Report No. FHWA-RD-78-138

USER'S MANUAL: FHWA LEVEL 2 HIGHWAY TRAFFIC NOISE PREDICTION MODEL, STAMINA 1.0

May 1979

Final Report

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Springfield, Virginia 22161

Prepared for

FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D. C. 20590

FOREWORD

This report is a user's manual for a computer program, STAMINA 1.0 that has been developed for predicting traffic noise impacts and will be of interest to traffic noise specialists involved in assessing traffic noise impacts and evaluating alternative traffic noise mitigation strategies.

Research in highway noise and vibration is included in the Federally Coordinated Program of Highway Research and Development as Task 4 of Project 3F, "Pollution Reduction and Environmental Enhancement." Dr. Howard Jongedyk is the Project Manager and Dr. Timothy M. Barry is the Task Manager.

The traffic noise model on which this computer program was based was developed by the Federal Highway Administration and is documented in FHWA report, FHWA-RD-77-108, "FHWA Highway Traffic Noise Prediction Model" which is available from the National Technical Information Service, Springfield, Virginia 22161.

Sufficient copies of this report are being distributed to provide a minimum of two copies to each FHWA regional office, and one copy to each FHWA division office and State highway agency. Direct distribution is being made to the division offices.

W. Wolman
for Charles F. Scheffey
Director, Office of Research

NOTICE

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16. Abstract

This report describes modifications to the TSC MOD-04 highway traffic noise prediction program to extend the scope of problem formulation. The FHWA Level 2 Highway Traffic Noise Prediction Model features:

- Revised Vehicle Reference Noise Emission Levels
- Specification of Site-Specific (Excess) Attenuation
- English/Metric and Metric/English conversion of engineering units for both input and output data
- Common Input Data Format with TSC MOD-04 model
- User Options to Improve Operating Efficiency

The report describes problem formulation, input data requirements, output error messages, examples of usage, and computer program documentation.

The FHWA Staff has given the Level 2 program the acronym STAMINA 1.0 for Standard Method In Noise Analysis (Version) 1.0.

17. Key Words
Highway Traffic Noise Prediction
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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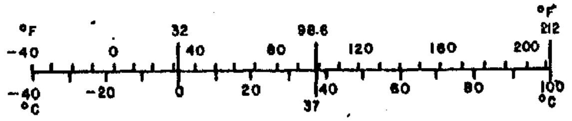
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

This study is one part of the continuing effort to refine and improve engineering methods for the prediction and abatement of traffic-generated noise from highways. The model assumes constant speed traffic conditions and, as an option, includes highway grade as a parameter in the traffic noise generation. Traffic speeds are limited to the range of 50 to 100 km/h (30 to 65 mph) due to the data limitations upon which vehicle noise emissions are based.

The FHWA Level 2 highway traffic noise emission model is an evolutionary development of the TSC MOD-04 prediction program (1,2).* Features of the FHWA Level 2 highway traffic noise emission model are described in Section 2. The third section of this report presents the input data format required to execute the program. Section 4 presents example problems indicating the input/output format of the FHWA Level 2 highway traffic noise emissions model.

Appendices are presented describing the basic theory used, the architecture of the program, and the listing of the source code.

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* Numbers in ( ) denote references at the end of the report.

2. FEATURES OF THE PREDICTION MODEL

The FHWA Level 2 highway traffic noise prediction model is an evolutionary development of the TSC MOD-04 model (2). The FHWA Level 2 program features several refinements and options over the TSC MOD-04 model that are expected to improve prediction accuracy and utility of the model.

The salient features of the FHWA Level 2 program include:

- Revised Vehicle Reference Noise Emission Levels:

  Based upon analysis of field test data (3), the FHWA Level 2 program utilizes revised speed-dependent noise emission levels for heavy trucks (type 2 vehicle) and for medium trucks (type 3 vehicle). Overall and octave band A-weighted sound levels are predicted as the user desires.

- Grade Corrections:

  The user may specify, as an option, sound level adjustments for heavy trucks dependent upon the roadway grade. This adjustment is used to simulate highway sound levels for heavy trucks moving up grades as defined by the roadway segment geometry.

- Excess Distance Attenuation:

  The FHWA Level 2 prediction model allows the user to specify a distance attenuation rate for traffic noise propagation. The distance attenuation rate is specified for each roadway/receiver combination. The attenuation rate may vary from 3dB/Distance Doubling to any higher rate desired.

- English/Metric and Metric/English Data Conversion:

  The FHWA Level 2 prediction model will accept and/or convert input/output data using either English (foot, mile, hour) units or Metric (metre, kilometre, hour) units as directed by the user.

- Input Data Annotation:

  The user may include titles and/or other annotation with input data for roadways, barriers, absorptive ground strips, and receivers to identify these parameters on the output listings.

- Common Input Data Format with TSC MOD-04:

  Existing data sets formatted for use with the TSC MOD-04 code may be used to execute the FHWA Level 2 program with very little change (See Section 3). Complex site data successfully executed by the TSC MOD-04 code need not be changed to execute on the FHWA Level 2 program.

- Bypass Reflection Calculations:

  The user may elect to bypass all reflection calculations in estimating receiver sound levels. This option is offered as a time-saving option since reflections would rarely increase the predicted levels more than 3 dB.

- Receiver Sound Level Criterion:

  The FHWA Level 2 program provides the user with an estimate of the overall equivalent sound level, LE(A), at each receiver. The user, however, may desire to know the individual contributions to LE(A) from each roadway segment or from each segment contributing traffic noise above a specified criterion level. The FHWA Level 2 program allows the user to specify a criteria level that results in a tabulation of the sound level contributions to LE(A) from each roadway segment exceeding the criterion level. This option is useful in evaluating traffic noise abatement at a receiver.

The revised vehicle reference noise emission levels used by the FHWA Level 2 prediction model are presented in Table 2-1 as coefficients of a regression equation of sound level varying linearly with the logarithm of the vehicle speed. Figure 2-1 presents a comparison of the TSC MOD-04 reference levels and the FHWA Level 2 reference levels as a function of vehicle speed. The reference vehicle sound levels for medium trucks (2 axle/6 tire) are presented in Figure 2-2. The reference vehicle sound levels for heavy trucks (3 to 5 axle) are presented in Figure 2-3. Both the A-weighted reference level and the A-weighted octave band levels are presented as functions of vehicle speed. These results are from Reference 3.

TABLE 2-1

COEFFICIENTS FOR A-WEIGHTED REFERENCE ENERGY MEAN EMISSION LEVELS

f_c	Automobiles (Type 1)			Medium Trucks (Type 3)			Heavy Trucks (Type 2)		
Hz.	C_0	C_1	S_0	C_0	C_1	S_0	C_0	C_1	S_0
OAL*	4.80	38.05	2.5	22.06	33.91	3.37	42.63	24.56	2.84
63	-2.14	27.18	2.5	44.88	5.48	4.72	80.61	-12.92	5.20
125	-3.17	32.61	2.5	52.39	6.90	4.76	56.94	6.19	3.73
250	-13.21	40.76	2.5	33.76	21.12	5.23	52.77	12.56	4.45
500	20.84	29.89	2.5	11.01	36.18	4.23	28.22	28.70	3.82
1k	9.83	32.61	2.5	-1.86	44.67	4.39	22.32	33.60	3.44
2k	-18.26	48.92	2.5	-1.19	43.93	4.04	33.08	25.59	3.11
4k	-7.20	38.05	2.5	3.49	36.54	3.82	35.46	20.61	3.42
8k	-18.21	40.76	2.5	15.70	24.77	3.85	34.90	15.50	3.89

$\overline{L}_0 = C_0 + C_1 \log(V)$ $(\overline{L}_0)_E = \overline{L}_0 + 0.115 S_0^2$ V is vehicle speed in miles per hour

* OAL denotes the Overall A-weighted sound Level

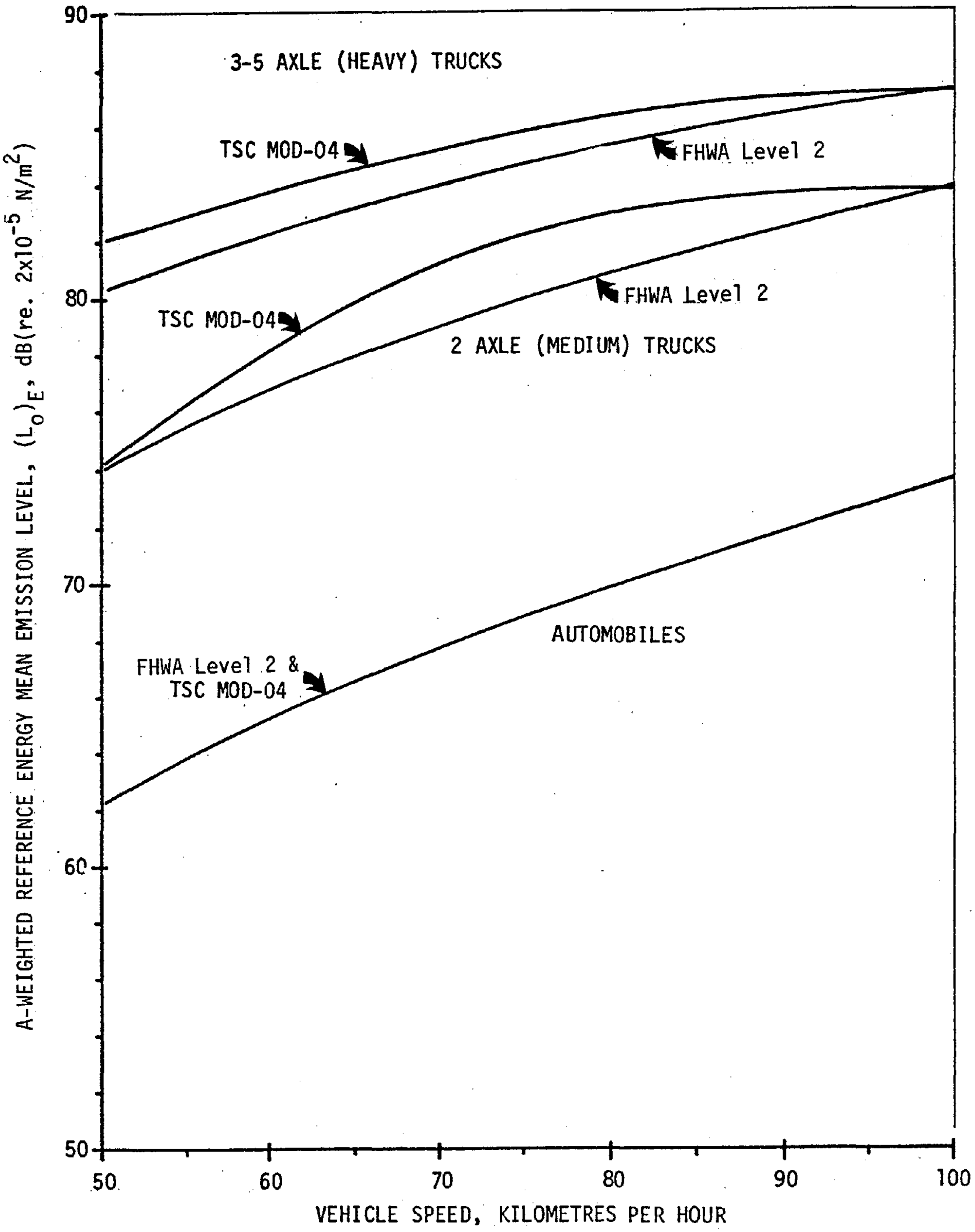


FIGURE 2-1 COMPARISON OF VEHICLE A-WEIGHTED REFERENCE EMISSION LEVELS

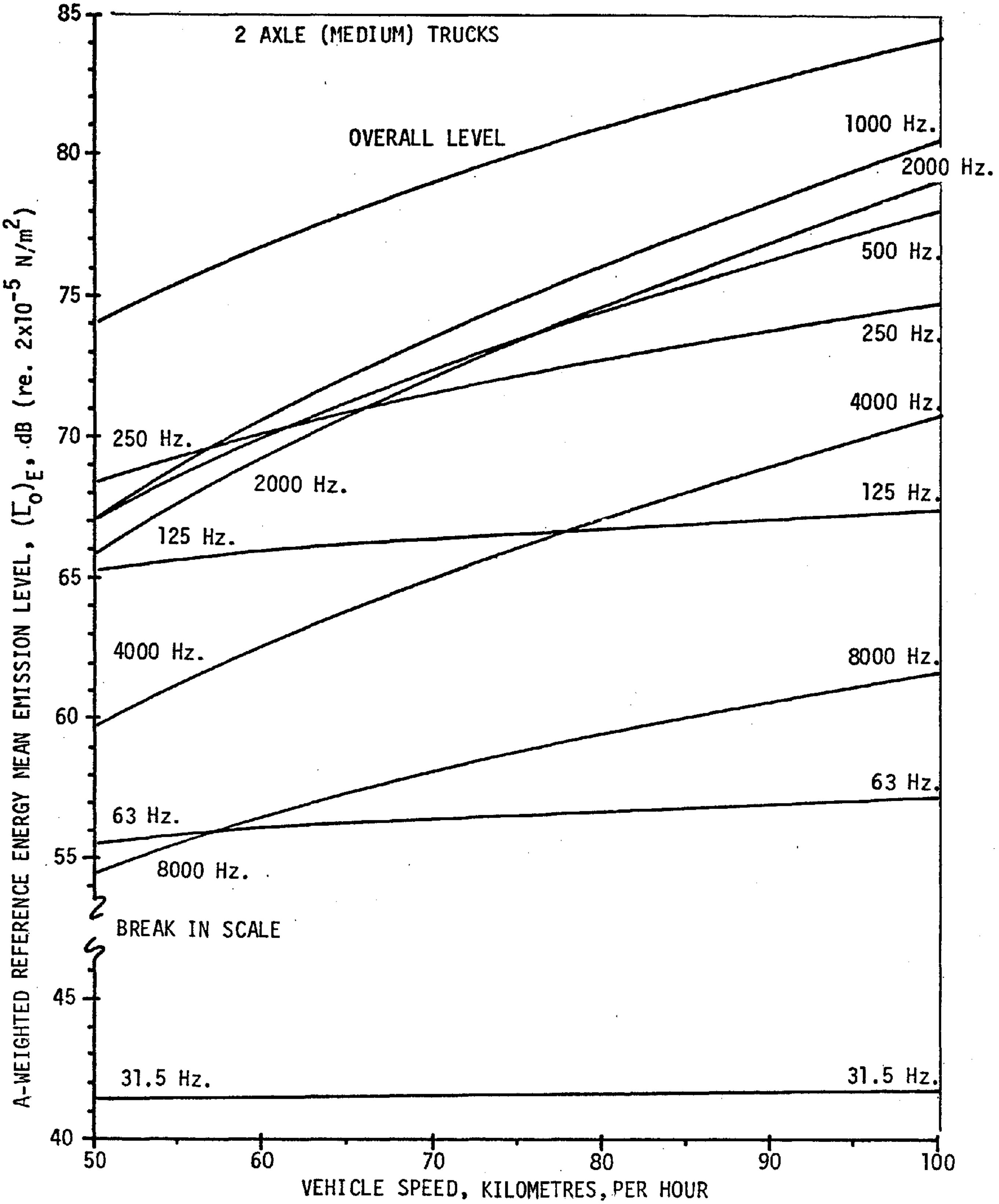


FIGURE 2-2 A-WEIGHTED OVERALL AND OCTAVE BAND REFERENCE ENERGY MEAN EMISSION LEVELS, $(\overline{L}_o)_E$: TWO AXLE (MEDIUM) TRUCKS

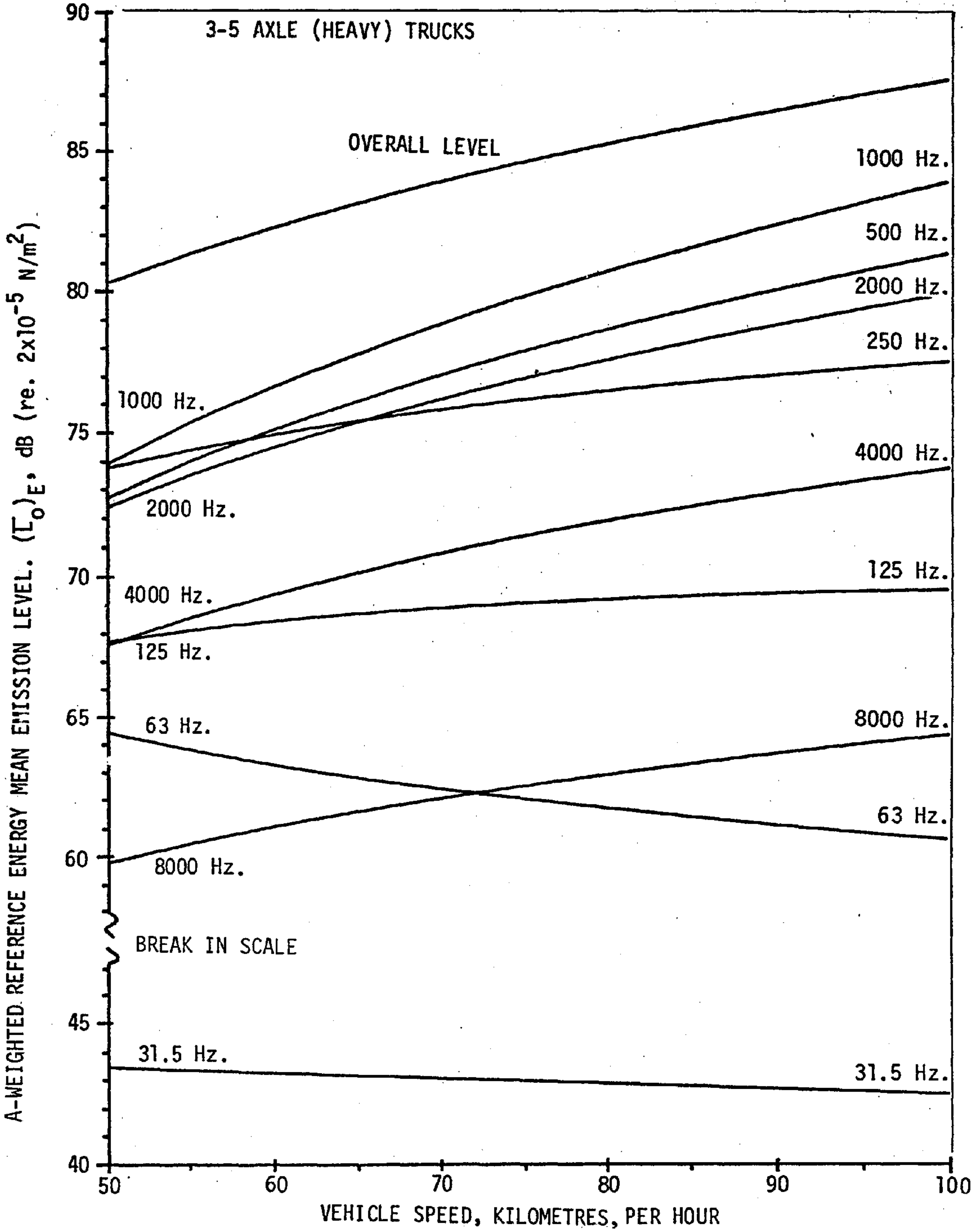


FIGURE 2-3 A-WEIGHTED OVERALL AND OCTAVE BAND REFERENCE ENERGY MEAN EMISSION LEVELS, $(\overline{L}_o)_E$: THREE THROUGH FIVE AXLE TRUCKS

3. INPUT DATA FORMAT

The input data format used by the FHWA Level 2 prediction program is identical to that used by the TSC MOD-04 program (2). To execute the FHWA Level 2 prediction program, the user may elect to use English/Metric conversions and to bypass the reflection calculations. This option is exercised by including an option card as the first card in the data set. Additionally, the FHWA Level 2 program requires a data block, Alpha Input, to define the excess attenuation parameters for each roadway-receiver pair.

The sequence of cards and/or data blocks required to define a problem for execution of the FHWA Level 2 program are indicated in Figure 3-1. The following step-by-step instructions are provided to assist the user in formatting input data to the computer program.

3.1 Input Data Format and Data Block Sequence

3.1.1 Input Data Format

The prediction code accepts input data from a card reader. Three types of input data format are allowed by the code:

- Integer Format

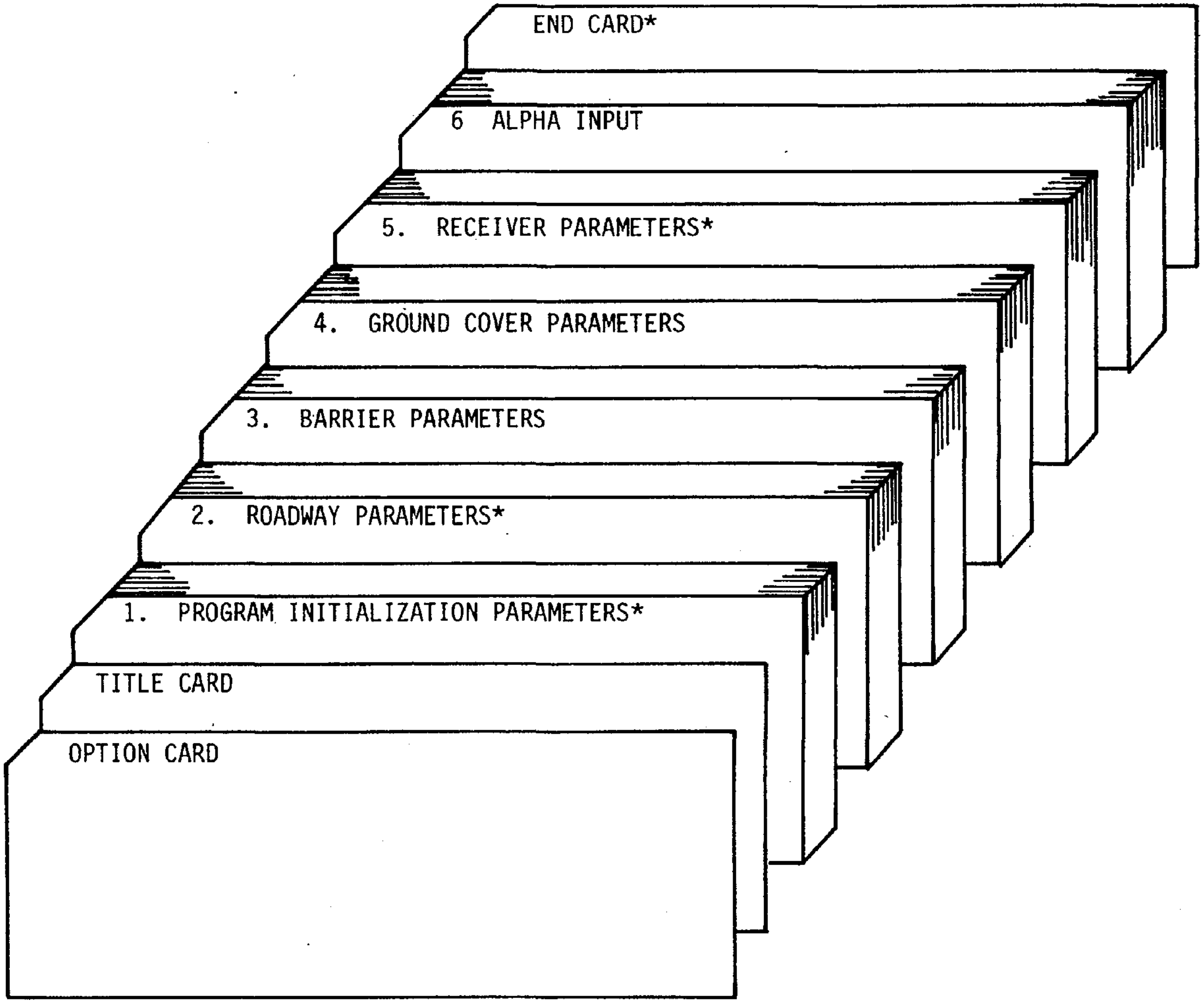
  A fixed point number written without a decimal point. All integers must be right-justified within the allotted field of the input card.

- Real Constant

  A floating point number written with a decimal point. Normally, the real number may be situated anywhere within its allotted field on the card.

- Alphanumeric

  Any combination of alphabetic and numeric characters. Alphanumeric data may be located anywhere within the allotted field on a card.



* Mandatory for Execution

FIGURE 3-1. DATA BLOCK SEQUENCE

3.1.2 Data Block Sequence

The input to the FHWA Level 2 program is composed of an optional parameter card, followed by a title card, which in turn is followed by up to six blocks of data. The input data format is indicated in Table 3-1.*

The option card is the first card in the input stream. It consists of three parameters, each pertaining to a new option offered by the FHWA Level 2 highway noise prediction program. An asterisk in column 1 identifies the option card. A 'Y' in column 14 indicates Metric input units are to be expected; and 'N' in column 14 denotes English input units. The letter 'Y' or 'N' in column 28 specifies either Metric or English output, respectively. The third parameter makes available the option to bypass all reflection computations. To invoke this option 'N' is placed in column 42. This parameter card is not a mandatory input. If it is not present, the program will default to accept all input in English units, to produce output listing in English units, and to perform all required reflection computations.

The input units assumed by the program under the options selected by the user is as follows:

PARAMETER	METRIC	ENGLISH
Length	Metre	Foot
Traffic Flow Rate	Vehicles Per Hour	Vehicles Per Hour
Vehicle Speed	Kilometres Per Hour	Miles Per Hour

The title card is the second card in the data set and contains arbitrary alphanumeric descriptive information in columns 2 through 60.

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* Table 3-1 is presented at the end of this section so as not to interrupt the text.

Data blocks following the title card may be arranged in an arbitrary sequence. Each data block is identified by an index as follows:

INDEX	DATA BLOCK
1	Program Initialization Parameters
2	Roadway Parameters
3	Barrier Parameters
4	Ground Cover Parameters
5	Receiver Parameters
6	Alpha Input

Each data block is preceded by a control card containing the data block index in column 5. The end of a data set is denoted by a control card with the integer 7 in column 5.

Multiple data sets may be run in sequence with each data set being initiated by the title card and ended by the control card with the integer 7 in column 5. Once a data set has been defined for execution of multiple data sets, it is sufficient to modify only the data blocks in the previous data set, as required, to define the new data set. Any data blocks not redefined by the new data set will remain unchanged from that in the preceeding problem.

The first data set must specify, as a minimum, the following data blocks:

INDEX	DATA BLOCK
1	Program Initialization Parameters
2	Roadway Parameters
5	Receiver Parameters

If either the barrier parameter data block or the absorptive cover ground cover data block are omitted for the first data set, all calculations involving barriers or ground cover are bypassed by the code. Subsequent to the execution of the first data set, the user may redefine any data block desired to create a new problem. Any data blocks unchanged will maintain their initial values in subsequent data sets. (See Section 3.7, Alpha Input).

3.2 Program Initialization Parameters

The data block containing the program initialization parameters is preceeded by a control card with the integer 1 in column 5. Following the control card, six or nine cards are used to complete the program initialization parameter data block.

The following five parameters must be specified in the indicated sequence with the parameter value entered as a real constant in columns 1 through 10 and the parameter index indicated as in integer in column 15.

PARAMETER (Real Constant: Cols. 1 through 10)	PARAMETER INDEX (Integer: Col. 15)
Receiver Height Adjustment	1
Number of Frequency Bands	2
Source Height Adjustment for Passenger Cars	3
Source Height Adjustment for Heavy Trucks	4
Source Height Adjustment for Medium Trucks	5
Source Height Adjustment for New Vehicles*	6

*Only if new vehicles are defined

If desired, the user may include alphanumeric information in columns 31 through 80 for convenience or specific information on each of the above cards. If no alphanumeric data is entered, the above titles will be printed by the program to identify the parameters in the output listing. If the user does not desire to define a "new" vehicle, column 20 of the medium truck source height adjustment card must contain the letter L denoting the last card in the data block.

3.2.1 Definition of Type 4 Vehicle

If the user defines a "new" (Type 4) vehicle, three additional cards are required to complete the Initialization Parameter data block. The first card of this set defines the source height adjustment for the Type 4 vehicle. The second card defines the Type 4 vehicle sound level spectra and the third card defines the standard deviations for the sound level spectra. The source height adjustment card for Type 4 vehicles contains the source height as a real constant between columns 1 through 10; the parameter index, 6, in column 15; the letter L in column 20; and the desired alphanumeric information in columns 31 through 80. The next card is the vehicle sound level spectra card. This card defines the Type 4 vehicle sound level at 50 ft. (15.2m). The last card defines the standard deviation of the Type 4 vehicle sound level spectra. Both the sound level card and the standard deviation card use identical input data formats: nine real constants located in columns 1 through 5, 6 through 10, etc. The constant in columns 1 through 5 corresponds to the A-weighted overall sound level or standard deviation. Each subsequent constant on each card corresponds to the A-weighted octave band sound level or standard deviation for the octave band center frequencies from 63 Hz to 8000 Hz inclusive. The user needs to define constants only for the number of octave bands specified in the program initialization parameters.

The user is reminded that the overall A-weighted sound level calculations are independent of the octave band calculations.

3.3 Roadway Parameters

The data block containing the roadway parameters is preceeded by a control card with the integer 2 in column 5 and another integer in columns 6 through 10 to indicate the number of roadways defining the site. (The present version of the FHWA Level 2 program allows the user to define a maximum number of 20 roadways).

For each roadway, the user must specify a data block defining the traffic flow conditions on the roadway and the geometric alignment of the roadway. To define the traffic flow conditions for a roadway, the user may define up to a maximum of five (5) combinations of vehicle flow rate, vehicle speed, and vehicle type.

For each traffic flow condition on a roadway, the user specifies (using two real constants) the traffic flow rate in vehicles per hour in columns 1 through 10 and the mean vehicle speed in appropriate units (km/h or mph) in columns 11 through 20. Vehicle type is specified using an integer 1 through 4 in column 25. One card is used to specify each traffic flow condition up to a maximum of 5 cards per roadway. For the last card defining a traffic flow condition for a roadway, the user must specify the letter "L" in column 31. If the user desires, 40 alphanumeric characters may be placed on the last traffic flow card to identify the roadway. This input begins in column 41 and may continue through column 80.

Following the data cards defining the traffic flow conditions on a roadway, the user must define the straight line roadway segments specifying the roadway alignment. For each point defining an end point of a roaday segment the user specifies the x-coordinate in columns 1 through 10, the y-coordinate in columns 11 through 20, and the z-coordinate (elevation) in columns 21 through 30. Each coordinate value is specified as a real constant expressed in appropriate units (metres or feet). The end points of each segment are specified on one card, sequentially, beginning with the initial point defining the roadway. Each roadway alignment may be approximated by up to ten (10) straight line segments (eleven points or data cards).

The FHWA Level 2 program allows the user to adjust the noise emissions for heavy trucks (type 2 vehicle) moving up grades. The program, however, does not allow the user to define a traffic flow direction. To include grade adjustments, the user must decide if a straight line segment is an upgrade segment. If the straight line segment is upgrade, then the user may include the grade adjustment by placing "1" in column 33 of the first coordinate card (point) defining the straight line segment. Doing this, causes the FHWA Level 2 program to calculate the grade of the straight line segment to increase the noise emission levels of heavy trucks appropriately. Details of the grade adjustment are presented in Appendix A. If the user does not desire a grade adjustment for upgrade segments or for level or downgrade segments, either a "0" or a blank space is placed in column 33. The grade adjustment specified for each segment is printed during output.

For each roadway coordinate card, the user may include an alpha numeric title beginning in column 41 and extending through column 80. This title will be printed with the output for the coordinates of the point. The title may be used to define either the coordinate point or the segment defined by two consecutive coordinate points.

The number of data blocks specifying roadways must correspond to the number of roadways specified on the control card for roadway parameters.

3.4 Barrier Parameters

The data block containing the barrier parameters (i.e., potential diffractions of sound) is preceeded by a control card specifying the integer 3 in column 5 and a right-justified integer in columns 6 through 10 specifying the number of barriers. The user may define a maximum of 20 barriers using the present version of the FHWA Level 2 program. As discussed in Reference 2, the user defines barriers to model site topography, noise abatement barriers, and buildings. The top contour of a barrier is approximated by a sequence of straight line segments. Each barrier segment is assumed to be totally impervious to sound transmission through the barrier.

The coordinates of points specifying the top of the barrier are defined utilizing the same format as that for roadway segments (see Section 3.3). The last card (coordinate point) defining a barrier contains in addition to the three real constants defining the point either the letter A (absorptive barrier) or the letter R (reflective barrier) in column 31. The user must define one set of barrier coordinates for each of the total number of barriers specified in the control cards.

The letter A in column 31 of the last card defining a barrier indicates that the preceeding points describe an obstacle that reflects sound weakly and can hence be approximated by a totally sound absorptive surface. This acoustic characteristic applies to both sides of the barrier.

The letter R in column 31 of the last card defining a barrier indicates that the preceeding points describe an obstacle that totally reflects sound. The prediction code considers reflections from vertical surfaces only. See option card format.

As an option, the user may include a 40 character alphanumeric title on the last barrier coordinate card. These data begin in column 41 and may extend through column 80.

Barrier segments are not allowed to cross a roadway segment.

3.5 Ground Cover Parameters

The data block containing the ground cover parameters is preceeded by a control card containing the integer 4 in column 5 and a second integer right-justified in column 6 through 10 indicating the total number of absorptive ground strips defined for the data set. The areas defining absorptive ground strips are specified by the centerline and the width of the rectangular patch. Two data cards are required to describe each ground strip. The first data card contains the x-, y-, and z- coordinates of one end point defining the centerline and the width of the strip in sequence.

These four numbers, in the indicated sequence, are specified as real constants in the fields between columns 1 through 10, 11 through 20, 21 through 30, and 31 through 40. The second card contains the x-, y-, and z- coordinates of the end point defining the centerline between columns 1 through 10, 11 through 20, and 21 through 30, respectively. Following these three real constants, the user specifies the letter G (low ground cover) or the letter T (high ground cover) in column 31.

The letter G in column 31 of the second data card defining a ground strip identifies the ground strip as high grass or shrubbery and the letter T in column 31 identifies the ground strip as trees. The computer code checks to see that the centerline defining a ground strip does not cross a roadway segment. The user, however, should ensure that the defined ground cover strip does not intersect a roadway especially if one is attempting to define a wide strip.

