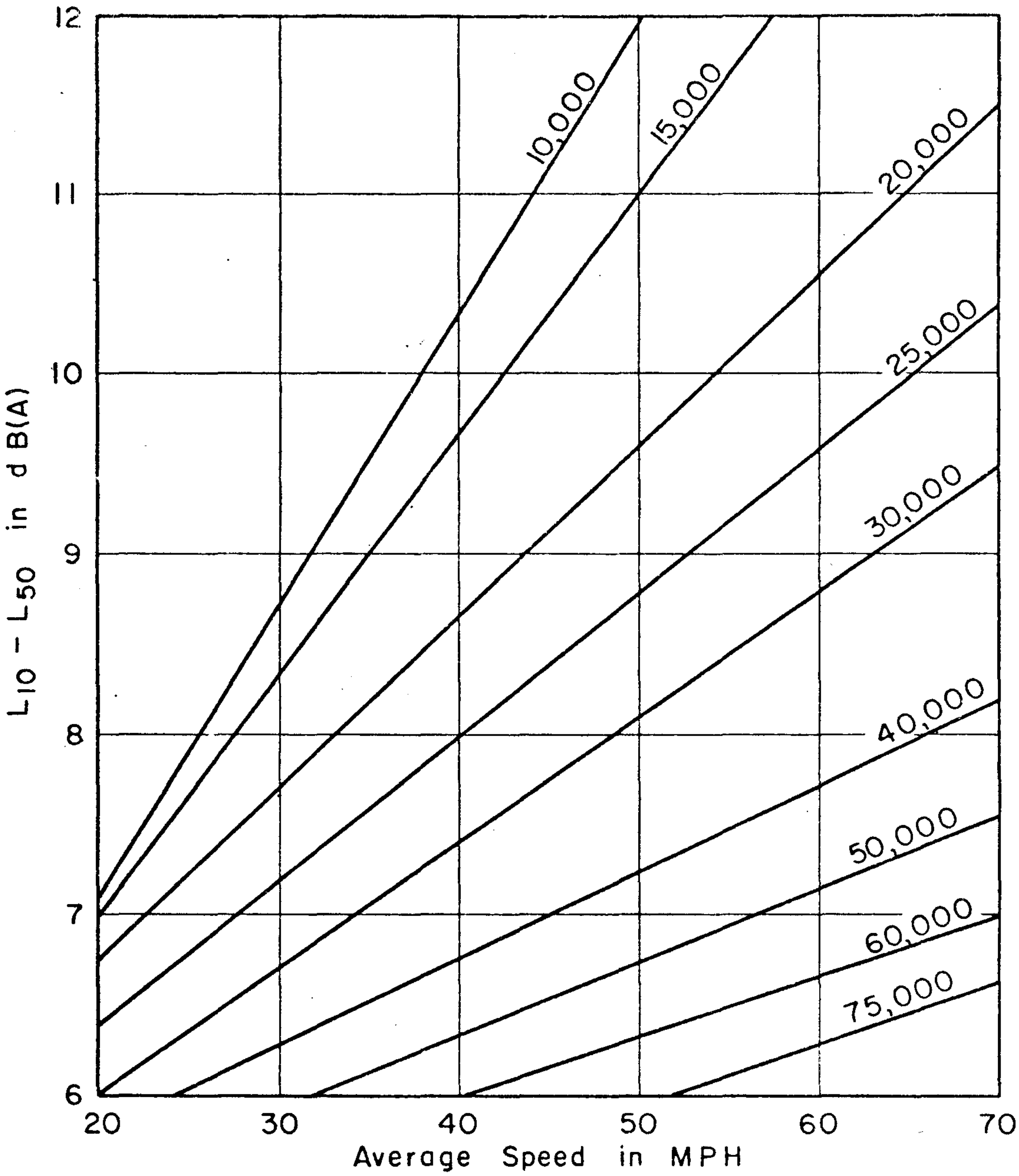
The procedure for determining the sound levels for a general highway situation are as follows:

(1) Traffic Data

The Average Daily Traffic volume, (ADT), Design Hourly Volume (DHV), Conversion Factor (K), Directional Distribution Factor (D), Percent of trucks during the design hour (T) and the total percent of trucks as related to ADT (T_s) should be obtained from File D-10. The conversion factor for Sound Sensitive Hourly Volumes (SSHV) is 3.3 percent.

(2) Effective Lane Location

The "effective lane" location is the imaginary line within a roadway at which the estimated sound level is assumed to be equivalent to the total sound produced across the entire roadway. Designation of an "effective lane" permits the designer to establish a base line from which distances can be measured so that sound levels can be estimated. If: (a) independent gradelines are to be used on divided highways resulting in differential elevations between opposing roadways; or (b) if the facility includes a median whose width is 25% or greater than the total width of the roadway from edge of pavement to edge of pavement (both



If v x d $\leq$ 75,000 use L_{10}

If v x d $\geq$ 75,000 use L_{50}

Where: v = Volume of Traffic in VPH

d = Distance from Effective Lane in Feet

For Values of $L_{10} - L_{50} < 6$, $L_{10} = L_{50}$

CONVERSION OF L_{50} TO L_{10}

FIGURE 4-204 J

directions including median); then sound may be estimated from an effective lane line established in each roadway and the resulting dB(A) values added together logarithmetically utilizing Figure No. 4-204H.

