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REPORT

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TECHNICAL NOTE 79-2

AVERAGE NOISE LEVELS FOR HIGHWAY VEHICLES

For

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control
Arlington, Virginia 22202

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REPORT

ABSTRACT

Noise emission data are presented for 14 vehicle categories representing the nation's highway vehicle fleet. The data are presented in a format supporting idealized noise versus speed relations for acceleration, deceleration and cruise operating modes. The kinematics of these modes are also presented. Noise data, collected from a variety of sources, represent the most recent available 50 foot (15 meter) passby levels. The purpose of this data collection is to provide vehicle input parameters for EPA's national highway noise exposure model. This model requires energy averaged quantities over each operating mode. The emission model was therefore integrated to give the required calculated model emission levels. In addition to the baseline (pre-regulatory) levels, calculated modal levels are presented for a variety of new vehicle regulatory standards.

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LIST OF SYMBOLS

L_1	maximum level at shift from first to second gear during normal operating acceleration
L_c	noise level under steady cruise condition
L_t	tire noise level
V_1	speed at which first to second gear shift occurs
V_2	speed at which second to third gear shift occurs
α	parameter defining slope of cruise noise versus speed relation
β	parameter defining slope of tire noise versus speed relation
Δ_1	drop in noise level at shift from first to second gear
Δ_2	drop in noise level at shift from second to third gear

1.0 INTRODUCTION

The Environmental Protection Agency has developed a model to estimate the national exposure to highway noise, and to study the effect of vehicle noise control regulations. The purpose of this technical note is to provide vehicle noise emission levels in the format required by the EPA model. Noise levels are presented for 14 categories of motor vehicles operating in a variety of modes, for the baseline (pre-regulatory) condition and for a variety of new vehicle standards.

The EPA highway noise exposure model divides the nation's road system into elements over which acceleration, deceleration, cruise, or idle operating modes occur. The modes are further subdivided into various speeds. Over each operating mode subdivision, the model requires a single emission level for each vehicle class representing an energy-average emission over the mode. Variable width noise contours are thus approximated in a stepwise manner. The noise levels computed in this note, for application to the model, are the equivalent levels which would be sensed by a microphone 50 feet distant from and moving with the vehicle.

The model for vehicle emissions is described in Section 2.0. The vehicle noise level data (essentially passby levels measured at 50 feet) are documented in Section 3.0. The calculated levels for input to the exposure model are presented in Section 4.0.

The vehicle source levels used here are obtained from EPA reports, and includes measurements sponsored by EPA and data collected from the literature for inclusion in various EPA background documents. One other major source of vehicle levels is a study conducted by FHWA. This shows automobile levels substantially in agreement with those cited in Section 3.0. However, the noise levels for medium and heavy trucks show some differences. For the sake of completeness, parallel calculations have been carried out using FHWA's truck levels. These are presented in Appendix A.

2.0 MODEL FOR CALCULATING AVERAGE VEHICLE NOISE LEVELS

2.1 Generalized Vehicle Noise Characteristics

The noise level produced by a given vehicle under any given operating condition at low speeds is largely dependent on two operating parameters, namely, the engine speed and the throttle setting. Of these, the engine speed is the most important parameter,[1] and this is related by the gear ratio to the vehicle speed. Experimental data[1] indicate that the noise level has a linear dependence on engine speed over much of the vehicle's operating range. Therefore, a generalized form for vehicle acceleration noise is as shown in Figure 1, where the noise level is plotted as a function of vehicle speed. In this figure, V_1 and V_2 represent the speeds at which the vehicle shifts into second and third gears, respectively.

The slope of the noise characteristic for operation in first gear is assumed to be constant. This agrees with the experimental data.[1] The slope depends on the type of transmission, being lower for automatic than for manual. The maximum noise level L_1 generated in first gear for a particular vehicle corresponds either to the level measured according to a standard test procedure for that vehicle or that measured by the roadside. For light vehicles, L_1 is the level measured according to the EPA Urban Acceleration Noise Test Procedure.[2] For heavy vehicles (GVWR $\geq$10,000 lbs), the noise level L_1 is obtained from roadside measurements. For motorcycles, the standard test procedure is as defined in the EPA Proposed Motorcycle Noise Emission Regulation.[4] The value of the speed V_1 at which the vehicle shifts from first to second gear is obtained from experimental data. The noise level at zero speed ($L_1 - \Delta_1$) is approximated by extrapolating the measured slope downwards from the 1 - 2 shift speed V_1.

The noise characteristic for operation in second gear is based on the assumption that the relationship between noise level and engine speed is the same in all gears and that the shift from second to third gear occurs at the same engine speed as the shift from first to second gear. The value of Δ_2 is then obtained by calculating V_2 in terms of the ratio between first and second gears, and then prescribing a straight line between the level ($L_1 - \Delta_2$) at V_1 and the level L_1 at V_2. The slope of the $V_1 - V_2$ segment is that of ? the 0 - V_1 segment times the ratio between second and first gears. Subsequent upshifts can be constructed in a similar manner.

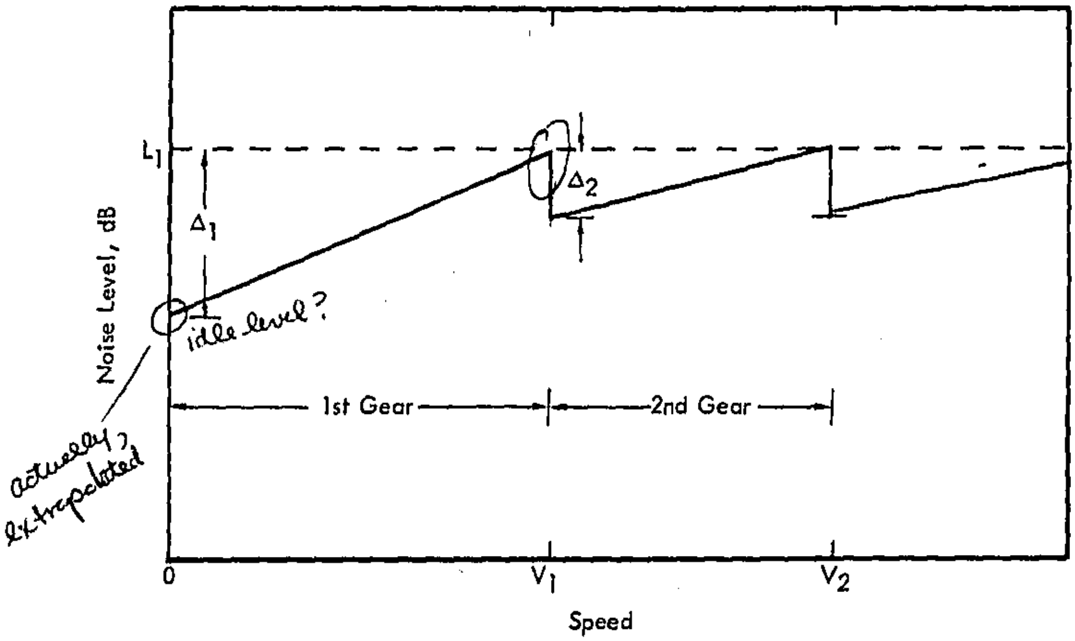
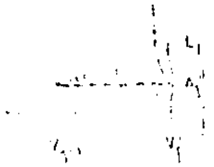


Figure 1. Model for Driveline Noise as a Function of Vehicle Speed.