As an option, the user may define a 40 character alphanumeric title on the last ground cover coordinate card. These data begin in column 41 and may extend through column 80.

3.6 Receiver Parameters

The data block containing the receiver parameters (location) is preceeded by a control card with the integer 5 in column 5 and a second integer right-justified in columns 6 through 10 to indicate the total number of receivers defined for the data set. Each receiver location is defined by a single data card specifying the x-, y-, and z-coordinates as real constants in the fields between columns 1 through 10, 11 through 20, and 21 through 30 respectively.

As an option, the user may specify a criterion level and a title for each receiver. These data are included on the receiver coordinate card. The criterion level is a real constant located between columns 33 through 38. The receiver title is a 40 character alphanumeric description beginning in column 41 and extending through column 80. Both the criterion level and the receiver title are printed during output.

The specified criterion level for a receiver instructs the FHWA Level 2 program to print a tabulation of selected roadway segments and the levels contributed by those segments for the receiver. The program does this selection for each segment contributing a sound level 5 dB below the criterion level for the receiver. For example, specifying the criterion level as 50 dB would result in a tabulation of all roadway segments contributing sound levels of 45 dB or greater at the receiver. This option does not increase computing time.

The present version of the FHWA Level 2 traffic noise prediction program allows the user to define up to 15 receiver locations. Each z-coordinate value specified on a receiver location data card will be altered by the value specified for the receiver height adjustment in the program initialization parameters.

The FHWA Level 2 program does not explicitly check for receiver locations on a line segment defining a roadway, an absorptive ground strip centerline or a vertical plane defining a barrier segment. However, such locations would cause the code to attempt the consideration of a zero distance between the receiver location point and a line segment or plane which would result in one of the error messages described in Section 4. As a rule-of-thumb, the user should always specify receiver locations two feet (0.61 metres) away from a line segment defining a roadway or ground strip centerline or from a vertical plane specifying a barrier segment.

At each receiver location the highway traffic sound level predictions will be computed as specified by the number of frequency bands defined in the program initialization parameters. If the number of frequency bands requested is specified by the integer 1 only the overall A-weighted sound level descriptors are calculated. If the number of frequency bands is specified by an integer between 2 and 9, the appropriate A-weighted octave band levels beginning at 63 Hz will be calculated up to the band index specified.

3.7 Alpha Input

The data block for alpha input begins with a card with the integer 6 in column 5, and the number of cards to follow in columns 9 and 10. In the succeeding cards, a value for alpha is assigned to each roadway relative to each receiver, (hereafter referred to as roadway-receiver pair). Each card contains an alpha value, a roadway number, and one or more (up to 15) receiver numbers.

Each roadway-receiver pair thus defined must be unique, i.e., may not be repeated in the same or succeeding cards. When a '0' is placed in column 7 instead of a valid roadway number, the specified alpha value will be assigned to <u>all</u> roadway-receiver pairs for the specified receiver(s).

The values of alpha for all roadway-receiver pairs are initialized to zero. Consequently, the alpha values for all undefined roadway-receiver pairs are zero.

Once alpha is defined, its values for all roadway-receiver pairs are preserved throughout each problem in the same input stream. Thus, alpha input is not mandatory for each problem. However, whenever there is a change in receiver definitions, alpha must be redefined. Otherwise, the execution of the program will be terminated.

The alpha input applies only to the prediction of the overall A-weighted sound levels. For the octave band sound level predictions, the program utilizes the frequency dependent attenuation modelled by the absorptive ground strips and atmospheric absorption (2). In conducting the overall A-weighted sound level calculations, the prediction code assumes that the alpha value is zero for any subsegment of a roadway-receiver geometry that is shielded by either a barrier or a ground strip. Unshielded subsegments of a roadway-receiver geometry are treated using the alpha value specified for the roadway-receiver pair.

TABLE 3-1
INPUT DATA FORMAT

- OPTION CARD

COLUMN (FORMAT)*	1(A1)	14(A1)	28(A1)	42(A1)
NAME	IØPT	METIN	METØUT	IREFL

* Format is (80A1) hence, descriptive material may be included between columns 2 through 13, 15 through 27, 29 through 41, and 43 through 80.

IØPT must be an asterisk (*) in column 1 if option data is to be read.
METIN = Y denotes input data in metric units; = N denotes English units
METOUT = Y denotes output in metric units; = N denotes English units
IREFL = Y denotes reflection calculations desired; = N denotes no reflection calculations.

See Section 4.3.2 for examples

- TITLE CARD

Column (format)	2(79A1)
NAME	PROBLEM TITLE: 60 Alphanumeric Characters Describing the Problem

TABLE 3-1
(CONTINUED)

DATA BLOCK 1: PROGRAM INITIALIZATION PARAMETERS (MANDATORY)

- Control Card (First Card In Data Block)

COLUMN (FORMAT)	5(I5)*
NAME	1

- CARD 2 (RECEIVER HEIGHT ADJUSTMENT: RDIN(1) or TRDIN(1))

COLUMN (FORMAT)	1(E10.0)	15(I5)	20(A1)	31(25A2)
NAME	RDIN(1)or TRDIN(1)	1	Blank	Optional User Supplied Parameter Title

- CARD 3 (NUMBER OF FREQUENCY BANDS: RDIN(2))

COLUMN (FORMAT)	1(E10.0)	15(I5)	20(A1)	31(25A2)
NAME	RDIN(2)	2	Blank	Optional User Supplied Parameter Title

- CARD 4 (SOURCE HEIGHT ADJUSTMENT FOR CARS: (RDIN(3) or TRDIN(3))

COLUMN (FORMAT)	1(E10.0)	15(I5)	20(A1)	31(25A2)
NAME	RDIN(3)or TRDIN(3)	3	Blank	Optional User Supplied Parameter Title

- CARD 5 (SOURCE HEIGHT ADJUSTMENT FOR HEAVY TRUCKS: RDIN(4) or TRDIN(4))

COLUMN (FORMAT)	1(E10.0)	15(I5)	20(A1)	31(25A2)
NAME	RDIN(4)or TRDIN(4)	4	Blank	Optional User Supplied Parameter Title

- CARD 6 (SOURCE HEIGHT ADJUSTMENT FOR MEDIUM TRUCKS: RDIN(5) or TRDIN(5))

COLUMN (FORMAT)	1(E10.0)	15(I5)	20(A1)	31(25A2)
NAME	RDIN(5)or TRDIN(5)	5	L or Blank	Optional User Supplied Parameter Title

NOTE: If the user supplies an optional (type 4) vehicle leave column 20 blank and include the next three cards. Otherwise, place an L in column 20 and ignore the next three cards.

- CARD 7 (SOURCE HEIGHT ADJUSTMENT FOR OPTIONAL VEHICLE: RDIN(6) or TRDIN(6))

COLUMN (FORMAT)	1(E10.0)	15(I5)	20(A1)	31(25A2)
NAME	RDIN(6)or TRDIN(6)	6	L	Optional User Supplied Parameter Title

* Integer formats are right justified in the indicated field, i.e., 15(I5) denotes a field from Column 11 through Column 15 with the integer right-justified at Column 15.

TABLE 3-1
(CONTINUED)

- CARD 8 (OVERALL, CO(1,4), AND OCTAVE BAND, CO(I,4), REFERENCE MEAN SOUND LEVELS)

COLUMN (FORMAT)	1(E5.0)	6(E5.0)	11(E5.0)	16(E5.0)	21(E5.0)	26(E5.0)	31(E5.0)	36(E5.0)	41(E5.0)
NAME	CO(1,4)	CO(2,4)	CO(3,4)	CO(4,4)	CO(5,4)	CO(6,4)	CO(7,4)	CO(8,4)	CO(9,4)

- CARD 9 (OVERALL, SO(1,4), AND OCTAVE BAND, SO(I,4), REFERENCE STANDARD DEVIATION OF SOUND LEVELS)

COLUMN (FORMAT)	1(E5.0)	6(E5.0)	11(E5.0)	16(E5.0)	21(E5.0)	26(E5.0)	31(E5.0)	36(E5.0)	41(E5.0)
NAME	SO(1,4)	SO(2,4)	SO(3,4)	SO(4,4)	SO(5,4)	SO(6,4)	SO(7,4)	SO(8,4)	SO(9,4)

RDIN (I) $(I \neq 2)$ Must be expressed in feet (METIN = N)

TDIN (I) $(I \neq 2)$ Must be expressed in metres (METIN = Y)

TABLE 3-1 (Continued)

DATA BLOCK 2: ROADWAY PARAMETERS (MANDATORY)

- CONTROL CARD (First Card in Data Block)

COLUMN (FORMAT)	5(I5)*	10(I5)
NAME	2	NR

- TRAFFIC FLOW DATA CARDS (ONE CARD FOR TRAFFIC FLOW CONDITION: 5 MAX PER ROADWAY)

COLUMN (FORMAT)	1(E10.0)	1(E10.0)	25(I5)	31(A1)	41(5A8)
NAME	VEH	XMH or XKH	ITY	L★	TRD(ID,J)★

- ROADWAY COORDINATE CARDS (TEN SEGMENTS (ELEVEN CARDS) MAXIMUM PER ROADWAY)

COLUMN (FORMAT)	1(E10.0)	11(E10.0)	21(E10.0)	31(A1)	33(I1)	41(5A8)
NAME	RX(J,NSEC) or TRX(J,NSEC)	RY(J,NSEC) or TRY(J,NSEC)	RZ(J,NSEC) or TRZ(J,NSEC)	L★	IGOO(J,NSEC)★★	TRS(ID,J)★★

Note: NR sets of Traffic Flow Cards and Roadway Coordinate cards are required in above sequence

NR is the number of roadways
VEH is the vehicle flow rate in number of vehicles per hour
XMH is the vehicle speed in miles per hour (METIN=N)
XKH is the vehicle speed in kilometres per hour (METIN=Y)
ITY is the vehicle type (1 = automobiles, 2 = heavy trucks, 3 = medium trucks,
4 = optional vehicle)
RX, RY, RZ are the (X,Y,Z) coordinates of a roadway segment end point in feet (METIN=N)
TRX, TRY, TRZ are the (X,Y,Z) coordinates of a roadway segment end point in metres (METONT=Y)
TRD(ID,J) is the 40 character comment for roadway J
IGOO(J,NSEC) is the grade parameter: no grade correction = 0; grade correction = 1)
TRS(ID,J,NSEC) is the 40 character comment for roadway J, segment NSEC

* See Footnote to Data Block 1

★ Last Card Only

★★ All Cards Except Last Card

TABLE 3-1
(CONTINUED)

DATA BLOCK 3: BARRIER PARAMETERS

- CONTROL CARD (First Card in Data Block)

COLUMN (FORMAT)	5(I5)*	10(I5)
NAME	3	NB

- BARRIER COORDINATE CARDS (TEN SEGMENTS (ELEVEN CARDS) MAXIMUM PER BARRIER)

COLUMN (FORMAT)	1(E10.0)	11(E10.0)	21(E10.0)	31(A1)	41(5A8)
NAME	BX(J,NSEC) or TBX(J,NSEC)	BY(J,NSEC) or TBY(J,NSEC)	BZ(J,NSEC) or TBZ(J,NSEC)	A or R★	TB(ID,J)★

Note: NB sets of Barrier Coordiante Cards are required in above sequence

NB is the number of barriers
BX, BY, BZ are the (X,Y,Z) coordinates of a barrier segment endpoint in feet (METIN=N)
TBX, TBY, TBZ are the (X,Y,Z) coordinates of a barrier segment endpoint in metres (METIN=Y)
A in column 31 denotes an absorptive barrier
R in column 31 denotes a reflective barrier (ignored if IREFL=N, accepted if IREFL=Y)
TB(ID,J) is the 40 character comment for barrier J

* See Footnote to Data Block 1

★ If Last Barrier Segment Coordinate Card

TABLE 3-1
(CONTINUED)

DATA BLOCK 4: GROUND COVER PARAMETERS

- CONTROL CARD (First Card in Data Block)

COLUMN (FORMAT)	5(I5)*	10(I5)
NAME	4	NG

- GROUND COVER COORDINATE CARDS (2 CARDS REQUIRED FOR EACH STRIP DEFINED. TEN STRIPS MAXIMUM)

First Coordinate Card

COLUMN (FORMAT)	1(E10.0)	11(E10.0)	21(E10.0)	31(E10.0)
NAME	XXG1(I,1) or TXXG1(I,1)	YYG1(I,1) or TYYG1(I,1)	ZZ(G1(I,1) or TZZG1(I,1)	BGS(I) or TBGS(I)

Second Coordinate Card

COLUMN (FORMAT)	1(E10.0)	11(E10.0)	21(E10.0)	31(A1)	41(5A8)
NAME	XXG1(I,2) or TXXG2(I,2)	YYG1(I,2) or TYYG1(I,2)	ZZG1(I,2) or TZZG1(I,2)	T or G	TG(ID,I)

Note: NG sets of Ground Cover Coordinate Cards are required in above sequence

NG is the number of ground strips
XXG1(I,J), YYG1(I,J), ZZG1(I,J) are the (X,Y,Z) coordinates of the Jth end point of the Ith ground cover strip in feet (METIN=N)
TXXG1(I,J),TYYG1(I,J),TZZG1(I,J) are the (X, Y, Z) coordiantes of the Jth end point of the Ith ground cover strip in metres (METIN=Y)
BGS(I) is the width of the ground strip in feet (METIN=N)
TBGS(I) is the width of the ground strip in metres (METIN=Y)
T in column 31 of the second coordinate card denotes trees
G in column 31 of the second coordinate card denotes high grass or shrubbery
TG(ID,I) is the 40 character comment for ground strip I

* See Footnote to Data Block 1

TABLE 3-1
(CONTINUED)

DATA BLOCK 5: RECEIVER PARAMETERS (MANDATORY)

- CONTROL CARD (First Card in Data Block)

COLUMN (FORMAT)	5(I5)*	10(I5)
NAME	5	NRC

- RECEIVER COORDINATE CARDS (ONE CARD FOR EACH RECEIVER LOCATION, 15 MAXIMUM)

COLUMN (FORMAT)	1(E10.0)	11(E10.0)	21(E10.0)	33(F5.0)	41(5A8)
NAME	XRC(I) or TXRC(I)	YRC(I) or TYRC(I)	ZRC(I) or TZRC(I)	BLEV(I)	TRC(ID,I)

NRC is the number of receivers
XRC, YRC, ZRC are the receiver (X, Y, Z) coordinates in feet (METIN=N)
TXRC, TYRC, TZRC are the receiver (X, Y, Z) coordinates in metres (METIN=Y)

NOTE: ZRC(I) and TZRC(I) are altered by the receiver height adjustment specified in Card 2 of DATA BLOCK 1.

BLEV(I) is the criterion level for receiver I
TRC(ID,I) is the 40 character comment for receiver I

---

* See Footnote to Data Block 1

TABLE 3-1
(CONCLUDED)

DATA BLOCK 6: ALPHA TABLE

- CONTROL CARD (First Card in Data Block)

COLUMN (FORMAT)	5(I5)*	10(I5)
NAME	6	I1

- ALPHA CARD: BASIC FORM

COLUMN (FORMAT)	1(F4.2)	7(I2)	10(15(1X,I2))
NAME	ALPHA	IR	IRC(K)

- ALPHA CARD: OPTIONAL FORM

COLUMN (FORMAT)	1(F4.2)	7(I2)	10(15(1X,I2))
NAME	ALPHA	0	IRC(K)

I1 is the number of alpha cards to be read
ALPHA is the excess distance sound level attenuation parameter (0.0 to 1.0) that applies to roadway IR and receiver numbers IRC(K).
IR is the roadway number. If IR is specified as zero (the optional form) the value of ALPHA will be assigned to all roadways for the receivers indicated.
IRC(K) are the list of receiver numbers for which the value of ALPHA applies for the declared roadway(s).
IF ALPHA is not specified for a roadway-receiver pair it is assumed to be zero.
If more than one value for ALPHA is specified for a roadway-receiver pair execution is terminated.

- END CARD (MANDATORY)

COLUMN (FORMAT)	5(I5)*
NAME	7

This card denotes the end of a data set and initiates the program execution.

* See Footnote to Data Block 1

4. PROBLEM FORMULATION, ERROR MESSAGES, AND EXAMPLES

4.1 Problem Formulation

As indicated in Section 2, the FHWA Level 2 highway traffic noise prediction program is an extension of the TSC MOD-04 program. Generally, the details required to model accurately a traffic noise prediction scenario apply equally to both programs.

4.1.1 Roadways and Roadway Segments

The program describes a roadway by the traffic flow conditions defined for the roadway. Each roadway may be defined by a maximum number of five different traffic flow conditions. The model allows a maximum number of twenty (20) roadways to be defined. Roadways may intersect or coincide geometrically.

The alignment of each roadway is defined by a connected series of straight line roadway segments. No increase in prediction accuracy is achieved by defining a straight line roadway by a series of straight line roadway segments. Computing time is directly related to the number of combinations of roadway segment/receiver configurations.

For upgrade roadway segments, heavy truck noise emissions may be increased as specified by the user. Using the concept of an equivalent lane, the user must group lanes and according to the traffic flow direction when including grade as a parameter in the noise prediction. The appropriate usage is illustrated in the example problem in Section 4.6.

4.1.2 Traffic Flow Conditions

The program describes a traffic flow condition as a combination of vehicle speed and vehicle traffic capacity for each of the four vehicle types recognized by the code. Vehicle speed is expressed in either miles per hour or kilometres per hour and vehicle traffic capacity is expressed as the number of vehicles per hour. Hence, the predicted energy mean levels and percentile levels are associated with an hourly time period.

Each roadway is defined by a maximum number of five traffic flow conditions. A roadway can be used to model a multi-lane highway using the geometric mean distance from source to receiver, $\sqrt{D_n D_f}$, based upon the near lane (D_n) distance and the far lane distance (D_f) as the user might deem appropriate. When using grade adjustments for heavy truck noise emissions, equivalent lanes must be determined from groups of lanes with identical traffic flow direction.

It is difficult to state guidance as to which traffic flow combinations may result in the "worst hour" sound levels at a receiver, especially for multi-roadway models. Generally, traffic flow mixes comprising a significant percentage of heavy trucks moving at high speed result in higher sound levels.

4.1.3 Diffraction of Sound

The program considers only the most effective diffraction of sound from a subsegment of a roadway segment to a receiver for source-receiver paths containing multiple diffractions (i.e., barriers). The user should attempt to recognize this characteristic so that the available number of barriers that can be defined (twenty maximum in the present version) are utilized efficiently. For example, a barrier placed on top of a berm should be modeled as a single barrier at the maximum elevation points rather than as two barriers.

The program defines a barrier by its top edge and does not recognize a bottom edge for the barrier. For example, a barrier defined for an elevated highway is simply a high screen from the defined top edge to the imaginary ground level.

The top edge of a barrier may be defined by up to a maximum number of ten (10) straight line segments. Barriers may intersect themselves or other barriers. Barriers may be specified as perfectly reflective or perfectly absorptive acoustically. The reflectivity or absorptivity acoustic characteristics of a barrier apply to both sides of the barrier.

The diffraction calculations used to estimate barrier attenuation are not dependent upon the absorptive characteristics declared for the barrier.

Barriers are not allowed to intersect roadways. Barriers may, however, intersect absorptive ground strips. Effects of acoustic diffraction around the end of a barrier are ignored.

4.1.4 Shrubbery and Trees

The program describes shrubbery and trees by a straight centerline and a width defining a rectangular patch of absorptive ground cover. Shrubbery is assumed to be ten feet (3m) high and trees are assumed to be twenty feet (6m) high above the defined centerline.

If during the analysis of a roadway segment or subsegment a diffraction is encountered on the source-receiver path, all attenuation effects of shrubbery and/or trees are ignored for that source-receiver path. Hence, the program cannot estimate the attenuation effects of plantings on berms, for example. If the user is in doubt concerning the utility of introducing a ground strip, do so since the prediction algorithm will make the correct judgements concerning attenuation of traffic noise. The defined centerline of an absorptive ground strip is not allowed to intersect a roadway segment. Absorptive ground strips may, however, intersect other ground strips or barriers.

Since the FHWA Level 2 program can account for excess distance attenuation effects by specifying the "alpha input", the user may decide to exclude the absorptive ground cover formulation from a scenario. However, the specification of a non-zero value of alpha will apply only to the A-weighted overall sound level predictions for roadway subsegments that are unshielded from the receiver. That is, excluding absorptive ground strips and specifying a non-zero value of alpha will model a "soft site" for the overall A-weighted sound level estimates and a "hard site" for the octave band calculations. This issue may be resolved only on the basis of the users' experience and the results of future research.

4.1.5 Reflectors

The program models a reflective surface using a barrier with reflective acoustic characteristics. The user should include large buildings or other potential reflective surfaces in his site model. The program is capable of defining only vertical plane surfaces. Hence, reflections from either inclined or horizontal surfaces cannot be considered by the prediction model.

The maximum increase in receiver sound levels resulting from reflections is 3 dB corresponding to an incoherent sound source. No effect of acoustic wavelength is considered. If the direct ray connecting a source point and an image receiver point intersects a barrier within two feet (0.6m) of the top edge, reflection is ignored.

The user may elect an option to bypass reflection calculations. In this case the barriers must still be declared as either absorptive or reflective, but the program will override any reflection calculations.

4.1.6 Formulating Geometry

The FHWA Level 2 highway traffic noise prediction program defines a site geometry using only straight line segments and vertical planes (barriers) described by the most elevated edge comprised of straight line segments. The program does not recognize a ground plane as such.

The user should basically attempt to define only maximum topographic elevations and should include important reflective surfaces (if desired).

It is good practice to utilize a scale plat of the site in formulating coordinates for roadways, barriers, absorptive ground strips, and receivers. Doing this will allow the user to avoid the grief and wasted time resulting from non-execution of the code as a result of a barrier or a ground strip segment intersecting a roadway. However, the present version of the program will check input data for intersections prior to beginning any calculations so that computation time is not wasted.

As a rule-of-thumb, the user should locate coordinate points for barriers, absorptive ground strips and receivers no closer than two feet (0.6m) from a non-compatable geometric element to avoid rejection of the input data.

4.1.7 Receiver Location and Predicted Results

The FHWA Level 2 highway traffic noise prediction program allows the user to specify up to a maximum of 15 receiver locations at which sound level estimates are to be conducted. A receiver should not be located within two feet (0.6m) of either a roadway segment, barrier surface, or an absorptive ground strip. Such locations may result in problems with the arithmetic for extreme geometric configurations. If the code encounters such problems, execution is stopped.

Since the model formulation does not physically model a ground plane it is necessary to specify an appropriate "alpha" value for the excess distance attenuation for each roadway-receiver combination. The user must exercise judgement in selecting the appropriate value for alpha.

4.2 Output Error Messages

The FHWA Level 2 highway traffic noise prediction program prints several error messages that assist the user in either identifying illegal input data or warning the user that an error has occurred.

The error messages printed by the program and the sequence of events taken by the program in the event that an error has occurred are described below. A fatal error is an error that stops execution of the program for all data sets following that set in which the error occurs. A reject error is an error in which the program stops execution of the data set in which the error occurs but continues its attempt to execute subsequent data sets. The user should note that a reject error may result in a subsequent fatal error due to the inherent flexibility of the input data sequence allowed by the program (see Section 3). Warning messages notify the user that a non-fatal restriction on the input data or error during execution has been encountered but that the program is continuing to execute the defined problem.

4.2.1 Error Messages Occurring During Data Set Input

Prior to execution of a data set the program checks the input data to see that for each vehicle type specified the vehicle speed falls within the range of 30 mph to 65 mph (50 km/h to 100 km/h) and also checks to insure that the geometric description of a roadway and a barrier included two end points.

Vehicle Speed Range Exceeded: If the user has specified a vehicle speed outside the range of 30 mph to 65 mph the following warning messages are printed as appropriate:

"VEHICLE SPEED SUPPLIED IS LESS THAN 30 MPH ADJUSTED TO 30"

OR

"VEHICLE SPEED SUPPLIED IS GREATER THAN 65 MPH ADJUSTED TO 65"

The program continues execution with the indicated adjustments for vehicle speed for the roadway being considered. If the program is operating under the Metric option, appropriate speeds in km/h are printed.

Illegal Definition of Roadway or Barrier: If the user has attempted to define either a roadway or a barrier by one coordinate point (two points minimum are required, see Section 3) the following fatal error messages are printed:

"INSUFFICIENT ROAD SECTIONS"
"INSUFFICIENT BARRIER SECTIONS"

If this error occurs, execution of the program stops. The user should correct the appropriate input data. If multiple data sets are to be executed with either receiver locations or roadway locations changed between different runs, it is required to redefine the "alpha input" table. If the "alpha input" table is not redefined, program execution will be terminated.

4.2.2 Error Messages Occurring During Check of Input Data

Subsequent to reading the input data, but prior to execution of sound level calculations, the program checks to see if either a barrier segment or the centerline of an absorptive ground strip intersects a roadway segment. The program checks for such intersections using only the x-y coordinates of the line segments. The user can prevent such errors by using a scale plat of the site to formulate the roadway segment, barrier segment, and absorptive ground strip coordinates. If such an intersection occurs the following reject error messages are printed as appropriate:

```
"ILLEGAL BARRIER INTERSECTS ROADWAY R XX RS XX B XX BS XX"
 where R XX denotes roadway number XX
       RS XX denotes roadway segment number XX
       B XX denotes barrier number XX
       BS XX denotes barrier segment number XX
"ILLEGAL GROUND STRIP INTERSECTS ROADWAY R XX RS XX AGS XX"
where R XX denotes roadway number XX
      RS XX denotes roadway segment number XX
      AGS XX denotes absorptive ground strip number XX
```

These reject error messages are printed for each intersection encountered in the input data for both barrier segements and absorptive ground strips. Hence, if illegal intersections are encountered, all such illegal data will be displayed to the user. Upon completing the data check, the program stops execution of the data set containing illegal intersections of roadway segments with barrier segments and/or ground strips and attempts to read the next data set. The user should check and correct the input data.

4.2.3 Error Messages Occurring During Sound Level Calculations

The FHWA Level 2 highway traffic noise prediction program checks for illegal operations during execution of subroutine GEOMRY. Subroutine

GEOMRY conducts the calculations associated with the basic problem considered by the prediction code (see Appendix A). Two basic types of errors can occur that are internal to the code in Subroutine GEOMRY: attempting to shift a point on a zero length line segment or encountering too many reflections at a receiver. The error messages are as follows:

```
"*** ANGLE SUBTENDED AT RECEIVER BY ROAD SEGMENT IS
     APPROACHING ZERO"

INITIAL PT. OF ROAD SEGMENT (COORDINATES)
END PT. OF ROAD SEGMENT (COORDINATES)
RECEIVER POINT (COORDINATES)
```

This message is a warning statement and the code continues execution.

```
"ERROR IN MOVE"
```

This is a reject error message indicating that the subroutine MOVE has attempted to shift a point on a line segment of zero length. The user should check the input data for roadway segments and barrier segments. The code halts execution and proceeds to the next data set.

```
"ERROR IN MOVE2"
```

This is a reject error message indicating that the subroutine MOVE2 has attempted to shift a point on a line segment of zero length (in the x-y plane). The user should check the input data for roadway segments and barrier segments. The code halts execution and proceeds to the next data set.

If the maximum allowable number of reflections (eleven) is exceeded at a receiver, the code halts execution and prints the following message:

"TOO MANY REFLECTIONS RCV XX R XX S XX"

where RCV XX is receiver number XX
R XX is roadway number XX
S XX is roadway segment number XX

The user should check the receiver location in relation to the reflective barriers defined for the problem to see if simplifications in the site model are possible or eliminate reflection calculations using the input data option.

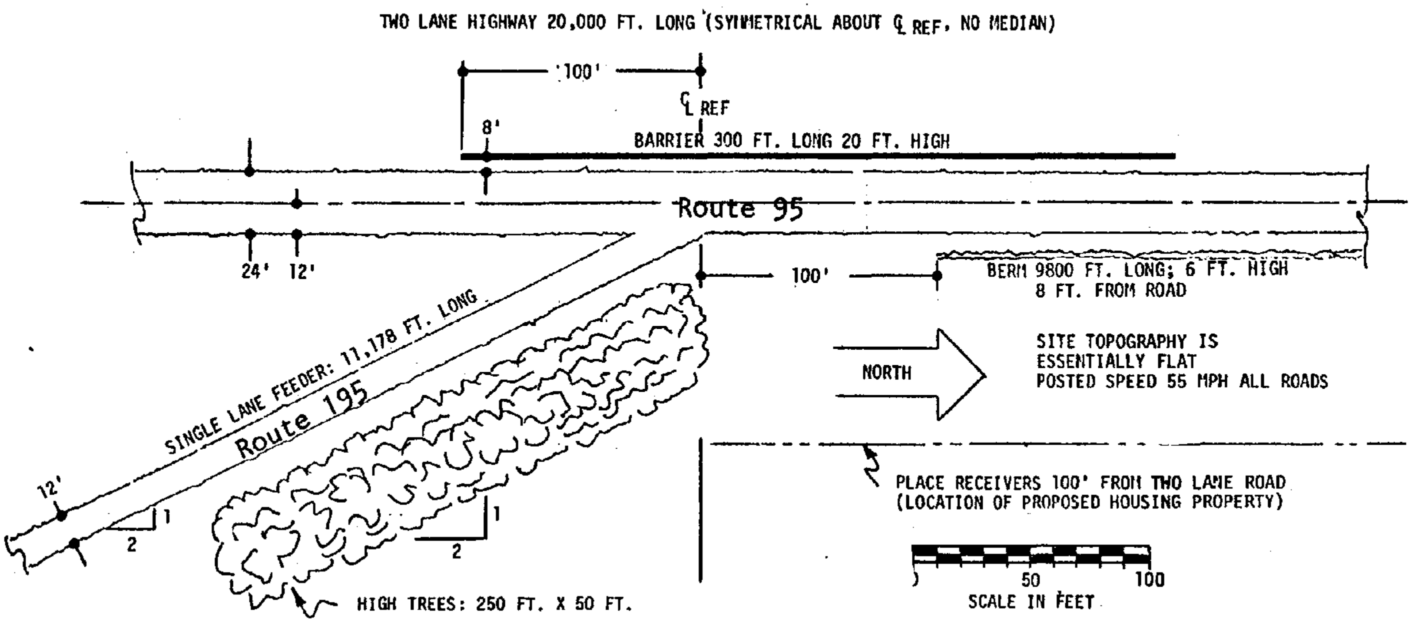
4.3 Example Problem 1

This section presents examples illustrating the translation of site information into the input data format required by the program. The first example illustrates the output data format utilized by the FHWA Level 2 program. This example is identical to that described in Reference (2).

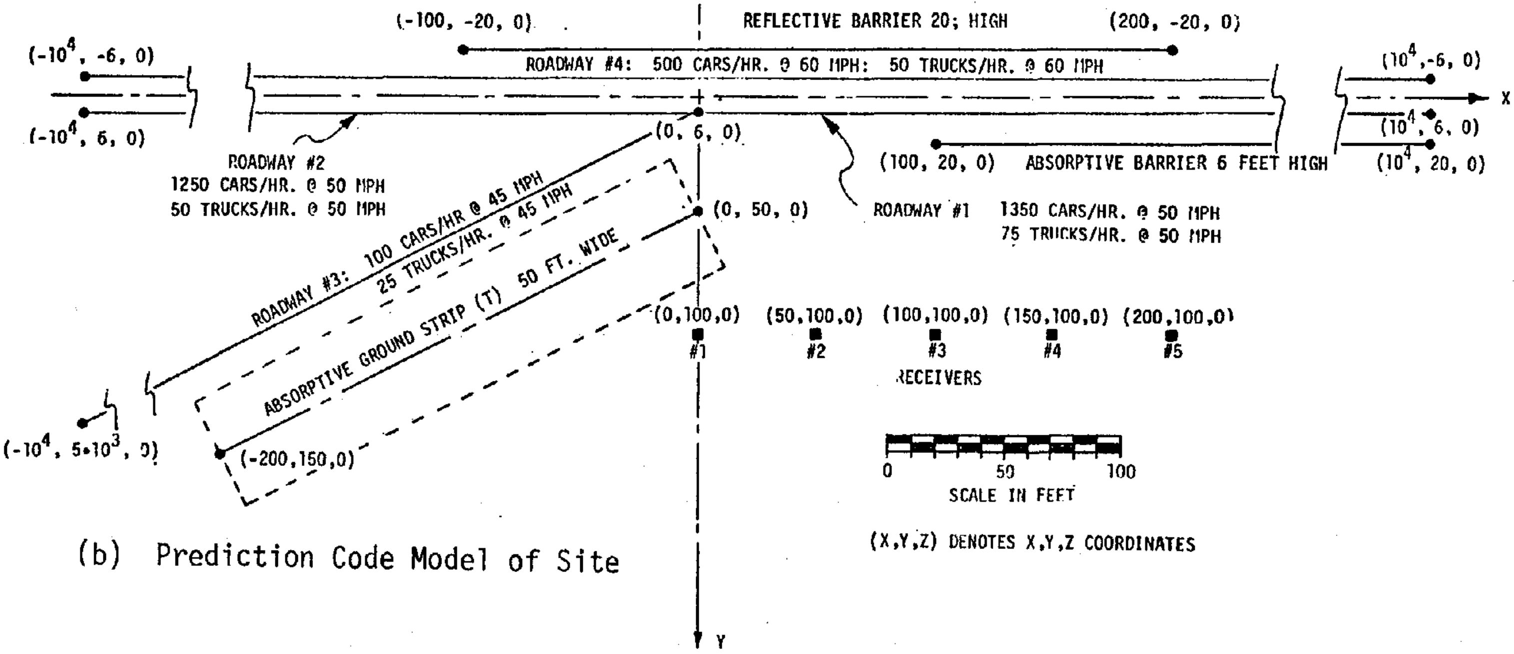
Figure 4-1 illustrates a highway situation comprising a two lane highway (Route 95) and a single feeder lane (Route 195) joining the highway. The lane widths are 12 feet (3.6m) with no median strip for the two lane highway. Except for a six foot (1.8m) high earth berm located on the north-eastern edge of the two lane highway the site topography is essentially flat. A 20 foot (6.1m) high barrier is located along the western edge of Route 95 and a stand of trees is located along Route 195. It is desired to evaluate the sound levels in the north-eastern quandrant of the site at 100 feet (30.48m) from the centerline of Route 95.