The location of the effective lane on any facility other than a two lane highway is determined from Figure No. 4-204D. For a two lane highway use the centerline as the effective lane line.

(3) Adjustment for Grades

No adjustment is necessary for automobiles on various grades; however, due to the change in operational characteristics, adjustment for trucks on grade is shown in Figure No. 4-204F.

(4) Adjustments for Percentage of Trucks

The percentage of trucks in the traffic stream during the design hour will be furnished by File D-10 upon request.

The effect of trucks in the traffic stream is shown in Figure No. 4-204E.

(5) Type of Highway

The position of a highway above or below the surrounding area has a definite effect on the sound levels along the facility. An at-grade highway results in a higher sound level at the right of way line than does a depressed or elevated section. This occurs because of the "barrier" effect resulting from retaining walls, side slopes, bridge decks, bridge parapets, etc., which interrupt the line of sight and consequently the line of sound wave propogation between the source and the observer. The reduction in sound levels resulting from such a "barrier" effect can be estimated from Figure No. 4-204K as explained below.

For depressed highway:

At "Height or Depth of Roadway in Feet" find depth of roadway. Move upward along this line to the intersection of the line marked "Depressed (all distances)." From this intersection move to the left and read or interpolate the reduction in dB(A) to be applied to the L_{10} or L_{50} value at any distance D_E.

For elevated highway:

At "Height or Depth of Roadway in Feet" find height of roadway. Move upward along this line to the intersection of the line representing the distance from effective lane to observer (D_E). From this intersection move to the left and read or interpolate the reduction in dB(A) to be applied to the L_{10} or L_{50} value.

(6) Pavement Type

Figure No. 4-204I shows the adjustments in sound levels that should be made due to type of pavement surface. For the great majority of cases, normal pavement is assumed.

(7) Sound Abatement Barriers

Barriers are acoustically impeding features (masonry, concrete, earth berms, wood fences, etc.) added