$$L(V) = L_1 - \Delta_j + \frac{\Delta_j}{V_j - V_{j-1}}(V - V_{j-1})$$

$$V = V_{j-1} + a_j(t - t_{j-1})$$

$$L(t) = L_1 - \Delta_j + \frac{\Delta_j}{V_j - V_{j-1}}\left[V_{j-1} + a_j(t - t_{j-1}) - V_{j-1}\right]$$

$$L(t) = L_1 - \Delta_j + \frac{\Delta_j}{V_j - V_{j-1}} a_j (t - t_{j-1}) \qquad a_j = \frac{V_j - V_{j-1}}{t_j - t_{j-1}}$$

$$\therefore \quad L(t)_j = L_1 - \Delta_j + \frac{\Delta_j}{t_j - t_{j-1}}(t - t_{j-1}) \qquad j = \text{GEHR NUMBER}$$

fr $T = t_j - t_{j-1}$

$$Leq(T) = 10 \log \frac{1}{t_j - t_{j-1}} \int_{t_{j-1}}^{t_j} 10^{\left[L_1 - \Delta_j + \frac{\Delta_j}{t_j - t_{j-1}}(t - t_{j-1})\right]/10} dt$$

$$\text{let } u = \left[-\Delta_j + \frac{\Delta_j}{t_j - t_{j-1}}(t - t_{j-1})\right]/10$$

$$Leq(T) = L_1 + 10 \log \frac{1}{t_j - t_{j-1}} \cdot \frac{10(t_j - t_{j-1})}{\Delta_j \ln(10)} \int_{-\Delta_j/10}^{0} 10^u du$$

$$Leq(T) = L_1 + 10 \log \frac{10}{\Delta_j \ln(10)}\left[1 - 10^{-\Delta_j/10}\right]$$

$$Leq(T) = L_1 + 10 \log \frac{4.34}{\Delta_j}\left[1 - 10^{-\Delta_j/10}\right]$$

TOTAL 0 to V_{max} (N gears)

$$10 \log \left[\frac{t_1 10^{Leq_1/10} + (t_2 - t_1) 10^{Leq_2/10} + (t_3 - t_2) 10^{Leq_3/10} + \dots + (t_N - t_{N-1}) 10^{Leq_N/10}}{t_N}\right]$$

2.2 Average Driveline Noise Levels During Acceleration

To calculate the average noise level generated by a vehicle under any given operation, it is necessary to know the noise level as a function of time throughout the operation. When accelerating from rest, light vehicles tend to operate somewhere between constant acceleration and constant throttle,[1,3] the actual operation depending on the traffic conditions and the individual driver. In calculating the average vehicle noise levels, it is assumed that accelerations from rest are constant in each gear, such that the speed is a linear function of time. The instantaneous driveline (including the engine, accessories, transmission and rear axle) noise level, L, during acceleration in the i^{th} gear can therefore be written as

$$L = (L_1 - \Delta_{\overset{i}{\textcircled{1}}}) + k_i \ t \qquad (1)$$

where $(L_1 - \Delta_i)$ is the effective noise level at the initiation of acceleration at time $t = 0$, (see Figure 1), and k_i depends on the acceleration characteristics. If the acceleration occurs over a time period T_i, then $k_i \ T_i = \Delta_i$. The equivalent level over the time period T_i is then

$$L_{eq(T_i)} = 10 \log_{10} \frac{1}{T_i} \int_{\textcircled{0}\ t_{i-1}}^{\textcircled{T_i} \leftarrow t_i} 10^{(L/10)} \ dt$$

$$= L_1 + 10 \log_{10} \left[\frac{4.34}{\Delta_i} \left(1 - 10^{-\Delta_i/10}\right) \right] \qquad (2)$$

The actual shift speeds after second gear are not expected to be consistent, so that continuing the generalized characteristic shown in Figure 1 beyond V_2 is not reasonable. Therefore, equivalent driveline noise levels at speeds greater than V_2 are taken to be equal to the equivalent level calculated for operation in second gear.

$$\frac{p^2}{p_0^2} = \left(\frac{V}{35}\right)^{\alpha} = \left[\frac{V_a + \left(\frac{V_b - V_a}{t_b - t_a}\right)(t - t_a)}{35}\right]^{\alpha}$$

$$\int_{t_a}^{t_b} \left(\frac{V}{35}\right)^{\alpha} dt = \frac{1}{35^{\alpha}} \int_{t_a}^{t_b} \left[V_a + \left(\frac{V_b - V_a}{t_b - t_a}\right)(t - t_a)\right]^{\alpha} dt$$

let $\xi = V_a + \frac{V_b - V_a}{t_b - t_a}(t - t_a)$

$$d\xi = \frac{V_b - V_a}{t_b - t_a}\, dt$$

$$\frac{1}{35^{\alpha}} \int_{V_a}^{V_b} \xi^{\alpha} \frac{t_b - t_a}{V_b - V_a}\, d\xi = \frac{1}{35^{\alpha}} \frac{t_b - t_a}{V_b - V_a} \left. \frac{\xi^{\alpha+1}}{\alpha+1} \right|_{V_a}^{V_b}$$

$$= \frac{1}{35^{\alpha}} \frac{t_b - t_a}{V_b - V_a} \frac{V_b^{\alpha+1} - V_a^{\alpha+1}}{\alpha+1}$$

$$\therefore L_{eq} = L_t(35) + 10 \log \frac{V_b^{\alpha+1} - V_a^{\alpha+1}}{(\alpha+1)35^{\alpha}(V_b - V_a)}$$

2.3 Tire Noise Levels During Acceleration

The driveline noise expression, Equation (2), is based on noise data collected at low speeds where tire noise is negligible. To determine the total vehicle noise levels during acceleration at higher speeds, it is necessary to add to this the noise generated by the tires. The tire noise level $L_t(V)$ at a vehicle speed V is calculated using the expression

$$L_t(V) \;=\; L_t(35) \;+\; 10\alpha \;\; \log_{10}(V/35),\ \mathrm{dB} \qquad (3)$$

where $L_t(35)$ is the tire noise level at 35 mph, and 10α takes the value 35 for light vehicles and 40 for heavy vehicles (GVWR ≥ 10,000 lbs). For acceleration or deceleration at a constant rate between speeds V_a and V_b during the time interval T_{ab}, the equivalent tire noise level observed by a microphone moving with the vehicle is given by the expression

$$L_{eq(T_{ab})} = L_t(35) \;+\; 10\log_{10}\left[\frac{1}{\alpha+1} \;\; \frac{\left(V_b^{\alpha+1} - V_a^{\alpha+1}\right)}{\left(V_b - V_a\right)\;(35)^{\alpha}}\right] \qquad (4)$$

Thus, the equivalent noise level for the total vehicle is the logarithmic summation of the levels given by Equations (2) and (4).

2.4 Cruise Noise Levels

Under cruise conditions at a constant speed, V, the instantaneous noise level $L_c(V)$ is given by the expression

$$L_c(V) \;=\; \begin{cases} L_c(35) \;+\; 10\beta \;\log_{10}(V/35) \text{ for } V \geq V_c & (5a) \\ L_c(V_c) \qquad\qquad\qquad\qquad \text{for } V < V_c & (5b) \end{cases}$$

$$L_{eq}^{(i)} = L_1 + 10 \log \frac{4.34}{\Delta_i} \left[1 - 10^{-\Delta_i/10} \right]$$

$L_1 = 63.7$

i	Δ_i	$L_{eq}^{(i)}$
1st GEAR	10	59.620
2nd GEAR	.9340	61.726

where V_c and β are quantities dependent on the vehicle type. The noise level and speed of a cruising vehicle are constant in time, so that the equivalent cruise noise level is equal to the instantaneous level $L_c(V)$.

2.5 Deceleration Noise Levels

There are few available data on the noise generated by decelerating vehicles. In the absence of poorly maintained vehicles, deceleration noise at any speed can be closely approximated by the cruise noise level at the same speed. Accordingly, for the deceleration operation, the noise levels are calculated using Equation (5a) at all speeds and the equivalent level over the operation is determined from using Equation (4) by replacing α and $L_t(35)$ with the quantities β and $L_c(35)$, respectively.

3.0 VEHICLE NOISE AND OPERATIONAL DATA

3.1 Vehicle Categories

The vehicle fleet is divided into the following 14 categories:

1. 8-cylinder automobiles (gasoline engines)
2. 6-cylinder automobiles (gasoline engines, automatic transmissions)
3. 6-cylinder automobiles (gasoline engines, manual transmissions)
4. 4-cylinder automobiles and light trucks (gasoline engines, automatic transmissions)
5. 4-cylinder automobiles and light trucks (gasoline engines, manual transmissions)
6. 6- and 8-cylinder light trucks (gasoline engines)
7. 4-, 6-, and 8-cylinder automobiles and light trucks (diesel engines)
8. Medium-duty trucks
9. Heavy-duty trucks
10. Intercity buses
11. Transit buses
12. School buses
13. Unmodified motorcycles
14. Modified motorcycles.