It is decided to evaluate the receiver sound levels for alternate site configurations as follows:

- Configuration (Data Set) 1: Site as described above deleting reflection calculations from the barrier.



(a) Site Plat with Field Notes



(b) Prediction Code Model of Site

FIGURE 4-1. SITE PLAT AND SITE MODEL FOR EXAMPLE PROBLEM

- Configuration (Data Set) 2: Configuration 1 with the absorptive ground strip (trees) and the barrier deleted.
- Configuration (Data Set) 3: Configuration 2 with the heavy trucks (Type 2) vehicle replaced with the user-defined (Type 4) vehicle.

For each problem, it is assumed that the site is "acoustically hard" for each roadway-receiver combination. That is, the "alpha input" is zero for all roadway-receiver combinations. Further, input data will be specified in English Units (foot, mile, hour) and the output data will be expressed in Metric Units (metre, kilometre, hour). The traffic flow parameters are determined as indicated in the site plat of Figure 4-1.

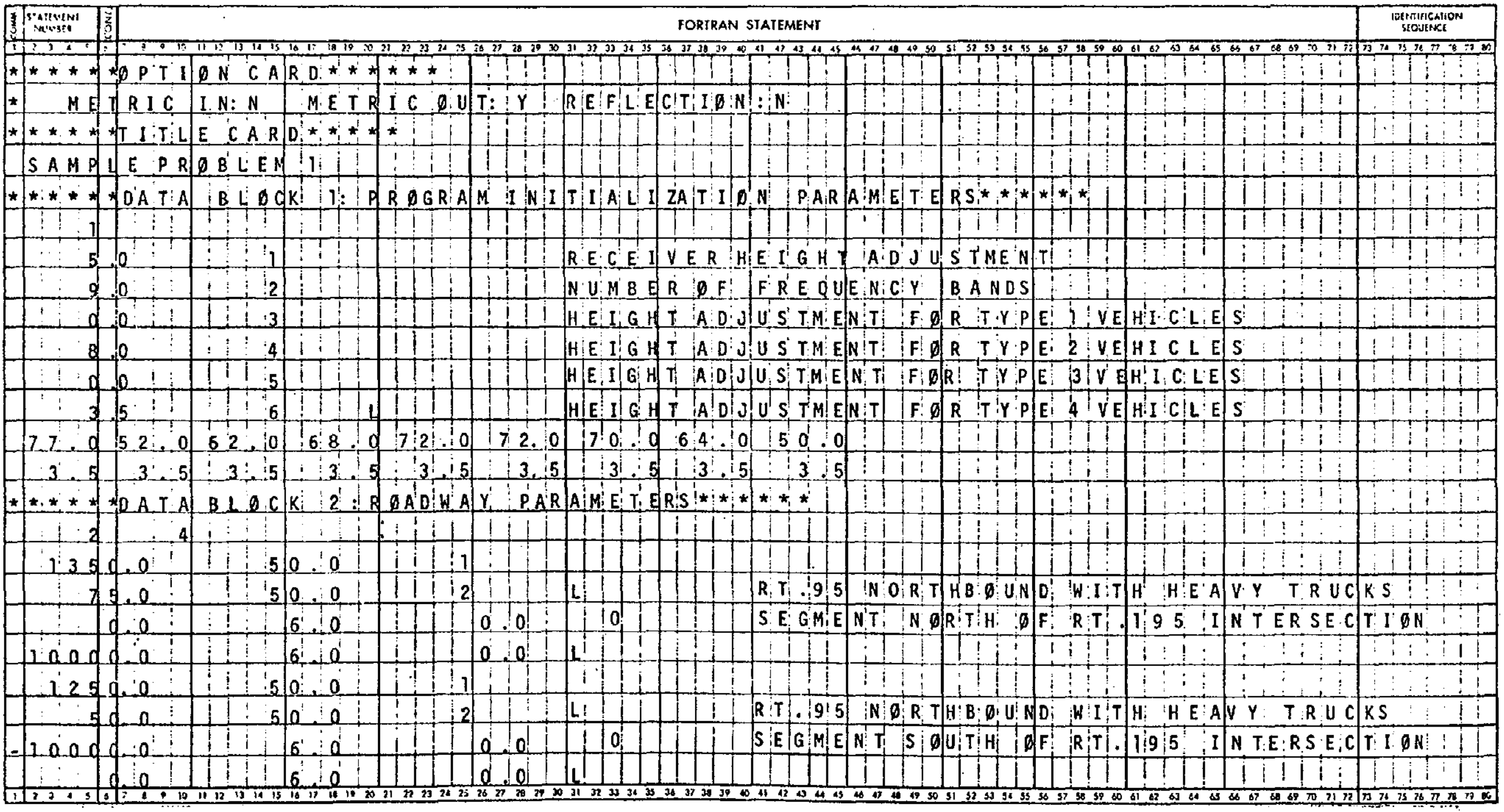
The input data for the sample problems is indicated in Figure 4-2 using a standard coding form. The notations enclosed by asterisks are for user reference and do not constitute data. Data Set 1 comprises the basic problem formulation. Data Set 2 modifies Data Set 1 by deleting the barrier and the ground strip. Data Set 3 modifies Data Set 2 by redefining the heavy truck (Type 2 vehicle) with the user-defined Type 4 vehicle.

4.4 Output Data for Example Problem 1

The FHWA Level 2 highway traffic noise computer program immediately prints output once the input file for a data set is read.

The heading is printed at the top of a page and indicates the selected option for engineering units for input and output data. Since the examples used English input and Metric output the heading is:

"TRAFFIC NOISE PREDICTION (INPUT UNITS: ENGLISH, OUTPUT UNITS: METRIC)"



```
******OPTION CARD******
*  METRIC IN:N  METRIC OUT: Y REFLECTION:N
******TITLE CARD*****
 SAMPLE PROBLEM 1
******DATA BLOCK 1: PROGRAM INITIALIZATION PARAMETERS******
    1
    5.0       1               RECEIVER HEIGHT ADJUSTMENT
    9.0       2               NUMBER OF FREQUENCY BANDS
    0.0       3               HEIGHT ADJUSTMENT FOR TYPE 1 VEHICLES
    8.0       4               HEIGHT ADJUSTMENT FOR TYPE 2 VEHICLES
    0.0       5               HEIGHT ADJUSTMENT FOR TYPE 3 VEHICLES
    3.5       6    L          HEIGHT ADJUSTMENT FOR TYPE 4 VEHICLES
 77.0 52.0 62.0 68.0 72.0 72.0 70.0 64.0 50.0
  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
******DATA BLOCK 2: ROADWAY PARAMETERS******
    2    4
  1350.0      50.0      1
    75.0      50.0      2     L         RT.95 NORTHBOUND WITH HEAVY TRUCKS
     0.0       6.0       0.0    0       SEGMENT NORTH OF RT.195 INTERSECTION
 10000.0       6.0       0.0  L
  1250.0      50.0      1
    50.0      50.0      2     L         RT.95 NORTHBOUND WITH HEAVY TRUCKS
-10000.0       6.0       0.0    0       SEGMENT SOUTH OF RT.195 INTERSECTION
     0.0       6.0       0.0  L
```

Figure 4-2. INPUT DATA FORMAT FOR EXAMPLE PROBLEM 1

```
   100.0      45.0      1
    25.0      45.0      2     L         RT.195 NØRTHWESTBØUND WITH HEAVY TRUCKS
-10000.0    5000.0       0.0    0       SEGMENT INTERSECTING RT.95 NORTHBOUND
     0.0       6.0       0.0  L
   500.0      60.0      1
    50.0      60.0      2     L         RT.95 SØUTHBØUND WITH HEAVY TRUCKS
-10000.0      -6.0       0.0    0       SEGMENT RUNNING NØRTH-SOUTH
 10000.0      -6.0       0.0  L
******DATA BLØCK 3:BARRIER PARAMETERS******
    3    2
  -100.0     -20.0      20.0
   200.0     -20.0      20.0  R         REFLECTIVE BARRIER W ØF RT.955
   100.0      20.0       6.0
 10000.0      20.0       6.0  A         ABSØRPTIVE BERM ØF RØADWAY #1
******DATA BLØCK 4:GRØUND CØVER PARAMETERS******
    4    1
     0.0      50.0       0.0      50.0
  -200.0     150.0       0.0  T         TREES N.E. ØF RT.195
******DATA BLØCK 5:RECEIVER PARAMETERS******
    5    5
     0.0     100.0       0.0    50.     N.E. ØF TREES
   50.0      100.0       0.0    50.     E ØF RØADWAY #1 & N ØF RECEIVER #1
  100.0      100.0       0.0    50.     E ØF ABSØRPTIVE BERM & N ØF RECEIVER #2
  150.0      100.0       0.0    50.     E ØF ABSØRPTIVE BERM & N ØF RECEIVER #3
```

Figure 4-2. INPUT DATA FORMAT FOR EXAMPLE PROBLEM 1 (Continued)

```
C STATEMENT CONT                  FORTRAN STATEMENT                               IDENTIFICATION
  NUMBER                                                                          SEQUENCE
   200.0     100.0       0.0    50.     E ØF ABSØRPTIVE BERM & N ØF RECEIVER #4
******ALPHA INPUT :ØPTIØNAL FØRMAT******
    6    1
 0.0  0  1  2  3  4  5
******END CARD******
    7
******END ØF FIRST PRØBLEM IN DATA STREAM******
******TITLE CARD******
 SAMPLE PRØBLEM 2
******DATA BLØCK 3*BARRIER PARAMETERS******
    3    1
   100.0      20.0      6.0
 10000.0      20.0      6.0  A         ABSØRPTIVE BERM E ØF RØADWAY #1
******DATA BLØCK 4:GRØUND CØVER PARAMETERS******
    4    0
******END CARD******
    7
******TITLE CARD******
 SAMPLE PRØBLEM 3
******DATA BLØCK 2:RØADWAY PARAMETERS******
    2    4
  1350.0      50.0      1
    75.0      50.0      4     L         RT.95N WITH TYPE 4 VEHICLES
     0.0       6.0       0.0    0        SEGMENT N ØF RT.195 INTERSECTIØN
```

Figure 4-2. INPUT DATA FORMAT FOR EXAMPLE PROBLEM 1 (Continued)

```
 10000.0       6.0       0.0  L
  1250.0      50.0      1
    50.0      50.0      4     L         RT.95N WITH TYPE 4 VEHICLES
 10000.0       6.0       0.0    0       SEGMENT S ØF RT.195 INTERSECTIØN
     0.0       6.0       0.0  L
   100.0      45.0      1
    25.0      45.0      4     L         RT.195 N.W. WITH TYPE 4 VEHICLES
 10000.0    5000.0       0.0    0       SEGMENT INTERSECTING RT.95N
     0.0       6.0       0.0  L
   500.0      60.0      1
    50.0      60.0      4     L         RT.95S WITH TYPE 4 VEHICLES
 10000.0      -6.0       0.0    0       SEGMENT RUNNING NØRTH-SØUTH
 10000.0      -6.0       0.0  L
******ALPHA INPUT:ØPIØNAL FØRMAT******
    6    1
 0.0  0  1  2  3  4  5
******END CARD******
    7
******END ØF EXAMPLE PRØBLEM DATA STREAM******
```

Figure 4-2. INPUT DATA FORMAT FOR EXAMPLE PROBLEM 1 (Concluded)

Next, the defined title is printed. Following the title, the input data is printed (using appropriate units) in the following sequence:

- Program Initialization Parameters: These data are printed only for the first problem in the data stream.

- Roadway Parameters: Roadway title, traffic count and speed by vehicle type, and coordinates of the roadway segment end-points with grade adjustment index and annotation are printed for each roadway and each problem in the data stream.

- Barrier Parameters: Following the barrier number, the letter A or R is printed in parenthesis. The barrier segment coordinates are printed in sequence. Following the first barrier coordinate, the barrier title is printed (Note: The barrier may be declared as reflective (R), but the specification is ignored if the user selects the option to bypass reflection calculations.)

- Absorptive Ground Strip Parameters: Following the ground strip number, the letter T or G is printed in parenthesis. The coordinates of one end point and the width of the strip are printed in the next line. The last line comprises the coordinates of the other end point of the strip and the title for the strip.

- Receiver Parameters: Receiver parameters are listed in the input sequence. The receiver number is printed followed by the receiver coordinates (x, y, z), the receiver criterion sound level (LC), and the receiver title. The z coordinate value printed is the input value plus the receiver height adjustment specified in the program initialization parameters.

- Alpha Input: A table of alpha values is printed to document the input specification. The alpha values printed correspond to each roadway (column) and each receiver (row). These values are defined by the user.

The printing of the input data is a reference listing for the user documenting the input data used for the traffic noise estimates.

Following the listing of the input data, the program then reprints the user-defined title and prints the predicted traffic noise levels by receiver in the format:

- Receiver Number, the X, Y, Z coordinates of the receiver (in engineering units specified), and the receiver title.
- A-weighted Octave Band Sound Levels (if the number of frequency bands is specified to be greater than 1 in the program initialization parameters). The title "OCTAVE BAND LEVELS (A)" is printed followed by the octave band center frequencies from 63 Hz to 8000 Hz. Under the indicated center frequency the predicted A-weighted octave band sound level is printed.
- A-weighted Sound Level Metrics: Following the octave band predictions the following heading is printed:

  LE(A) LEOB(A) L90 L50 L10 SIGMA

  - LE(A) is the overall A-weighted equivalent sound level estimated using the theory of Appendix A and the "alpha" values specified for the receiver.
  - L90 is the overall A-weighted sound level exceeded 90% of the time (hour) estimated using the theory of Appendix A (Equation (A-14)). Calculated from L50 and SIGMA.
  - L50 is the overall A-weighted sound level exceeded 50% of the time (hour) using the theory of Appendix A (Equation (A-12)). Calculated from LE(A) and SIGMA.
  - L10 is the overall A-weighted sound levels exceeded 10% of the time (hour) using the theory of Appendix A (Equation (A-13)). Calculated from L50 and SIGMA.
  - SIGMA is the estimated standard deviation of the sound level variation during the hour. See Appendix A, Equation (A-7) and Equation (A-10).
  - LEOB(A) is the estimated A-weighted overall octave band sound level obtained by taking an intensity summation of the A-weighted octave band levels. Since the octave band levels are estimated using frequency-dependent distance attenuation resulting from ground strips and atmospheric absorption (2) the value LEOB(A) may not agree exactly with the LE(A) estimate using the "alpha" input.

The FHWA Level 2 highway traffic noise prediction program performs calculations by receiver locations considering all other parameters. Hence, if predicted results are obtained without an error message being printed, the program has completed the required sound level estimates for the receiver(s).

Following the receiver sound level estimates, the FHWA Level 2 program will print a table of "receiver sound level contributions" at the user's option. If the criterion level has been set to zero, this tabulation is not printed. This option allows the user to identify roadways or roadway segments contributing to the total receiver sound level, LE(A), in excess of the specified criterion level. For a given problem, several roadway segments may result in sound level contributions of nearly equal magnitude. The criterion level specified for a receiver is in terms of the total sound level at the receiver. In order to list all roadway segments that may significantly contribute to the total sound level, the FHWA Level 2 program uses an internal criterion level 5 dB below the user specified criterion level to select which segments and levels are to be printed.

In this example problem, the criterion level is specified as 50 dB for all receivers. Each roadway is defined by a single segment and all roadways and intervening attenuation contribute sound levels exceeding the internal 45 dB criterion level used by the program. Hence, the tabulation comprises a column of numbers presenting the contribution of each roadway segment to the total receiver sound level, LE(A). The reader may wish to verify that the intensity summation of the sound levels from each segment equals the total receiver sound level.

The computation related to filling the tabulation of the sound level contributions for each receiver is conducted as part of the calculations required to obtain the LE(A) estimate. Hence, requesting the tabulation does not increase the computing time of the FHWA Level 2 program.

Figure 4-3 presents the FHWA Level 2 highway traffic noise prediction output listing corresponding to the input data presented in Figure 4-2.

4.5 Examples of "Alpha Input"

The FHWA Level 2 highway traffic noise prediction program utilizes input data format for all data blocks except "Alpha Input" that is identical to the TSC MOD-04 prediction program. The "Alpha Input" is a feature option of the FHWA Level 2 model.

```
     TRAFFIC NOISE PREDICTION (INPUT UNITS: ENGLISH ,OUTPUT UNITS: METRIC  )

SAMPLE PROBLEM 1

PROGRAM INITIALIZATION PARAMETERS
 1.52400D+00           1      RECEIVER HEIGHT ADJUSTMENT
 9.00000D+00           2      NUMBER OF FREQUENCY BANDS
 0.0                   3      HEIGHT ADJUSTMENT FOR TYPE 1 VEHICLES
 2.43840D+00           4      HEIGHT ADJUSTMENT FOR TYPE 2 VEHICLES
 0.0                   5      HEIGHT ADJUSTMENT FOR TYPE 3 VEHICLES
 1.06680D+00           6      HEIGHT ADJUSTMENT FOR TYPE 4 VEHICLES
    OPTIONAL NOISE SPECTRUM
    CONSTANTS :    77.0    52.0    62.0    68.0    72.0    72.0    70.0    64.0    50.0
    STD. DEV. :     3.5     3.5     3.5     3.5     3.5     3.5     3.5     3.5     3.5
ROADWAY    1     RT.95 NORTHBOUND WITH HEAVY TRUCKS
NUMBER OF              VEH/H         KMPH
TYPE 1 VEH
   1                   1.35000D+03   8.04670D+01
NUMBER OF              VEH/H         KMPH
TYPE 2 VEH
   1                   7.50000D+01   8.04670D+01
                      SOURCE COORD IN M
NUMBER      X            Y            Z            GRADE    COMMENTS
   1      0.0          1.82880D+00  0.0            0      SEGMENT NORTH OF RT.195 INTERSECTION
   2      3.0480D+03   1.82880D+00  0.0            0
ROADWAY    2     RT.95 NORTHBOUND WITH HEAVY TRUCKS
NUMBER OF              VEH/H         KMPH
TYPE 1 VEH
   1                   1.25000D+03   8.04670D+01
NUMBER OF              VEH/H         KMPH
TYPE 2 VEH
   1                   5.00000D+01   8.04670D+01
                      SOURCE COORD IN M
NUMBER      X            Y            Z            GRADE    COMMENTS
   1     -3.04800D+03  1.82880D+00  0.0            0      SEGMENT SOUTH OF RT.195 INTERSECTION
   2      0.0          1.82880D+00  0.0            0
ROADWAY    3     RT.195 NORTHWESTBOUND WITH HEAVY TRUCKS
NUMBER OF              VEH/H         KMPH
TYPE 1 VEH
   1                   1.00000D+02   7.24200D+01
NUMBER OF              VEH/H         KMPH
TYPE 2 VEH
   1                   2.50000D+01   7.24200D+01
                      SOURCE COORD IN M
NUMBER      X            Y            Z            GRADE    COMMENTS
   1     -3.04800D+03  1.52400D+03  0.0            0      SEGMENT INTERSECTING RT.95 NORTHBOUND
   2      0.0          1.82880D+00  0.0            0
ROADWAY    4     RT.95 SOUTHBOUND WITH HEAVY TRUCKS
NUMBER OF              VEH/H         KMPH
TYPE 1 VEH
   1                   5.00000D+02   9.65600D+01
NUMBER OF              VEH/H         KMPH
TYPE 2 VEH
   1                   5.00000D+01   9.65600D+01
                      SOURCE COORD IN M
NUMBER      X            Y            Z            GRADE    COMMENTS
   1     -3.04800D+03 -1.82880D+00  0.0            0      SEGMENT RUNNING NORTH-SOUTH
   2      3.04800D+03 -1.82880D+00  0.0            0
BARRIER     1  (R)    BARRIER COORD IN M
NUMBER      X            Y            Z
   1     -3.04800D+01 -6.09600D+00  6.09600D+00     REFLECTIVE BARRIER W OF RT.95S
   2      6.09600D+01 -6.09600D+00  6.09600D+00
BARRIER     2  (A)    BARRIER COORD IN M
NUMBER      X            Y            Z
   1      3.04800D+01  6.09600D+00  1.82880D+00     ABSORPTIVE BERM E OF ROADWAY #1
   2      3.04800D+03  6.09600D+00  1.82880D+00
ABSORBING STRIP    1  (1)

PT          X            Y            Z            WIDTH
   1      0.0          1.52400D+01  0.0         1.52400D+01
   2     -6.09600D+01  4.57200D+01  0.0            TREES N.E. OF RT.195
RECEIVER              RECEIVER COORD IN M
NUMBER      X            Y            Z            LC       COMMENTS
   1      0.0          3.04800D+01  1.52400D+00   50.0     N.E. OF TREES
   2      1.52400D+01  3.04800D+01  1.52400D+00   50.0     E OF ROADWAY #1 & N OF RECEIVER #1
   3      3.04800D+01  3.04800D+01  1.52400D+00   50.0     E OF ABSORPTIVE BERM & N OF RECEIVER #2
   4      4.57200D+01  3.04800D+01  1.52400D+00   50.0     E OF ABSORPTIVE BERM & N OF RECEIVER #3
   5      6.09600D+01  3.04800D+01  1.52400D+00   50.0     E OF ABSORPTIVE BERM & N OF RECEIVER #4
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1

```
          ALPHA   TABLE

NRC/NR     1     2     3     4

 1        0.0   0.0   0.0   0.0
 2        0.0   0.0   0.0   0.0
 3        0.0   0.0   0.0   0.0
 4        0.0   0.0   0.0   0.0
 5        0.0   0.0   0.0   0.0




SAMPLE PROBLEM 1
RECEIVER             XRC          YRC          ZRC
    1                0.0          30.5         1.5       N.E. OF TREES

                          UCTAVE BAND LEVELS (A)
           63      125     250     500    1000    2000    4000    8000
          47.6     55.2    61.8    64.8    67.2    64.9    57.6    48.4

          LE(A)  LEDB(A)   L90     L50     L10    SIGMA
          71.8    71.5     61.5    68.4    75.3     5.4


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1        1
          66.2
   2        1
          65.4
   3        1
          61.2
   4        1
          67.8



RECEIVER             XRC          YRC          ZRC
    2               15.2          30.5         1.5      E OF ROADWAY #1 & N OF RECEIVER #1

                          OCTAVE BAND LEVELS (A)
          `63      125     250     500    1000    2000    4000    8000
          47.2     54.9    61.6    64.7    67.3    65.0    57.9    48.7

          LE(A)  LEUB(A)   L90     L50     L10    SIGMA
          71.6    71.5     60.8    68.0    75.2     5.6


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1        1
          67.1
   2        1
          64.1
   3        1
          59.4
   4        1
          67.7
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
RECEIVER              XRC           YRC           ZRC
   3                  30.5          30.5          1.5     E OF ABSORPTIVE BERM & N OF RECEIVER #2

                             OCTAVE BAND LEVELS (A)
             63       125      250      500     1000     2000     4000     8000
            46.4      54.2     60.9     64.1    66.8     64.5     57.6     48.3

          LE(A)   LEOB(A)    L90      L50      L10      SIGMA
           71.0     70.9     60.3     67.4     74.5      5.6


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1         1
           67.0
   2         1
           62.7
   3         1
           57.6
   4         1
           67.1


RECEIVER              XRC           YRC           ZRC
   4                  45.7          30.5          1.5     E OF ABSORPTIVE BERM & N OF RECEIVER #3

                             OCTAVE BAND LEVELS (A)
             63       125      250      500     1000     2000     4000     8000
            45.5      53.2     60.1     63.3    66.2     63.9     57.2     47.5

          LE(A)   LEOB(A)    L90      L50      L10      SIGMA
           70.1     70.2     60.0     66.8     73.6      5.3


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1         1
           66.3
   2         1
           61.4
   3         1
           56.2
   4         1
           66.1


RECEIVER              XRC           YRC           ZRC
   5                  61.0          30.5          1.5     E OF ABSORPTIVE BERM & N OF RECEIVER #4

                             OCTAVE BAND LEVELS (A)
             63       125      250      500     1000     2000     4000     8000
            44.8      52.5     59.4     62.6    65.7     63.3     56.9     46.8

          LE(A)   LEOB(A)    L90      L50      L10      SIGMA
           69.4     69.7     59.5     66.2     72.9      5.3


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1         1
           65.8
   2         1
           60.3
   3         1
           55.1
   4         1
           65.4
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
     TRAFFIC NOISE PREDICTION (INPUT UNITS: ENGLISH ,OUTPUT UNITS: METRIC  )

SAMPLE PROBLEM 2
ROADWAY     1      RT.95 NORTHBOUND WITH HEAVY TRUCKS
NUMBER OF                VEH/H         KMPH
TYPE 1 VEH
   1                     1.3500D+03    8.0467D+01
NUMBER OF                VEH/H         KMPH
TYPE 2 VEH
   1                     7.5000D+01    8.0467D+01
                        SOURCE COORD IN M
NUMBER      X              Y             Z            GRADE    COMMENTS
   1      0.0            1.8288D+00    0.0              0      SEGMENT NORTH OF RT.195 INTERSECTION
   2      3.0480D+03     1.8288D+00    0.0              0
ROADWAY     2      RT.95 NORTHBOUND WITH HEAVY TRUCKS
NUMBER OF                VEH/H         KMPH
TYPE 1 VEH
   1                     1.2500D+03    8.0467D+01
NUMBER OF                VEH/H         KMPH
TYPE 2 VEH
   1                     5.0000D+01    8.0467D+01
                        SOURCE COORD IN M
NUMBER      X              Y             Z            GRADE    COMMENTS
   1     -3.0480D+03     1.8288D+00    0.0              0      SEGMENT SOUTH OF RT.195 INTERSECTION
   2      0.0            1.8288D+00    0.0              0
ROADWAY     3      RT.195 NORTHWESTBOUND WITH HEAVY TRUCKS
NUMBER OF                VEH/H         KMPH
TYPE 1 VEH
   1                     1.0000D+02    7.2420D+01
NUMBER OF                VEH/H         KMPH
TYPE 2 VEH
   1                     2.5000D+01    7.2420D+01
                        SOURCE COORD IN M
NUMBER      X              Y             Z            GRADE    COMMENTS
   1     -3.0480D+03     1.5240D+03    0.0              0      SEGMENT INTERSECTING RT.95 NORTHBOUND
   2      0.0            1.8288D+00    0.0              0
ROADWAY     4      RT.95 SOUTHBOUND WITH HEAVY TRUCKS
NUMBER OF                VEH/H         KMPH
TYPE 1 VEH
   1                     5.0000D+02    9.6560D+01
NUMBER OF                VEH/H         KMPH
TYPE 2 VEH
   1                     5.0000D+01    9.6560D+01
                        SOURCE COORD IN M
NUMBER      X              Y             Z            GRADE    COMMENTS
   1     -3.0480D+03    -1.8288D+00    0.0              0      SEGMENT RUNNING NORTH-SOUTH
   2      3.0480D+03    -1.8288D+00    0.0              0
BARRIER     1  (A)      BARRIER COORD IN M
NUMBER      X              Y             Z
   1      3.0480D+01     6.0960D+00    1.8288D+00      ABSORPTIVE BERM E OF ROADWAY #1
   2      3.0480D+03     6.0960D+00    1.8288D+00
RECEIVER                RECEIVER COORD IN M
NUMBER      X              Y             Z            LC         COMMENTS
   1      0.0            3.0480D+01    1.5240D+00    50.0        N.E. OF TREES
   2      1.5240D+01     3.0480D+01    1.5240D+00    50.0        E OF ROADWAY #1 & N OF RECEIVER #1
   3      3.0480D+01     3.0480D+01    1.5240D+00    50.0        E OF ABSORPTIVE BERM & N OF RECEIVER #2
   4      4.5720D+01     3.0480D+01    1.5240D+00    50.0        E OF ABSORPTIVE BERM & N OF RECEIVER #3
   5      6.0960D+01     3.0480D+01    1.5240D+00    50.0        E OF ABSORPTIVE BERM & N OF RECEIVER #4


            A L P H A   T A B L E

 NRC/NR     1     2     3     4

   1       0.0   0.0   0.0   0.0
   2       0.0   0.0   0.0   0.0
   3       0.0   0.0   0.0   0.0
   4       0.0   0.0   0.0   0.0
   5       0.0   0.0   0.0   0.0
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
SAMPLE PROBLEM 2
RECEIVER            XRC         YRC         ZRC
     1              0.0         30.5        1.5     N.E. OF TREES

                        OCTAVE BAND LEVELS (A)
              63     125    250    500   1000   2000   4000   8000
            48.0    55.7   62.4   65.6   68.2   66.0   59.0   50.2

          LE(A)  LEOB(A)  L90     L50     L10    SIGMA
           72.5    72.4   62.4    69.2    76.1     5.3


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1         1
          66.2
   2         1
          66.7
   3         1
          62.6
   4         1
          68.5


RECEIVER            XRC         YRC         ZRC
     2             15.2         30.5        1.5     E OF ROADWAY #1 & N OF RECEIVER #1

                        OCTAVE BAND LEVELS (A)
              63     125    250    500   1000   2000   4000   8000
            47.4    55.2   61.9   65.1   67.7   65.6   58.6   49.7

          LE(A)  LEOB(A)  L90     L50     L10    SIGMA
           72.0    71.9   61.7    68.6    75.6     5.4


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1         1
          67.1
   2         1
          65.0
   3         1
          60.3
   4         1
          68.1


RECEIVER            XRC         YRC         ZRC
     3             30.5         30.5        1.5     E OF ABSORPTIVE BERM & N OF RECEIVER #2

                        OCTAVE BAND LEVELS (A)
              63     125    250    500   1000   2000   4000   8000
            46.6    54.4   61.1   64.4   67.1   65.0   58.1   49.0

          LE(A)  LEOB(A)  L90     L50     L10    SIGMA
           71.2    71.3   60.9    67.9    74.8     5.4


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1         1
          67.0
   2         1
          63.4
   3         1
          58.5
   4         1
          67.3
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
RECEIVER             XRC          YRC          ZRC
    4                45.7         30.5         1.5     E OF ABSORPTIVE BERM & N OF RECEIVER #3

                           OCTAVE BAND LEVELS (A)
             63     125     250     500    1000    2000    4000    8000
            45.6    53.4    60.2    63.5    66.5    64.2    57.6    48.0

          LE(A)  LEDB(A)   L90      L50      L10     SIGMA
           70.3    70.5    60.5     67.2     73.8     5.2


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1         1
           66.3
   2         1
           62.1
   3         1
           57.0
   4         1
           66.4



RECEIVER             XRC          YRC          ZRC
    5                61.0         30.5         1.5     E OF ABSORPTIVE BERM & N OF RECEIVER #4

                           OCTAVE BAND LEVELS (A)
             63     125     250     500    1000    2000    4000    8000
            44.9    52.7    59.6    62.8    65.9    63.6    57.2    47.3

          LE(A)  LEDB(A)   L90      L50      L10     SIGMA
           69.6    69.9    60.0     66.6     73.1     5.1


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   50.0  DB
ROADWAY  SEGMENT

   1         1
           65.8
   2         1
           61.0
   3         1
           55.8
   4         1
           65.7
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
     TRAFFIC NOISE PREDICTION (INPUT UNITS: ENGLISH ,OUTPUT UNITS: METRIC  )


SAMPLE PROBLEM 3
ROADWAY    1      RT.95N WITH TYPE 4 VEHICLES
NUMBER OF               VEH/H         KMPH
TYPE 1 VEH
   1                    1.3500D+03   8.0467D+01
NUMBER OF               VEH/H         KMPH
TYPE 4 VEH
   1                    7.5000D+01   8.0467D+01
                       SOURCE COORD IN M
NUMBER      X             Y             Z            GRADE   COMMENTS
   1      0.0           1.8288D+00   0.0              0      SEGMENT N OF RT.195 INTERSECTION
   2      3.0480D+03    1.8288D+00   0.0              0
ROADWAY    2      RT.95N WITH TYPE 4 VEHICLES
NUMBER OF               VEH/H         KMPH
TYPE 1 VEH
   1                    1.2500D+03   8.0467D+01
NUMBER OF               VEH/H         KMPH
TYPE 4 VEH
   1                    5.0000D+01   8.0467D+01
                       SOURCE COORD IN M
NUMBER      X             Y             Z            GRADE   COMMENTS
   1    -3.0480D+03     1.8288D+00   0.0              0      SEGMENT S OF RT.195 INTERSECTION
   2      0.0           1.8288D+00   0.0              0
ROADWAY    3      RT.195 N.W. WITH TYPE 4 VEHICLES
NUMBER OF               VEH/H         KMPH
TYPE 1 VEH
   1                    1.0000D+02   7.2420D+01
NUMBER OF               VEH/H         KMPH
TYPE 4 VEH
   1                    2.5000D+01   7.2420D+01
                       SOURCE COORD IN M
NUMBER      X             Y             Z            GRADE   COMMENTS
   1    -3.0480D+03     1.5240D+03   0.0              0      SEGMENT INTERSECTING RT.95N
   2      0.0           1.8288D+00   0.0              0
ROADWAY    4      RT.95S WITH TYPE 4 VEHICLES
NUMBER OF               VEH/H         KMPH
TYPE 1 VEH
   1                    5.0000D+02   9.6560D+01
NUMBER OF               VEH/H         KMPH
TYPE 4 VEH
   1                    5.0000D+01   9.6560D+01
                       SOURCE COORD IN M
NUMBER      X             Y             Z            GRADE   COMMENTS
   1    -3.0480D+03    -1.8288D+00   0.0              0      SEGMENT RUNNING NORTH-SOUTH
   2      3.0480D+03   -1.8288D+00   0.0              0
BARRIER    1  (A)      BARRIER COORD IN M
NUMBER      X             Y             Z
   1      3.0480D+01    6.0960D+00   1.8288D+00       ABSORPTIVE BERM E OF ROADWAY #1
   2      3.0480D+03    6.0960D+00   1.8288D+00
RECEIVER                RECEIVER COORD IN M
NUMBER      X             Y             Z             LC       COMMENTS
   1      0.0           3.0480D+01   1.5240D+00     50.0       N.E. OF TREES
   2      1.5240D+01    3.0480D+01   1.5240D+00     50.0       E OF ROADWAY #1 & N OF RECEIVER #1
   3      3.0480D+01    3.0480D+01   1.5240D+00     50.0       E OF ABSORPTIVE BERM & N OF RECEIVER #2
   4      4.5720D+01    3.0480D+01   1.5240D+00     50.0       E OF ABSORPTIVE BERM & N OF RECEIVER #3
   5      6.0960D+01    3.0480D+01   1.5240D+00     50.0       E OF ABSORPTIVE BERM & N OF RECEIVER #4



             ALPHA  TABLE

   NRC/NR       1      2      3      4

     1        0.0    0.0    0.0    0.0
     2        0.0    0.0    0.0    0.0
     3        0.0    0.0    0.0    0.0
     4        0.0    0.0    0.0    0.0
     5        0.0    0.0    0.0    0.0
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
SAMPLE PROBLEM 3
RECEIVER              XRC           YRC           ZRC
    1                 0.0           30.5          1.5       N.E. OF TREES

                           OCTAVE BAND LEVELS (A)
             63       125      250      500     1000     2000     4000     8000
           43.6      52.5     57.3     61.9     64.2     63.6     55.8     47.6

          LE(A)  LEOB(A)   L90      L50      L10     SIGMA
           68.9    68.9    62.6     67.3     72.0      3.7


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1         1
           62.8
   2         1
           64.1
   3         1
           57.9
   4         1
           64.2


RECEIVER              XRC           YRC           ZRC
    2                 15.2          30.5          1.5       E OF ROADWAY #1 & N OF RECEIVER #1

                           OCTAVE BAND LEVELS (A)
             63       125      250      500     1000     2000     4000     8000
           43.1      51.9     56.8     61.3     63.6     63.0     55.1     46.9

          LE(A)  LEOB(A)   L90      L50      L10     SIGMA
           68.3    68.2    61.8     66.6     71.5      3.8


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1         1
           63.5
   2         1
           62.5
   3         1
           55.6
   4         1
           63.7


RECEIVER              XRC           YRC           ZRC
    3                 30.5          30.5          1.5       E OF ABSORPTIVE BERM & N OF RECEIVER #2

                           OCTAVE BAND LEVELS (A)
             63       125      250      500     1000     2000     4000     8000
           42.2      51.0     55.8     60.2     62.4     61.7     53.8     45.4

          LE(A)  LEOB(A)   L90      L50      L10     SIGMA
           67.1    67.0    60.7     65.5     70.3      3.8


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1         1
           62.8
   2         1
           60.9
   3         1
           53.7
   4         1
           62.6
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Continued)

```
RECEIVER            XRC          YRC           ZRC
    4               45.7         30.5          1.5      E OF ABSORPTIVE BERM & N OF RECEIVER #3

                          OCTAVE BAND LEVELS (A)
            63      125     250     500    1000    2000    4000    8000
           41.1    49.8    54.5    58.8    60.7    59.8    51.7    43.1

          LE(A)  LEDB(A)   L90      L50      L10     SIGMA
           65.7    65.4    59.9     64.3     68.7      3.4


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1        1
           61.1
   2        1
           59.5
   3        1
           52.2
   4        1
           61.2



RECEIVER            XRC          YRC           ZRC
    5               61.0         30.5          1.5      E OF ABSORPTIVE BERM & N OF RECEIVER #4

                          OCTAVE BAND LEVELS (A)
            63      125     250     500    1000    2000    4000    8000
           40.3    49.0    53.6    57.7    59.3    58.1    49.8    40.6

          LE(A)  LEDB(A)   L90      L50      L10     SIGMA
           64.5    64.0    59.5     63.4     67.3      3.1


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF    50.0  DB
ROADWAY  SEGMENT

   1        1
           59.7
   2        1
           58.4
   3        1
           51.1
   4        1
           60.1
```

Figure 4-3. OUTPUT LISTING FOR EXAMPLE PROBLEM 1 (Concluded)

Since the Level 2 model does not explicitly define a ground plane and/or a horizontal surface, it is necessary to specify excess distance attenuation as "alpha" for each roadway relative to each receiver. A value for "alpha" for any roadway-receiver must be greater than -1.0.