SOUND LEVEL ADJUSTMENT
ELEVATED AND DEPRESSED ROADWAYS

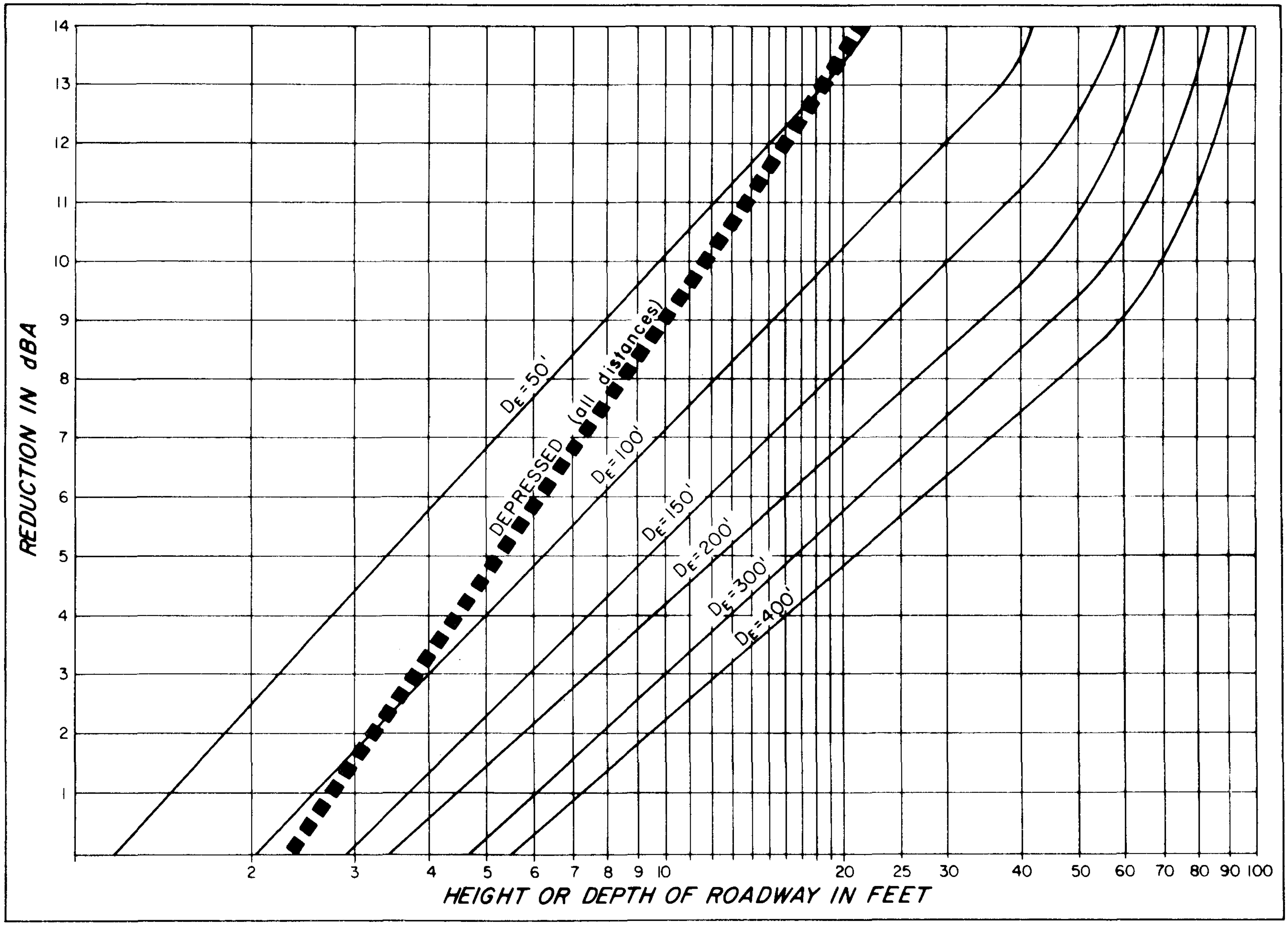
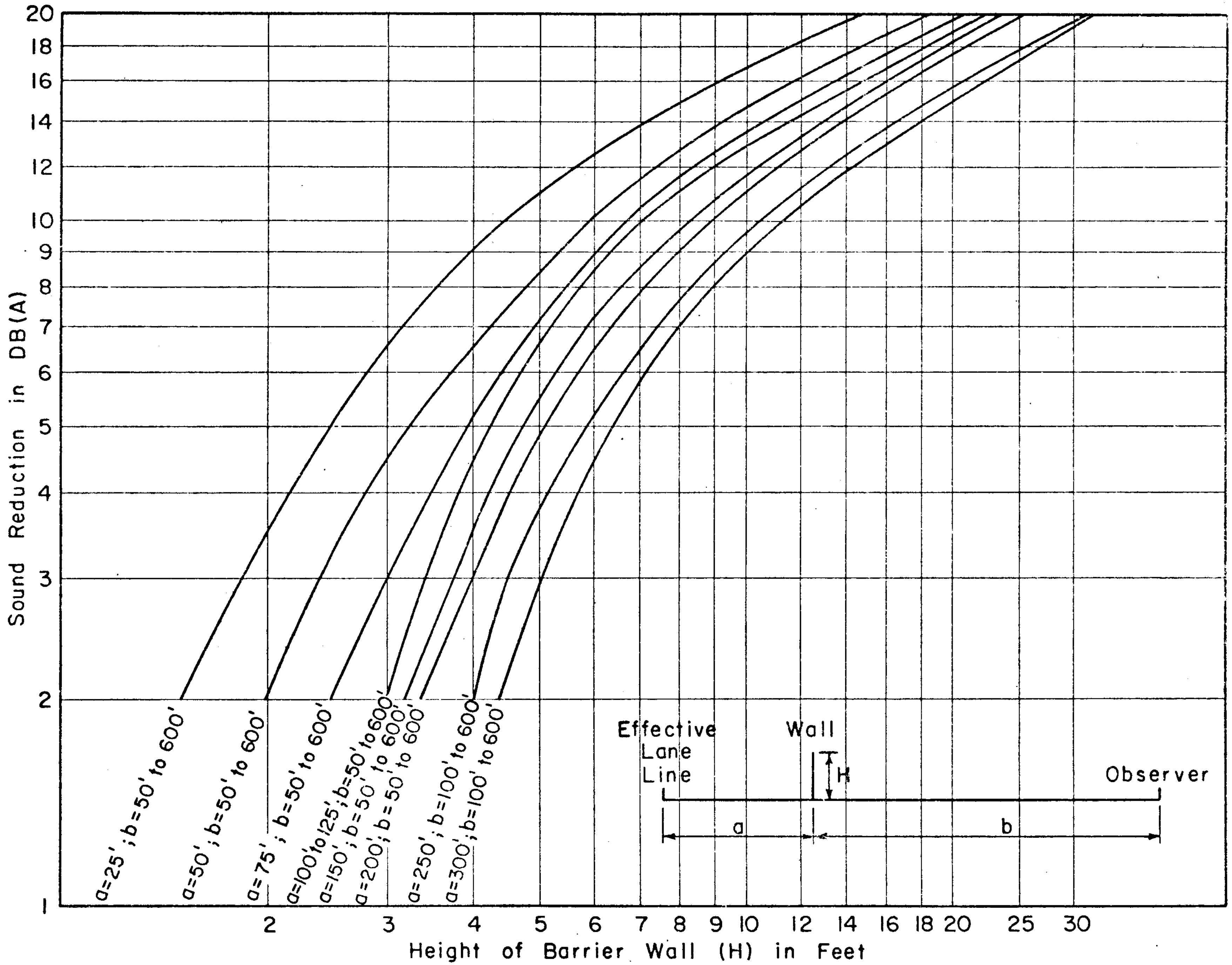


FIGURE E-11



SOUND ATTENUATING BARRIER WALL

FIGURE 4-204 L

to or existing on the cross-section, which by their nature and placement reduce sound levels at or beyond the right of way line. Barrier walls are usually used on at-grade facilities; however, they may be used on depressed or elevated sections. The reduction in sound as a result of a barrier wall is given in Figure No. 4-204L. The length of such a barrier wall can become critical if the point at which a sound level is to be estimated is near the obstruction. As a general rule, to be effective, the length of the wall should be 8 times the distance from the wall to the observer. In determining the height of a barrier wall it should be remembered that the source is assumed to be approximately 2.5' above the pavement for automobiles and 5.5' above the ground at the observer. (See Figure No. 4-204Q)

Foliage barriers are the least effective but will result in a 5 dB(A) sound level reduction for every 100 feet of foliage between observer and the roadway, provided trees and/or shrubs are at least 15 feet tall and sufficiently dense so that no visual path between them and the roadway exists.