3.2 Vehicle Noise Data

To determine average vehicle noise levels for acceleration, cruise and deceleration operations, it is necessary to obtain values of the parameters L_1, Δ_1, and Δ_2 in Figure 1, the parameters α and β in Equations (3) and (5), and the noise levels L(35) for cruise and coast. The values of these quantities for each of the vehicle categories are presented in Table 1. The levels shown in the table are energy average fleet values, i.e., $L_{eq(e)}$.

Veh #1

Cruise 30mph

$L = L_{35} + 32 \log\left(\frac{v}{35}\right)$

$64.5 + 32 \log\left(\frac{v}{35}\right)$

$30\text{mph} \ni 62.4$

$L_T = L_{35} + 10d \log\left(\frac{v}{35}\right)$

$= 63.4 + 35 \log\left(\frac{v}{35}\right)$

$30\text{mph} \ni 61.1$

57.4

$63.4 + 35 \log\left(\frac{v}{35}\right)$

70.3 at <u>55</u>

Table 1. Fleet Average Noise Emission Parameters for Highway Vehicles

Category	L_1, dB	Δ_1, dB	Δ_2, dB	Cruise			Coast (Tires)	
				$L_c(35)$	10β	V_c, mph	$L_t(35)$	10α
1	63.7	10	4.3	64.5	32	25	63.4	35
2	64.9	10	4.3	64.5	32	25	63.4	35
3	67.0	20	8.6	64.5	32	25	63.4	35
4	67.0	10	4.3	64.5	32	25	63.4	35
5	69.3	20	8.6	65.7	32	25	4 64.4?	35
6	67.4	10	4.3	67.4	32	25	66.3	35
7	70.3	13	5.6	66.3	32	25	63.4	35
8	78.5	8	5	77.5	25	$\boxed{35}$	70 72.5*	40
9	85.0	5	5	83.6	20	35	75 77.3*	40
10	85.0	8	5	77.3	19	30	70.0	40
11	81.0	0	0	74.5	23	30	70.0	40
12	81.0	8	5	74.5	23	30	70.0	40
13	80.0	20	8	73.0	25	0	--	--
14	94.2	20	8	87.2	25	0	--	--

63.4?

incorrect! numbers.

** SEE Appendix A **

L_1 = maximum level prior to first shift, dB

Δ_1 = difference between L_1 and starting level (see Figure 1), dB

Δ_2 = level drop at the 1 - 2 shift (see Figure 1), dB

V_c = speed below which cruise level is constant, mph

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*Based on 1974 roadside data. Current tire values would be 70 dB for Category 8 and 75 dB for Category 9, due to increased use of rib tires.[5] Baseline calculation (Table 9) uses the current lower value. Note that cruise levels are also diminished, since a large component is due to tires.

NOTE LEVEL IN TABLE 9 $= 10\log\left[10^{7.75} - 10^{7.25} + 10^{7.}\right] = 76.9$

for vehicle 8

AUTOMOBILE

#1 $L_c = \begin{cases} 64.5 + 32\log\left(\frac{V}{35}\right) & 8\ V \geq 25 \\ = 64.5 + 32\log(25/35) & V \leq 25 \end{cases}$ $L_c(60) = 72.0$ ✓

General assumptions made in preparing this table are:

- The simplified models presented in Section 2.0 are adequate representations of vehicle noise time histories. Specifically, these models are the sawtooth driveline noise representation, and the log-linear laws for tire and cruise noise with a plateau in cruise noise below a speed V_c.
- The value of L_1 is directly related to the noise level measured in a standard test procedure. For all categories except motorcycles, L_1 was taken as equal to test levels, L_1 for motorcycles was taken to be somewhat less, as described below.
- The parameters Δ_1 and Δ_2 and the shift speeds V_1 and V_2 are obtained from extensive field data for light vehicles. For other vehicles, estimates of these values are based on limited test data, transmission gear ratio, and engine noise characteristics.
- Cruise noise parameters are based on roadside measurements of in-use vehicles. Values of V_c are to a large degree estimates, which may be revised in the future if better data become available.
- Tire noise levels are based primarily on coastby data.

Specific data sources for each of the vehicle categories are summarized below.

Categories 1 through 7

The data for light vehicles are taken from an experimental study conducted for EPA in 1977.[2] The values of L_1 and V_1 for 14 1977 model light vehicles representative of the nation's fleet are presented in Table 2. Δ_1 is calculated from the measured data as described in Section 2.1. The average speed V_1 for the shift from first to second gear is 20 mph. Typical drive ratios between first and second gear are in the range 1.6 to 1.8, with a mean of about 1.75. Therefore, the average speed V_2 for the shift from second to third gear is 35 mph, and the value of $\Delta_2 = \Delta_1 \times (35-20)/35 = 0.43 \Delta_1$ (see Figure 1).

Table 2. EPA Levels, Shift Speeds and Δ_1 for Light Vehicles*

Vehicle No.	Category	Trans. Type	L_1, dB	V_1, mph	Δ_1, dB
001	1	A	62.9	24.6	12.0
002	1	A	63.6	19.9	7.9
003	1	A	61.1	27.1	8.2
004	4	A	59.2	13.0	13.4
005	5	M	67.5	19.6	20.2
007	–	M	69.4	21.5	15.0
009	7	A	69.9	22.0	13.4
010	2	M	65.0	17.4	16.9
011	5	M	67.9	16.8	20.7
013	3	M	65.8	22.0	18.0
015	6	M	70.7	16.2	22.0
016	6	A	65.8	20.7	10.0
018	2	A	62.8	23.1	7.0
020	5	M	69.3	18.8	22.8

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[*] From Reference 2. Vehicle Number is identification number used in Reference 2. Values of L_1 are from Table 3.1, and V_1 from Appendix C. Δ_1 is derived from time histories in the data base supporting Reference 2.

The noise level L_1 for each of the seven categories in Table 1 is the energy averaged value of the levels for the vehicles tested in that category. The tire and cruise noise levels are also energy averaged values, based upon experimental data, with the tire levels increased by 2 dB to account for the increase in surface texture between the experimental test pad and real road surfaces.[2,6] (See Table 3.)

The total vehicle noise level as a function of speed is a combination of driveline and tire noise levels, as shown in Figure 2 for Category 1 vehicles.

Category 8

The transmission shift speeds V_1 and V_2 are assumed to be 20 and 35 mph, respectively, as determined for Categories 1 through 7. The value of Δ_1 is estimated to be 8 dB, this figure being supported by data in Reference 7. Δ_2 is assumed to be 5 dB as for Category 9.

Cruise noise levels at low and high speeds are taken from roadside measurements.[8,9] Tire levels are obtained by the process of source decomposition, assuming a 40 log V scaling relationship with vehicle speed and a constant average driveline level.[10]

Category 9

Heavy duty trucks differ from vehicles in other categories in that they are equipped with 10 - 15 speed manual transmissions. Taking a typical drive ratio of 1.4 between successive gears, and assuming that the engine speed at each shift changes so as to maintain the same vehicle speed, the value of Δ_2 is on the order of 5 dB, assuming a scaling relationship of between 30 log (engine speed) and 40 log (engine speed). For this model, Δ_1 is also given the value of 5 dB.