The relation between "alpha", α, and a distance attenuation rate in terms of "dB per distance doubling", η, is (3)

$$\alpha = -(1-\eta/10\log(2)) = -(1-\eta/3)$$

or

$$\eta = 3(\alpha+1), \text{ dB per Distance Doubling (dB/DD)}$$

Hence, the following relations should be remembered:

- $\alpha = -1.0$; $\eta = 0$ dB/DD (Zero Distance Attenuation)
- $\alpha = -0.5$; $\eta = 1.5$ dB/DD
- $\alpha = 0.0$; $\eta = 3.0$ dB/DD (Classical Line Source)
- $\alpha = 0.5$; $\eta = 4.5$ dB/DD
- $\alpha = 1.0$; $\eta = 6.0$ dB/DD (Classical Point Source)

Since the Level 2 program utilizes numerical integrations over the roadway relative to each receiver, any value greater than -1 may be specified for "alpha".

The "Alpha Input" data block is not mandatory. If the data block is not specified the program considers all values of alpha to be zero.

If the user desires to specify non-zero values for "alpha" he must elect one of the input options as follows:

- Option 1, Default: Do not define "alpha" for a roadway-receiver combination. This results in alpha being specified zero for all such roadway-receiver pairs.
- Option 2, Receiver Specification: A single value of alpha may be specified that applies to <u>all</u> roadways relative to a defined set of receivers.

- Option 3, Roadway Specification: A single value of alpha may be specified that applies to a single roadway relative to a defined set of receivers.

The specific data format for "Alpha Input" is presented in Section 3.7. A value of "alpha" specified for a roadway applies to all segments of that roadway relative to the receiver.

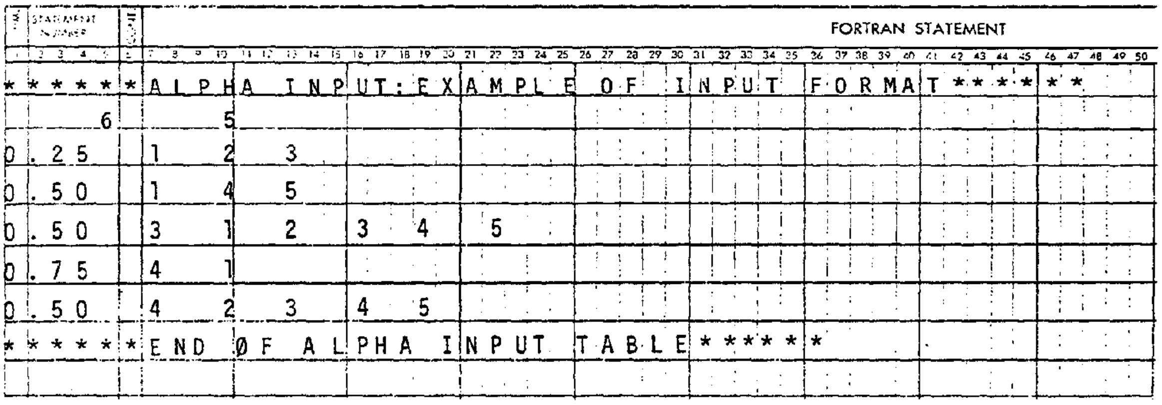
As an example of formulating "Alpha Input" suppose that the problem comprises six roadways and five receivers. Hence, 30 values of "alpha" are required. From the review of receiver locations relative to each roadway the following values of "alpha" are judged appropriate:

	Roadway Number					
Receiver Number	1	2	3	4	5	6
1	0.0	0.0	0.5	0.75	0.0	0.0
2	0.25	0.0	0.5	0.50	0.0	0.0
3	0.25	0.0	0.5	0.50	0.0	0.0
4	0.50	0.0	0.5	0.50	0.0	0.0
5	0.50	0.0	0.5	0.50	0.0	0.0

From this tabulation, it is seen that four values of alpha are required to specify the problem. It is seen that no single value of alpha applies to all roadways for any receiver. Option 2 above is not useful. Since "alpha" for roadways 2, 5, and 6 for all receivers and for roadway 1-receiver 1 is zero, the user may elect either the default option or the roadway specification option. The latter option is, of course, the most positive approach.

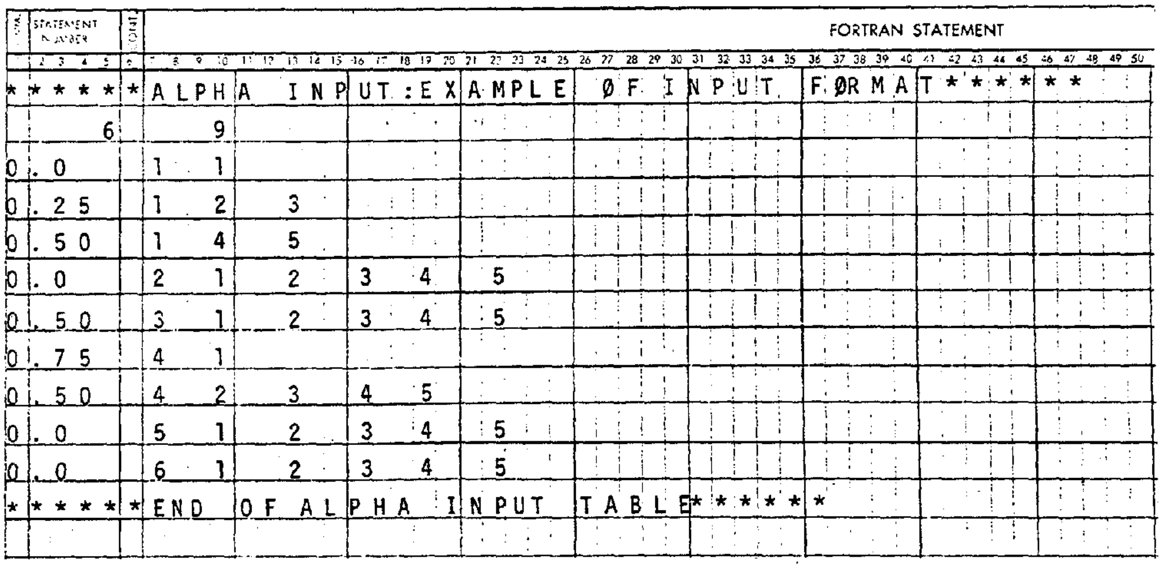
Figure 4-4 presents the "Alpha Input" data block using a combination of default options and roadway specifications. Figure 4-5 presents the "Alpha Input" data block using only roadway specifications.

As this example indicates, it is most efficient to determine the "Alpha Table" first and then formulate the input data.



```
******ALPHA INPUT:EXAMPLE OF INPUT FORMAT*******
    6    5
0.25  1  2  3
0.50  1  4  5
0.50  3  1  2  3  4  5
0.75  4  1
0.50  4  2  3  4  5
******END OF ALPHA INPUT TABLE******
```

Figure 4-4. ALPHA INPUT EXAMPLE USING COMBINATION OF DEFAULT OPTION AND ROADWAY SPECIFICATION



```
******ALPHA INPUT:EXAMPLE OF INPUT FORMAT*******
    6    9
0.0   1  1
0.25  1  2  3
0.50  1  4  5
0.0   2  1  2  3  4  5
0.50  3  1  2  3  4  5
0.75  4  1
0.50  4  2  3  4  5
0.0   5  1  2  3  4  5
0.0   6  1  2  3  4  5
******END OF ALPHA INPUT TABLE******
```

Figure 4-5. ALPHA INPUT EXAMPLE USING ROADWAY SPECIFICATION

4.6 Example Problem 2

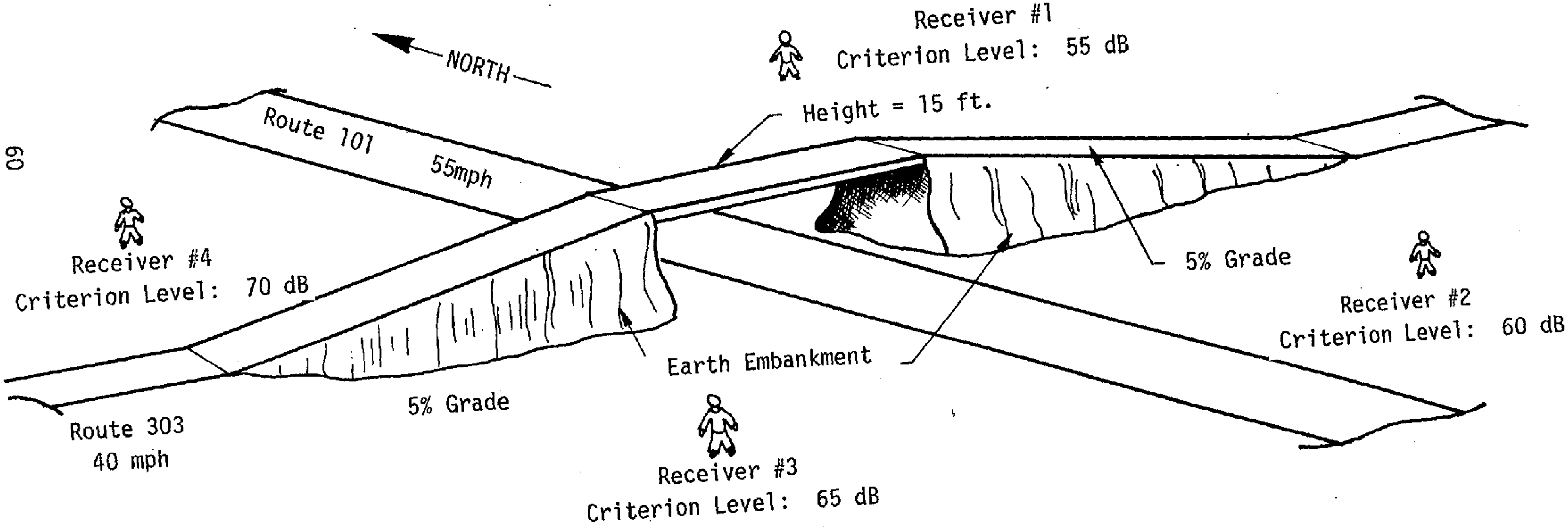
This example problem illustrates the use of the grade correction option included in the FHWA Level 2 computer program and the variation of receiver criterion levels. The problem is an overpass at the intersection of two roadways. The site configuration is illustrated in Figure 4-6. Route 101 runs north-south and comprises two lanes of undivided roadway. Route 101 is level. Route 303 runs east-west and comprises two lanes. The overpass on Route 303 is 15 feet (4.6 metres) high with a 5% grade at each approach. The approaches to the overpass are earthen embankments. Otherwise the site is flat. The travel speed on Route 101 is 55 mph and on Route 303 is 40 mph. Each lane carries an identical traffic flow.

To use the grade correction, one must divide the roadways into lane groups with the same travel direction. For this example, a single equvalent lane may be used to simulate the traffic flow on Route 101, but both lanes must be described for Route 303 since upgrade lane segments are required at each approach to the overpass.

The receivers are located symmetrically about the intersection. With no grade correction, each receiver would receive identical sound levels. However, introducing the grade correction alters the noise emissions such that Receivers No. 1 and No. 3 would be expected to receive identical sound levels and Receivers No. 2 and No. 4 would be expected to receive identical sound levels. The earthen embankments are simulated using four barriers with the top edges paralleling the grade on Route 303.

To indicate the interrelationship between the specified criterion level and the tabulation of sound level contributions at such receiver. It is decided to simulate each lane as a roadway and to divide the lane segments such that shielded segments of Route 101 are distinctly specified. Ground level is taken as the reference (Z=0) elevation.

Figure 4-7 illustrates the roadway coordinates for each defined segment. Roadway No. 1 is the north bound lane of Route 101. Roadway No. 2 is the south-bound lane of Route 101. Each of these roadways are divided into two segments with the common point at the intersection of the east-west centerline of Route 303.



Each Lane Carries the Following Traffic:

Automobiles	251 vehicles per hour
Medium Trucks	9 vehicles per hour
Heavy Trucks	26 vehicles per hour

Figure 4-6. SITE CONFIGURATION: EXAMPLE PROBLEM 2

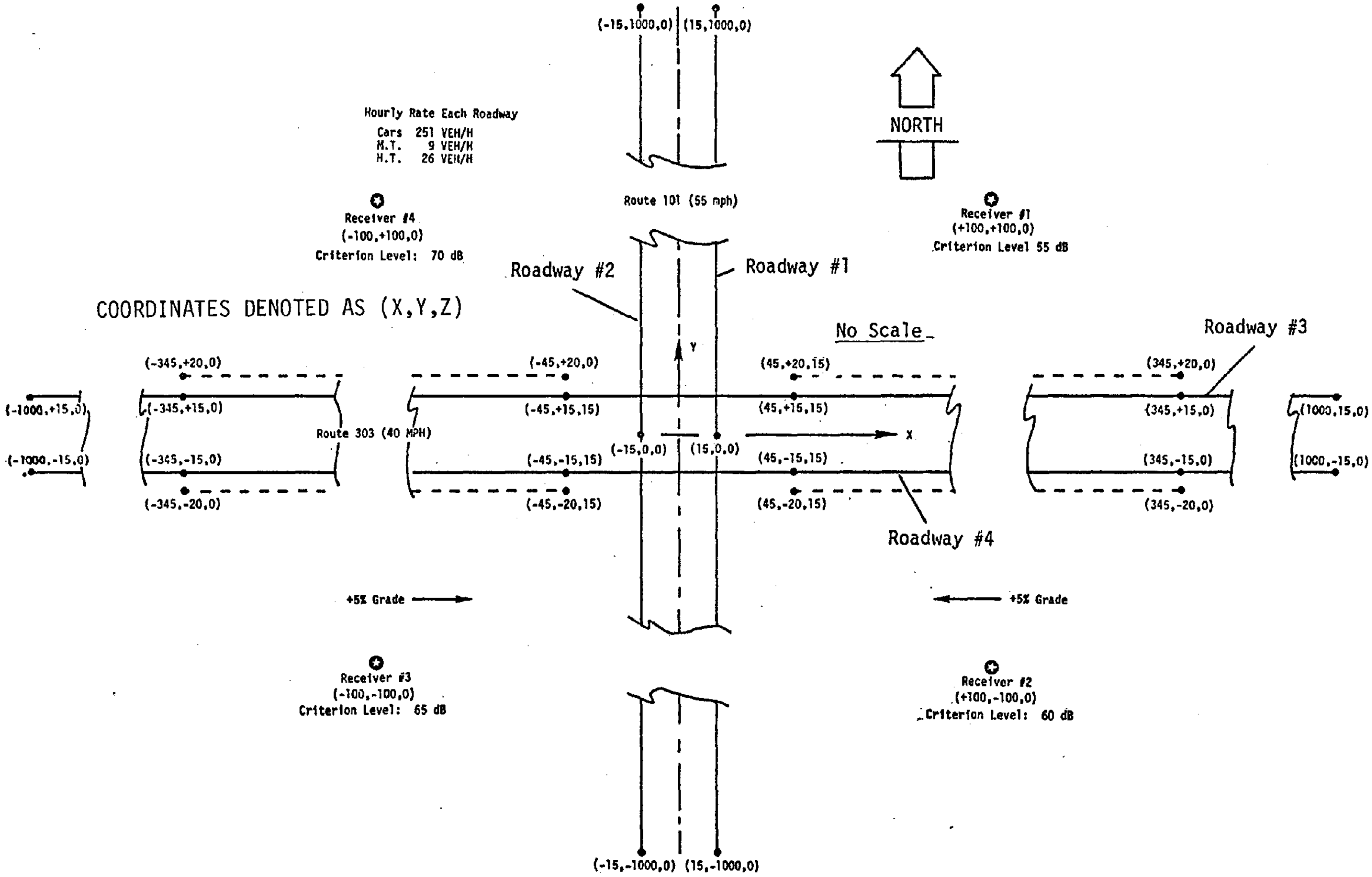


Figure 4-7. ROADWAY,BARRIER, AND RECEIVER COORDINATES

Route 303 is divided into two roadways each comprising five segments. Roadway No. 3 is the west bound segment of Route 303. Roadway No. 4 is the east bound segment of Route 303. The reader should realize that the five segments are required to simulate the roadway so that the upgrade segments may be distinguished.

For this example problem, it is assumed that each roadway-receiver configuration may be simulated using alpha = 0.5. If the user desired to set $\alpha=0$ for the elevated segments of Route 303, it would be necessary to define these segments as roadways (See Sections 3.7 and 4.5).

The annotated input data for the sample problem is illustrated in Figure 4-8. From the input data, the reader sees that input is in English units and output is in Metric units.

The traffic noise predictions conducted by the FHWA Level 2 program are presented in Figure 4-9. The program prints the annotated input data as described in Section 4.4. Next, the receiver sound levels are printed.

For receiver 1, the hourly equivalent sound level is estimated to be 64.7 dBA. The criterion level for Receiver 1 was specified as 55 dB. As discussed in Section 4.4, all roadway segments contributing more than 50 dB at the receiver will be printed. It is noted in the predicted results for Receiver No. 1, the upgrade segment on Route 303 contributes a slightly greater sound level at the receiver than the entire northbound lane of Route 101 even though the traffic speed on Route 101 is 15 mph greater than that on Route 303.

The reader may verify that the predicted sound levels for Receivers 1 and 3 and for Receivers 2 and 4 are identical. In the case of Receiver 4, the criterion level was specified as 70 dB. Since no roadway segments contributed more than 65 dB at Receiver 4 (see the output for Receiver 2 and recognize the symmetry of the example problem) a message is printed that no roadway segments exceeded criterion level of 70 dB. The reader should recognize that the internal limit is 65 dB and the message is printed to clearly state that the criterion limit was not exceeded.

COMM. STATEMENT NUMBER CONT. FORTRAN STATEMENT IDENTIFICATION SEQUENCE

```
*      METIN=N      METOUT=Y  REFLECTION=N
 EXAMPLE ILLUSTRATING GRADE ADJUSTMENTS AND TITLE OPTIONS
    1
    5.0       1               HEIGHT ADJUSTMENT FOR RECEIVERS
    9.0       2               CALCULATE 9 OCTAVE BANDS
    0.0       3               SOURCE HEIGHT FOR AUTOMOBILES
    8.0       4               SOURCE HEIGHT FOR HEAVY TRUCKS
    2.3       5    L          SOURCE HEIGHT FOR MEDIUM TRUCKS
    2    4
  251.       55.        1
   26.       55.        2
    9.       55.        3     L         ROUTE 101 NORTHBOUND
   15.     1000.        0.      0       SEGMENT NORTH OF ROUTE 303
   15.        0.        0.      0       SEGMENT SOUTH OF ROUTE 303
   15.    -1000.        0.    L
  251.       55.        1
   26.       55.        2
    9.       55.        3     L         ROUTE 101 SOUTHBOUND
  -15.     1000.        0.      0       SEGMENT NORTH OF ROUTE 303
  -15.        0.        0.      0       SEGMENT SOUTH OF ROUTE 303
  -15.    -1000.        0.    L
  251.       40.        1
   26.       40.        2
    9.       40.        3     L         ROUTE 303 WESTBOUND
```

Figure 4-8. INPUT DATA FOR EXAMPLE PROBLEM 2

```
 1000.       15.        0.      0       LEVEL SEGMENT EAST ØF RØUTE 101
  345.       15.        0.      1       SEGMENT WITH 5 PERCENT UPGRADE
   45.       15.       15.      0       LEVEL SEGMENT ØVER RØUTE 101
  -45.       15.       15.      0       SEGMENT WITH 5 PERCENT DOWNGRADE
 -345.       15.        0.      0       LEVEL SEGMENT WEST ØF RØUTE 101
-1000.       15.        0.    L
  251.       40.        1
   26.       40.        2
    9.       40.        3     L         RØUTE 303 EASTBØUND
-1000.      -15.        0.      0       LEVEL SEGMENT WEST ØF RØUTE 101
 -345.      -15.        0.      1       SEGMENT WITH 5 PERCENT UPGRADE
  -45.      -15.       15.      0       LEVEL SEGMENT ØVER RØUTE 101
   45.      -15.       15.      0       SEGMENT WITH 5 PERCENT DOWNGRADE
  345.      -15.        0.      0       LEVEL SEGMENT EAST ØF RØUTE 101
 1000.      -15.        0.    L
    3    4
  345.       20.        0.
   45.       20.       15.    A         RAMP ØN N.E. SIDE ØF RØUTE 303
  -45.       20.       15.
 -345.       20.        0.    A         RAMP ØN N.W. SIDE ØF RØUTE 303
  345.      -20.        0.
   45.      -20.       15.    A         RAMP ØN S.E. SIDE ØF RØUTE 303
  -45.      -20.       15.
 -345.      -20.        0.    A         RAMP ØN S.W. SIDE ØF RØUTE 303
```

Figure 4-8. INPUT DATA FOR EXAMPLE PROBLEM 2 (Continued)

```
    5    4
  100.      100.        0.      55.     RECEIVER NØ.1 N.E. ØF ØVERPASS
  100.     -100.        0.      60.     RECEIVER NØ.2 S.E. ØF ØVERPASS
 -100.     -100.        0.      65.     RECEIVER NØ.3 S.W. ØF ØVERPASS
 -100.      100.        0.      70.     RECEIVER NØ.4 N.W. ØF ØVERPASS
    6    1
0.5   0  1  2  3  4
    7
```

Figure 4-8. INPUT DATA FOR EXAMPLE PROBLEM 2 (Concluded)

```
     TRAFFIC NOISE PREDICTION (INPUT UNITS: ENGLISH ,OUTPUT UNITS: METRIC  )

EXAMPLE ILLUSTRATING GRADE ADJUSTMENTS AND TITLE OPTIONS

PROGRAM INITIALIZATION PARAMETERS
 1.52400D+00          1      HEIGHT ADUSTMENT FOR RECEIVERS
 9.00000D+00          2      CALCULATE 9 OCTAVE BANDS
 0.0                  3      SOURCE HEIGHT FOR AUTOMOBILES
 2.43840D+00          4      SOURCE HEIGHT FOR HEAVY TRUCKS
 7.01040D-01          5      SOURCE HEIGHT FOR MEDIUM TRUCKS
ROADWAY    1      ROUTE 101 NORTHBOUND
NUMBER OF              VEH/H        KMPH
TYPE 1 VEH
   1                   2.5100D+02   8.8514D+01
NUMBER OF              VEH/H        KMPH
TYPE 2 VEH
   1                   2.6000D+01   8.8514D+01
NUMBER OF              VEH/H        KMPH
TYPE 3 VEH
   1                   9.0000D+00   8.8514D+01
                      SOURCE COORD IN M
NUMBER      X            Y             Z          GRADE   COMMENTS
   1     4.5720D+00   3.0480D+02   0.0              0     SEGMENT NORTH OF ROUTE 303
   2     4.5720D+00   0.0          0.0              0     SEGMENT SOUTH OF ROUTE 303
   3     4.5720D+00  -3.0480D+02   0.0              0
ROADWAY    2      ROUTE 101 SOUTHBOUND
NUMBER OF              VEH/H        KMPH
TYPE 1 VEH
   1                   2.5100D+02   8.8514D+01
NUMBER OF              VEH/H        KMPH
TYPE 2 VEH
   1                   2.6000D+01   8.8514D+01
NUMBER OF              VEH/H        KMPH
TYPE 3 VEH
   1                   9.0000D+00   8.8514D+01
                      SOURCE COORD IN M
NUMBER      X            Y             Z          GRADE   COMMENTS
   1    -4.5720D+00   3.0480D+02   0.0              0     SEGMENT NORTH OF ROUTE 303
   2    -4.5720D+00   0.0          0.0              0     SEGMENT SOUTH OF ROUTE 303
   3    -4.5720D+00  -3.0480D+02   0.0              0
ROADWAY    3      ROUTE 303 WESTBOUND
NUMBER OF              VEH/H        KMPH
TYPE 1 VEH
   1                   2.5100D+02   6.4374D+01
NUMBER OF              VEH/H        KMPH
TYPE 2 VEH
   1                   2.6000D+01   6.4374D+01
NUMBER OF              VEH/H        KMPH
TYPE 3 VEH
   1                   9.0000D+00   6.4374D+01
                      SOURCE COORD IN M
NUMBER      X            Y             Z          GRADE   COMMENTS
   1     3.0480D+02   4.5720D+00   0.0              0     LEVEL SEGMENT EAST OF ROUTE 101
   2     1.0516D+02   4.5720D+00   0.0              1     SEGMENT WITH 5 PERCENT UPGRADE
   3     1.3716D+01   4.5720D+00   4.5720D+00       0     LEVEL SEGMENT OVER ROUTE 101
   4    -1.3716D+01   4.5720D+00   4.5720D+00       0     SEGMENT WITH 5 PERCENT DOWNGRADE
   5    -1.0516D+02   4.5720D+00   0.0              0     LEVEL SEGMENT WEST OF ROUTE 101
   6    -3.0480D+02   4.5720D+00   0.0              0
ROADWAY    4      ROUTE 303 EASTBOUND
NUMBER OF              VEH/H        KMPH
```

Figure 4-9. OUTPUT LISTING FOR EXAMPLE PROBLEM 2

```
TYPE 1 VEH
   1                    2.5100D+02   6.4374D+01
NUMBER OF               VEH/H        KMPH
TYPE 2 VEH
   1                    2.6000D+01   6.4374D+01
NUMBER OF               VEH/H        KMPH
TYPE 3 VEH
   1                    9.0000D+00   6.4374D+01
                       SOURCE COORD IN M
NUMBER      X            Y            Z           GRADE    COMMENTS
   1   -3.0480D+02  -4.5720D+00   0.0            0      LEVEL SEGMENT WEST OF ROUTE 101
   2   -1.0516D+02  -4.5720D+00   0.0            1      SEGMENT WITH 5 PERCENT UPGRADE
   3   -1.3716D+01  -4.5720D+00   4.5720D+00     0      LEVEL SEGMENT OVER ROUTE 101
   4    1.3716D+01  -4.5720D+00   4.5720D+00     0      SEGMENT WITH 5 PERCENT DOWNGRADE
   5    1.0516D+02  -4.5720D+00   0.0            0      LEVEL SEGMENT EAST OF ROUTE 101
   6    3.0480D+02  -4.5720D+00   0.0            0
BARRIER     1  (A)     BARRIER COORD IN M
NUMBER      X            Y            Z
   1    1.0516D+02   6.0960D+00   0.0               RAMP ON N.E. SIDE OF ROUTE 303
   2    1.3716D+01   6.0960D+00   4.5720D+00
BARRIER     2  (A)     BARRIER COORD IN M
NUMBER      X            Y            Z
   1   -1.3716D+01   6.0960D+00   4.5720D+00        RAMP ON N.W. SIDE OF ROUTE 303.
   2   -1.0516D+02   6.0960D+00   0.0
BARRIER     3  (A)     BARRIER COORD IN M
NUMBER      X            Y            Z
   1    1.0516D+02  -6.0960D+00   0.0               RAMP ON S.E. SIDE OF ROUTE 303
   2    1.3716D+01  -6.0960D+00   4.5720D+00
BARRIER     4  (A)     BARRIER COORD IN M
NUMBER      X            Y            Z
   1   -1.3716D+01  -6.0960D+00   4.5720D+00        RAMP ON S.W. SIDE OF ROUTE 303
   2   -1.0516D+02  -6.0960D+00   0.0
RECEIVER                RECEIVER COORD IN M
NUMBER      X            Y            Z            LC        COMMENTS
   1    3.0480D+01   3.0480D+01   1.5240D+00    55.0      RECEIVER NO.1 N.E. OF OVERPASS
   2    3.0480D+01  -3.0480D+01   1.5240D+00    60.0      RECEIVER NO.2 S.E. OF OVERPASS
   3   -3.0480D+01  -3.0480D+01   1.5240D+00    65.0      RECEIVER NO.3 S.W. OF OVERPASS
   4   -3.0480D+01   3.0480D+01   1.5240D+00    70.0      RECEIVER NO.4 N.W. OF OVERPASS


         A L P H A    T A B L E

REC/BR      1      2      3      4
N
 1        0.50   0.50   0.50   0.50
 2        0.50   0.50   0.50   0.50
 3        0.50   0.50   0.50   0.50
 4        0.50   0.50   0.50   0.50



EXAMPLE ILLUSTRATING GRADE ADJUSTMENTS AND TITLE OPTIONS
RECEIVER             XRC          YRC          ZRC
     1               30.5         30.5         1.5      RECEIVER NO.1 N.E. OF OVERPASS

                              OCTAVE BAND LEVELS (A)
              63     125     250     500    1000    2000    4000    8000
             46.8    53.6    60.1    62.1    64.2    61.9    55.0    46.0

           LE(A)   LEOB(A)    L90     L50     L10    SIGMA
            69.7    68.7     56.6    64.9    73.1     6.5


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING CRITERION LEVEL OF   55.0  DB
ROADWAY  SEGMENT

   1          1    2
            64.0 52.1
   2          1    2
            61.8 53.3
   3          2    3    4
            64.4 54.4 54.2
   4          2    3    4
            52.7 53.1 59.7
```

Figure 4-9. OUTPUT LISTING FOR EXAMPLE PROBLEM 2 (Continued)

```
RECEIVER              XRC           YRC            ZRC
    2                30.5,         -30.5            1.5      RECEIVER NC.2 S.E. OF OVERPASS

                          OCTAVE BAND LEVELS (A)
            63       125     250      500     1000     2000     4000     8C00
           46.8     53.6    60.1     62.1     64.2     61.8     55.0     46.0

         LE(A)   LEOB(A)    L90       L50      L10      SIGMA
          69.5     68.7     57.2      65.1     73.0      6.2


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTICNS EXCEEDING CRITERION LEVEL OF   60.0  DB
ROADWAY  SEGMENT

   1        2
           64.0
   2        2
           61.8
   3        2
           62.4
   4        2    4
           56.9 61.7


RECEIVER              XRC           YRC            ZRC
    3               -30.5          -30.5            1.5      RECEIVER NC.3 S.W. OF OVERPASS

                          OCTAVE BAND LEVELS (A)
            63       125     250      500     1000     2000     4000     8C00
           46.8     53.6    60.1     62.1     64.2     61.9     55.0     46.0

         LE(A)   LEOB(A)    L90       L50      L10      SIGMA
          69.7     68.7     56.6      64.9     73.1      6.5


ROADWAY SEGMENT SOUND LEVEL CONTRIBUTICNS EXCEEDING CRITERION LEVEL OF   65.0  DB
ROADWAY  SEGMENT

   1        2
           61.8
   2        2
           64.0
   4        2
           64.4


RECEIVER              XRC           YRC            ZRC
    4               -30.5           30.5            1.5      RECEIVER NC.4 N.W. OF OVERPASS

                          OCTAVE BAND LEVELS (A)
            63       125     250      500     1000     2000     4000     8C00
           46.8     53.6    60.1     62.1     64.2     61.9     55.0     46.0

         LE(A)   LEOB(A)    L90       L50      L10      SIGMA
          69.5     68.7     57.2      65.1     73.0      6.2


NO ROADWAY SEGMENTS EXCEED CRITERION LEVEL CF   70.0  DB
```

Figure 4-9. OUTPUT LISTING FOR EXAMPLE PROBLEM 2 (Concluded)

REFERENCES

1. Rudder, F. F., Jr., and Lam P.: "Update of TSC Highway Traffic Noise Prediction Code (1974)", U.S. Department of Transportation, Federal Highway Administration, Office of Research, Report FHWA-RD-77-19, January 1977.