Information contained in Figure No. 4-204L was derived from the following:

Equation 1:

Y = Sound Reduction Factor =

$$2\left[a\left(\sqrt{(1+a^2/H^2)}-1\right)+ b\left(\sqrt{(1+b^2/H^2)}-1\right)\right]$$

Where a = horizontal distance in feet from source to barrier

b = horizontal distance in feet from barrier to the observer position

H = the perpendicular height of the barrier wall in feet.

Equation 2:

Reduction in dB(A) =

$$10(\log_{10} 10.1Y)$$

NOTE: The resultant values do not include the effect of source and observer height. For such effects refer to Figure No. 4-204Q.

The solution to these equations can be obtained by requesting File D-19 to furnish a computer tabulation of dB(A) reductions considering different combinations of variables. A computer program has been developed for this purpose.

b. Design Procedures

A brief discussion is given and examples of procedures for determining sound levels for two-lane rural highways, multi-lane rural highways, arterial streets and freeways are illustrated in the following paragraphs.

(1) Two-Lane Rural Highways

Directional Distribution of Traffic has practically no effect on sound generation from two-lane rural highways. Therefore, the traffic volume is expressed in total vehicles per hour in both directions. The source of all traffic sound can be effectively located at the centerline of the roadway. The percentage of trucks in the traffic stream has relatively greater impact on lower volume highways; therefore, the following would apply:

a. Under uniform flow conditions on grades less than two percent, no adjustment for trucks on grades is required. However, where grades exceed two percent, or when the effect of trucks on the traffic generated sound is significant, Figures 4-204E and/or 4-204F should be used.

b. In evaluating sound levels at "stop" condition intersections an adjustment should be made for increased L_{10} sound levels due to the truck acceleration or deceleration. Figure No. 4-204G shows the L_{10} sound level adjustment that should be made for vehicles at intersections. No adjustment is made to L_{50} sound levels.

c. Night and day sound levels should be estimated to determine compatibility with adjacent land use.

d. Design speed is assumed appropriate for sound level evaluation during morning and afternoon peaks unless the Level of Service Analysis indicates that an operating speed different than design speed should be used.

e. L_{50} or L_{10} should be used according to Figure 4-204J. Figure 4-204M illustrates the procedure for evaluating sound levels on two-lane rural highways.

TWO-LANE RURAL HIGHWAY

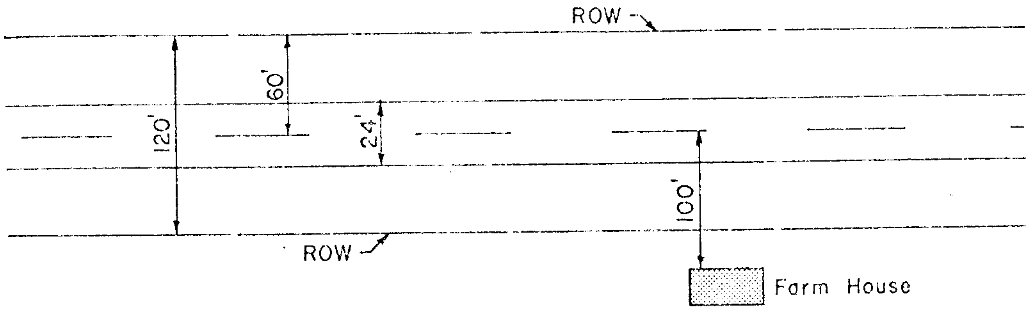
GIVEN: 2 lane rural highway on 3% grade as shown in sketch

ADT = 2000 vpd
Normal pavement type
D = (Does not apply to two-lane highway)
K = 12%
T = 10%
T_s = 6%

Design Speed = 70 MPH

Where T = truck percentage during design hour
T_s = total percent of trucks during 24 hour period

FIND: Sound level in dB(A) at farmhouse for day and night conditions



SOLUTION: Day Conditions

DHV = 2000 (.12) = 240 vph   Use 250 vph

Since DHV x d (250 x 100) = 25,000 or less than 75,000, L_{10} sound level should be used (Figure 4-204J).

Operating Speed = 70 MPH (See Figure 4-8)

Obtain L_{50} from Figure 4-204C by drawing a line connecting 250 vph at 70 MPH (Line F) with 100 foot (dimension from effective lane line to farmhouse) Line H, read 56 dB(A) on Line G for L_{50}.

Using 25,000 and 70 MPH in Figure 4-204J, L_{10} - L_{50} = 10 dB(A); therefore, L_{10} = 56 + 10 = 66 dB(A)

Figure 4-204E and 4-204F show a total adjustment of 4 dB(A) for 6% trucks on a 3% grade; therefore, the adjusted sound level would equal 66 + 4 or 70 dB(A).

No sound level adjustment is necessary for normal pavement.

The adjusted sound level at the farmhouse should not exceed the recommended maximum level of 70 dB(A) set forth in Figure 4-204B.