Cruise noise levels for low and high speeds are taken from roadside measurements[8] in states with no heavy vehicle noise regulations. Tire levels are obtained in the same manner as for Category 8.[10]

Table 3. Fleet Average Cruise and Coast-By Noise Levels at 35 mph, dB

Category	Measured Data[2] from Test Pad		Corrected Data*	
	Cruise	Coast	Cruise	Coast
1 2 3 4	63.0	61.4	64.5	63.4
5	64.3	62.4	65.7	64.4
6	66.0	64.3	67.4	66.3
7	65.4	61.4	66.3	63.4

*2 dB added to tire noise levels to account for difference in surface texture between experimental test pad and typical road surface.[2,6]

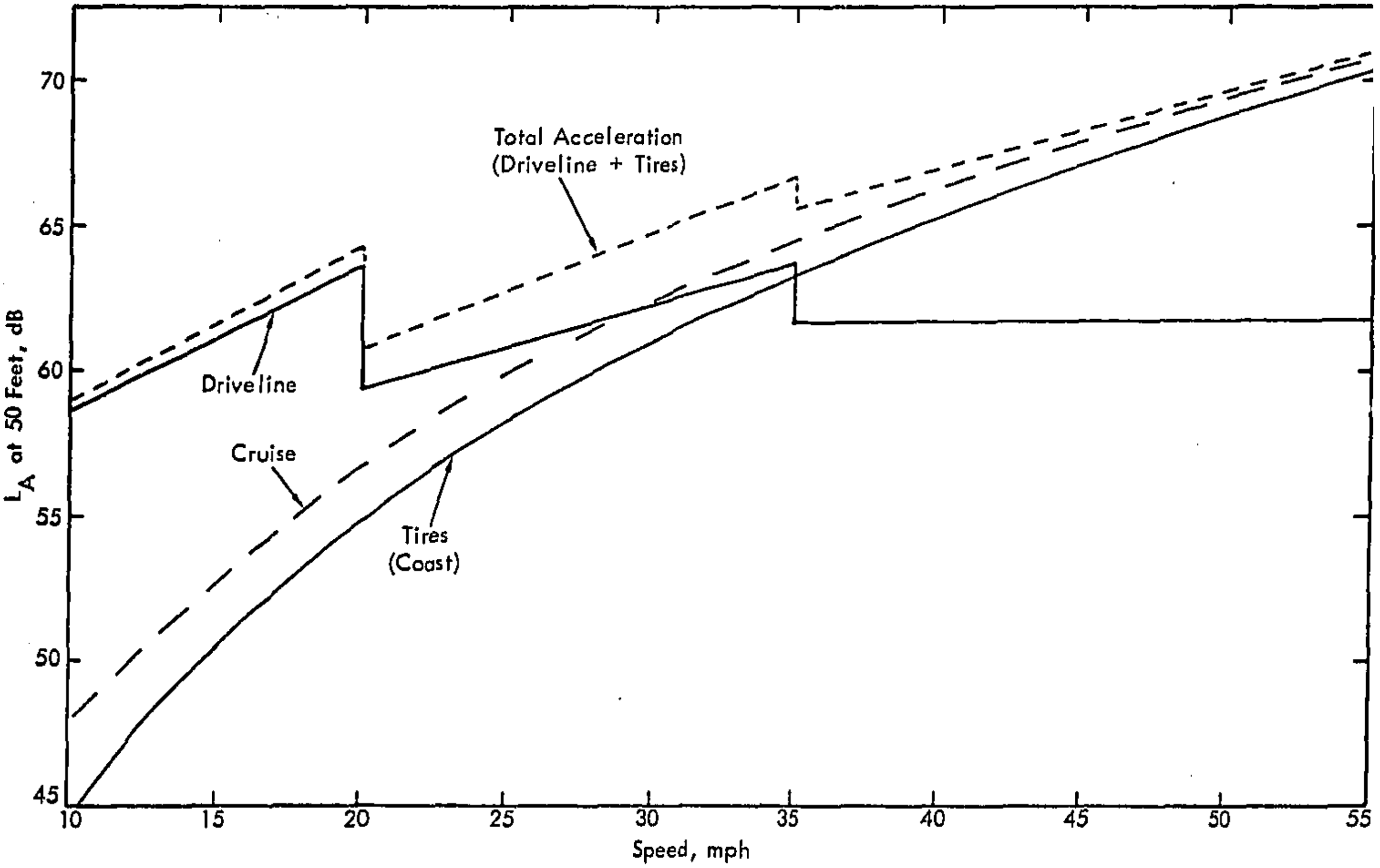

Figure 2. Noise Versus Speed, Category 1.

Categories 10 through 12

The transmission shift speeds V_1 and V_2 are assumed to be 20 and 35 mph, respectively, as determined for Categories 1 through 7 (light vehicles). The values of Δ_1 and Δ_2 for Categories 10 and 12 (intercity and school buses) are assumed to be the same as those for Category 8 (medium trucks). Transit buses (Category 11) are equipped with automatic transmissions and operated at high throttle settings, with the result that Δ_1 and Δ_2 are very low. In this model, it is assumed that $\Delta_1 = \Delta_2 = 0$.

The noise levels for cruise and acceleration are based on Table 6.6 of Reference 11. The $L_{eq(e)}$ values in Table 1 are 1 dB higher than the mean values given in Reference 11, based on σ being typically of order 3 dB.

Categories 13 through 14

The values of Δ_1 and Δ_2 are assumed to be the same as for Category 5 (4-cylinder light vehicles with manual transmissions). Noise level data are taken from Reference 12, and tire noise is assumed to be negligible.

3.3 Vehicle Acceleration and Deceleration Characteristics

To calculate the noise contours alongside the highway, the EPA model requires as input the time and distance for vehicles to accelerate to the limiting speeds. The acceleration data used to determine these quantities are shown in Table 4. The times and distances for acceleration and deceleration are presented in Tables 5 through 8.

Table 4. Acceleration and Deceleration Values for Highway Vehicles

Category	Acceleration	Deceleration
1-7,[1,13] 13-14*	0.15g, $V < 20$ mph 0.12g, $V > 20$ mph	-0.17g
8-9[13]	0.09g, $V < 30$ mph 0.065g, $V > 30$ mph	-0.1g, $V < 35$ mph -0.08g, $V > 35$ mph
10-12**	0.09g, $V < 30$ mph 0.08g, $V > 30$ mph	-0.12g, $V < 30$ mph -0.08g, $V > 30$ mph

*Assumed to be the same as Categories 1 through 7.

**Based on 95th percentile of acceleration/deceleration distributions in Reference 14.

Table 5. Time to Accelerate to Given Speeds

Vehicle Category	Time in Seconds to Accelerate Over Speed Range					
	0-20 mph	0-30 mph	0-35 mph	0-40 mph	0-50 mph	0-60 mph
1-7	6.1	9.9	11.8	13.7	17.5	21.3
8, 9	10.1	15.2	18.7	22.2	29.2	36.2
10-12	10.1	15.2	18.0	20.9	26.6	32.3
13, 14	6.1	9.9	11.8	13.7	17.5	21.3

Table 6. Distance to Accelerate to Given Speeds

Vehicle Category	Distance in Feet to Accelerate Over Speed Range					
	0-20 mph	0-30 mph	0-35 mph	0-40 mph	0-50 mph	0-60 mph
1-7	89	228	319	423	674	981
8, 9	149	334	501	694	1,157	1,723
10-12	149	334	470	627	1,003	1,463
13, 14	89	228	319	423	674	981

Table 7. Time to Decelerate From Given Speeds

Vehicle Category	Time in Seconds to Decelerate Over Speed Range					
	20-0 mph	30-0 mph	35-0 mph	40-0 mph	50-0 mph	60-0 mph
1-7	5.4	8.0	9.4	10.7	13.4	16.1
8, 9	9.1	13.7	16.0	22.8	28.5	34.2
10-12	7.6	11.4	19.9	22.8	28.5	34.2
13, 14	5.4	8.0	9.4	10.7	13.4	16.1

Table 8. Distance to Decelerate From Given Speeds

Vehicle Category	Distance in Feet to Decelerate Over Speed Range					
	20-0 mph	30-0 mph	35-0 mph	40-0 mph	50-0 mph	60-0 mph
1-7	79	177	241	315	492	708
8, 9	134	301	410	669	1,045	1,504
10-12	111	251	512	669	1,045	1,504
13, 14	79	177	241	315	492	708

Veh 1-7

$V_1 = 20$mph Δ_1 = from data

$V_2 = 1.75 \times 20 = 35$ 1.75 = gear ratio (1st - 2nd)

$\Delta_2 = \Delta_1 \times \frac{35-20}{35} = .43\Delta_1$

Example

category ① $\Delta_1 = 10$ $\Delta_2 = 4.3$

0-20 — 6.1 sec
0-30 — 9.9 "
0-40 13.7 "
0-50 17.5 "
0-60 21.3 "

0-35 = 11.8

$$L_{eq} = L_1 + 10\log\frac{4.34}{\Delta}\left[1-10^{-\Delta/10}\right]$$

$$L_{eqT} = \underset{\substack{\parallel \\ 63.4}}{L_T(35)} + 10\log\frac{1}{\alpha+1}\;\frac{V_b^{\alpha+1}-V_a^{\alpha+1}}{(V_b-V_a)\,35^{\alpha}} \qquad \alpha = 3.5$$