2. Rudder, F. F., Jr., and Lam P.: "User's Manual: TSC Highway Noise Prediction Code: MOD-0-4", U.S. Department of Transportation, Federal Highway Administration, Office of Research, Report FHWA-RD-77-18, January 1977.

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

APPENDIX A

BASIC FORMULATION OF THE COMPUTERIZED PREDICTION MODEL

This appendix presents the basic formulation for the traffic noise prediction scheme utilized by the computer program. The first subsection describes the theory supporting the prediciton of the overall A-weighted energy mean sound level of the traffic flow on a finite roadway segment. Distance attentuation is assumed to be in excess of classical cylindrical spreading from a line source.

The second subsection presents the coded formulation used by the program.

Since the FHWA Level 2 prediction model is an evolutionary development of the TSC MOD-04 program, the notation used in this appendix is consistent with the latter model (1). The use of the excess attenuation parameter γ in this formulation is identical to the excess attenuation parameter α of the FHWA Level 1 prediction model (2).

A.1 Energy Mean Sound Level

The geometric relationship between the roadway segment and the receiver is illustrated in Figure A-1. Considering the traffic flow to be represented by a uniform source strength, λ, distributed along the roadway segment, the acoustic intensity ratio at the receiver is expressed as:

$$I/I_0 = \lambda 10^{\overline{L}_0/10} (D_0/D)^{\gamma+2} \quad 10^{-\varepsilon/10} \int_{\overline{x}_1}^{\overline{x}_2} \frac{dx}{[1+(x/D)^2]^{\gamma+2}} \qquad \text{(A-1)}$$

where $\overline{L}_0$ is the reference sound level at a distance D_0 from the roadway segment

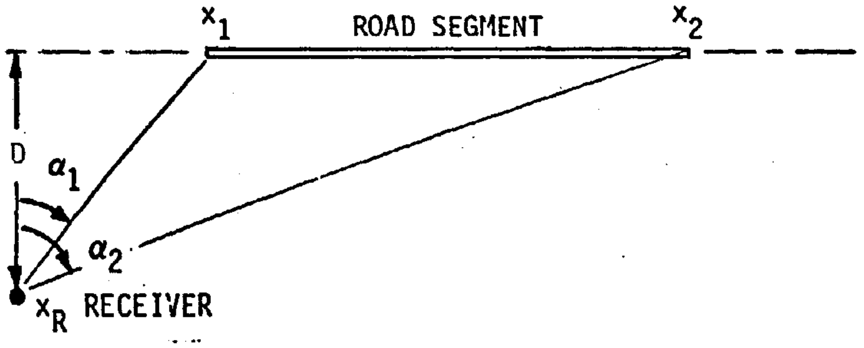
D is the distance from the roadway segment to the receiver

λ is the source concentration (See Equation (A-6))

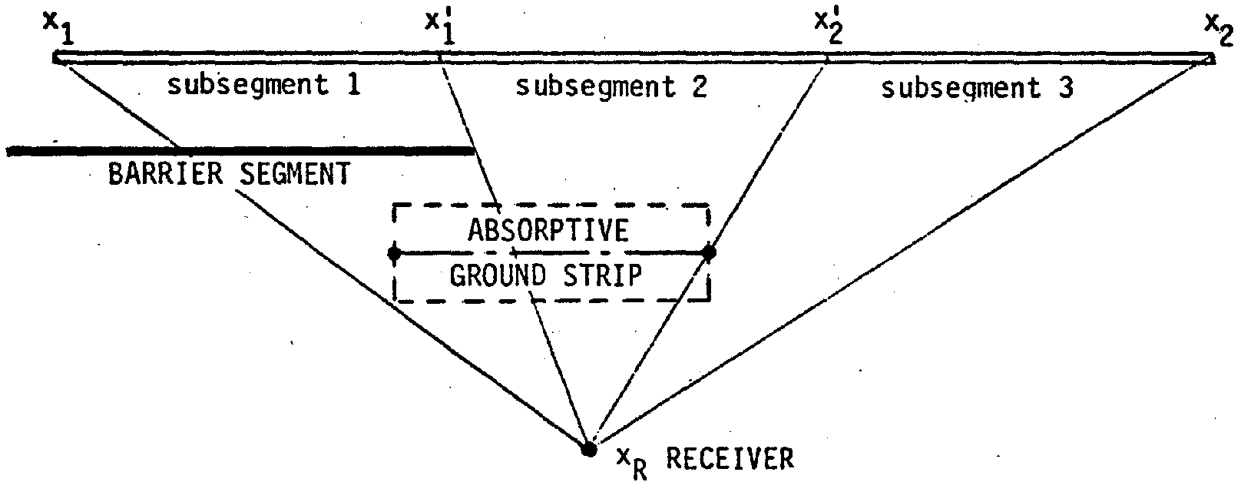
ε is an excess attenuation parameter independent of distance

γ is an excess attenuation parameter proportional to distance from the source

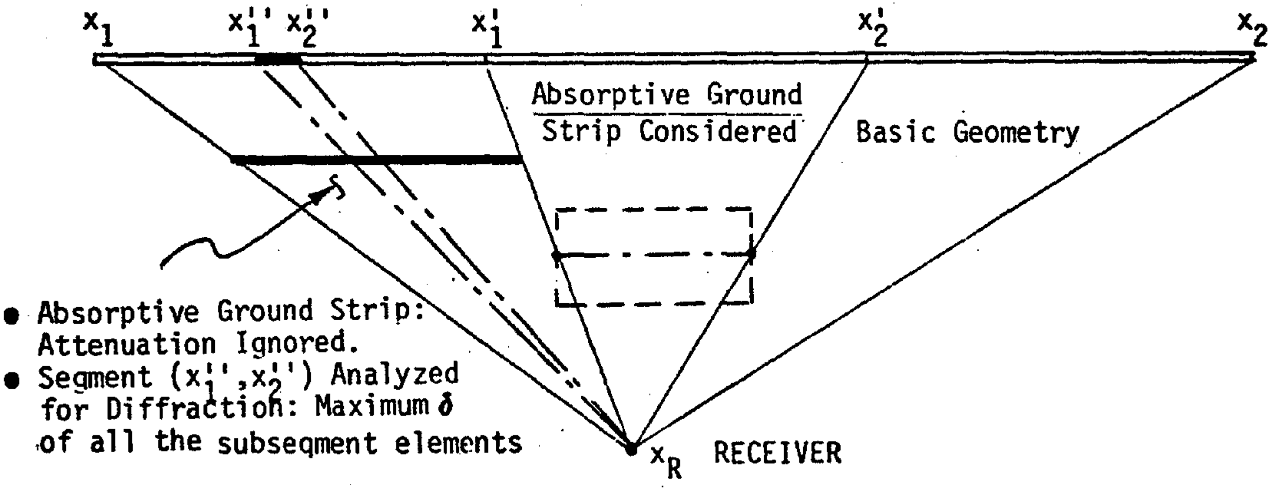
$I_0 = \langle p_{ref}^2 \rangle / \rho c$, the reference intensity.



(a) Basic Roadway/Receiver Geometry



(b) Subdivision of Roadway Segments into Elements



(c) Computer View of Roadway/Receiver Geometry

FIGURE A-1. BASIC SOURCE/RECEIVER GEOMETRY

The relationship indicated in Equation (A-1) assumes that all sources on the roadway segment are identical nondirectional sources. Distance attentuation is assumed to follow an attenuation rate in excess of inverse square spreading as indicated by the parameter γ. The excess attenuation parameter, ε, is included to formulate the problem in a fashion consistent with the excess attenuation coded in the program (i.e., trees, high shrubbery, atmospheric absorption, and barrier diffraction).

The integration indicated in Equation (A-1) may be simplified by changing variables as follows:

$$x = D \tan(\alpha) \qquad \text{(A-2)}$$

The result obtained is:

$$I/I_0 = \lambda D_0 \, 10^{(\overline{L}_0-\varepsilon)/10} \, (D_0/D)^{\gamma+1} \, \Psi_\gamma(\alpha_2, \alpha_1) \qquad \text{(A-3)}$$

where $\Psi_\gamma(\alpha_2, \alpha_1) = \int_{\alpha_1}^{\alpha_2} \cos^\gamma(\alpha) d\alpha$

It will be noted that the function $\Psi_\gamma(\alpha_2, \alpha_1)$ is identical to the "finite length roadway adjustment factor" used in the FHWA Level 1 formulation (2).

From Equation (A-3) the energy mean sound level is

$$L_e = 10 \log (I/I_0) = \overline{L}_0 - \varepsilon + 10 \log (\lambda D_0 (D_0/D) I^*) \qquad \text{(A-4)}$$

where $I^* = (D_0/D)^\gamma \, \Psi_\gamma(\alpha_2, \alpha_1)$

One of the prediction tasks of the FHWA Level 2 program is to estimate the percentile sound levels generated by the traffic flow.

To accomplish this, Kurze's traffic flow noise theory is used (3). Kurze's theory assumes a uniform distribution of identical point sources along the finite roadway segment.

To estimate the percentile sound levels, it is required to calculate statistical moments (called cumulants) for constant speed road traffic. By normalizing the acoustic intensity at the receiver by its energy mean value (given by Equation (A-4)) and performing some algebra (See Reference 3) one obtains the following expression for the nth order cumulant:

$$\kappa_n = \frac{(N/(\bar{x}_1-\bar{x}_2))\Phi_\gamma^n(\alpha_1,\alpha_2)}{\lambda^n D^{n-1}[\Psi_\gamma(\alpha_1,\alpha_2)]^n} \qquad \text{(A-5)}$$

where

N is the number of vehicles occupying the roadway segment

$\Phi_\gamma^n(\alpha_2, \alpha_1) = \int_{\alpha_1}^{\alpha_2} [\cos(\alpha)]^{n(\gamma+2)-2} d\alpha$

λ, D, γ are defined in Equation (A-1)

$\Psi_\gamma(\alpha_2, \alpha_1)$ is defined in Equation (A-3)

$\bar{x}_1$, $\bar{x}_2$, α_1, α_2 are defined in Figure A-1

By normalizing the acoustic intensity at the receiver by its energy mean sound level, the first order cumulant must be indentically equal to unity. From this requirement and the assumption of a uniform distribution of noise sources along the roadway segment, the source concentration, λ, is defined as

$$\lambda \equiv N/(\bar{x}_2-\bar{x}_1) = Q/V, \text{ vehicles per unit length} \qquad \text{(A-6)}$$

where Q is the traffic flow rate

V is the traffic speed

Using a first order approximation, the standard deviation of the fluctuating sound level at the receiver is estimated by (3)

$$\sigma_L = (10/\ln(10))\ \sqrt{\ln(1+\kappa_2)} \qquad \text{(A-7)}$$

where $\kappa_2 = \dfrac{\Phi_\gamma^2(\alpha_2, \alpha_1)}{\lambda D[\Psi_\gamma(\alpha_2, \alpha_1)]^2}$ is the second order cumulant

The realtionship of Equation (A-7) is exact for a Gaussian or normal distribution of sound levels.

By setting the excess distance attenuation factor, γ, to zero the model described by the TSC MOD-04 code is obtained.

The results of this section apply to a single vehicle type operating on a finite roadway segment.

A.2 Coded Formulation

Since the FHWA Level 2 program is an evolutionary development of the TSC-MOD-04 prediction model, it is necessary to formulate the theory of Section A.1 in a consistent format. The only coding changes required for this transformation are related to the numerical integration of the functions Ψ_γ (α_2, α_1) and $\Phi_\gamma^2(\alpha_2, \alpha_1)$. These changes are confined to SUBROUTINE GEOMETRY.

Using a subscript "i" to denote a roadway segment and a subscript "j" to denote a traffic flow condition (vehicle type and speed condition) on the roadway, the energy mean sound level at the receiver is formatted as

$$L_e = 100 + 10 \log (I^*) \qquad \text{(A-8)}$$

The acoustic intensity at the receiver is *

$$I^* = \sum_{i=1}^{NR} \{[(D_0/D_i)^{\gamma_i}\, \Psi_{\gamma i}(\alpha_{2i},\alpha_{1i})\, /D_i]\{\ \sum_{j=1}^{NQS} \lambda_{ij}\, 10^{(\overline{L}_{oij}-66-\varepsilon_{ij})/10} \times e^{\frac{1}{2}(\overline{\sigma}_{ij}/4.35)^2}\} \qquad \text{(A-9)}$$

and the second moment of the acoustic intensity is

$$\kappa_2 = \kappa_2^*/(I^*)^2 \qquad \text{(A-10)}$$

$$\kappa_2^* = \sum_{i=1}^{NR}\Big\{[(D_0/D_i)^{2\gamma_i}\Phi_{\gamma_i}(\alpha_{2i},\alpha_{1i})\, /D_i^3]\Big\{\sum_{j=1}^{NQS} \lambda_{ij}\, 10^{2(\overline{L}_{oij}-66-\varepsilon_{ij})/10} e^{\frac{1}{2}(2\overline{\sigma}_{ij}/4.35)^2}\Big\}\Big\} \qquad \text{(A-11)}$$

where $$\Psi_{\gamma i}(\alpha_{2i},\ \alpha_{1i}) = \int_{\alpha_{1i}}^{\alpha_{2i}} [\cos(\alpha)]^{\gamma_i}\, d\alpha$$

$$\Phi_{\gamma_i}(\alpha_{2i},\ \alpha_{1i}) = \int_{\alpha_{1i}}^{\alpha_{2i}} [\cos(\alpha)]^{2(\gamma_i+1)}\, d\alpha$$

These results assume that the distribution of sound levels from a vehicle condition "j" (i.e., vehicle type and speed) are normally distributed. The above results apply both to the overall A-weighted sound level and the octave band sound level predictions conducted by the computer program. As indicated in Equations (A-9) and (A-10), the attenuation parameter, γ_i, applies for each roadway-receiver combination. The integrations indicated following Equation (A-11) are calculated numerically by the program.

If the attenuation parameter, γ_i, is set to zero in the above results, the formulation is identical to the theory of the TSC MOD-04 prediction model.

*NOTE: For D_o = 50 feet; $D_o^2 = (50)^2 = (100/2)^2 = 10^4 \cdot 10^{-6/10} = 10^{10} \cdot 10^{-66/10}$ (ie., Equations (A-9) and (A-10) are for length expressed in feet)

The estimation of percentile sound levels from the roadway is based upon the assumption that the distribution of sound level during the hour is Gaussian or Normal. Based upon the estimate of the overall A-weighted sound level, L_e (Equation (A-8)), and the standard deviation, σ_L (Equation (A-7)), the percentile sound levels are:

$$L_{50} = L_e - \sigma_L^2/8.7 \quad ,\text{dB} \tag{A-12}$$

$$L_{10} = L_{50} + 1.25\sigma_L \quad ,\text{dB} \tag{A-13}$$

$$L_{90} = L_{50} - 1.25\sigma_L \quad ,\text{dB.} \tag{A-14}$$

A.3 Spectral Calculations

The theory presented in Sections A.1 and A.2 represent the basic formulation of the traffic noise prediction model used by the FHWA Level 2 program. This theory applies to both the overall level and the octave band level predictions. The program logic specifies either the overall level or an octave band level using an integer index, IF. The index IF is assigned values from IF = 1 to IF = NF. The parameter NF is an upper limit on the number of frequency bands to be calculated. The maximum value for NF is nine. (See Section 3.2 and Subroutine INPUT.) The program conducts each prediction for the requested overall and octave band levels independently. All levels are A-weighted. For IF = 1; the overall A-weighted equivalent sound level, LE(A), is calculated. For roadway receiver configurations with neither a barrier nor an absorptive ground strip between the roadway and the receiver, the program uses the defined values for γ (See Section 3.7, Alpha Input). If γ equals zero, distance attenuation due to atmospheric absorption at 500 Hz is calculated (see Section A.5). If γ is greater than zero, attenuation due to atmospheric absorption is bypassed. For traffic noise propagation over a barrier or across a ground strip, the octave band center frequency at 500 Hz is assumed and the appropriate attenuation, including air absorption, is calculated with γ equal to zero.

For IF equal to or greater than 2, the FHWA Level 2 program conducts octave band sound level calculations for IF = 2, ..., NF. The overall octave band level, LEOB(A), is calculated as the intensity summation of the octave band levels. For these calculations the theory of Sections A.1 and A.2 is used with $\gamma = 0$. The attenuation due to barriers, absorptive ground strips, and atmospheric absorption is calculated at the appropriate octave band center frequency. The octave band center frequency, is calculated from 63 Hz (IF = 2) through 8000 Hz (IF = 9) using the algorithm:

$$f_n = 2^n \cdot 10^3/64 \tag{A-15}$$

$n = IF = 2, 3, \ldots, 9.$

Equation (A-15) is also used to derive algorithms for calculating barrier diffraction (subroutine BARFAC), absorptive ground strip attenuation, and atmospheric absorption (Subroutine GEOMRY).

A.4 Attenuation of Sound Levels

The traffic noise prediction code provides for the consideration of the attenuation of sound levels from the source to the receiver due to the following physical factors:

- Distance between source and receiver
- Barriers between source and receiver
- Trees and shrubbery between source and receiver
- Atmospheric absorption
- Reflection of sound to the receiver (negative attenuation).

The basic attenuation included in the acoustic model is an inverse square law spreading of sound intensity (i.e., 3 dB per distance doubling) that is frequency independent. All other forms of excess attenuation considered by the prediction code consider both frequency and distance effects in calculating attenuation as may be appropriate to the models utilized.

By plotting the predicted values of equivalent sound level, LE(A), and the statistical levels (L_{90}, L_{50}, and L_{10}) versus distance, the user will note slight differences in distance attenuation rates for the different descriptors. The reason for this is that both sound level and the composite value of standard deviation decrease with distance at different rates (see Equation (A-9)),

The statistical sound level descriptors are functions of both the equivalent sound level and the standard deviation of the sound level — hence, one would expect to observe differences.

A.5 Atmospheric Absorption

The traffic noise prediction code utilizes an empirical formula for the attenuation of sound resulting from atmospheric absorption. This formula is dependent upon frequency and distance between the source and the receiver and is specialized for ambient temperatures around 68°F and relative humidity in the range of 50 to 70 percent (4).

The empirical formula utilized is

$$\varepsilon_A = 5.4 \cdot 10^{-4} (2.35)^{(n-5)} r \quad \text{dB} \qquad \text{(A-16)}$$

where n is the octave band frequency index (see Equation (A-15))

r is the source-receiver distance in feet

Attenuation of sound for atmospheric absorption is accomplished in Subroutine GEOMRY. For the overall A-weighted sound level prediction, the value used is that for 500 Hz (i.e., $n = 5$ in Equation (A-15)).

The distance used by the prediction code in calculating atmospheric absorption is the distance from the receiver to the nearest point on the roadway segment or sub-segment being analyzed.

A.6 Diffraction

Diffraction of sound is caused by obstacles in the direct or reflected propagation paths from the roadway to the receiver. Such obstacles can be artificial barriers, earth berms, hills, buildings, etc. For the calculation of attenuation by diffraction, the obstacle can be modeled by a rigid, impervious screen oriented perpendicular to the ground plane so that sound is diffracted over the top edge of the screen exclusively. The shape of hills and the thickness of barriers are neglected because of the lack of available knowledge. The sound absorption and transmission properties of barriers are not considered because they play a minor role in most practical cases. The neglect of diffraction around the ends of barriers will introduce no significant errors, and it simplifies considerably the computational procedures. Furthermore, a diffracting barrier is then completely specified by the coordinates of the two end points of the top line defining the barrier segment.

The attenuation of sound by barriers is determined primarily by the difference, δ, between the path length of the shortest ray from the source over the top edge of the barrier to the receiver and the path length of the direct ray from the source to the receiver in the absence of the barrier (Figure A-2).

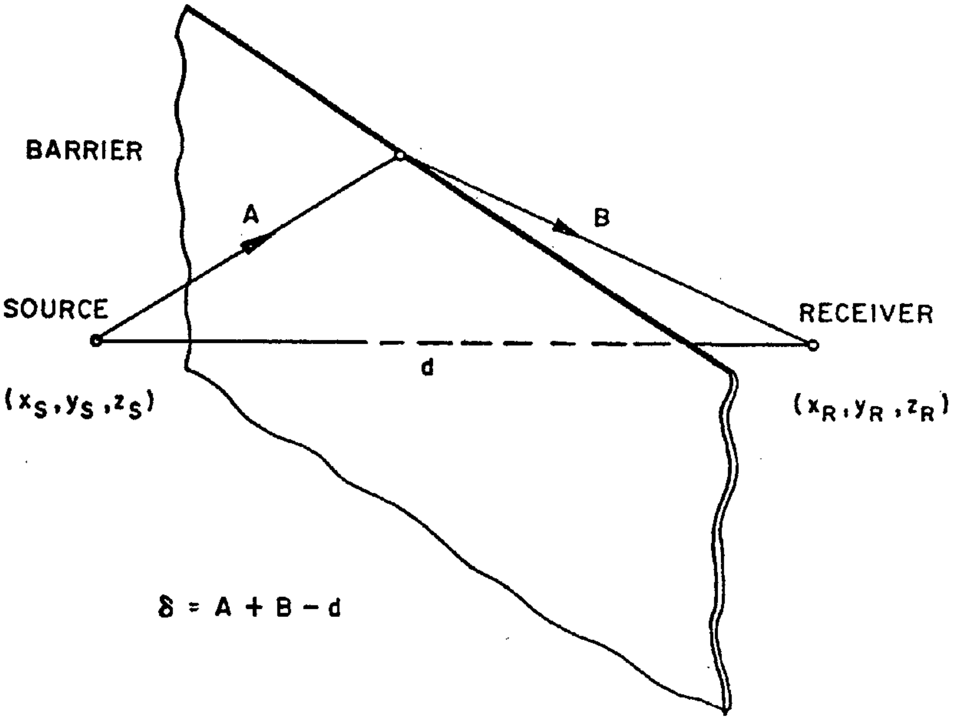


Figure A-2. DEFINITION OF THE PATH LENGTH DIFFERENCE δ FOR SOUND DIFFRACTION BY A BARRIER

For large path length differences, the attenuation in the acoustical shadow zone of a barrier is limited by effects of refraction and scattering of sound in the atmosphere. Based on data (5), the coded procedures have a maximum attenuation of 20 dB.

The attenuation for a barrier is not zero for zero path length difference (i.e., for a ray grazing over the barrier). For this situation, the theory of Fresnel diffraction yields an attenuation of about 5 dB. The attenuation becomes negligible when a direct sound ray traveling from the source to the receiver passes far over the top edge of the barrier. To simplify computations, diffraction effects are no longer considered when the height difference between the direct ray and the top of the barrier is greater than 20 feet.

For height differences of 20 feet or less, the Fresnel number is expressed as:

$$N = \frac{2\delta}{\lambda}, \qquad \text{(A-17)}$$

where δ is the path length difference and λ is the wavelength corresponding to the center frequency of an octave band. For normal atmospheric conditions, the speed of sound in air is assumed to be 1120 ft/sec. Thus, for a center frequency f, the Fresnel number becomes:

$$N = \frac{2f}{c}\,\delta = f\delta/560 \qquad \text{(A-18)}$$

The barrier attenuation is calculated as a function of the Fresnel number, using an analytic approximation to the measured data of Maekawa (6):

$$\varepsilon_B = 20\cdot\log_{10}\left(\frac{\sqrt{2\pi N}}{\tanh\sqrt{2\pi N}}\right) + 5, \text{ dB for } N \geq -0.2 \qquad \text{(A-19)}$$

$$\varepsilon_B = 0 \qquad \text{otherwise}$$

Equation(A-19)is applicable to both positive and negative values of N. However, for the actual computation, the values of attenuation are calculated as a function of N using the following relationships (see Subroutine BARFAC):

$$\begin{aligned}
\varepsilon_B &= 0 && \text{dB for } N \leq -0.2 \\
\varepsilon_B &= 20 \cdot \log_{10}\left(\frac{\sqrt{2\pi|N|}}{\tan \sqrt{2\pi|N|}}\right) + 5 && \text{dB for } -0.2 < N \leq 0 \\
\varepsilon_B &= 20 \cdot \log_{10}\left(\frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}}\right) + 5 && \text{dB for } 0 < N \leq 5.03 \\
\varepsilon_B &= 20 && \text{dB for } N > 5.03
\end{aligned} \qquad \text{(A-20)}$$

The last line in Equation (A-20) accounts for the above-mentioned upper limit to barrier attenuation.

As shown in Figure A-3, the attenuation of the A-weighted sound pressure level of typical passenger car noise is almost identical with the sound attenuation in the 500 Hz band. Hence, the primary number important for the attenuation of road traffic noise is the path length difference, δ.

The path length difference accounts for heights and distances of a point source, a receiver, and the top edge of a barrier. Furthermore, it accounts for the reduced attenuation of rays oblique to the top edge of the barrier (7).

For noise from a road segment and for a barrier at oblique angle to the road, the coded procedures find the path length difference δ_N for sound from the nearest point on the road segment affected by the barrier. Then, by assuming a monotonic variation of the path length difference from other points on the road, the extreme ends of the road segment are considered. If the path length differences, δ_1 and δ_2, for these end points differ from δ_N by more than a number that results in an attenuation difference of about 1 dB, the road segment between the near point N and the point 1 or the point 2, respectively, is cut in half. New path length differences are calculated for the new end points of the road segment, and the procedure of reducing the length of the road segment is repeated until the attenuation by diffraction is approximately constant.

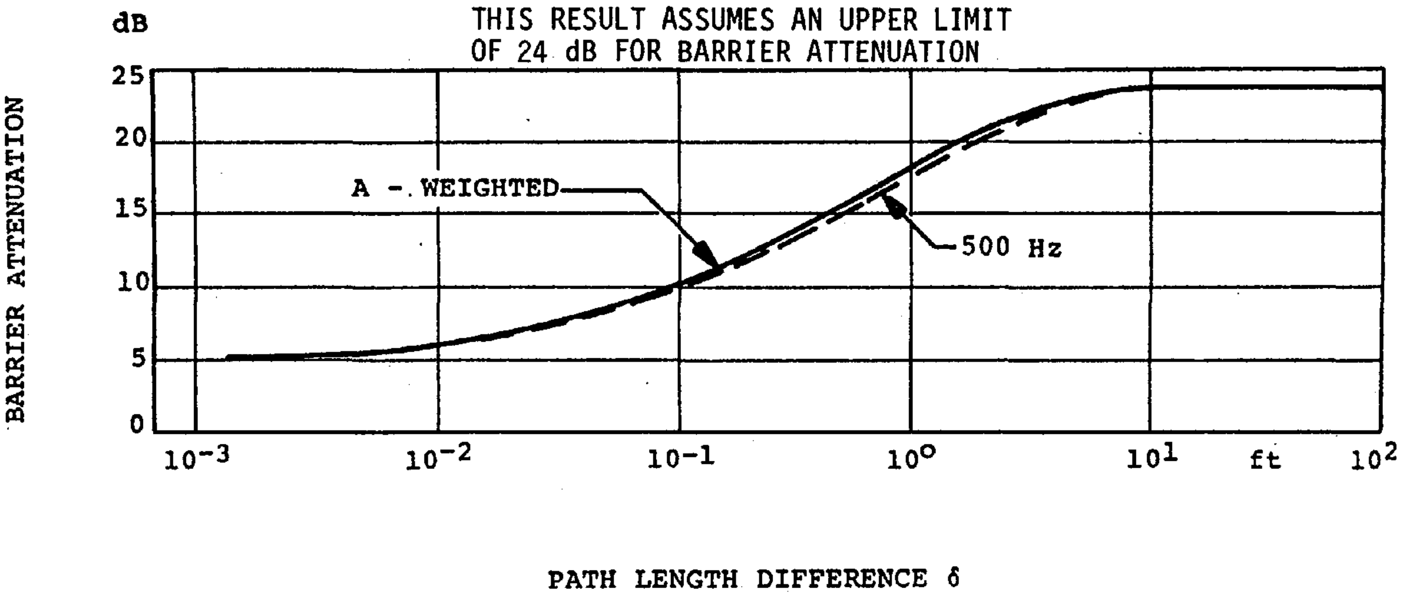


Figure A-3. BARRIER ATTENUATION AS A FUNCTION OF THE PATH LENGTH DIFFERENCE δ FOR A FREQUENCY OF 500 Hz AND FOR A-WEIGHTED LEVEL OF TYPICAL PASSENGER CAR NOISE

The criterion used for the acceptance of a sufficiently small difference in path length differences (i.e., uniform attenuation) is:

$$|\delta_2 - \delta_1| - \frac{\delta_1 + \delta_2}{100}\left(1 + \frac{\delta_1 + \delta_2}{2}\right) \leq 0.1 \qquad \text{(A-21)}$$

The numbers are based on a frequency of 500 Hz, for which the effect of Equation(A-21)on the attenuation is plotted in Figure A-4.

In case of multiple diffraction by several barriers in parallel, the coded procedures consider the strongest diffraction exclusively.

This is a conservative procedure resulting in attenuations that are somewhat too small, but it seems to be the most reasonable way to bypass the very complicated and not yet fully understood problem of multiple diffraction.

A.7 Ground Absorption

Ground attenuation is a function of the structure and the covering of the ground, both of which influence its acoustic properties, and of the heights of the source and receiver above the ground.

For these procedures, a very simple approximation of rectangular ground strips is assumed, defined by two end points of a center line and by a width, and which have either a low cover such as shrubbery and thick grass, or a high cover, such as trees.

The height of a sound ray traveling from the source to the receiver over the ground strip is checked only with respect to the center line of the strip. Thus, it is assumed that the plane of the ground strip is approximately parallel to a plane defined by a road segment and a receiver. If the height of the direct sound

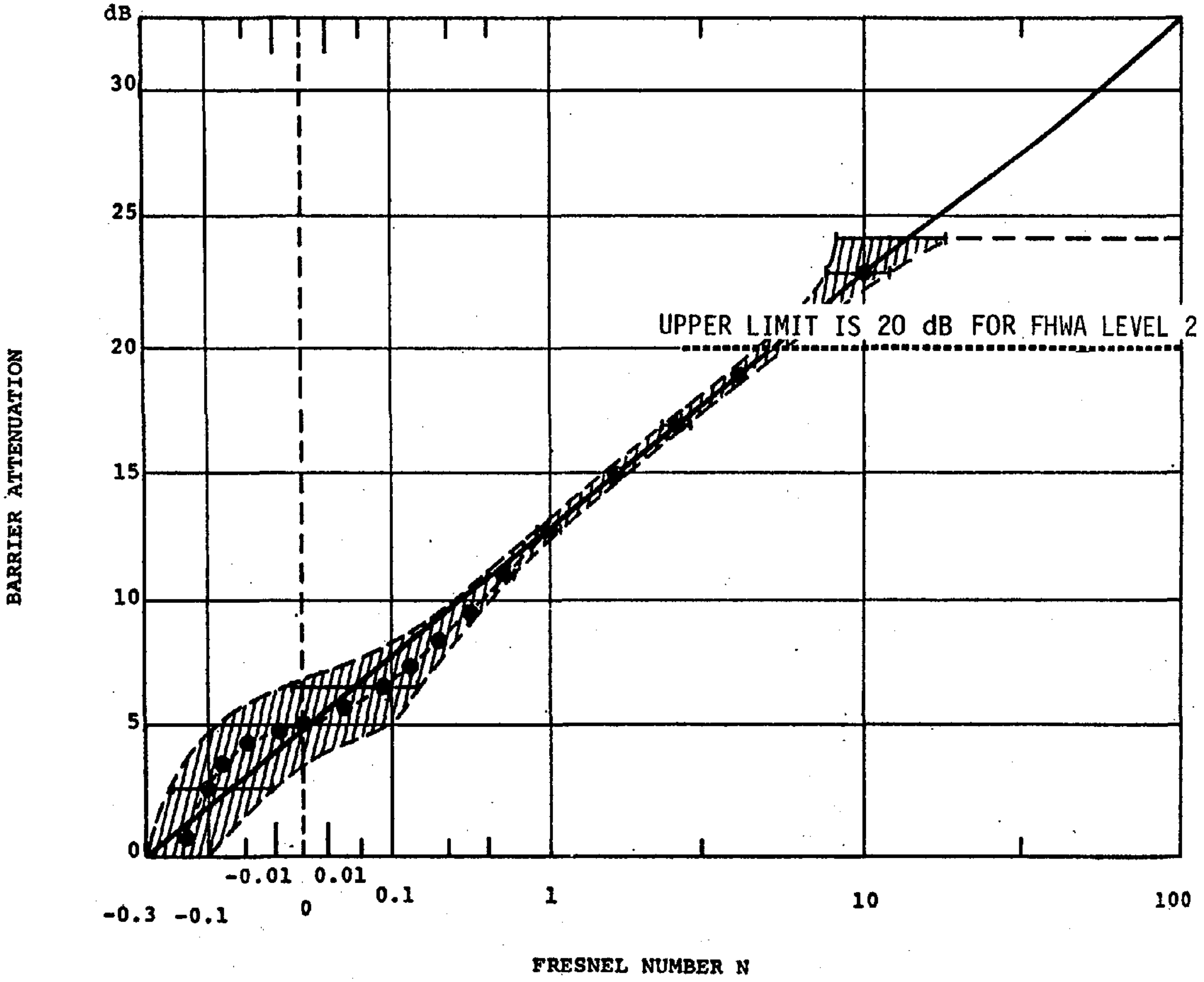


FIGURE A-4. BARRIER ATTENUATION AS A FUNCTION OF THE FRESNEL NUMBER FOR DIFFRACTION ray from the source to the receiver is more than 10 feet above a ground strip with a low cover or more than 30 feet above a ground strip with high cover, any sound attenuation due to ground absorption is neglected. The heights of 10 and 30 feet are based on rough estimates rather than on field experience and might be revised if found necessary.