CONCLUSION:

Since the estimated sound level of 70 dB(A) is equal to the recommended level of 70 dB(A), the design is acceptable.

Figure 4-204M

SOLUTION: Night Conditions

SSHV conversion factor is 3.3%
SSHV = 2000 (.033) = 66 vph   Use 70 vph

Since SSHV x d (70 x 100) = 7,000 and is less than 75,000, L_{10} sound level should be used (Figure 4-204J).

Use design speed = 70 MPH

From Figure 4-204C, by drawing a line connecting 70 vph at 70 MPH (Line F) with 100 foot (dimension from effective lane line to farmhouse), Line H, read 45 dB(A) on Line G for L_{50}.

Using Figure 4-204J with 7,000 and 70 MPH, $L_{10} - L_{50}$ = 12 dB(A) or L_{10} = 45 + 12 = 57 dB(A)   (NOTE: 12 dB(A) difference is maximum ever achieved. Therefore, for product equal to or less than 17,000, 12 dB(A) will apply)

No sound level adjustment is necessary for normal pavement.

The adjusted sound level should not exceed the recommended maximum level of 65 dB(A) set forth in Figure 4-204B.

Figure 4-204E and 4-204F show a total adjustment of 5dB(A) for 10% trucks on a 3% grade; therefore, the adjusted sound level would equal 57 + 5 or 62 dB(A).

CONCLUSION:

Since the estimated sound level of 62 dB(A) is less than the recommended level of 65 dB(A), the design is acceptable.

NOTE: If an intersection were located in close proximity to the farmhouse which imposes a "STOP" condition on the highway being evaluated, an additional 2 dB(A) for automobiles and 4 dB(A) for trucks should be included in the estimated sound level (Figure 4-204G).

Figure 4-204M

(2) Multilane Rural Highway

The procedures for evaluating the sound level on multi-lane rural highways are somewhat the same as for two-lane rural highways. The differences are:

a. If the median width is <u>less than</u> 25% of the total width of both roadways and median, measured from edge of pavement to edge of pavement, the two-way DHV is used as in two-lane highway sound analysis procedures.

b. If the median width is equal to or greater than 25% of the total width of both roadways and median the sound level which will occur at the position of the observer (on one side) is calculated only for the near roadway, applying the higher directional distribution factor to the nearest roadway.

c. Generally, no adjustment in sound level for intersections on multilane rural highways is required unless an intersection imposes a "STOP" condition on the multilane highway being evaluated. In such a case, the sound level adjustment for vehicle start-up shown in Figure 4-204G would apply.

Figure 4-204N illustrates the procedure for evaluating sound levels on multi-lane rural highways.

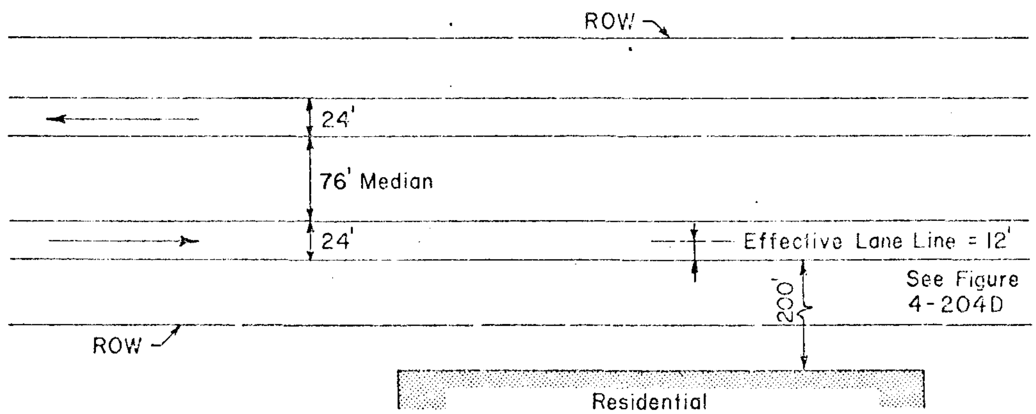
GIVEN: 4 lane divided highway on a 2% grade as shown in sketch

Normal pavement type
ADT = 30,000 vpd
D = 60%
K = 9%
T = 5%
T_s = 10%

Design Speed = 70 MPH

Where T = truck percentage during design hour
T_s = total percent trucks during 24 hour period

FIND: Sound level in dB(A) at Residential Area for Day and Night Conditions



SOLUTION: Day Conditions

Since 76 feet is more than 25% of 124 feet, a sound level is calculated from the near roadway only.

DHV = 30,000 vpd x 0.6 x 0.09 = 1,620 vph   Use 1,600 vph

Operating Speed for DHV is 60 MPH (See Figure 4-12)

Distance from edge of pavement to effective lane line is 12 feet; therefore, effective lane distance (D_E) from residential area is 200 + 12 or 212 feet.

Since DHV x d (1,600 x 212) is greater than 75,000, L_{50} should be used (Figure 4-204J)

From Figure 4-204C, by drawing a line connecting 1,600 vph at 60 MPH (Line E) with 212 feet (dimension from effective lane line to residential area) Line H, read 62 dB(A) on Line G for L_{50}.

Figure 4-204N

No sound adjustment is necessary for normal pavement.