① 0-20mph $\alpha+1 = 4.5$

L_{eq} (engine) = $63.7 + 10\log\frac{4.34}{10}\left[1-10^{-10/10}\right]$ = 59.617 6.1 sec

L_{eq} (Tires) =

$= 63.4 + 10\log\frac{1}{4.5}\left[\frac{20.00^{4.5}}{20.00 \cdot 35^{3.5}}\right] = 48.36$

$\Sigma = 59.9$

③ 0-30mph

Engine 0:20 + 20-30 (6.1 sec, 3.8 sec)

TIRES $63.4 + 10\log\frac{1}{4.5}\;\frac{30^{4.5}-0^{4.5}}{(30-0)\,35^{3.5}} = 54.52$

Engine 0-20 59.6 over 6.1 sec

20-30 $63.7 + 10\log\frac{4.34}{4.3}\left[1-10^{-.43}\right]$ = 61.723 over 3.8

$$10\log\frac{6.1\cdot10^{5.96} + 3.8\cdot10^{6.17}}{9.9} \cdot 60.5$$

Σ = 61.48 = 61.5

0-35

L_T = 56.87

$$\frac{6.1\times10^{5.46} + 5.7\cdot10^{6.17}}{11.8}$$

⇒ 60.76

Σ = 62.25 = 62.2

4.0 AVERAGE VEHICLE NOISE LEVELS

The energy averaged noise levels for each vehicle category for cruise, acceleration and deceleration are computed on the following basis:

- Cruise noise levels are calculated using Equations (5).
- Acceleration noise levels consist of the first and second gear levels as appropriate at speeds below V_2, and second gear levels at speeds greater than V_2, plus tire noise levels, weighted over the appropriate time intervals given in Table 5.
- Deceleration noise levels are based on Equation (5a) weighted over the appropriate time intervals given in Table 7.

The values of the baseline average levels for existing vehicles are given in Table 9.

The effect of regulations on the average noise levels is shown in Tables 10 through 17. In computing these modified levels, the following assumptions are made:

- Only driveline noise levels are affected.
- The distribution of noise levels for vehicles in any one category is Gaussian, with σ = 2.5 dB.
- Vehicles are designed with a margin of 2.5 dB below the regulatory level, with a standard deviation of 2.5 dB about this design level.
- The regulatory design level corresponds to L_1 for all categories except motorcycles.
- For motorcycles, L_1 is 3 dB below the regulatory design level. This follows from the 3 dB difference between test and in-use levels reported in Reference 12.

$$\underline{0-50} = \underbrace{0-20}_{6.1} + \underbrace{20-30}_{11.4}$$

$$L_{eq}(E) = 10 \log \frac{6.1 \cdot 10^{5.962} + 11.4 \cdot 10^{6.172}}{17.5}$$

$$= 61.10$$

$$L_{eq}(T) = 63.4 + 10 \log \frac{1}{4.5} \left[\left(\frac{50}{35} \right)^{3.5} \right] = 62.29$$

$$\sum = 64.74$$

$$\underline{0-60}$$

$$= \underbrace{0-20}_{6.1} + \underbrace{20-60}_{15.2}$$

$$L_{eq}(E) = 61.22$$

$$L_{eq}(T) = 63.4 + 10 \log \left[\frac{1}{4.5} \left[\frac{60}{35} \right]^{3.5} \right] = 65.06$$

$$\sum = 66.56$$

$L_{eq}(1)$ 63.4 + 10 log [illegible] $\left(\frac{V}{35}\right)$

α = 3.5

$L_{eq}^{(1)} = 59.620$

$L_{eq}^{(2)} = 61.726$

		$L_{eq}(1)$
0-20	6.1	48.362
0-30	9.9	54.525
0-35	11.8	56.767
0-40	13.7	58.916
0-50	17.5	62.289
0-60	21.3	65.061

(TIRES)

Table 9. Baseline Average Noise Levels for Existing Vehicles

CATEGORY 1 — 8 CYL CARS

25 59.8

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	59.6 59.9	50.5
30.	62.4	61.5 ✓	56.1
35.	64.5	62.3 62.248	58.3
40.	66.4	63.1 63.030	60.1
50.	69.5	64.9 64.74	63.2
60.	72.0	66.8 66.56	65.8

CATEGORY 2 — 6 CYL AUTO CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	60.8	50.5
30.	62.4	62.5	56.1
35.	64.5	63.2	58.3
40.	66.4	63.9	60.1
50.	69.5	65.5	63.2
60.	72.0	67.1	65.8

CATEGORY 3 — 6 CYL MANUAL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	60.3	50.5
30.	62.4	62.5	56.1
35.	64.5	63.3	58.3
40.	66.4	64.0	60.1
50.	69.5	65.6	63.2
60.	72.0	67.2	65.8

CATEGORY 4 — 4 CYL AUTO CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	62.9	50.5
30.	62.4	64.3	56.1
35.	64.5	64.9	58.3
40.	66.4	65.4	60.1
50.	69.5	66.6	63.2
60.	72.0	68.0	65.8

#8

$$L_c = \begin{cases} L(35) + 10\beta \log\left(\frac{V}{35}\right) & V > V_c \\ \cancel{L}_c & V < V_c \end{cases}$$

$10\beta = 25$

$V_c = 35$

$L(35) = 77.5$

$$L_t = L_t(35) + 10\alpha \log\left(\frac{V}{35}\right)$$
$$= \begin{Bmatrix} 72.5 \\ 70 \end{Bmatrix} + 40 \log\left(\frac{V}{35}\right)$$

$$L_c = 10 \log \left[I_E + I_t \right]$$

$$L_c = 10 \log \left[I_E - \left(\frac{V}{35}\right)^4 10^{7.25} + \left(\frac{V}{35}\right)^4 10^7 \right]$$

$$= 10 \log \left[I_E + \left(\frac{V}{35}\right)^4 \left(10^7 - 10^{7.25}\right) \right]$$

$$= 10 \log \left[I_E + \left(\frac{V}{35}\right)^4 10^7 \left[\frac{10^7 - 10^{7.25}}{10^7} \right] \right]$$

$$= 10 \log \left[I_E + I_t \left[-.778 \right] \right]$$

$$L_t = 10 \log \left(\frac{V}{35}\right)^4 10^{7.25 \text{ or } 7}$$

$$I_t = \left(\frac{V}{35}\right)^4 10^{7.25 \text{ or } 7.0}$$

$$L_c = 10 \log \left[I_E - 0.778\, I_t \right]$$

$L_c = 77.5 + 25 \log\left(\frac{V}{35}\right)$ includes 72.5 dB tire

$L_c = 10 \log \left(I_E + I_t \right)$ need 70 dB tire

for $V = 60$

$L_c = 83.352$

$L_t^{72.5} = 81.863$

$L_t^{70} = 79.363$

$$L_c' = 10 \log \left[\underset{\underset{I_c}{\uparrow}}{10^{8.3352}} - \underset{\underset{I_t^{72.5}}{\uparrow}}{10^{8.1863}} + \underset{\underset{I_t^{7}}{\uparrow}}{10^{7.9363}} \right]$$

$$= 81.7$$

Table 9 (Cont'd)

CATEGORY 5 — 4 CYL MANUAL CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	61.0	62.6	51.7
30.	63.6	64.6	57.3
35.	65.7	65.3	59.5
40.	67.6	65.9	61.3
50.	70.7	67.3	64.4
60.	73.2	68.7	67.0

CATEGORY 6 — 6 AND 8 CYL LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	62.7	63.3	53.4
30.	65.3	65.1	59.0
35.	67.4	65.8	61.2
40.	69.3	66.5	63.0
50.	72.4	68.2	66.1
60.	74.9	69.9	68.7

CATEGORY 7 — DIESEL LIGHT VEHICLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	61.6	65.3	52.3
30.	64.2	66.7	57.9
35.	66.3	67.1	60.1
40.	68.2	67.5	61.9
50.	71.3	68.4	65.0
60.	73.8	69.4	67.6

CATEGORY 8 — MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	77.2	75.1	65.8
30.	77.2	75.6	70.0
35.	→ 76.9 – 77.5	75.9	71.6
40	78.1	76.2	73.0
50.	80.2	76.8	75.1
60.	← $\boxed{81.7}$	77.7	76.8