In general, the amount of ground attenuation cannot be stated in terms of excess attenuation per unit of distance. To a first approximation, however, such behavior can be assumed in the range of distances of 200 to 2000 feet unless the total attenuation exceeds 20 dB (4).

No attempt has been made to calculate accurate distances over a ground strip with the computer program. Instead, a mean path length, r, over ground strips is calculated with the formula

$$r = \frac{\pi/2}{(1/w) + (1/\ell)} \qquad \text{(A-22)}$$

where w is the width of the strip and ℓ the length of the center line.

The following analytical approximations to average values of measured data are used to calculate the attenuation of sound propagating (4):

1) Through shrubbery and over thick grass

$$\varepsilon_G = \left[0.18 \log (f) - 0.31\right] \frac{r}{3.28} \text{ dB}, \qquad \text{(A-23)}$$

(See Figure A-6)

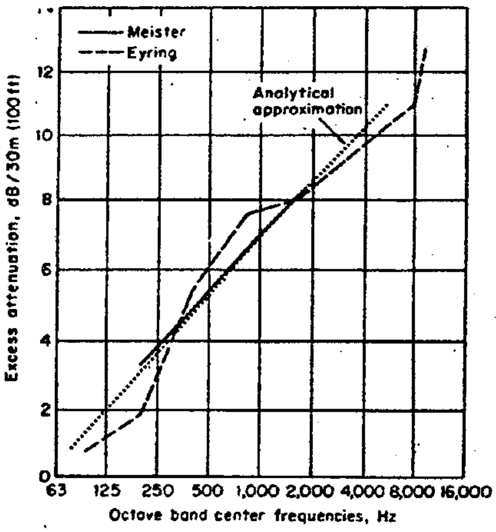


Figure A-5. ATTENUATION FOR SOUND PROPAGATION THROUGH SHRUBBERY AND OVER THICK GRASS, MEASURED DATA AND ANALYTICAL APPROXIMATION

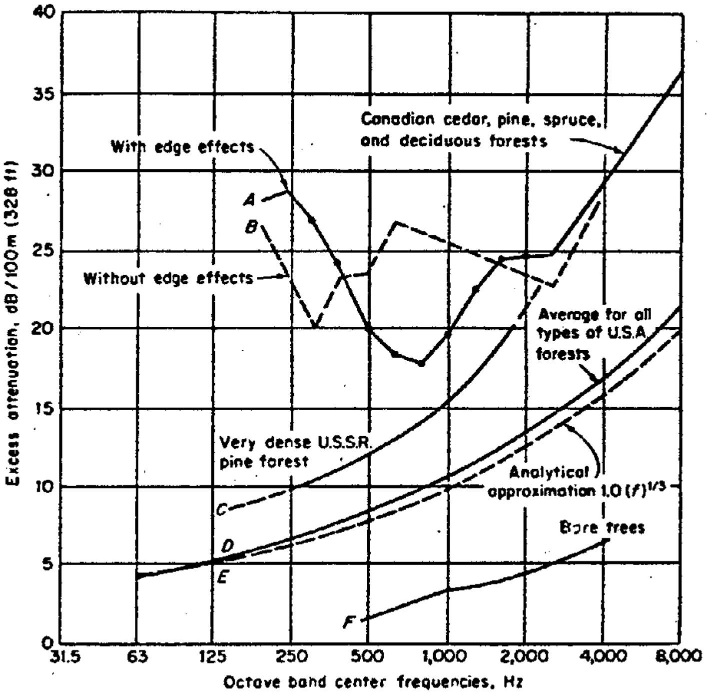


Figure A-6. ATTENUATION FOR SOUND PROPAGATION IN TREE ZONES, MEASURED DATA AND ANALYTICAL APPROXIMATION FOR AVERAGE USA FORESTS

2) Through tree zones

$$\varepsilon_G = 0.01\,(f)^{1/3}\,r/3.28 \quad \text{dB} \tag{A-24}$$

(See Figure A-6)

where r is given in feet and f in Hz. With r in feet and with octave band index numbers n, where, for example, n = 5 for the octave band center frequency f = 500 Hz, these relations become, using Equation (A-15):

1) For shrubbery and thick grass

$$\begin{aligned} \varepsilon_G &= (0.016n - 0.028)r \text{ dB} && \text{if } D_G \leq 20 \text{ dB} \\ \varepsilon_G &= 20 \text{ dB} && \text{if } D_G > 20 \text{ dB} \end{aligned} \tag{A-25}$$

2) For tree zones

$$\begin{aligned} \varepsilon_G &= (2^{n/3})\,r/131.2 \text{ dB} && \text{if } D_G \leq 20 \text{ dB} \\ \varepsilon_G &= 20 \text{ dB} && \text{if } D_G > 20 \text{ dB} \end{aligned} \tag{A-26}$$

The notation in the second lines of Equations (A-25) and (A-26) indicate that the attenuation is limited to 20 dB based upon field experience (5).

Consistent with the assumption that the ground attenuation is proportional to the mean path length of the sound over the ground strip, the procedures accumulate attenuations of various ground strips in series. However, since the path length considered represents a statistical average for rays propagating in all directions over the strip, the path length over two equal, parallel strips is not just twice the path length over a single strip of twice the width but is generally shorter. Consequently, the attenuation calculated for one strip will be smaller than the attenuation calculated for two strips in parallel each having half the width.

The purpose of using the statistical formulation for path length given by Equation (A-22) is to obtain reasonable predictions for the effects of ground absorption on an average basis. There exist, however, particular cases where the model will not be very accurate. For example, the attenuation of sound from a short road segment by long, narrow absorbing strips is overestimated, whereas the attenuation by a wide strip oriented perpendicularly to the road is underestimated. To some extent, these modeling errors compensate for one another in most practical situations. In general, inaccuracies are inherent to the entire problem of ground absorption.

A.8 Reflection

The sound field at a receiver results from contributions of direct (or diffracted) and reflected rays. In many practical cases of sound propagation from a highway, corrections applied for reflections are small compared to the inaccuracies involved in the prediction of ground attenuation and in uncertainties with acoustical shadow zones owing to wind and temperature gradients in the atmosphere. Therefore, the model has been designed to account for reflections with a first-order approximation.

The reflection model utilized by the traffic noise prediction code disregards phase relations between the various contributions and considers incoherent waves for which the total sound intensity is the sum of the intensities of the individual contributions.

Reflections from the road surface are always present. However, the contributions from these reflections are implicitly included in reference levels at a short distance from individual vehicles on the road.

Reflections at the ground plane farther from the roadway are disregarded because they generally result in a complex interference pattern with the direct ray. Consideration of these effects is beyond the scope of a first-order approximation for reflections.

Reflections at any inclined plane result in rays directed either toward the ground, and thus being neglected, or toward the sky, and thus not contributing to the sound intensity at a normal receiver location close to the ground. Therefore, only reflections on planes that are perpendicular to the ground plane are considered by the prediction code.

Within the first-order approximation, this model also neglects the actual frequency-dependent magnitude of reflection coefficients and distinguish only between reflection coefficients 0 and 1 of reflecting surfaces (i.e., perfect absorption or perfect reflection, respectively).

In order to determine whether a reflective barrier is high enough to be effective, the procedures consider the possibly reflected ray that travels a minimum distance from the road segment to the receiver. A reflective plane perpendicular to the ground is considered high enough if the direct ray strikes the barrier at least 2 feet below the top edge of the barrier. For reflection points within 2 feet of the top edge, diffraction effects are considered by the model to be strong enough for all frequencies so that the reflected ray is sufficiently reduced in amplitude to be negligible.

Also neglected by the model are reflections from planes that are either very short or very remote so that the contribution to the sound intensity at the receiver is less than 10 percent of the intensity received via direct (or diffracted) rays from the road segment under consideration. The analytical formulation for this criterion is

$$\frac{d\Delta\alpha'}{d'\Delta\alpha} \; 10^{-\varepsilon_B/10} < 0.1 \qquad \text{(A-27)}$$

where d = distance from the receiver to the road segment in feet

$\Delta\alpha$ = aspect angle of the road segment at the receiver

d' = distance from the road segment to a receiver location imaged about the reflector

$\Delta\alpha'$ = aspect angle of the barrier at the image receiver

ε_B = attenuation in dB by diffraction of the direct ray due to a possible barrier (referred to a frequency of 500 Hz).

Single reflections are considered exclusively; contributions from rays that strike two or more reflectors are ignored. It is essential for the future calculation of higher order statistical parameters of road traffic noise that the reflections of sound from a certain road segment be treated as amplifications of the direct (or diffracted) rays and not as uncorrelated contributions from independent road segments. The factor F multiplying the intensity of the direct sound from a road segment is calculated in Subroutine GEOMRY using

$$F = 10^{-\varepsilon_B/10} + \sum_{i=1}^{N} \frac{\Delta\alpha_i' d}{\Delta\alpha d_i'} \, 10^{-\varepsilon_i/10} \qquad \text{(A-28)}$$

where the subscript i indicates reflections at N different surfaces, each of which might be diffracted by a barrier before or after reflection and therefore might have an attenuation ε_i. The factor F is calculated as a function of frequency. The notation in Equation (A-28) is the same as in Equation (A-27) except for the angle $\Delta\alpha'$ which denotes the aspect angle of the road segment at the image receiver (Figure A-7).

A.9 Combination of Attenuation and Reflection

A.9.1 Atmospheric Absorption

The overall procedures account for atmospheric absorption in combination with barrier diffraction, ground absorption and reflections. The path length used for calculating the atmospheric absorption is the direct distance from the source to the receiver and is not corrected for the path length difference δ of diffracted rays nor for the increased path length of reflected rays. The factor F, defined by Equation (A-28) is multiplied by $10^{-D_A/10}$, where D_A is defined by Equation (A-16), in order to calculate, for each individual road segment, the factor

$$10^{-\varepsilon/10} = F \cdot 10^{-\varepsilon_A/10} \cdot 10^{-\varepsilon_G/10} \qquad \text{(A-29)}$$

This composite attenuation factor is employed for the calculation of the energy mean level in Equations (A-8)and (A-9).

A.9.2 Ground Absorption

The prediction procedure includes ground absorption if such attenuation is significant only for the case of no diffraction of sound from the source to the receiver. That is, if in analyzing a <u>sub</u>-segment of a roadway segment, diffraction of the direct ray from the source to the receiver is encountered, the prediction code ignores the attenuation resulting from ground cover of all types for the <u>sub</u>-segment of roadway being analyzed. As indicated by Equation (A-29), the same ground absorption is assumed for both the direct rays and for all reflections.

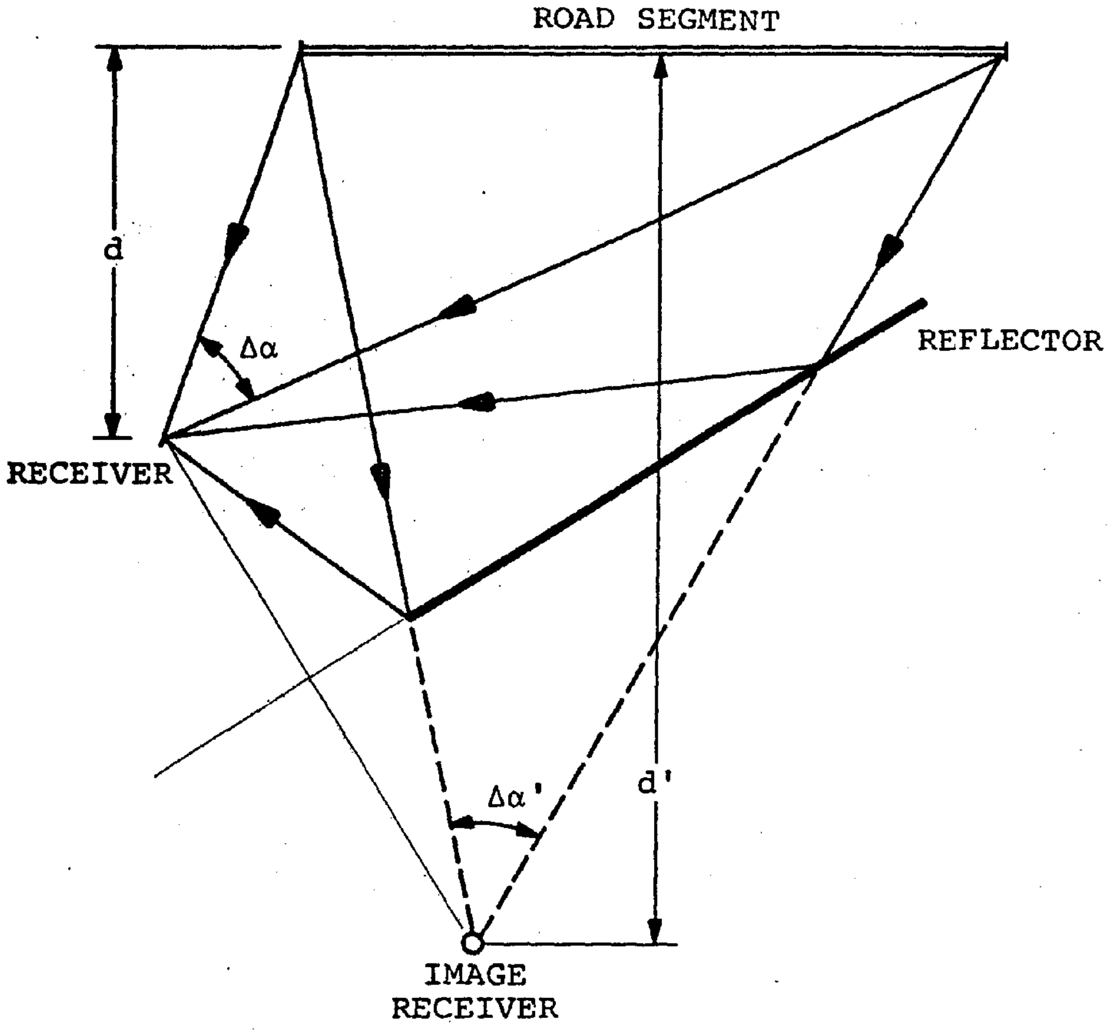


Figure A-7. EXAMPLE FOR RAY TRACES FROM A REFLECTOR, INDICATING THE CONSTRUCTION BY MEANS OF AN IMAGE RECEIVER

A.9.3 Reflection Before or After Diffraction

The procedures account for reflections in combination, with diffraction provided that there is only a single diffraction before or after the reflection and that the path length increase due to diffraction is less than 5.6 feet. Doubly diffracted reflections are neglected as well as very weak single reflections that suffer, in the 500 Hz band, the maximum attenuation of 20 dB assumed for barrier diffraction.

The attenuation of reflected rays by diffraction is calculated for one location on the road segment only: the point nearest to the image receiver. No attempt is made to refine this calculation by checking for the attenuation from other points on the road segment, since the contribution of diffracted reflections will be generally small and, hence, inaccuracies of the calculation will be negligible.

REFERENCES

1. Rudder, F. F., Jr., and Lam, P.: "Users Manual: TSC Highway Noise Prediction Code: MOD-04", U.S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-77-18, January 1977.

2. Barry, T. M. and Reagan, J.A.: "FHWA HIGH TRAFFIC NOISE PREDICTION MODEL", U.S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-77-108, July 1978.

3. Kurze, U. J.: "Noise from Complex Road Traffic", Journal of Sound and Vibration, Vol. 19, No. 2, 1971, pp. 167-177.

APPENDIX B

DECLARED SIZE OF ARRAYS

B.1 PARAMETERS DEFINING THE PROBLEM

The basic parameters used by the prediction code and upon which the declared size of an array depends are as follows:

- Number of Roadways, NR: Declared as 20
- Number of Roadway Sections, NRSM1(NR): Declared as 10
- Number of Vehicle Types, NQ: Declared as 4
- Number of Traffic Flow Conditions on a Roadway, NQS(NR,NQ): Declared as 5
- Number of Receivers, NRC: Declared as 15
- Number of Octave Frequency Bands, NF: Declared as 9
- Number of Barriers, NB: Declared as 20
- Number of Barrier Segments, NBSM1(NB): Declared as 10
- Number of Ground Strips, NG: Declared as 10
- Number of Types of Ground Strips, IDUM(NG): Declared as 2
- Number of Allowable Reflections, IDXR: Declared as 10
- Number of Program Initialization Parameters, IP: Declared as 6

The following sections of this appendix define the declared size of all arrays depending upon the above parameters. Arrays not explicitly presented in the following sections are used to describe coordinates in (x,y) space (declared as 2) or (x, y, z) space (declared as 3) and the usage should be evident to the user.

B.2 MAIN PROGRAM - GENERAL DIMENSION STATEMENTS

The arrays listed below with general dimension statements appear in the MAIN PROGRAM. The user should refer to the parameter list in Section B.1

```
RDIN(IP)
XRC(NRC),YRC(NRC),ZRC(NRC)
NQS(NR,NQ)
XLE(NF)
```

GAMA(NRC,NR)
XMPH(NR,NQS,NQ),VEXPH(NR,NQS,NQ)
RX(NR,NRSM1+1),RY(NR,NRSM1+1),RZ(NR,NRSM1+1)
NRSM1(NR)

B.3 BLOCK DATA-GENERAL DIMENSION STATEMENTS

The arrays listed below with general dimension statements appear in BLOCK DATA. The user should refer to the parameter list in Section B.1.

CO(NF,NQ),C1(NF,NQ),SO(NF,NQ)
GAMA(NRC,NR)

B.4 SUBROUTINE INPUT-GENERAL DIMENSION STATEMENTS

The arrays listed below with general dimension statements appear in subroutine INPUT. The user should refer to the parameter list in Section B.1.

NQS(NR,NQ),VTEMP(NQ)
BX(NB,NBSM1+1),BY(NB,NBSM1+1),BZ(NB,NBSM1+1)
IBLAST(NB),NBSM1(NB)
XXG1(NG,IDUM),YYG1(NG,IDUM), ZZG1(NG,IDUM)
BGS(NG),IDUM(NG)
RX(NR,NRSM1+1),RY(NR,NRSM1+1),RZ(NRSM1+1)
NRSM1(NR)
XMPH(NR,NQS,NQ),VEXPH(NR,NQS,NQ)
RDIN(IP)
XRC(NRC),YRC(NRC),ZRC(NRC)
CO(NF,NQ),C1(NF,NQ),SO(NF,NQ)
GAMA(NRC,NR)

B.5 SUBROUTINE CHECK-GENERAL DIMENSION STATEMENTS

The arrays listed below with general dimension statements appear in subroutine CHECK. The user should refer to the parameter list in Section B.1

```
BX(NB,NBSM1+1),BY(NB,NBSM1+1),BZ(NB,NBSM1+1)
IBLAST(NB),NBSM1(NB)
XXG1(NG,IDUM),YYG1(NG,IDUM),ZZG1(NG,IDUM)
BGS(NG),IDUM(NG)
RX(NR,NRSM1+1),RY(NR,NRSM1+1),RZ(NR,NRSM1+1)
NRSM1(NR)
```

B.6 SUBROUTINE INTER-GENERAL DIMENSION STATEMENTS

The arrays listed below with general dimension statements appear in subroutine INTER. The user should refer to the parameter list in Section B.1.

```
CO(NF,NQ),C1(NF,NQ)
SO(NF,NQ)
XMPH(NR,NQS,NQ),VEXPH(NR,NQS,NQ),NQS(NR,NQ)
XLREF(NR*NQS*NF*NQ),CQ(NR*NQS*NF*NQ)
```

B.7 SUBROUTINE GEOMRY-GENERAL DIMENSION STATEMENTS

The arrays listed below with general dimension statements appear in subroutine GEOMRY. The user should refer to the parameter list in Section B.1.

```
B1(3,2,NB*(NBSM1+1)),R1(3,2,NB*(NBSM1+1)),
RB1(3,2,NB*(NBSM1+1)),TA1(3,2,NG),
KBCODE(NB*(NBSM1+1)),KNUMB(NB*(NBSM1+1)),
KRNUMB(NB*(NBSM1+1)), KRDNUM(NB*(NBSM1+1))
KGCODE(NG),BGT(NG),IKIN(NG),BGS(NG),IDUM(NG),
DELPO(NQ),DELP1(NQ),DELP2(NQ),FB(NF,NQ),
DELR(NQ,IDXR),FG(NF),HGA(IDUM),
XIMG(3,IDXR),ZS(NQ),RDIN(IP),NQS(NR,NQ),
XLE(NF),XMPH(NR,NQS,NQ),VEXPH(NR,NQS,NQ),
BX(NB,NBSM1+1),BY(NB,NBSM1+1),BZ(NB,NBSM1+1),
IBLAST(NB),NBSM1(NB),XXG1(NG,IDUM),YYG1(NG,IDUM),
ZZG1(NG,IDUM),XLREF(NR*NQ*NF*NQS),
CQ(NR*NQ*NF*NQS).
GAMA(NRC,NR)
```

APPENDIX C

ALLOCATION OF COMMON BLOCK DATA

Table C-1, below, indicates the allocation of common block data within the highway traffic noise prediction code. The user may refer to the listings in Appendix C and Appendix E, as appropriate, for the variables assigned to each common block.

TABLE C-1

ASSIGNMENT OF COMMON BLOCK DATA

COMMON BLOCK TITLE	MAIN PROGRAM	BLOCK DATA	INPUT	CHECK	INTER	DEGEN	GEOMRY
/INOU/	●	●	●	●	x	●	●
/STORE1/	x	x	●	●	x	x	●
/STORE2/	x	x	●	●	x	x	●
/STORE3/	●	x	●	●	x	x	x
/STORE4/	●	x	●	x	●	x	●
/INPT1/	●	x	●	x	x	x	●
/INPT2/	●	x	●	●	x	x	●
/INPT3/	●	x	●	x	x	x	x
/INPT4/	●	x	●	x	x	x	x
/DRIV2/	●	x	●	x	●	x	●
/DRIV3/	●	x	x	x	x	x	●
/DRIV4/	●	x	x	x	x	x	●
/BLK2/	●	x	●	x	x	x	●
/CONSTS/	x	●	●	x	●	x	x
/GEO1/	●	x	x	x	x	x	●
/INTER1/	x	x	x	x	●	x	●
/TIT1/	●	x	●	x	x	x	●
/OPTION/	●	●	●	x	x	x	●
/TABLE/	●	●	●	x	x	x	x
/FUNC/	x	x	x	x	x	x	●

● Denotes Assignment of Common
x Denotes No Assignment of Common

APPENDIX D

ARCHITECTURE OF PREDICTION CODE

D.1 INTRODUCTION

The version of the highway traffic noise prediction code described in this manual differs slightly from previous versions (See Section 2.) of the code. As compared to the 1974 version, the user will note that the present version includes an additional subroutine called CHECK and a BLOCK DATA subprogram. The complete program comprises the MAIN PROGRAM and thirty-four (34) subprograms. The data management within the code is accomplished by MAIN, INPUT, and GEOMRY. The subroutines calculating acoustical parameters are BLOCK DATA, INTER, BARFAC, and IEPS. The 27 remaining subprograms are related to the geometric description of the problem.

The program is written in FORTRAN IV language and is intended to run in the batch mode. As described in this manual, data input is via a card reader and output is via a line printer (See Appendix C; COMMON/INOU/).

The MAIN program is described in detail in this appendix. Detail descriptions of the subprograms are provided in appendix. Following the description of each subprogram, the listing for that block of code is presented. The organization of the prediction code is illustrated in Figure D-1.

D.2 MAIN PROGRAM DESCRIPTION

The MAIN program controls the flow of operations required to perform the highway traffic noise estimates at each receiver. The MAIN program calls various subprograms that conduct the bulk of the calculations. The basic program variables initialized by the MAIN program are NQ=3, NG=0, and NB=0 (i.e., three vehicle types, no absorptive ground strips, and no barriers).

The main program immediately reads and prints the user-defined title. Next, the MAIN program calls SUBROUTINE INPUT to read the input data defining the problem (See Section 6 and Appendix E). If the user fails to properly define a roadway and/or a barrier by at least two end points, an error message is printed and the MAIN program attempts to read the next data set (See Section 5.8).

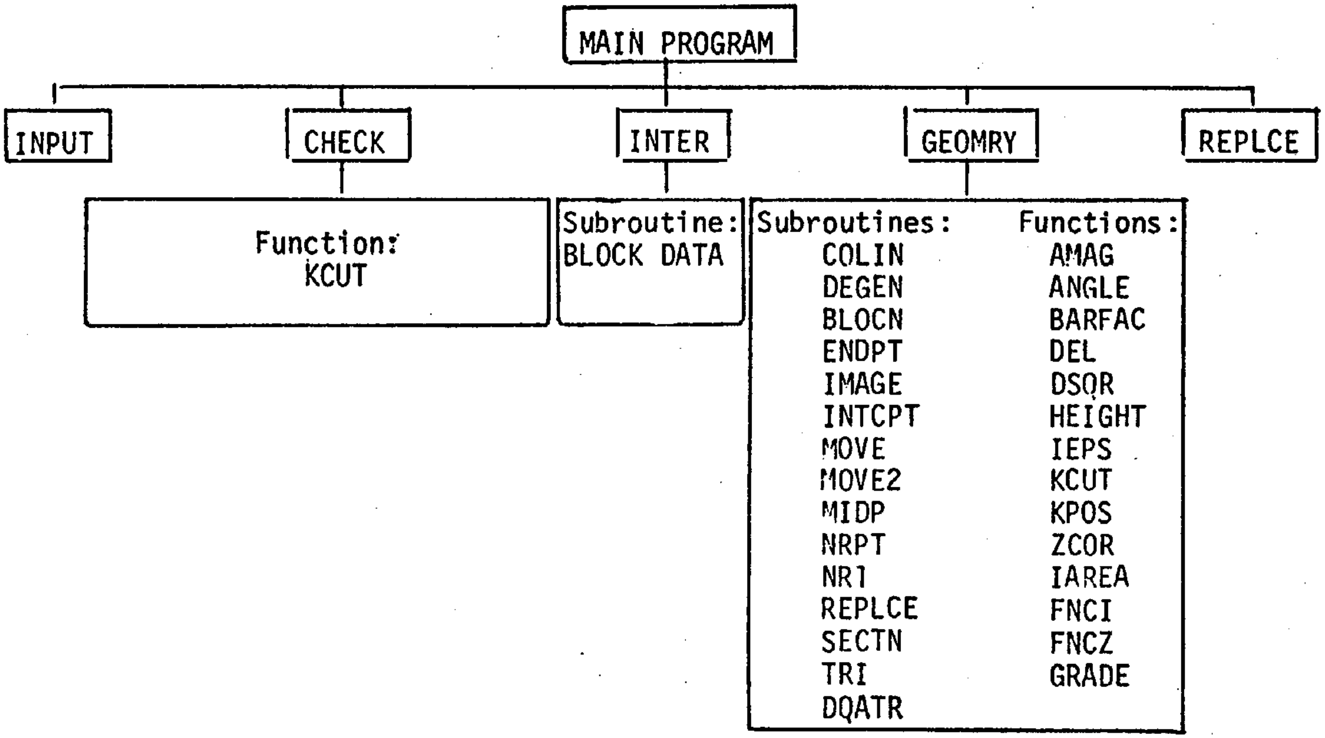


FIGURE D-1 ARCHITECTURE OF PREDICTION CODE :FHWA LEVEL 2

Following execution of INPUT, the MAIN program calls SUBROUTINE CHECK to determine if either a barrier segment or an absorptive ground strip center line intersect a roadway segment. If such an intersection occurs an error message is printed for each such intersection (See Section 5.8). Following the execution of CHECK, the MAIN program is ready to begin sound level estimates if no errors have been encountered.

The MAIN program next calculates the reference distance sound levels and standard deviations for each vehicle type, traffic flow condition, and each frequency band specified for all roadways. This calculation is conducted by SUBROUTINE INTER. Following execution of subroutine INTER, the MAIN program begins the receiver sound level estimates in the following sequence:

The array, XLE(J), is initialized to zero. This array contains the normalized values of the acoustic intensity at the receiver for the overall A-weighted intensity, XLE(1), and the A-weighted octave band intensity (XLE(J),J=2,9).

The MAIN program next selects the roadway number and initializes the coordinates of the first end point of the roadway segment (array, XR1(J)). The next end point of the roadway segment is specified (array XR2(J)) and the basic problem is defined for the prediction code (i.e., roadway segment/receiver geometry. See Section 3.1).

To perform the calculations related to the basic problem defined for the code, the MAIN program calls subroutine GEOMRY. The vast bulk of the calculations performed by the prediction code are conducted in subroutine GEOMRY. If no errors are encountered in subroutine GEOMRY (See Section 5.8), the MAIN program continues the roadway analysis for each roadway segment until all roadways have been considered. The normalized acoustic intensity is accumulated in the array XLE(J) in subroutine GEOMRY.

Following the analysis of all roadways (sources) for the specified receiver, the MAIN program next calculates the standard deviation, SIGL, for the composite traffic noise and adjusts the normalized acoustic intensity, XLE(J), into absolute units of sound level (also stored in array XLE(J)). The main program then calculates the sound level descriptors LE(A) (XLE(1)), L50, L10, and L90. The output data is pinted for the specified receiver and the MAIN program selects the next receiver continuing the above sequence until all receivers have been considered.

The flow diagram for the main program is illustrated in Figure D-2. Statement numbers are presented at points on the flow diagram so that the user may refer to specific blocks of code as required.

D.3 MAIN PROGRAM VARIABLE LIST

The variables used in the MAIN program are listed below. Array variables are not indicated as such; however, the user may refer to Appendix B, as required, to determine appropriate array sizes. Variables not listed are described in the subprograms where they are utilized.