No adjustment is necessary for 2% grade.

Figure No. 4-204E shows an adjustment of 3 dB(A) for 5% trucks; therefore, the sound level would equal 62 + 3 or 65 dB(A).

The adjusted sound level at the residential area should not exceed the recommended maximum level of 70 dB(A) set forth in Figure 4-204B.

CONCLUSION:

Since the estimated sound level of 65 dB(A) is less than the recommended level of 70 dB(A), the design is acceptable.

SOLUTION: Night Conditions

SSHV conversion factor is 3.3%
SSHV = 15,000 (.033) = 495 vph   Use 500 vph

Since SSHV x d (500 x 212) = 106,000 and is more than 75,000, L_{50} sound level should be used (Figure 4-204J).

Use Design Speed = 70 MPH

From Figure 4-204C, by drawing a line connecting 500 vph at 70 MPH (Line F) with 212 feet (dimension from effective lane line to farmhouse) Line H, read 56 dB(A) on Line G for L_{50}.

No sound level adjustment is necessary for normal pavement.

Figure 4-204E shows an adjustment of 3 dB(A) for 10% trucks; therefore, the adjusted sound level would equal 56 + 3 dB(A), or 59 dB(A).

The adjusted sound level should not exceed the recommended maximum level of 65 dB(A) set forth in Figure 4-204B.

CONCLUSION:

Since the estimated sound level of 65 dB(A) during the peak period and 59 dB(A) during SSHV is less than the recommended level of 70 dB(A) and 65 dB(A) respectively, the design is acceptable.

*Since, for SSH analysis purposes, this facility can be treated as a two lane highway (D= 50%) the effective lane line is located at the centerline or 12' from edge of pavement.

Figure 4-204N

(3) Urban and Suburban Arterials

Estimation procedures for determining the sound level generated by traffic on urban and suburban arterials is the same as utilized in analyzing multi-lane rural facilities. For property near a signalized intersection, an adjustment for increased sound levels associated with vehicle start-up as set forth in Figure 4-204G should be included.

Figure 4-204P illustrates the procedure for evaluating sound levels on an urban and suburban arterial.

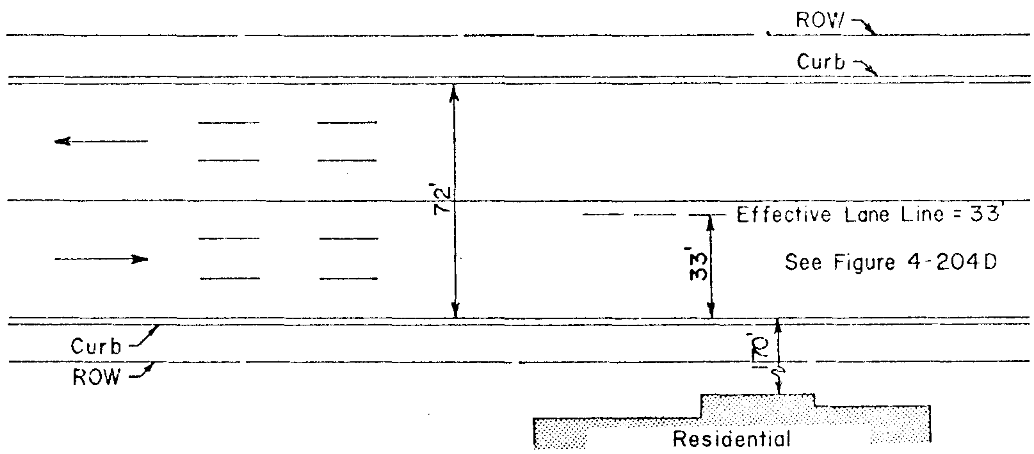
GIVEN: 6 lane undivided arterial on a 0% grade as shown in sketch

Normal pavement type
ADT = 40,000 vpd
D = 60%
K = 10%
T = 4%
T_s = 8%

Design Speed = 50 MPH

Where T = truck percentage during design hour
T_s = total percent trucks during 24 hour period

FIND: Sound level in dB(A) at Residential Area for Day and Night Conditions



SOLUTION: Day Conditions

DHV = 40,000 x 0.10 = 4,000 vph

Use Operating Speed for DHV = 45 MPH (See Figure 4-12)*

Since DHV x d (4000 x 203) is greater than 75,000, L_{50} should be used (Figure 4-204J).

From Figure 4-204C, by drawing a line connecting 4000 vph at 45 MPH (half way between Lines C and D) with 203 feet (dimension from effective lane line to residential area) Line H, read 62 dB(A) on Line G for L_{50}.

No sound adjustment is necessary for normal pavement.

No sound adjustment is necessary for 0% grade.

Figure 4-204E shows an adjustment of 3 dB(A) for 4% trucks; therefore, the sound level would equal 62 + 3 or 65 dB(A)

The adjusted sound level at the residential area should not exceed the recommended maximum level of 70 dB(A) set forth in Figure 4-204B.

*Operating speed for urban highway may be assumed to be the same as rural multilane unless analysis of signals would indicate reduced operating speed.

Figure 4-204P

CONCLUSION:

Since the estimated sound level of 65 dB(A) is less than the recommended level of 70 dB(A), the design is acceptable.