$L_c = 77.5 + 25 \log\left(\frac{V}{35}\right) \quad V \geq 35$

$\quad = 77.5 \quad V \leq 35$

Table 9 (Cont'd)

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	83.6	82.7	73.9
30.	83.4	82.8	77.3
35.	83.2 83.6	82.9	78.6
40.	84.2	83.0	79.6
50.	85.7	83.4	81.4
60.	86.8	84.0	82.7

CATEGORY 10 INTERCITY BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	76.0	81.6	68.1
30.	76.0	82.0	71.4
35.	77.3 - 77.3	82.2	72.7
40.	78.4	82.3	73.8
50.	80.2	82.6	75.6
60.	81.7	82.8	77.1

CATEGORY 11 TRANSIT BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	73.0	81.0	63.7
30.	73.0	81.0	67.8
35.	74.5	81.0	69.3
40.	75.8	81.1	70.6
50.	78.1	81.2	72.9
60.	79.9	81.5	74.7

CATETORY 12 SCHOOL BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	73.0	77.6	63.7
30.	73.0	78.1	67.8
35.	74.5	78.3	69.3
40.	75.8	78.4	70.6
50.	78.1	78.9	72.9
60.	79.9	79.4	74.7

Table 9 (Cont'd)

CATEGORY 13 UNMODIFIED MOTORCYCLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	66.9	73.3	61.5
30.	71.3	74.9	65.9
35.	73.0	75.2	67.6
40.	74.4	75.4	69.0
50.	76.9	75.7	71.4
60.	78.9	75.9	73.4

CATEGORY 14 MODIFIED MOTORCYCLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	81.1	87.5	75.7
30.	85.5	89.1	80.1
35.	87.2	89.4	81.8
40.	88.6	89.6	83.2
50.	91.1	89.9	85.6
60.	93.1	90.1	87.6

Table 10. Average Noise Levels for Light Vehicles
(Categories 1 through 7) Subject to a 68 dB Noise Regulation

CATEGORY 1

8 CYL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	59.6	50.5
30.	62.4	61.5	56.1
35	64.5	62.3	58.3
40.	66.4	63.1	60.1
50.	69.5	64.9	63.2
60.	72.0	66.8	65.8

CATEGORY 2

6 CYL AUTO CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	60.8	50.5
30.	62.4	62.5	56.1
35.	64.5	63.2	58.3
40.	66.4	63.9	60.1
50.	69.5	65.5	63.2
60.	72.0	67.1	65.8

CATEGORY 3

6 CYL MANUAL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.3	59.5	50.2
30.	62.2	61.8	55.9
35.	64.3	62.7	58.1
40.	66.2	63.5	59.9
50.	69.4	65.2	63.1
60.	71.9	67.0	65.6

CATEGORY 4

4 CYL AUTO CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.3	62.1	50.2
30.	62.2	63.6	55.9
35.	64.3	64.2	58.1
40.	66.2	64.8	59.9
50.	69.4	66.1	63.1
60.	71.9	67.6	65.6

Table 10 (Cont'd)

CATEGORY 5 — 4 CYL MANUAL CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.3	59.5	50.7
30.	62.9	62.0	56.6
35.	65.1	63.0	58.8
40.	67.1	63.9	60.7
50.	70.3	65.8	63.9
60.	72.9	67.7	66.6

CATEGORY 6 — 6 AND 8 CYL LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	61.9	62.1	53.0
30.	65.0	64.1	58.7
35.	67.2	64.9	60.9
40.	69.0	65.8	62.8
50.	72.2	67.7	65.9
60.	74.8	69.5	68.5

CATEGORY 7 — DIESEL LIGHT VEHICLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	58.8	61.2	50.3
30.	62.5	63.0	56.2
35.	64.8	63.7	58.4
40.	66.7	64.3	60.3
50.	69.9	65.8	63.6
60.	72.6	67.4	66.2

Table 11. Average Noise Levels for Light Vehicles (Categories 1 through 7)
Subject to a 66 dB Noise Regulation

CATEGORY 1
8 CYL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.8	59.6	50.5
30.	62.4	61.5	56.1
35.	64.5	62.3	58.3
40.	66.4	63.1	60.1
50.	69.5	64.9	63.2
60.	72.0	66.8	65.8

CATEGORY 2
6 CYL AUTO CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.4	60.1	50.2
30.	62.2	61.9	55.9
35.	64.4	62.7	58.1
40.	66.2	63.4	60.0
50.	69.4	65.1	63.1
60.	71.9	66.9	65.7

CATEGORY 3
6 CYL MANUAL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	58.1	57.5	49.6
30.	61.8	60.3	55.4
35.	64.0	61.3	57.7
40.	65.9	62.3	59.6
50.	69.2	64.4	62.8
60.	71.8	66.4	65.4

CATEGORY 4
4 CYL AUTO CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	58.1	60.1	49.6
30.	61.8	61.9	55.4
35.	64.0	62.7	57.7
40.	65.9	63.4	59.6
50.	69.2	65.1	62.8
60.	71.8	66.9	65.4

Table 11 (Cont'd)

CATEGORY 5 — 4 CYL MANUAL CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	58.3	57.5	50.3
30.	62.6	60.5	56.2
35.	64.9	61.7	58.5
40.	66.8	62.8	60.4
50.	70.1	65.1	63.7
60.	72.8	67.2	66.4

CATEGORY 6 — 6 AND 8 CYL LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	60.8	60.1	52.4
30.	64.6	62.6	58.3
35.	66.9	63.7	60.5
40.	68.8	64.8	62.4
50.	72.0	67.0	65.7
60.	74.7	69.1	68.3

CATEGORY 7 — DIESEL LIGHT VEHICLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	57.7	59.2	49.7
30.	62.0	61.3	55.6
35.	64.3	62.2	57.9
40.	66.3	63.0	59.9
50.	69.6	64.9	63.1
60	72.2	66.7	65.8

Table 12. Average Noise Levels for Light Vehicles (Categories 1 through 7)
Subject to a 64.dB Noise Regulation

CATEGORY 1 — 8 CYL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	58.9	58.1	50.0
30.	62.0	60.3	55.7
35.	64.2	61.3	57.9
40.	66.1	62.3	59.8
50.	69.3	64.4	63.0
60.	71.9	66.4	65.6

CATEGORY 2 — 6 CYL AUTO CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	58.2	58.1	49.6
30.	61.8	60.3	55.5
35.	64.0	61.3	57.7
40.	66.0	62.3	59.6
50.	69.2	64.4	62.8
60.	71.8	66.4	65.4

CATEGORY 3 — 6 CYL MANUAL CARS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	57.2	55.5	49.2
30.	61.5	58.9	55.1
35.	63.8	60.2	57.4
40.	65.8	61.4	59.3
50.	69.0	63.8	62.6
60.	71.7	66.1	65.3

CATEGORY 4 — 4 CYL AUTO CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	57.2	58.1	49.2
30.	61.5	60.3	55.1
35.	63.8	61.3	57.4
40.	65.8	62.3	59.3
50.	69.0	64.4	62.6
60.	71.7	66.4	65.3

Table 12 (Cont'd)

CATEGORY 5 — 4 CYL MANUAL CAR AND LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	57.6	55.5	50.0
30.	62.4	59.3	56.0
35.	64.7	60.7	58.3
40	66.7	62.0	60.2
50.	70.0	64.6	63.6
60.	72.7	66.9	66.3

CATEGORY 6 — 6 AND 8 CYL LT

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	59.9	58.1	52.0
30.	64.4	61.3	58.0
35.	66.7	62.6	60.2
40.	68.6	63.9	62.2
50.	71.9	66.5	65.5
60.	74.6	68.8	68.2

CATEGORY 7 — DIESEL LIGHT VEHICLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	56.9	57.2	49.3
30.	61.7	59.8	55.3
35.	64.0	60.9	57.5
40.	66.0	62.0	59.5
50.	69.3	64.2	62.8
60.	72.0	66.3	65.6

Table 13. Average Noise Levels for Trucks, Buses, and Motorcycles (Categories 8 through 13) Subject to an 83 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	77.2	75.1	65.8
30.	77.2	75.6	70.0
35.	76.9	75.9	71.6
40.	78.1	76.2	73.0
50.	80.2	76.8	75.1
60.	81.7	77.7	76.8