CAP2	Cumulant for the A-weighted acoustic intensity
I	Index for receiver loop
IQ	Index for vehicle type
J	Index for frequency band
M	Index for roadway number
N	Index for road section number
NB	Number of barriers
NF	Number of frequency bands
NG	Number of absorptive ground strips
NLIM	Number of points defining a roadway
NQ	Number of vehicle types
NQS	Vector notation for number of vehicle types for each roadway
NR	Number of roadways
NRC	Number of receivers
NRSM1	Number of sections for one roadway
RDIN	Vector notation for initialization parameters
RX	x-coordinate of roadway point
RY	y-coordinate of roadway point
RZ	z-coordinate of roadway point
SIGL	Standard deviation of A-weighted sound intensity
XAL	Energy mean A-weighted overall sound level

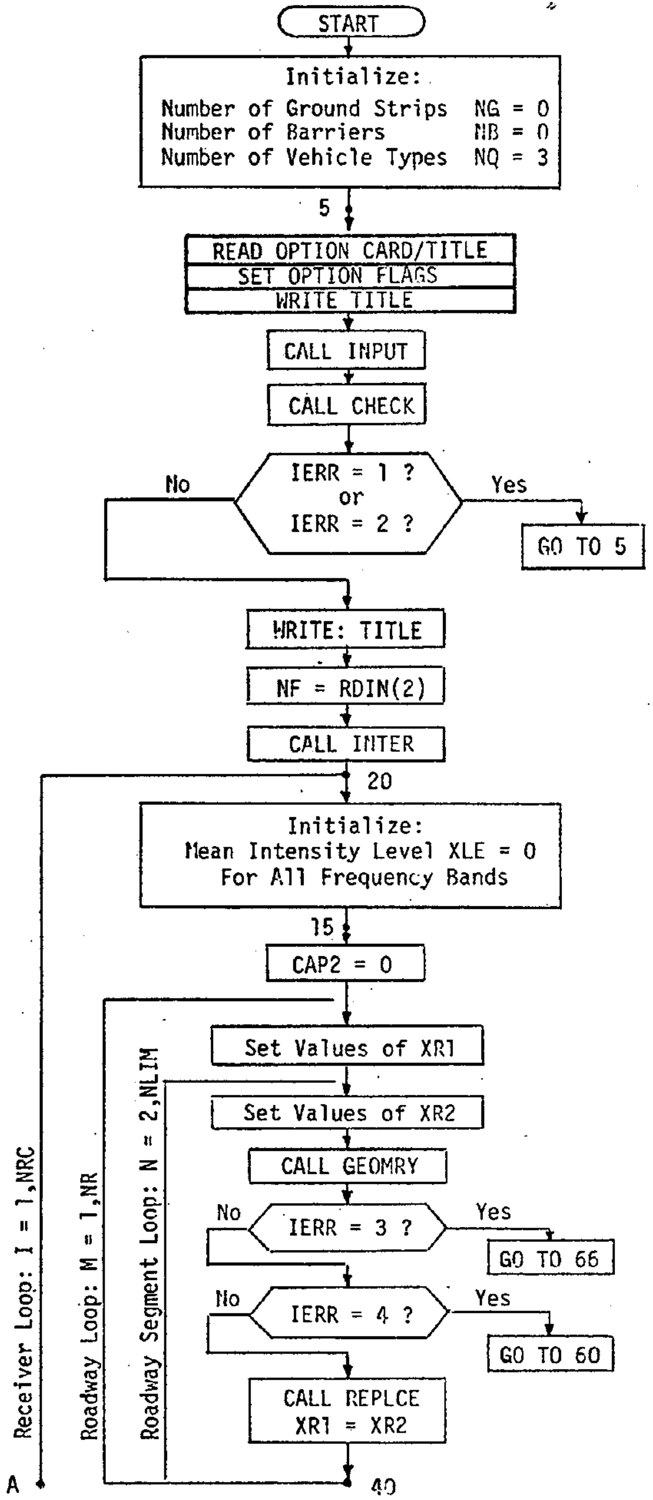


FIGURE D-2. MAIN PROGRAM FLOW DIAGRAM

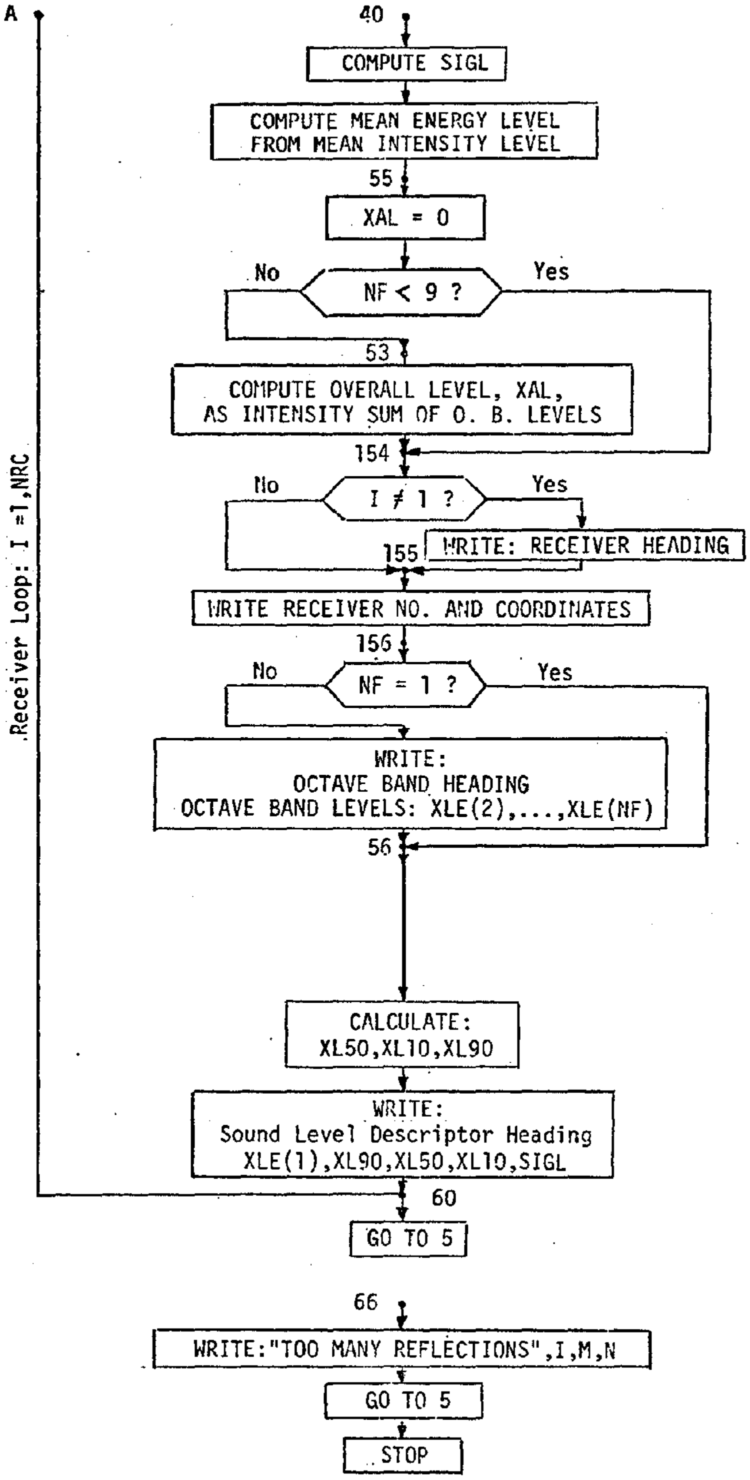


FIGURE D-2. MAIN PROGRAM FLOW DIAGRAM (Concluded)

XLE	Energy mean A-weighted intensity and level in frequency bands
XL10	A-weighted sound exceeded 10% of the time
XL50	A-weighted sound exceeded 50% of the time
XL90	A-weighted sound exceeded 90% of the time
XR1	Road section initial point
XR2	Road section end point
XRC	x-coordinate of receiver
YRC	y-coordinate of receiver
ZRC	z-coordinate of receiver
NZQR	Number of roadways with sound level exceeding criterion
NZQS	Number of roadway segments with sound level exceeding criterion
BLEV	Criterion sound level
NZQ1	Roadway number of the roadways with sound level exceeding criterion
NZQ2	Segment number of the segments with sound level exceeding criterion.

D.4 MAIN PROGRAM LISTING

The block of code comprising the MAIN program of the highway traffic noise prediction code is presented in the listing on the following pages.

```
C  PL. PUT ANY COMMENTS IN THIS LINE THAT UU WANT TO...
C  TRAFFIC NOISE PREDICTION MODEL
C  MAIN PROGRAM   02/79   SAI MOD
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER UNIT(2,2)
      DIMENSION XR1(3),XR2(3)
      COMMON/INOU/INPT,IOUT
      COMMON/BLK2/NQ
      COMMON /INPT1/RDIN(6),TRDIN(6)
      COMMON/INPT2/NR,NE,NG
      COMMON/INPT3/XRC(15),YRC(15),ZRC(15),NRC
      COMMON/INPT4/TXRC(15),TYRC(15),TZRC(15)
      COMMON/DRIV2/NQS(20,4),NF
      COMMON /DRIV3/XLE(9)
      COMMON/STORE4/XMPH(20,5,4),VEXPH(20,5,4)
      COMMON/DRIV4/CAP2
      COMMON/STORE3/RX(20,11),RY(20,11),RZ(20,11),NRSM1(20)
      COMMON/GEO1/IBAR,ISEG,IGRA
      COMMON /OPTION/METIN,METOUT,IREFL
      COMMON /TABLE/GAMA(15,20),IFIRST
      COMMON/TIT1/TRC(5,15),BLEV(15),ZZQ,IGOO(20,11),N
      DIMENSIONALZQ(20,10),NZQ1(20),NZQ2(20,10),NNZQS(20)
      INTEGER TITLE(80)
      DATA IOPT/'*   '/,IYES/'Y   '/,NO/'N   '/
      DATA UNIT/'ENGL','ISH ','METR','IC  '/
C  NUMBER OF VEHICLE TYPE IS SET TO 3 IN THIS PROGRAM
      NG=0
      NB=0
      NQ = 3
C  READ OPTION CARD, IF ANY
C  DEFAULT IS ENGLISH INPUT, ENGLISH OUTPUT, AND COMPUTE REFLECTIONS
      READ (INPT,1005,END=999) TITLE
      IF (TITLE(1).NE.ICPT) GO TO 10
      IF (TITLE(14).EQ.IYES) METIN=1
      IF (TITLE(28).EQ.IYES) METOUT=1
      IF (TITLE(42).EQ.NO)   IREFL=0
    5 READ(INPT,1005,END=999)TITLE
   10 I = METIN + 1
      J = METOUT + 1
      DO777MRR=1,20
      NZQ1(MRR)=0
      DO777MRS=1,10
      NZQ2(MRR,MRS)=0
      ALZQ(MRR,MRS)=0.D0
  777 CONTINUE
      WRITE(IOUT,2009)UNIT(1,I),UNIT(2,I),UNIT(1,J),UNIT(2,J)
      WRITE(IOUT,1002) TITLE
      CALL INPUT
```

MAIN PROGRAM LISTING

```
      CALL CHECK(IERR)
      IF (IERR.EQ.1.OR.IERR.EQ.2) GO TO 5
      WRITE (IOUT,1001)
      WRITE(IOUT,1002)TITLE
      WRITE(IOUT,1003)
      NF=RDIN(2)
C   PERFORM INTERPOLATION
      DO 20 M=1,NR
      DO 20 IQ=1,NQ
      NQC1=NQS(M,IQ)
      IF (NQC1.NE.0) CALL INTER(M,IQ)
   20 CONTINUE
C   MAIN LOOP OF PROGRAM
      DO 60 I=1,NRC
      NZQR=0
      DO 15 J=1,NF
      XLE(J)=0.D0
   15 CONTINUE
      CAP2=0.0
      DO 40 M=1,NR
      NZQS=0
      XR1(1)=RX(M,1)
      XR1(2)=RY(M,1)
      XR1(3)=RZ(M,1)
      NLIM=NRSM1(M)+1
      DO 41 N=2,NLIM
      XR2(1)=RX(M,N)
      XR2(2)=RY(M,N)
      XR2(3)=RZ(M,N)
      GAM = GAMA(I,M)
      ZZQ=0.D0
      CALL GEOMRY(XRC(I),YRC(I),ZRC(I),XR1,XR2,IERR,M,GAM)
      IF(IERR.EQ.3)GO TO 66
      IF(IERR.EQ.4)GO TO 60
      IF(BLEV(I).LE.0.D0)GOTO977
      IF(ZZQ.LE.0.D0)GOTO977
      ZQ=DLOG10(ZZQ)*1.D1+1.D2
      IF(ZQ.LT.BLEV(I)-5.D0)GOTO977
      NZQS=NZQS+1
      IF(NZQS.EQ.1)NZQR=NZQR+1
      NZQ1(NZQR)=M
      NZQ2(NZQR,NZQS)=N-1
      ALZQ(NZQR,NZQS)=ZQ
977   CONTINUE
      CALL REPLCE(XR2,XR1)
41    CONTINUE
      IF(NZQS.NE.0)NNZQS(NZQR)=NZQS
   40 CONTINUE
```

MAIN PROGRAM LISTING (Continued)

```
      SIGL=4.35*DSQRT(DLOG(1.0+CAP2/XLE(1)**2))
      DO 55 J=1,NF
      XLE(J)=1.D2+1.D1*DLOG10(XLE(J))
   55 CONTINUE
C  COMPUTE SUM OF ALL OCTAVE BAND LEVELS
      XAL = 0.
      IF (NF.LT.2) GO TO 154
      DO 53 J=2,NF
53    XAL = XAL + 10. ** (XLE(J)/10.)
      XAL = 10. * DLOG10(XAL)
154   IF (I.NE.1) WRITE(IOUT,1006)
  155 IF (METOUT.EQ.0) WRITE(IOUT,1004)I,XRC(I),YRC(I),ZRC(I)
     1, (TRC(ID,I),ID=1,5)
      IF (METOUT.EQ.1) WRITE(IOUT,1004)I,TXRC(I),TYRC(I),TZRC(I)
     1, (TRC(ID,I),ID=1,5)
  156 IF(NF.EQ.1) GO TO 56
      WRITE(IOUT,2010)
      WRITE(IOUT,2001)
      WRITE(IOUT,2002) (XLE(II),II=2,NF)
56    XL50=XLE(1)-SIGL**2/8.7
      XL10=XL50+1.28*SIGL
      XL90=XL50-1.28*SIGL
      WRITE(IOUT,2003)
      WRITE(IOUT,2004)XLE(1),XAL,XL90,XL50,XL10,SIGL
      IF(BLEV(I).GT.0.D0.AND.NZQR.EQ.0)WRITE(IOUT,782)BLEV(I)
782   FORMAT('0NO ROADWAY SEGMENTS EXCEED CRITERION LEVEL OF',F7.1,
     1'  DB')
      IF(NZQR.EQ.0)GOTO60
      WRITE(IOUT,783)BLEV(I)
783   FORMAT('0ROADWAY SEGMENT SOUND LEVEL CONTRIBUTIONS EXCEEDING',
     1' CRITERION LEVEL OF',F7.1,'  DB')
      WRITE(IOUT,778)
778   FORMAT(' ROADWAY',T11,'SEGMENT'/)
      DO779MRR=1,NZQR
      NZQS=NNZQS(MRR)
      WRITE(IOUT,780)NZQ1(MRR),(NZQ2(MRR,MRS),MRS=1,NZQS)
780   FORMAT(1X,I4,T10,10I5/)
      WRITE(IOUT,781)(AIZQ(MRR,MRS),MRS=1,NZQS)
781   FORMAT(T11,10F5.1/)
779   CONTINUE
   60 CONTINUE
      GO TO 5
   66 WRITE(IOUT,1009)I,M,N
      GO TO 5
999   STOP
1001  FORMAT(1H1)
1002  FORMAT(80A1)
1003  FORMAT(11H RECEIVER  10X,3HXRC9X,3HYRC9X,3HZRC)
1004  FORMAT(4X,I3,5X,3F12.1,5X,5A8)
1005  FORMAT(80A1)
1006  FORMAT(11H1RECEIVER  10X,3HXRC9X,3HYRC9X,3HZRC)
1009  FORMAT(26H TOO MANY REFLECTIONS,RCV ,I2,4H  R ,I2,4H  S ,I2)
2001  FORMAT( 14X,2H635X,3H1254X,3H2504X,3H5003X,4H10003X,4H20003X,
     X 4H40003X,4H8000)
2002  FORMAT(10X,8F7.1)
2003  FORMAT(/11X,5HLE(A),2X,7HLEOB(A),3X,3HL90,5X,3HL50,5X,3HL10,
     X       4X,5HSIGMA)
2004  FORMAT(8X,6F8.1//)
2009  FORMAT(1H1,5X,'TRAFFIC NOISE PREDICTION (INPUT UNITS: ',2A4,
     1          ',OUTPUT UNITS: ',2A4,')'//)
2010  FORMAT(/25X,22HOCTAVE BAND LEVELS (A))
      END
```

MAIN PROGRAM LISTING (Concluded)

APPENDIX E
SUBPROGRAM DESCRIPTIONS

This appendix contains the descriptions of the thirty-four (34) subprograms utilized by the prediction code to estimate highway traffic sound level estimates. The code utilizes 20 Subroutine subprograms and 14 Function subprograms. Each subprogram is described as an independent block of text using a standardized format.

For each subprogram the following format is used to describe the subprogram:

PURPOSE: The purpose of the subprogram is described
SUBPROGRAMS USED: The subprograms used by the subprogram are listed
VARIABLES: The variables used by the subprogram are described in sequence: Input parameters, subprogram parameters, output parameters
RESTRICTIONS: Any restrictions that should be recognized by the user are described
ACCURACY: The accuracy of the subprogram is described (if appropriate)
SIZE: The compiled size of the subprogram is given in bytes
REFERENCES: Any appropriate references are listed
FIGURES: Any figures required to understand the subroutine are presented
LISTING: The subprogram is listed.

E.1 SUBROUTINE INPUT

PURPOSE: Performs all inputs to the program, except for the title cards which are read in from MAIN. All input data are stored in common blocks and listed.

SUBROUTINES USED: None

VARIABLES: Input Parameters

METIN - Option flag indicating units of input.
METOUT - Option flag indicating units of output.

Subroutine Parameters

NQ4 - A flag to indicate the existence of type 4 vehicles.
VALUE - Initialization parameter.
IDN - Index for program initialization parameter.
ILAST - Indicator for last card of a group of data.
ALPHA(I) - Optional alphanumeric information provided by user.
I - Index.
BLNK - Alphanumeric constant "ƀ ƀ"
ALP1(I,IDN) - Default initialization parameters description.
LAST - Alphanumeric constant "L".
IGO - Index for data blocks.
I1 - Number of items in data block.
I2 - Dummy variable
VEH - Number of vehicles per hour.
XMH - Speed in mph for the group of vehicles in question.
XKH - Speed in kph for the group of vehicles in question.
ITY - Vehicle type.
J - Index.
K - Index.
NSEC - Section number.
NQC1 - Vehicle group number within one vehicle type and one roadway.

SUBROUTINE INPUT (Continued)

XKPH(I,J,K)	- Vehicle speed in kph per group per vehicle type per roadway.
TRX(J,NSEC) TRY(J,NSEC) TRZ(J,NSEC)	- Coordinates for the endpoints of roadway sections in metric.
TBX(J,NSEC) TBY(J,NSEC) TBZ(J,NSEC)	- Coordinates for the endpoints of barrier sections in metric.
TXXG1(I,J) TYYG1(I,J) TZZG1(I,J)	- Coordinates for the endpoints of ground strips in metric.
IERR	- Error flag for ALPHA input.
M5	- Indicator for receiver input.
M6	- Indicator for ALPHA input.
IMOD(I,J)	- Array indicating presence of ALPHA data.
GAM	- ALPHA value.
IR	- Roadway number
IRC	- Receiver number
IR1 IR2	- Indexes.
L	- Index.
VTEMP(NQC1)	- Number of vehicles per hour.
IDM	- Type of ground strip.
IFIRST	-
TC1 TSO	- Spectron for sound level and standard deviation for type 4 vehicle, in metric.
IA	- Alphanumeric constant 'A'.
IR	- Alphanumeric constant 'R'.
IG	- Alphanumeric constant 'G'.
IT	- Alphanumeric constant 'T'.
IRDUM	- Dummy variable.
TRDIN(IDN)	- Array for storing initialization parameters in metric.
XNIGHT	- Equivalent to RNIN(1), receiver height adjustment.

SUBROUTINE INPUT (Continued)

Output Parameters

NR	- Number of roadways.
NQ	- Number of vehicle types.
NRSM1(J)	- Number of sections for 1 roadway.
RDIN(IDN)	- Array for storing initialization parameters.
RX(J,NSEC) RY(J,NSEC) RZ(J,NSEC)	- Coordinates for the endpoints of roadway sections in feet.
C0(I,4), C1 S0(I,4)	- User defined spectra for sound level and standard deviation for type 4 vehicle.
NQS(J,ITY)	- Number of vehicle groups per vehicle type per roadway.
VEXPH(I,J,K)	- Number of vehicles per type per hour
XMPH(I,J,K)	- Vehicle speed in mph per group per vehicle type per roadway.
NB	- Number of barriers.
NBSM1(J)	- Number of sections for 1 barrier.
IBLAST(J)	- Barrier type.
BX(J,NSEC) BY(J,NSEC) BZ(J,NSEC)	- Coordinates for the endpoint of barrier sections in feet.
NG	- Number of ground strips.
XXG1(I,J) YYG1(I,J) ZZG1(I,J)	- Coordinates for the endpoints of ground strips in feet.
BGS(I)	- Width of absorptive ground strip.
IDUM(I)	- Type of absorptive ground strip.
GAMMA(I,J)	- ALPHA array.
ID	- Index for 40 character description.
TRD(ID,J)	- 40 character description of roadway #J.
TRS(ID,J,NSEC)	40 character description of roadway #J segment #NSEC.
TB(ID,J)	- 40 character description of barrier #J.
TG(ID,I)	- 40 character description of groundstrip #I.
TRC(ID,I)	- 40 character description of receiver #I.

SUBROUTINE INPUT (Continued)

IGOO(J,NSEC) - Parameter indicating whether upgrade or not. (IGOO = 1 upgrade, IGOO = level or downgrade).
BLEV(I) - Criteria on level of receiver #I.
NRC - Number of receivers.
XRC(I)
YRC(I) } - Receivers coordinates
ZRC(I)

RESTRICTIONS: Input vehicle speed should be within the range of 30-65 mph (or 50-105 kph). Speed less than 30 mph (or 50 kph) will be adjusted by the program to 30 (or 50). Speed over 65 mph (or 105 kph) will be adjusted to 65 (or 105). If data for type 4 vehicle is provided, the number of vehicle types is 4, otherwise, it is defaulted to 3. If the user desires to allow speed dependence for user-defined type 4 vehicle, the comment cards from card #21000-22800 in the program listing should be removed. This data would be entered in the program initialization parameter data block. See Sections 3.2, 6.0, and Appendix A, Section A.2.

SIZE: 39378

REFERENCES: None

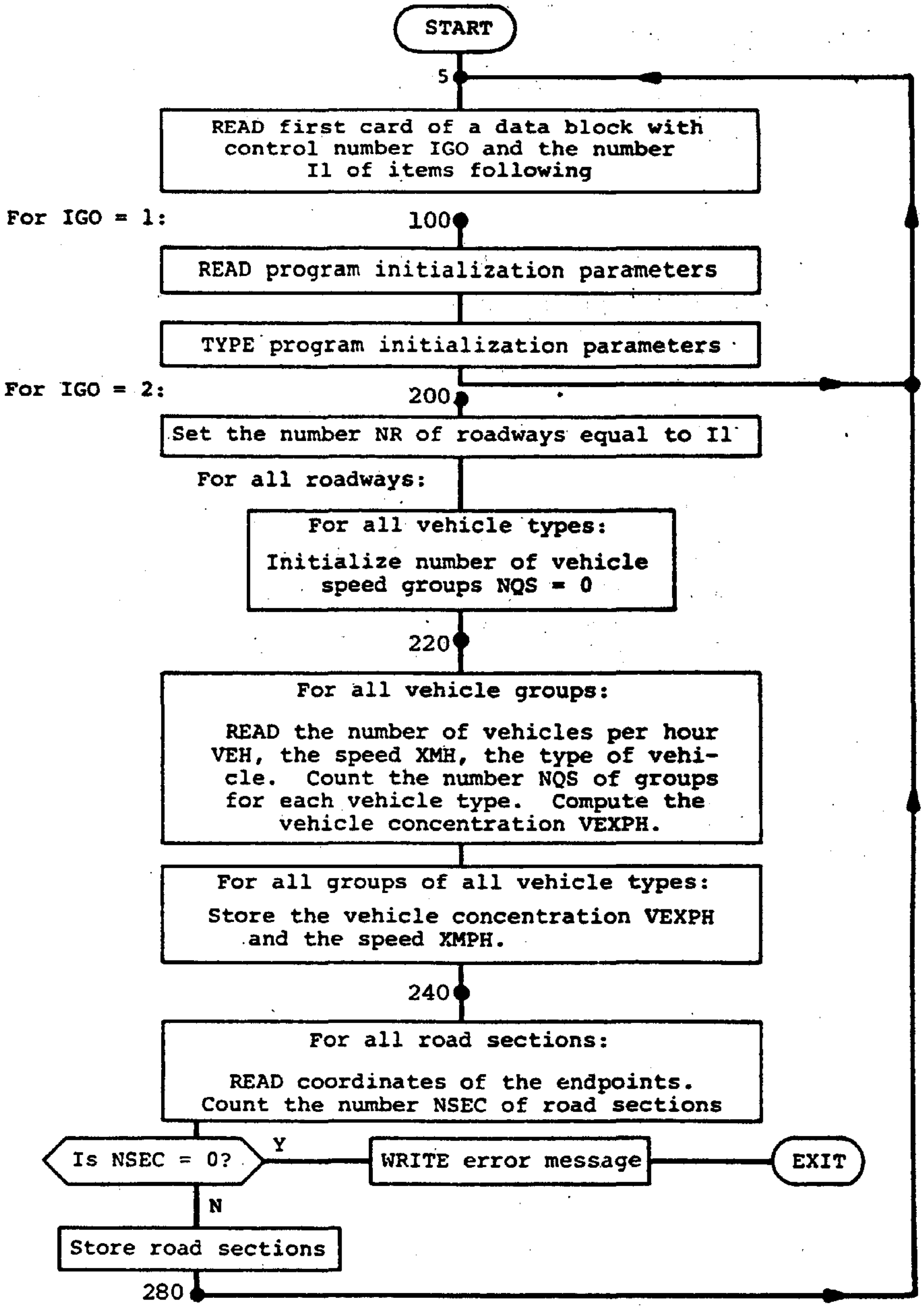


FIGURE E-1. SUBROUTINE INPUT: FLOW DIAGRAM

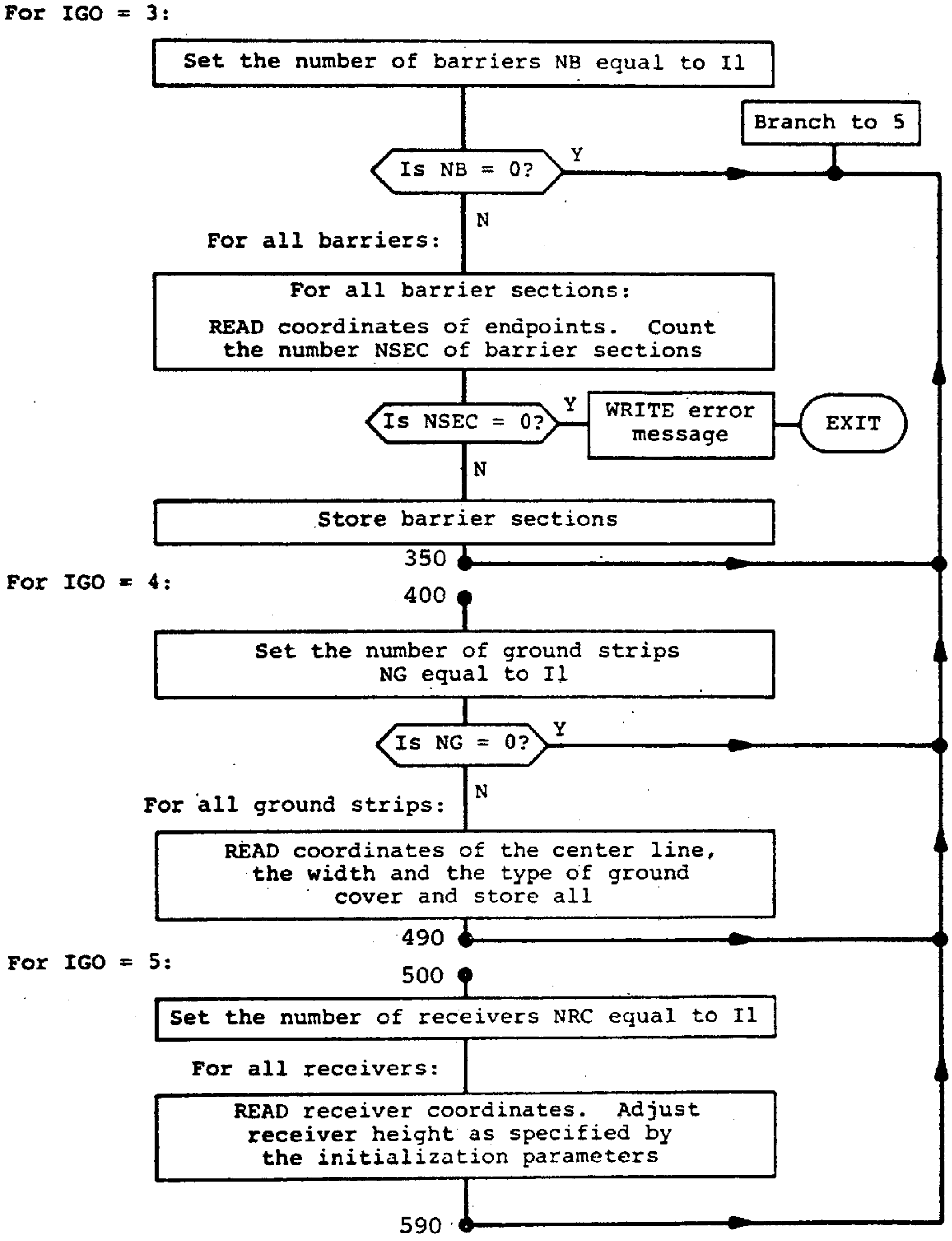


FIGURE E-1. (Continued)

FOR IGO = 6:

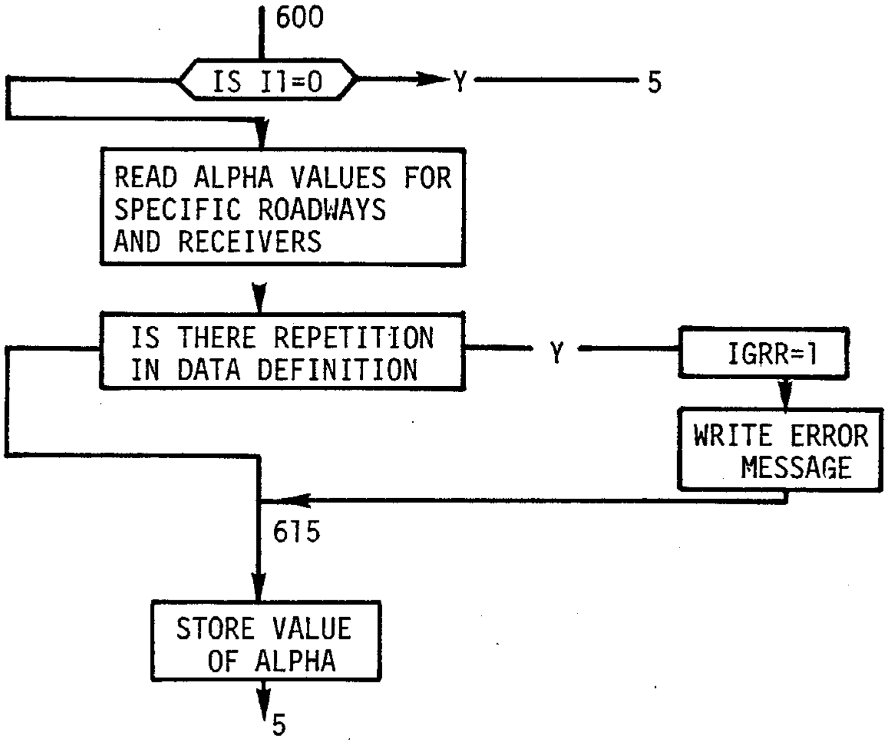


FIGURE E-1. (Continued)

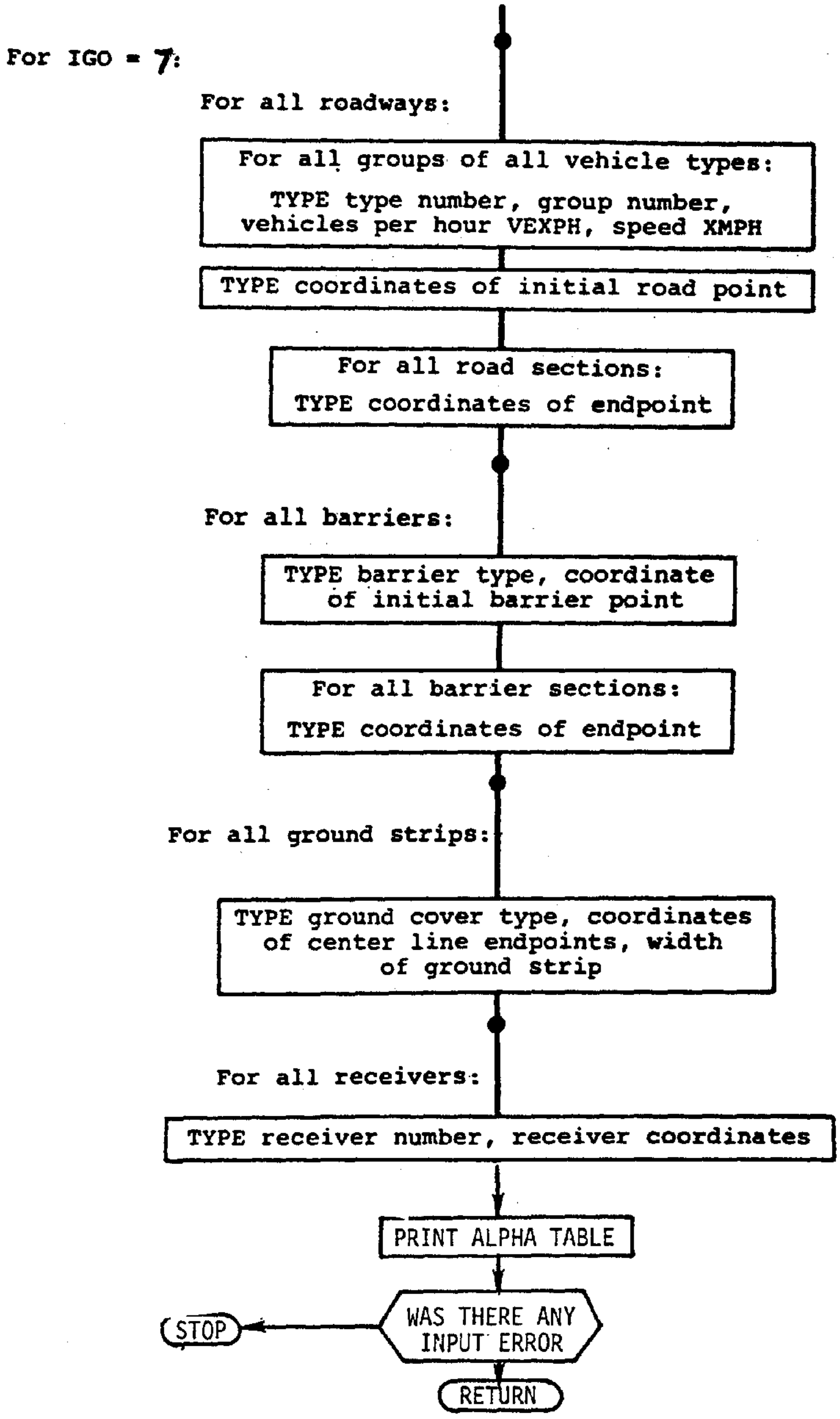


FIGURE E-1. (Concluded)

```
C  INPUT          02/79   SAI MOD
      SUBROUTINE INPUT
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER ALPHA(25),ALP1(14,6),BLNK
      DIMENSION VTEMP(5),IRC(15),IMOD(15,20)
      DIMENSION TBX(20,11),TBY(20,11),TBZ(20,11)
      DIMENSION TXXG1(10,2),TYYG1(10,2),TZZG1(10,2),TBGS(10)
      DIMENSION TRX(20,11),TRY(20,11),TRZ(20,11)
      DIMENSION TCO(9)
      DIMENSION XKPH(20,5,4)
      COMMON/DRIV2/NQS(20,4),NF
      COMMON/STORE1/BX(20,11),BY(20,11),BZ(20,11),IBLAST(20),NBSM1(20)
      COMMON/STORE2/XXG1(10,2),YYG1(10,2),ZZG1(10,2),BGS(10),IDUM(10)
      COMMON/STORE3/RX(20,11),RY(20,11),RZ(20,11),NRSM1(20)
      COMMON/STORE4/XMPH(20,5,4),VEXPH(20,5,4)
      COMMON/INOU/INPT,IOUT
      COMMON/BLK2/NQ
      COMMON /INPT1/RDIN(6),TRDIN(6)
      COMMON/INPT2/NR,NB,NG
      COMMON/INPT3/XRC(15),YRC(15),ZRC(15),NRC
      COMMON/INPT4/TXRC(15),TYRC(15),TZRC(15)
      COMMON /CONSTS/CO(9,4),C1(9,4),SO(9,4)
      COMMON /OPTION/METIN,METOUT,IREFL
      COMMON /TABLE/GAMA(15,20),IFIRST
      COMMON/TIT1/TRC(5,15),BLEV(15),ZZQ,IGCO(20,11),N
      DIMENSIONTRD(5,20),TRS(5,20,11),TB(5,20),TG(5,10)
      EQUIVALENCE (RDIN(1),XNIGHT)
      DATA ALP1 /'RECE','IVER',' HEI','GHT ','ADJU','STME','NT  ',
     A            '    ','    ','    ','    ','    ','    ','    ',
     2            'NUMB','ER O','F FR','EQUE','NCY ','BAND','S   ',
     B            '    ','    ','    ','    ','    ','    ','    ',
     3            'HEIG','HT A','DJUS','TMEN','T FO','R PA','SSEN',
     C            'GER ','CARS',' (TY','PE 1',' VEH','ICLE','S)  ',
     4            'HEIG','HT A','DJUS','TMEN','T FO','R HE','AVY ',
     D            'TRUC','KS  ',' (TY','PE 2',' VEH','ICLE','S)  ',
     5            'HEIG','HT A','DJUS','TMEN','T FO','R ME','DIUM',
     E            ' TRU','CKS ',' (TY','PE 3',' VEH','ICLE','S)  ',
     6            'HEIG','HT A','DJUS','TMEN','T FO','R NE','W VE',
     F            'HICL','ES  ',' (TY','PE 4',' VEH','ICLE','S)  '/
      DATA   IA/2HA /,IG/2HG /
      DATA   IR/2HR /
      DATA   IT/2HT /
      DATA LAST/2HL /
      DATA BLNK/2H  /
      M5 = 0
      M6 = 0
    5 READ(INPT,1000)IGO,I1,I2
      GO TO(100,200,300,400,500,600,700),IGO
C GARBAGE DATA....PROGRAM INITIALIZATION PARAMETERS
  100 WRITE(IOUT,2000)
      NQ4 = 0
      DO 110 I=1,6
 110  RDIN(I) = 0.0
 120  READ(INPT,1001) VALUE,IDN,ILAST,(ALPHA(I),I=1,25)
      RDIN(IDN)=VALUE
      TRDIN(IDN) = VALUE
      IF (IDN.EQ.2) GO TO 130
      IF (METIN.EQ.0) TRDIN(IDN)=VALUE*0.3048
      IF (METIN.EQ.1)  RDIN(IDN)=VALUE*3.28083
      IF (IDN.EQ.6) NQ4=1
      IF (METOUT.EQ.0) VALUE= RDIN(IDN)
      IF (METOUT.EQ.1) VALUE=TRDIN(IDN)
 130  DO 140 I=1,25
```