SOLUTION: Night Conditions

SSHV conversion factor is 3.3%
SSHV = 40,000 (.033) = 1320 vph Use 1300 vph

Since SSHV x d (1300 x 200) = 260,000 and is more than 75,000, L_{50} sound level should be used.

Design Speed = 50 MPH

From Figure 4-204C, by drawing a line connecting 1300 vph at 50 MPH (Line D) with 203 feet (dimension from effective lane line to residential area) Line H, read 60 dB(A) on Line G for L_{50}.

No sound level adjustment is necessary for normal pavement.

Figure 4-204E shows an adjustment of 5 dB(A) for 8% trucks; therefore, the adjusted sound level would equal 60 + 5 or 65 dB(A).

The adjusted sound level should not exceed the recommended maximum level of 65 dB(A) set forth in Figure 4-204B.

CONCLUSION:

Since the estimated sound level of 65 dB(A) is equal to the recommended level of 65 dB(A), the design is acceptable.

Figure 4-204P

(4) Freeways

The procedures used in evaluating sound levels on multi-lane rural and Urban-Suburban Arterials are also followed in analyzing sound levels along freeways.

Generally, in estimating the sound level along freeways, it is not necessary to specifically evaluate the effect of ramps or frontage roads. Analysis of the freeway proper will usually yield results indicative of the noise levels that can be expected. In specific instances (for example, sound sensitive locations) evaluation of ramps and/or frontage roads may be made if necessary.

Figure No. 4-204Q illustrates the procedure for evaluating sound levels on a freeway.

FREEWAY

GIVEN: 6 lane divided freeway on a 1% grade, on a structure, elevated 10 feet above natural ground

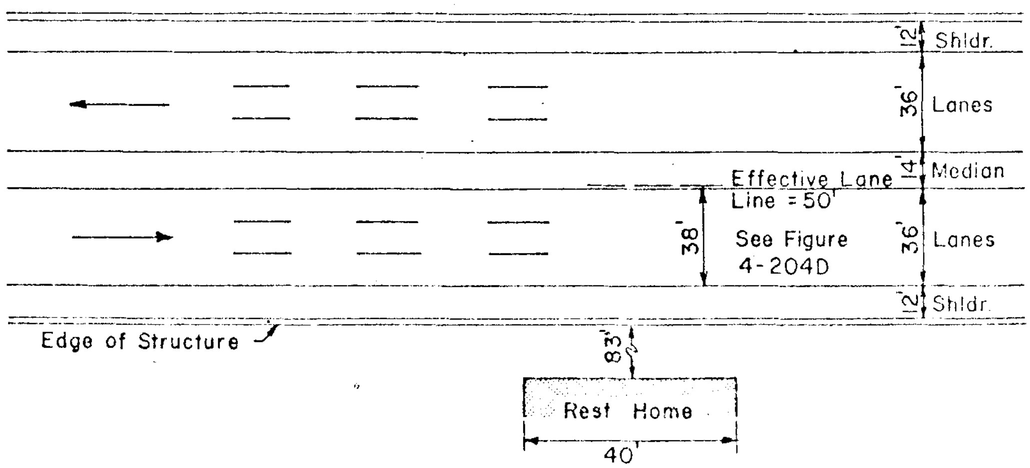
Urban area greater than one million population

Normal pavement type
ADT = 65,000 vpd
K = 10.5%
D = 60%
T = 3%
T_s = 6%

Design Speed = 60 MPH

Where T = truck percentage during design hour
T_s = truck percentage per day

FIND: Sound level in dB(A) at rest home for day and SSHV conditions



SOLUTION: Day Conditions

Since the 14' median is not 25% of the roadway, calculate dB(A) using full roadway and two-way DHV

Effective lane from Figure 4-204D = 38' feet from pavement edge

DHV = 65,000 x 0.105 = 6825 vph Use 7000 vph (Two-way)
DHV = 7000 x 0.60 = 4200 vph (One-way)
From Figure 4-22, LOS = C (PHF = 0.91) Therefore, operating speed = 50 MPH

Since DHV x d (7000 x 133) = 931,000 is greater than 75,000, therefore, L_{50} should be used.

From Figure 4-204C, by drawing a line connecting 7000 vph at 50 MPH (Line D) with 133 feet (dimension from effective lane line to rest home) Line H, read 70 dB(A) on Line G for L_{50}.

Figure 4-204Q

No sound adjustment is necessary for normal pavement.

No sound adjustment is necessary for 1% grade.

Figure 4-204E shows an adjustment of 3 dB(A) for 3% trucks, therefore the sound level would equal 70 + 3 or 73 dB(A).

For a 10' elevated roadway and a distance from the effective lane to rest home of 133', Figure 4-204K shows an attenuation of 6 dB(A).

Therefore, the adjusted sound level is 73 - 6 or 67 dB(A).

The adjusted sound level at the rest home should not exceed the recommended maximum level of 60 dB(A) as set forth in Figure 4-204B.

CONCLUSION:

Since the estimated sound level of 67 dB(A) is more than the recommended level of 60 dB(A), the design is not acceptable.

To lower the sound level to that which is acceptable, the following choices are available:

1. Construct a higher elevated structure (design considerations may not permit)
2. Construct a sound barrier

TRY SOUND BARRIER WALL

The height and length of a sound abatement wall must be such as to lower the 67 dB(A) value (calculated above) to the recommended level of 60 dB(A) or a reduction of 7 dB(A).