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	79.8	78.9	70.2
30.	80.0	79.1	73.9
35.	80.2	79.3	75.3
40.	81.5	79.6	76.5
50.	83.7	80.4	78.6
60.	85.6	81.5	80.4

CATEGORY 10 INTERCITY BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	72.4	77.8	64.5
30.	73.0	78.3	68.1
35.	74.5	78.5	69.5
40.	75.9	78.6	70.8
50.	78.3	79.0	73.0
60.	80.5	79.6	75.0

CATEGORY 11 TRANSIT BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	73.0	81.0	63.7
30.	73.0	81.0	67.8
35.	74.5	81.0	69.3
40.	75.8	81.1	70.6
50.	78.1	81.2	72.9
60.	79.9	81.5	74.7

Table 13 (Cont'd)

CATEGORY 12 SCHOOL BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	73.0	77.6	63.7
30.	73.0	78.1	67.8
35.	74.5	78.3	69.3
40.	75.8	78.4	70.6
50.	78.1	78.9	72.9
60.	79.9	79.4	74.7

CATEGORY 13 UNMODIFIED MOTORCYCLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	65.1	71.5	59.7
30.	69.5	73.1	64.1
35.	71.2	73.4	65.8
40.	72.6	73.6	67.2
50.	75.1	73.9	69.6
60.	77.1	74.1	71.6

Table 14. Average Noise Levels for Trucks, Buses, and Motorcycles (Categories 8 through 13) Subject to an 80 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	76.9	74.8	65.5
30.	76.9	75.3	69.8
35.	76.6	75.6	71.4
40.	77.9	75.9	72.7
50.	80.0	76.6	74.9
60.	81.6	77.5	76.7

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	77.0	75.9	67.5
30.	77.7	76.3	71.4
35.	78.3	76.6	73.0
40.	79.9	77.1	74.4
50.	82.6	78.4	77.0
60.	85.0	80.1	79.1

CATEGORY 10 INTERCITY BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	69.6	74.8	61.8
30.	71.0	75.3	65.7
35.	72.8	75.6	67.4
40.	74.5	75.8	68.9
50.	77.4	76.5	71.5
60.	80.0	77.4	73.9

CATEGORY 11 TRANSIT BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	70.4	78.2	61.3
30.	71.1	78.2	65.6
35.	72.9	78.3	67.4
40.	74.5	78.4	68.9
50.	77.3	78.7	71.5
60.	79.6	79.2	73.7

Table 14 (Cont'd)

CATEGORY 12 SCHOOL BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	70.4	74.8	61.3
30.	71.1	75.3	65.6
35.	72.9	75.6	67.4
40.	74.5	75.8	68.9
50.	77.3	76.5	71.5
60.	79.6	77.4	73.7

CATEGORY 13 UNMODIFIED MOTORCYCLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	62.1	68.5	56.7
30.	66.5	70.1	61.1
35.	68.2	70.4	62.8
40.	69.6	70.6	64.2
50.	72.1	70.9	66.6
60.	74.1	71.1	68.6

Table 15. Average Noise Levels for Trucks and Buses (Categories 8 through 12) Subject to a 77 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	74.2	71.8	62.8
30.	74.3	72.4	67.2
35.	74.5	72.9	68.9
40.	76.0	73.3	70.4
50.	78.5	74.4	73.0
60.	80.6	75.8	75.0

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	74.3	72.9	65.0
30.	75.8	73.5	69.4
35.	77.0	74.2	71.2
40.	78.8	75.1	72.9
50.	82.0	77.0	75.8
60.	84.7	79.2	78.4

CATEGORY 10 INTERCITY BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	67.1	71.8	59.3
30.	69.6	72.4	63.8
35.	71.6	72.8	65.7
40.	73.5	73.2	67.4
50.	76.8	74.3	70.5
60	79.7	75.6	73.2

CATEGORY 11 TRANSIT BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	67.8	75.2	58.9
30.	69.6	75.3	63.8
35.	71.7	75.4	65.7
40.	73.6	75.6	67.5
50.	76.8	76.2	70.5
60.	79.5	77.1	73.1

Table 15 (Cont'd)

CATEGORY 12 SCHOOL BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	67.8	71.8	58.9
30.	69.6	72.4	63.8
35.	71.7	72.8	65.7
40.	73.6	73.2	67.5
50.	76.8	74.3	70.5
60.	79.5	75.6	73.1

Table 16. Average Noise Levels for Motorcycles (Category 13) Subject to a 78 dB Noise Regulation

CATEGORY 13	UNMODIFIED MOTORCYCLES		
SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	60.1	66.5	54.7
30.	64.5	68.1	59.1
35.	66.2	68.4	60.8
40.	67.6	68.6	62.2
50.	70.1	68.9	64.6
60.	72.1	69.1	66.6

Table 17. Average Noise Levels for Trucks, Buses, and Motorcycles (Categories 8 through 13) Subject to a 75 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	72.3	69.8	61.0
30.	72.8	70.6	65.7
35.	73.3	71.1	67.6
40.	75.0	71.8	69.2
50.	77.8	73.2	71.9
60.	80.2	75.0	74.2

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	72.6	70.9	63.5
30.	74.8	71.9	68.3
35	76.4	72.9	70.3
40.	78.3	74.0	72.1
50.	81.7	76.3	75.3
60.	84.6	78.8	78.0

CATEGORY 10 INTERCITY BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	65.6	69.8	57.9
30.	68.9	70.6	62.8
35.	71.1	71.1	64.9
40.	73.1	71.6	66.8
50.	76.6	73.0	70.1
60.	79.6	74.7	72.9

CATEGORY 11 TRANSIT BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	63.4	73.2	57.6
30.	68.9	73.3	62.8
35.	71.1	73.5	64.9
40.	73.1	73.8	66.8
50.	76.6	74.7	70.1
60.	79.5	75.9	72.9

Table 17 (Cont'd)

CATEGORY 12 SCHOOL BUSES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	66.2	69.8	57.6
30.	68.9	70.6	62.8
35.	71.1	71.1	64.9
40.	73.1	71.6	66.8
50.	76.6	73.0	70.1
60.	79.5	74.7	72.9

CATEGORY 13 UNMODIFIED MOTORCYCLES

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	57.1	63.5	51.7
30.	61.5	65.1	56.1
35.	63.2	65.4	57.8
40.	64.6	65.6	59.2
50.	67.1	65.9	61.6
60.	69.1	66.1	63.6

REFERENCES

1. Sharp, B.H., and Donovan, P.R., "Light Vehicle Noise: Volume I — Development of a Test Procedure to Measure the Noise Emissions of Light Vehicles Operating in Urban Areas", Wyle Research Report WR78-2, prepared for the U.S. Environmental Protection Agency, November 1978.

2. Sharp, B.H., Donovan, P.R., and Kohli, V.K., "Light Vehicle Noise: Volume II — Implementation and Evaluation of a Test Procedure to Measure the Noise Emission of Light Vehicles Operating in Urban Areas", Wyle Research Report WR78-13, prepared for the U.S. Environmental Protection Agency, November 1978.

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4. "Proposed Motorcycle Noise Emission Standards — Background Document", U.S. Environmental Protection Agency, November 1977.

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6. Burke, R.E., "A Baseline Measurement of Highway Vehicle Noise Levels", Wyle Research Report WR 77-8, prepared for the U.S. Environmental Protection Agency, March 1977.

7. Sharp, B.H., Plotkin, K.J., Davy, B.A., and Sutherland, L.C., "A Study of the Effect of Environmental Variables on the Measurement of Noise from Motor Vehicles", Wyle Research Report WCR 74-18, prepared for the Motor Vehicle Manufacturers Association, 1974.

8. Sharp, B.H., "A Survey of Truck Noise Levels and the Effects of Regulations", Wyle Research Report WR 74-8, prepared for the U.S. Environmental Protection Agency, December 1974.

9. Prahl, F.A., "Noise Model for Slow-Speed Trucks on Baltimore City Streets", paper KK2, 91st Meeting of the Acoustical Society of America, April 1976.

10. Plotkin, K.J., "National Exposure to Highway Noise Through the Year 2000", Wyle Research Report WR 77-13, prepared for the U.S. Environmental Protection Agency, July 1979.

11. "Proposed Bus Noise Emission Regulation", U.S. Environmental Protection Agency, August 1977.

12. "Proposed Motorcycle Noise Emission Regulation", U.S. Environmental Protection Agency, November 1977.

REFERENCES (Cont'd)

13. Kruse, R.E., and Huls, T.A., "Development of Federal Urban Driving Cycle", SAE Paper 730553, May 1973.

14. Nash, R.W., EPA Office of Air and Waste Management. Private Communication of Bus and Truck Operational Data, June 8, 1978.

APPENDIX A

The Federal Highway Administration has collected roadside data for medium- and heavy-duty trucks which give the following relationships (Reference A1):

Medium Trucks

$$L_{eq(e)} = 74.4 + 33.9 \log_{10}(V/35), \text{ dB} \qquad \text{(A1)}$$

where V is the vehicle speed in mph.

Heavy Trucks

$$L_{eq(e)} = 80.7 + 24.6 \log_{10}(V/35), \text{ dB} \qquad \text{(A2)}$$

where V is the vehicle speed in mph.

mean levels

Using the relationships given in Equations (A1) and (A2) the noise emission parameters are as shown in Table A1.

Table A1

Noise Emission Parameters for Categories 8 and 9 Using FHWA Data

$L_c(35)$ $L_t(35)$

Category	L_1	Cruise			Coast	
		L_{35}	10β	V_c	L_{35}	10α
8	76.5	74.4	33.9	35	70.0	40
9	82.8	80.7	24.6	35	75.0	40

72.5? see next page

80.7 is OK! checks with FHWA data $\sigma = 2.84$

In Table A1, the values for L_1 are modified from those in Table 2 of the main text according to the difference in 35 mph cruise levels. V_c and coast parameters are retained. The coast levels shown here are based on the quieter tire levels discussed in Section 3.0. The calculated average operational levels for existing vehicles are given in Table A2. The average levels with noise regulations specifying standards of 83, 80, 77 and 75 dB are shown in Tables A3 through A6.

It should be noted that there is an inconsistency between the cruise and tire levels in Table A1 for medium trucks (Category 8). The tire levels as shown are too low, relative to L_1, for the cruise parameters to be correct. If L_{35} = 72.5 dB for tires (see Table 2), then better consistency is obtained. A parallel calculation has therefore been performed for medium trucks with these higher tire levels. This is shown in Tables A7 through A9 for baseline levels and for regulations of 77 and 75 dBA, respectively.

REFERENCE

A1. Ma, Y.Y., and Rudder, F.F., "Statistical Analysis of FHWA Traffic Noise Data", U.S. Department of Transportation, Federal Highway Administration Report No. FHWA-RD-78-64, July 1978.

Table A2. Baseline Average Truck Noise Levels Using FHWA Data

CATEGORY 8

MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	75.5	73.1	60.8
30.	75.5	73.7	66.8
35	75.5	74.0	69.1
40.	77.5	74.4	71.0
50.	80.8	75.3	74.3
60.	83.4	76.5	77.0

not consistent with Table A1

CATEGORY 9

HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	81.4	80.5	70.0
30.	81.4	80.6	74.4
35.	81.4	80.8	76.0
40.	82.8	81.0	77.4
50.	85.2	81.6	79.8
60.	87.2	82.5	81.8

$80.7 + 24.6 \log(60/35) = 86.46$

$86.46 + .115(2.84^2) = 87.39$

$86.46 + .115(2.8^2) = 87.36$

$86.46 + .115(2.5^2) = 87.18$

$\therefore$ tables include $\sigma = 2.5$?

Table A3. Average Noise Levels for Trucks (FHWA Noise Data) Subject to an 83 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	75.5	73.1	60.8
30.	75.5	73.7	66.8
35.	75.5	74.0	69.1
40.	77.5	74.4	71.0
50.	80.8	75.3	74.3
60.	83.4	76.5	77.0

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	79.8 79.4	78.9	68.6
30.	80.0 79.6	79.1	73.0
35.	80.2	79.3	74.7
40.	81.7 81.3	79.6	76.2
50.	84.3 83.8	80.4	78.7
60.	86.5 86.0	81.5	80.8

includes $\sigma = 2.84$?

$\sigma = 2.5$

Table A4. Average Noise Levels for Trucks (FHWA Noise Data) Subject to an 80 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	75.5	73.1	60.8
30.	75.5	73.7	66.8
35.	75.5	74.0	69.1
40.	77.5	74.4	71.0
50.	80.8	75.3	74.3
60.	83.4	76.5	77.0

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	77.0 76.6	75.9	65.9
30.	77.7 77.3	76.3	70.7
35.	78.4	76.6	72.5
40.	80.1 79.7	77.1	74.2
50.	83.0 82.7	78.4	77.0
60.	85.5 85.3	80.1	79.4

Table A5. Average Noise Levels for Trucks (FHWA Noise Data)
Subject to a 77 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	74.2	71.8	59.8
30.	74.4	72.4	65.8
35.	74.6	72.9	68.1
40.	76.6	73.3	70.1
50.	80.0	74.4	73.5
60.	82.7	75.8	76.2

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	74.3	72.9	63.6
30.	75.8	73.5	68.8
35.	77.0	74.2	70.8
40.	78.9	75.1	72.7
50.	82.2	77.0	75.8
60.	85.0	79.2	78.5

Table A6. Average Noise Levels for Trucks (FHWA Noise Data) Subject to a 75 dB Noise Regulation

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	72.3	69.8	58.3
30.	72.9	70.6	64.5
35.	73.4	71.1	66.9
40.	75.5	71.8	68.9
50.	78.9	73.2	72.3
60.	81.7	75.0	75.1

CATEGORY 9 HEAVY TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	72.6 72.2	70.9	62.3
30.	74.8 74.6	71.9	67.8
35.	76.4	72.9	70.0
40.	78.4 78.2	74.0	72.0
50.	81.9 81.7	76.3	75.3
60.	84.8 84.7	78.8	78.1

$\uparrow$

GENERATED

REG LEVEL = 75

Design Level = 72.5

$\Delta L_1 = L_1 - L_1^R \underset{(\text{see A.1})}{\overset{}{=}} 82.8 - 72.5 = 10.3$ (Engine Only)

At 60mph

$(\overline{L}_0)_E^C =$ ~~[illegible]~~ 87.4 ~~[illegible]~~

$\overline{L}_0^C = 87.4 - .115(2.8)^2 =$ ~~[illegible]~~ 86.5

$L_{tires}(60) = 84.4$

$\Rightarrow L_{Engine} = (-84.4 + 86.5) \Rightarrow$ ~~[illegible]~~ 82.2

$L_{engine}^R = 82.2 - 10.3 + e$ ~~[illegible]~~ 71.9

$71.9 + .115(2.5^2) = 72.6$

$10 \log [10^{7.26} + 10^{8.44}] = \boxed{84.7}$

Table A7. Baseline Average Truck Noise Levels Using FHWA Data and Increased Tire Levels

CATEGORY 8 MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	75.5	73.1	60.8
30.	75.5	73.8	66.8
35.	75.5	74.3	69.1
40.	77.5	74.9	71.0
50.	80.8	76.2	74.3
60.	83.4	77.8	77.0

Table A8. Average Noise Levels for Trucks
(FHWA Noise Data and Increased Tire Levels)
Subject to a 77 dB Noise Regulation

CATEGORY 8

MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	74.3	71.8	60.0
30.	74.6	72.6	66.1
35.	74.9	73.2	68.4
40.	76.9	73.9	70.4
50.	80.3	75.5	73.8
60	83.1	77.3	76.6

Table A9. Average Noise Levels for Trucks (FHWA Noise Data and Increased Tire Levels) Subject to a 75 dB Noise Regulation

CATEGORY 8

MEDIUM TRUCKS

SPEED	CRUISE	ACCEL FROM 0	DECEL TO 0
20.	72.5	69.8	58.9
30.	73.4	70.9	65.1
35.	74.2	71.7	67.5
40.	76.3	72.6	69.6
50.	79.8	74.6	73.1
60.	82.7	76.7	76.0