Utilizing Figure 4-204L with "a" = 50' (distance from source to the wall), and "b" = 83' (distance from wall to observer), assuming that the wall would be an increase in bridge parapet height at edge of shoulder, a barrier height of approximately 5' is needed for a 7 dB(A) reduction. The length of the barrier should be four times the distance "b" or 332' measured from the left edge of the rest home and extending to the left plus four times the distance "b" or 332' measured from the right edge of the rest home and extending to the right plus the width of the rest home, or 332' + 332' + 40' = 704' of barrier wall.

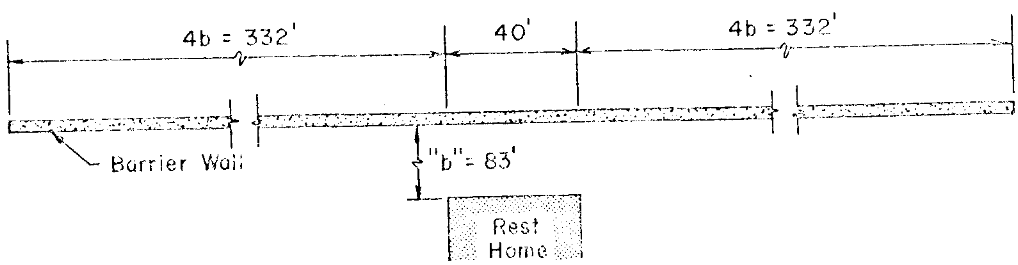


Figure 4-204Q

SOLUTION: Night Conditions

SSHV conversion factor is 3.3%
SSHV = 65,000 x 0.033 = 2145 vph   Use 2200 vph

Since SSHV x d (2200 x 133) = 292,600 and is more than 75,000, L_{50} sound level should be used.

Design Speed = 60 MPH

From Figure 4-204C, by drawing a line connecting 2200 vph at 60 MPH (Line E) with 133' feet (dimension from effective lane to residence) on Line H, read 66 dB(A) on Line G for L_{50}.

No sound level adjustment is necessary for normal pavement.

No sound level adjustment is necessary for 1% grade.

Figure 4-204E shows an adjustment of 3 dB(A) for 6% trucks; therefore, the adjusted sound level would be 66 + 3 or 69 dB(A).

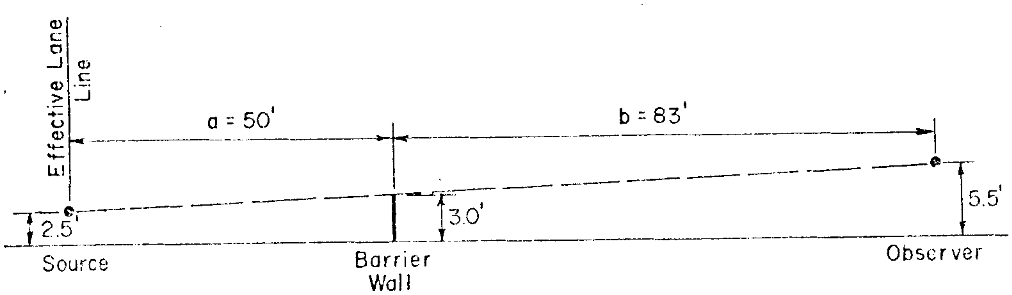
From Figure 4-204K, for a 10' elevated roadway at a distance of 133 feet from effective lane to rest home, an attenuation of 6 dB(A) is indicated. Therefore, the adjusted sound level would be 69 - 6 or 63 dB(A).
Figure 4-204B shows a recommended maximum sound level of 50 dB(A) at night for rest homes. Therefore, the design is unacceptable without a barrier wall.

TRY SOUND BARRIER WALL

The sound level at the structure must be reduced by 13 dB(A).

Utilizing Figure 4-204L with "a" = 50' and "b" = 83', a barrier height of 9 feet is needed for a 13 dB(A) reduction.

NOTE: If the section were an at-grade one, the height of the barrier wall would have to be adjusted to account for the height of the line of sight between the source of the sound (2.5' above the pavement at the effective lane line for automobiles) and the observer (5.5' above the ground) as the following sketch illustrates:



Therefore, a 3' height of wall would have to be added to the height given in Figure 4-204L to obtain the necessary attenuation. However, due to the elevated section given in this problem, the line of sight intersects the edge of the structure and no additional height needs to be added to that given in Figure 4-204L.

Note that the sound emitted from the muffler stacks of diesel trucks will not be reduced unless the wall is of sufficient height to obstruct the line of sight between this source and the observer or approximately 13'. The values obtained from Figure 4-204L take this effect into account. The effect of observer height, however, must be determined by the designer and in the case of multi-storied buildings adjacent to a freeway the observer height may well be of a sufficient distance from ground level as to make any economical barrier wall completely ineffective. In these cases the "inside a structure" criteria from Figure 4-204B would be used since "outside a structure" becomes meaningless above the first floor of a building.

CONCLUSION:

Since SSHV traffic, Night Condition, will govern; a barrier wall at least nine feet high, seven hundred and four feet long should be included in the design.

Figure 4-204Q