SUBROUTINE INPUT: LISTING

```
      IF(ALPHA(I).NE.BLNK) GO TO 150
 140  CONTINUE
      WRITE(IOUT,2016) VALUE,IDN,(ALP1(I,IDN),I=1,14)
      GO TO 160
 150  WRITE(IOUT,2001) VALUE,IDN,(ALPHA(I),I=1,25)
 160  IF(ILAST.NE.LAST) GO TO 120
      IF (NQ4.EQ.0) GO TO 5
      NQ = 4
      DO 165 I =1,9
 165  C1(I,4) = 0.0
      IF (METIN.EQ.1) GO TO 180
      READ(INPT,1006) (C0(I,4),I=1,9),(S0(I,4),I=1,9)
C    1               ,(C1(I,4),I=1,9)
      DO 170 I=1,9
      TC0(I) = C0(I,4) - C1(I,4)*DLOG10(1.60934D0)
  170 CONTINUE
      GO TO 195
  180 READ (INPT,1006) (TC0(I),I=1,9),(S0(I,4),I=1,9)
C    1                ,(C1(I,4),I=1,9)
      DO 190 I=1,9
      C0(I,4) = TC0(I) - C1(I,4)*DLOG10(0.62137D0)
  190 CONTINUE
C
  195 IF (METOUT.EQ.0) WRITE(IOUT,2015) (C0(I,4),I=1,9),(S0(I,4),I=1,9)
C    1                                  ,(C1(I,4),I=1,9)
      IF (METOUT.EQ.1) WRITE(IOUT,2015) (TC0(I),I=1,9),(S0(I,4),I=1,9)
C    1                                  (C1(I,4),I=1,9)
      GO TO 5
C
C
C VEHICLE DATA
C
 200  NR=I1
      DO 280 J=1,NR
      NSEC=1
      DO 210 K=1,NQ
 210  NQS(J,K)=0
 220  IF (METIN.EQ.1) GO TO 224
C  ENGLISH INPUT
      READ(INPT,1002) VEH,XMH,ITY,ILAST
     1,(TRD(ID,J),ID=1,5)
      IF (XMH.GE.30.) GO TO 222
      XMH=30.
      WRITE(IOUT,2020)
       GO TO 230
 222  IF (XMH.LE.65.) GO TO 230
      XMH=65.
      WRITE(IOUT,2030)
      GO TO 230
C  METRIC INPUT
 224  READ (INPT,1002) VEH,XKH,ITY,ILAST
     1,(TRD(ID,J),ID=1,5)
      IF (XKH.GE.50.) GO TO 226
      XKH = 50.0
      WRITE (IOUT,3020)
      GO TO 230
 226  IF (XKH.LE.105.) GO TO 230
      XKH = 105.0
      WRITE (IOUT,3030)
 230  IF (METIN.EQ.0) XKH=XMH*1.60934
      IF (METIN.EQ.1) XMH=XKH*0.621371
      NQS(J,ITY)=NQS(J,ITY)+1
      NQC1=NQS(J,ITY)
```

SUBROUTINE INPUT: LISTING (Continued)

```
      VEXPH(J,NQC1,ITY) =VEH/XMH/5280.
      XMPH(J,NQC1,ITY)=XMH
      XKPH(J,NQC1,ITY)=XKH
      IF(ILAST.NE.LAST) GO TO 220
C ROADWAY DATA SECTIONS
 240  IF (METIN.EQ.1) GO TO 242
      READ(INPT,1010)RX(J,NSEC),RY(J,NSEC),RZ(J,NSEC),ILAST
     1,IGOO(J,NSEC),(TRS(ID,J,NSEC),ID=1,5)
      TRX(J,NSEC) = RX(J,NSEC) * 0.3048
      TRY(J,NSEC) = RY(J,NSEC) * 0.3048
      TRZ(J,NSEC) = RZ(J,NSEC) * 0.3048
      GO TO 246
 242  READ (INPT,1010) TRX(J,NSEC),TRY(J,NSEC),TRZ(J,NSEC),ILAST
     1,IGOO(J,NSEC),(TRS(ID,J,NSEC),ID=1,5)
      RX(J,NSEC) = TRX(J,NSEC) * 3.28083
      RY(J,NSEC) = TRY(J,NSEC) * 3.28083
      RZ(J,NSEC) = TRZ(J,NSEC) * 3.28083
 246  IF(ILAST.EQ.LAST) GO TO 250
      NSEC=NSEC+1
      GO TO 240
 250  IF(NSEC-1.NE.0) GO TO 260
      WRITE(IOUT,2010)
      CALL EXIT
 260  NBSM1(J)=NSEC-1
 280  CONTINUE
      GO TO 5
C
C BARRIER DATA SECTIONS
C
 300  NB=I1
      IF(NB.EQ.0)GO TO 5
      DO 350 J=1,NB
      NSEC=1
 310  IF (METIN.EQ.1) GO TO 315
      READ(INPT,1003)BX(J,NSEC),BY(J,NSEC),BZ(J,NSEC),IBLAST(J)
     1,(TB(ID,J),ID=1,5)
      TBX(J,NSEC) = BX(J,NSEC) * 0.3048
      TBY(J,NSEC) = BY(J,NSEC) * 0.3048
      TBZ(J,NSEC) = BZ(J,NSEC) * 0.3048
      GO TO 317
 315  READ (INPT,1003) TBX(J,NSEC),TBY(J,NSEC),TBZ(J,NSEC),IBLAST(J)
     1,(TB(ID,J),ID=1,5)
      BX(J,NSEC) = TBX(J,NSEC) * 3.28083
      BY(J,NSEC) = TBY(J,NSEC) * 3.28083
      BZ(J,NSEC) = TBZ(J,NSEC) * 3.28083
 317  IF(IBLAST(J).EQ.IA.OR.IBLAST(J).EQ.IB)GO TO 320
      NSEC=NSEC+1
      GO TO 310
 320  IF(NSEC-1.NE.0) GO TO 330
      WRITE(IOUT,2011)
      CALL EXIT
 330  NBSM1(J)=NSEC-1
 350  CONTINUE
      GO TO 5
C ABSORBING GROUND STRIPS
 400  NG=I1
      IF(NG.EQ.0)GO TO 5
      DO 490 I=1,NG
      IF (METIN.EQ.1) GO TO 450
      READ(INPT,1004)XXG1(I,1),YYG1(I,1),ZZG1(I,1),BGS(I)
      TXXG1(I,1) = XXG1(I,1) * 0.3048
      TYYG1(I,1) = YYG1(I,1) * 0.3048
```

SUBROUTINE INPUT: LISTING (Continued)

```
      TZZG1(I,1) = ZZG1(I,1) * 0.3048
      TBGS(I) = BGS(I) * 0.3048
      READ(INPT,1003)XXG1(I,2),YYG1(I,2),ZZG1(I,2),IDUM(I)
     1,(TG(ID,I),ID=1,5)
      TXXG1(I,2) = XXG1(I,2) * 0.3048
      TYYG1(I,2) = YYG1(I,2) * 0.3048
      TZZG1(I,2) = ZZG1(I,2) * 0.3048
      GO TO 480
 450  READ (INPT,1004) TXXG1(I,1),TYYG1(I,1),TZZG1(I,1),TBGS(I)
      XXG1(I,1) = TXXG1(I,1) * 3.28083
      YYG1(I,1) = TYYG1(I,1) * 3.28083
      ZZG1(I,1) = TZZG1(I,1) * 3.28083
      BGS(I) = TBGS(I) * 3.28083
      READ (INPT,1003) TXXG1(I,2),TYYG1(I,2),TZZG1(I,2),IDUM(I)
     1,(TG(ID,I),ID=1,5)
      XXG1(I,2) = TXXG1(I,2) * 3.28083
      YYG1(I,2) = TYYG1(I,2) * 3.28083
      ZZG1(I,2) = TZZG1(I,2) * 3.28083
 480  IF(IDUM(I).EQ.IG) IDUM(I)=1
      IF(IDUM(I).EQ.IT) IDUM(I)=2
 490  CONTINUE
      GO TO 5
C RECEIVER DATA
 500  NRC=I1
      M5 = 1
      DO 590 I=1,NRC
      IF (METIN.EQ.1) GO TO 550
      READ(INPT,1011)XRC(I),YRC(I),ZRC(I),IRDUM
     1,BLEV(I),(TRC(ID,I),ID=1,5)
      TXRC(I) = XRC(I) * 0.3048
      TYRC(I) = YRC(I) * 0.3048
      TZRC(I) = ZRC(I) * 0.3048
      GO TO 580
 550  READ (INPT,1011) TXRC(I),TYRC(I),TZRC(I),IRDUM
     1,BLEV(I),(TRC(ID,I),ID=1,5)
      XRC(I) = TXRC(I) * 3.28083
      YRC(I) = TYRC(I) * 3.28083
      ZRC(I) = TZRC(I) * 3.28083
 580  ZRC(I)=ZRC(I)+XNIGHT
      TZRC(I) = TZRC(I) + TRDIN(1)
 590  CONTINUE
      GO TO 5
C
C  GAMMA DATA
C
 600  IF (I1.EQ.0) GO TO 5
      IERR = 0
      M6 = 1
      DO 605 J=1,20
      DO 605 I=1,15
 605  IMOD(I,J) = 0
      DO 690 I=1,I1
      READ (INPT,2050) GAM,IRX,IRC
      IR1 = 1
      IR2 = NR
      IF (IRX.EQ.0) GO TO 610
      IR1 = IRX
      IR2 = IRX
 610  DO 630 J=IR1,IR2
      DO 620 K=1,15
      L = IRC(K)
      IF (L.EQ.0) GO TO 630
      IF (IMOD(L,J).EQ.0) GO TO 615
```

SUBROUTINE INPUT: LISTING (Continued)

```
      IERR = 1
      WRITE (IOUT,2060) L,J
  615 IMOD(L,J) = 1
      GAMA(L,J) = GAM
  620 CONTINUE
  630 CONTINUE
  690 CONTINUE
      GO TO 5
C
C  PRINT INPUT DATA
C
  700 DO 720 J=1,NR
      WRITE(IOUT,2002)J
     1,(TRD(ID,J),ID=1,5)
      DO 710 K=1,NQ
      NQC1=NQS(J,K)
      IF(NQC1.EQ.0) GO TO 710
      DO 705 I=1,NQC1
  705 VTEMP(I)=VEXPH(J,I,K)*XMPH(J,I,K)*5280.
      IF(METOUT.EQ.0)WRITE(IOUT,2004)K,(I,VTEMP(I),XMPH(J,I,K),I=1,NQC1)
      IF(METOUT.EQ.1)WRITE(IOUT,3004)K,(I,VTEMP(I),XKPH(J,I,K),I=1,NQC1)
  710 CONTINUE
      IF(METOUT.EQ.0)WRITE(IOUT,2005)RX(J,1),RY(J,1),RZ(J,1)
     1,IGOO(J,1),(TRS(ID,J,1),ID=1,5)
      IF(METOUT.EQ.1)WRITE(IOUT,3005)TRX(J,1),TRY(J,1),TRZ(J,1)
     1,IGOO(J,1),(TRS(ID,J,1),ID=1,5)
      NSEC=NRSM1(J)+1
      DO 715 I=2,NSEC
      IF(METOUT.EQ.0)WRITE(IOUT,2006)I,RX(J,I),RY(J,I),RZ(J,I)
     1,IGOO(J,I),(TRS(ID,J,I),ID=1,5)
      IF(METOUT.EQ.1)WRITE(IOUT,2006)I,TRX(J,I),TRY(J,I),TRZ(J,I)
     1,IGOO(J,I),(TRS(ID,J,I),ID=1,5)
  715 CONTINUE
  720 CONTINUE
      IF(NB.EQ.0)GO TO 735
      DO 730 J=1,NB
      IF(METOUT.EQ.0)WRITE(IOUT,2007)J,IBLAST(J),BX(J,1),BY(J,1),BZ(J,1)
     1,(TB(ID,J),ID=1,5)
      IF(METOUT.EQ.1)WRITE(IOUT,3007)J,IBLAST(J),TBX(J,1),TBY(J,1),
     1                                      TBZ(J,1)
     1,(TB(ID,J),ID=1,5)
      NSEC = NBSM1(J) + 1
      DO 725 I=2,NSEC
      IF(METOUT.EQ.0)WRITE(IOUT,2006)I,BX(J,I),BY(J,I),BZ(J,I)
      IF(METOUT.EQ.1)WRITE(IOUT,2006)I,TBX(J,I),TBY(J,I),TBZ(J,I)
  725 CONTINUE
  730 CONTINUE
  735 IF(NG.EQ.0) GO TO 745
      DO 740 I=1,NG
      IF(IDUM(I).EQ.1)IDM=IG
      IF(IDUM(I).EQ.2)IDM=IT
      IF (METOUT.EQ.0)
     1   WRITE(IOUT,2012)I,IDM,XXG1(I,1),YYG1(I,1),ZZG1(I,1),
     2   BGS(I),XXG1(I,2),YYG1(I,2),ZZG1(I,2)
     1,(TG(ID,I),ID=1,5)
      IF (METOUT.EQ.1)
     1   WRITE(IOUT,2012)I,IDM,TXXG1(I,1),TYYG1(I,1),TZZG1(I,1),
     2   TBGS(I),TXXG1(I,2),TYYG1(I,2),TZZG1(I,2)
     1,(TG(ID,I),ID=1,5)
  740 CONTINUE
  745 IF(METOUT.EQ.0)WRITE(IOUT,2008)
      IF(METOUT.EQ.1)WRITE(IOUT,3008)
```

SUBROUTINE INPUT: LISTING (Continued)

```
       DO 750 I=1,NRC
       IF(METOUT.EQ.0) WRITE(IOUT,2051)I,XRC(I),YRC(I),ZRC(I)
      1,BLEV(I),(TRC(ID,I),ID=1,5)
       IF(METOUT.EQ.1) WRITE(IOUT,2051)I,TXRC(I),TYRC(I),TZRC(I)
      1,BLEV(I),(TRC(ID,I),ID=1,5)
  750  CONTINUE
C  PRINT ALPHA TABLE
       WRITE(IOUT,4000)(I,I=1,NR)
       WRITE(IOUT,4002)
       DO 760 J=1,NRC
  760  WRITE(IOUT,4001)J,(GAMA(J,I),I=1,NR)
C  TEST FOR PRESENCE OF ERROR DURING GAMMA INPUT
       IF (IERR.EQ.1) STOP
C  CHECK FOR RECEIVER DEFINITION CHANGES
       IF (IFIRST.EQ.1) GO TO 770
       IFIRST = 1
       RETURN
  770  IF (M5.EQ.0.OR.M6.EQ.1) RETURN
       WRITE (IOUT,2070)
       STOP
  1000 FORMAT(3I5)
  1001 FORMAT(E10.0,I5,4X,A1,10X,25A2)
  1002 FORMAT(2E10.0,I5,5X,A1,9X,5A8)
  1003 FORMAT(3E10.0,A1,9X,5A8)
  1004 FORMAT(4E10.0)
  1006 FORMAT(9E5.0)
 1010  FORMAT(3E10.0,A1,1X,I1,7X,5A8)
 1011  FORMAT(3E10.0,A1,1X,F5.0,3X,5A8)
  2000 FORMAT(34H0PROGRAM INITIALIZATION PARAMETERS)
  2001 FORMAT(1X,1PE12.5,I10,5X,25A2)
  2002 FORMAT(10H ROADWAY  ,I3,5X,5A8)
  2004 FORMAT(10H NUMBER OF13X,5HVEH/H8X,3HMPH/5H TYPE,I2,4H VEH/(3X,I2
      1,15X,1P2E13.4))
  3004 FORMAT(10H NUMBER OF13X,5HVEH/H8X,4HKMPH/5H TYPE,I2,4H VEH/(3X,I2
      1,15X,1P2E13.4))
  2005 FORMAT(22X,18HSOURCE COORD IN FT/
      17H NUMBER,5X,1HX12X,1HY12X,1HZ,9X,'GRADE',3X,'COMMENTS'/
      14X,1H1,2X,1P3E13.4,I5,5X,5A8)
  3005 FORMAT(22X,18HSOURCE COORD IN M /
      17H NUMBER,5X,1HX12X,1HY12X,1HZ,9X,'GRADE',3X,'COMMENTS'/
      14X,1H1,2X,1P3E13.4,I5,5X,5A8)
  2006 FORMAT(3X,I2,2X,1P3E13.4,I5,5X,5A8)
  2007 FORMAT(10H BARRIER  I3,2X,1H(A1,1H),4X,19HBARRIER COORD IN FT/
      1          7H NUMBER,5X,1HX12X,1HY12X,1HZ/4X,1H1,2X,1P3E13.4,5X,5A8)
  3007 FORMAT(10H BARRIER  I3,2X,1H(A1,1H),4X,19HBARRIER COORD IN M /
      1          7H NUMBER,5X,1HX12X,1HY12X,1HZ/4X,1H1,2X,1P3E13.4,5X,5A8)
  2008 FORMAT(9H RECEIVER13X,20HRECEIVER COORD IN FT/7H NUMBER5X,1HX12X,
      1'Y',12X,1HZ,11X,'IC',6X,'COMMENTS')
  3008 FORMAT(9H RECEIVER14X,20HRECEIVER COORD IN M /7H NUMBER5X,1HX12X,
      1'Y',12X,1HZ,11X,'IC',6X,'COMMENTS')
  2010 FORMAT(27H INSUFFICIENT ROAD SECTIONS)
  2011 FORMAT(30H INSUFFICIENT BARRIER SECTIONS)
  2012 FORMAT(18H ABSORBING STRIP  I3,2X,1H(A1,1H)//5H PT  7X,1HX12X,1HY1
      A2X,1HZ12X,5HWIDTH/4X,1H12X,1P4E13.4/4X,1H22X,1P3E13.4,5X,5A8)
  2015 FORMAT(5X,23HOPTICNAL NOISE SPECTRUM,
      X         (/5X,'CONSTANTS :',9F7.1/5X,'STD. DEV. :',9F7.1))
  2016 FORMAT(1X,1PE12.5,I10,5X,14A4)
  2020 FORMAT('0VEHICLE SPEED SUPPLIED IS LESS THAN 30 MPH. ADJUSTED TO 3
      10.')
  2030 FORMAT('0VEHICLE SPEED SUPPLIED IS GREATER THAN 65 MPH. ADJUSTED T
      1O 65.')
  3020 FORMAT('0VEHICLE SPEED SUPPLIED IS LESS THAN 50 KMPH. ADJUSTED TO
      150.')
```

SUBROUTINE INPUT: LISTING (Continued)

```
 3030 FORMAT('0VEHICLE SPEED SUPPLIED IS GREATER THAN 105 KMPH. ADJUSTED
     1 TO 105.')
 2050 FORMAT(F4.2,16(1X,I2))
2051  FORMAT(3X,I2,2X,1P3E13.4,0PF7.1,5X,5A8)
 2060 FORMAT('0* * INPUT ERROR * *'/'0ALPHA(',I2,',',I2,') HAS BEEN',
     1         ' DEFINED MORE THAN ONCE.')
 2070 FORMAT('0RECEIVER DEFINITION HAS BEEN MODIFIED, BUT NO ',
     1         'CORRESPONDING ALPHA DATA IS SUPPLIED - RUN TERMINATED.')
 4000 FORMAT(1H1,10X,'A L P H A    T A B L E'/'0NRC/NR',20I6)
 4001 FORMAT(1X,I2,5X,20F6.2)
 4002 FORMAT(1H )
      END
```

SUBROUTINE INPUT: LISTING (Concluded)

E.2 SUBROUTINE CHECK (IERR)

PURPOSE: To check for intersection of roadways and barriers or ground strips. If intersection exists, the program would return with an error code and execution would be terminated.

SUBPROGRAMS USED:
KCUT (X1, X2, X3, X4)
REPLCE (X2, X1)

VARIABLES:

Input Parameters

NR - Number of roadways
NRSM1(NR) - Number of roadway segments in each roadway
RX(M,N), RY(M,N) } X,Y coordinates of roadway segments
NB - Number of barriers
NBSM1(NB) - Number of segments in each barrier
BX(IBAR,ISEG), BY(IBAR,ISEG) } X,Y Coordinates of barrier segments
NG - Number of ground strips
XXG1(IGRA,I), XXG2(IGRA,I) } X,Y coordinates of ground strips

Subroutine Parameters

XR1(I) - Point 1 of roadway segment
XR2(I) - Point 2 of roadway segment
XB1(I) - Point 1 of barrier segment
XB2(I) - Point 2 of barrier segment
XG1(I) - Point 1 of ground strip
XG2(I) - Point 2 of ground strip

Output Parameters

IERR - Error code
IERR = 1, if barrier intersects roadway
= 2, if ground strip intersects roadway

SUBROUTINE CHECK (Continued)

RESTRICTION: None

SIZE: 1422

REFERENCE: None

```
C   CHECK        02/78   SAI MOD
      SUBROUTINE CHECK(IERR)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/INOU/INPT,IOUT
      COMMON/STORE1/BX(20,11),BY(20,11),BZ(20,11),IBLAST(20),NBSM1(20)
      COMMON/STORE2/XXG1(10,2),YYG1(10,2),ZZG1(10,2),BGS(10),IDUM(10)
      COMMON/STORE3/RX(20,11),RY(20,11),RZ(20,11),NRSM1(20)
      COMMON/INPT2/NR,NB,NG
      DIMENSION XR1(2),XR2(2)
      DIMENSION XB1(2),XB2(2),XG1(2),XG2(2)
      IERR=0
      DO 40 M=1,NR
      XR1(1) = RX(M,1)
      XR1(2) = RY(M,1)
      NLIM = NRSM1(M) + 1
      DO 40 N=2,NLIM
      XR2(1) = RX(M,N)
      XR2(2) = RY(M,N)
      IF (NB.EQ.0) GO TO 20
      DO 10 IBAR=1,NB
      XB1(1) = BX(IBAR,1)
      XB1(2) = BY(IBAR,1)
      NLBIM = NBSM1(IBAR) + 1
      DO 10 ISEG=2,NLBIM
      XB2(1) = BX(IBAR,ISEG)
      XB2(2) = BY(IBAR,ISEG)
      IF (KCUT(XR1,XR2,XB1,XB2).NE.1) GO TO 5
      WRITE(IOUT,1006)M,N,IBAR,ISEG
      IERR=1
    5 CALL REPLCE(XB2,XB1)
   10 CONTINUE
   20 IF (NG.EQ.0) GO TO 35
      DO 30 IGRA=1,NG
      XG1(1) = XXG1(IGRA,1)
      XG1(2) = YYG1(IGRA,1)
      XG2(1) = XXG1(IGRA,2)
      XG2(2) = YYG1(IGRA,2)
      IF (KCUT(XR1,XR2,XG1,XG2).NE.1) GO TO 30
      WRITE(IOUT,1008)M,N,IGRA
      IERR=2
   30 CONTINUE
   35 CALL REPLCE(XR2,XR1)
   40 CONTINUE
      RETURN
 1006 FORMAT('0ILLEGAL BARRIER INTERSECTS ROADWAY',5X,'R ',I2,2X
     1,3HRS I2,2X,2HB I2,2X,3HBS I2)
 1008 FORMAT('0ILLEGAL GROUND STRIP INTERSECTS ROADWAY',5X,2
     1HR I2,3HRS I2,2X,4HAGS I2)
      END
```

SUBROUTINE CHECK: LISTING

E.3 SUBROUTINE INTER (NR, IQ)

PURPOSE: To determine, by interpolation, vehicle emission and corresponding standard deviation, given a certain roadway, vehicle type and speed.

SUBPROGRAMS USED: BLOCK DATA (Transferred through COMMON/CONSTS/)

VARIABLES: Input Parameters

NR - Roadway number
IQ - Vehicle type number
C0(NF,NQ)
C1(NF,NQ) Constants obtained by non-linear regression, using the following equation:

$$L(V) = C0(IF,IQ) + C1(IF,IQ) * \log (V)$$

where

V = speed at 25, 35, 45, 55 & 65 mph
$L(V)$ = sound level at V

S0(NF,NQ) Standard deviations obtained by similar method as above.

NQS(NR,IQ) - Number of traffic flow conditions
XMPH - Speed at which interpolation is done

Subroutine Parameters

V - Same as XMPH(NR,IQ)
INDEX - Position in arrays where the calculated emission level and the corresponding standard deviation are stored
MULT - Factor to be multiplied to obtain INDEX

SUBROUTINE INTER (NR, IQ) (Continued)

Output Parameters

XLREF(INDEX)- Value of reference acoustic intensity

CQ(INDEX) - Value of reference standard deviation factor

RESTRICTION: The constants for vehicle types 1 - 3 and their standard deviations are provided in the program. If a new type of vehicle is introduced, its corresponding constants and standard deviations must be read in from cards. See Subroutine INPUT.

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

SIZE: 882

```
C   INTER          03/78    SAI MOD
      SUBROUTINE INTER(NR,IQ)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CONSTS/C0(9,4),C1(9,4),S0(9,4)
      COMMON/STORE4/XMPH(20,5,4),VEXPH(20,5,4)
      COMMON/DRIV2/NQS(20,4),NF
      COMMON /INTER1/XLREF(3600),CQ(3600)
      DO 10 IF=1,NF
      CC0 = C0(IF,IQ)
      CC1 = C1(IF,IQ)
      SS0 = S0(IF,IQ)
      MULT = 5 * ((IF-1) + 9*(IQ-1))
      NQQ = NQS(NR,IQ)
      DO 10 I=1,NQQ
      V = XMPH(NR,I,IQ)
      INDEX = NR + 20*((I-1)+MULT)
      XLREF1 = CC0 + CC1*DLOG10(V)
      XLREF(INDEX) = 10. ** ((XLREF1-66.)/10.)
      CQ(INDEX) = DEXP(0.5*(SS0*0.23026)**2)
 10   CONTINUE
      RETURN
      END
```

SUBROUTINE INTER: LISTING

E.4 SUBROUTINE BLOCK DATA

PURPOSE: To provide a data block of coefficients for the interpolation polynomials used by subroutine INTER in calculating the vehicle noise emission characteristics.

SUBPROGRAMS
USED: None

VARIABLES:
CO(NF,NQ) - Constant terms in the vehicle sound level interpolation polynomial for the frequency bands NF and vehicle type NQ.
C1(NF,NQ) - Coefficients of the log term in the vehicle sound level interpolation polynomial
SO(NF,NQ) - Constant terms in the vehicle sound level standard deviation interpolation polynomial for the frequency band NF and the vehicle type NQ.
INPT - Constant specifying the input device to be used by the prediction code (5 denotes a card reader)
IOUT - Constant specifying the input device to be used by the prediction code (6 denotes a line printer)

RESTRICTIONS: The constants CO(NF,NQ), CI(NF,NQ), SO(NF,NQ) are stored as follows:

CO(1,1), CO(2,1),...CO(9,1); CO(1,2),...CO(9,2); CO(1,3),...CO(9,3); etc.

The user should note that all constants relating to the type 4 vehicle (NQ=4) are set to zero unless they are defined by the user upon input.

SIZE: 0

REFERENCES: See Section A.2 of Appendix A, Subroutine INTER and Subroutine INPUT.

```
C  BLOCK DATA   03/78   SAI MOD
      BLOCK DATA
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CONSTS/C0(9,4),C1(9,4),S0(9,4)
      COMMON/INOU/INPT,IOUT
      COMMON /OPTION/METIN,METOUT,IREFL
      COMMON /TABLE/GAMA(15,20),IFIRST
      DATA INPT/5/,IOUT/6/
      DATA METIN/0/,METOUT/0/,IREFL/1/,GAMA/300*0.0/,IFIRST/0/
      DATA C0/4.80,-2.14,-3.17,-13.21,10.84,9.83,-18.26,-7.20,-18.21,
     2 42.62,80.61,56.94,52.77,28.22,22.32,33.08,35.46,34.90,
     3 22.06,44.88,52.39,33.76,11.00,-1.86,-1.19,3.49,15.70,
     4 9*0.0/
      DATA C1/38.05,27.18,32.61,40.76,29.89,32.61,48.92,38.05,40.76,
     2 24.56,-12.92,6.19,12.56,28.70,33.60,25.59,20.61,15.50,
     3 33.91,5.48,6.90,21.12,36.18,44.67,43.93,36.54,24.77,
     4 9*0.0/
      DATA S0/9*2.5,
     2 2.84,5.20,3.73,4.45,3.82,3.44,3.11,3.42,3.89,
     3 3.37,4.72,4.76,5.23,4.23,4.39,4.04,3.82,3.85,
     4 9*0.0/
      END
```

BLOCK DATA: LISTING

E.5 SUBROUTINE COLIN (X1V, X2V, X3V) Continued

PURPOSE: The subroutine checks to see if the point X3V is colinear with the points X1V, X2V in the x-y plane. The x-y coordinates of the point X3V are altered by the subroutine so that the point X3V is not colinear with points X1V, X2V, if the points are judged to be collinear.

SUBPROGRAMS USED: IAREA (X1V, X2V, X3V), ANGLE (X1V, X2V, X3V)

VARIABLES: Input Parameters

X1V(I), X2V(I), X3V(I) - Three points in the x-y plane defined by their components.

x - component I = 1

y - component I = 2

Subprogram Parameters

ANG - The angle between the line segments (X1V,X3V) and (X2V, X3V).

Output Parameters

X3V(I) - The components of a point in the x-y plane, X3V(I),that is near to the input values X3V(I) but that is not considered by the routine to be colinear with the points X1V, X2V. (See RESTRICTIONS).

RESTRICTIONS: The criteria used to judge whether or not X3V is colinear with X1V, X2V is the area of the triangle formed by the points X1V, X2V, X3V and, possibly, the magnitude of the variable ANG.

SUBROUTINE COLIN (X1V, X2V, X3V) Concluded

ACCURACY: That of the criteria.

SIZE: 738

REFERENCES: See Subprograms IAREA and ANGLE.

```
      SUBROUTINE COLIN(X1V,X2V,X3V)
C CHECK WHETHER RECEIVER IS CO-LINEAR WITH ROADWAY SEGMENT
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2)
      IF(IAREA(X1V,X2V,X3V).EQ.0) GO TO 10
    5 ANG=ANGLE(X1V,X2V,X3V)
      IF(ANG.GE.2.6E-5) RETURN
   10 X3V(1)=X3V(1)+1.0
      IF(IAREA(X1V,X2V,X3V).EQ.0) GO TO 20
      ANG=ANGLE(X1V,X2V,X3V)
      IF(ANG.GE.2.6E-5) RETURN
   20 X3V(2)=X3V(2)+1.0
      IF(IAREA(X1V,X2V,X3V).EQ.0) GO TO 5
      RETURN
      END
```

SUBROUTINE COLIN: LISTING

E.6 SUBROUTINE DEGEN (X1V, X2V, X3V, X4V, X5V, LOC)

PURPOSE:	This subroutine preprocesses data for subroutine BLOCN to ensure that degenerate geometrical alignments between the points X1V, X2V, X3V and a line segment X4V, X5V that may confuse the logic of subroutine BLOCN do not occur. Physically, the line segment defined by the x(I=1) and y(I=2) coordinates of the points X1V(I) and and X2V(I) represents a road segment, the point X3V(I) represents a receiver, and the line segment defined by the points X4V(I) and X5V(I) represent either a barrier or an absorption ground strip. THIS SUBROUTINE SHOULD BE USED ONLY AS A PREPROCESSOR FOR SUBROUTINE BLOCN.
SUBPROGRAMS USED:	IAREA (X1V, X2V, X3V), MOVE2 (X1V, X2V, X3V, DELTA, IERR)

VARIABLES:

Input Parameters

X1V(I), X2V(I) - Points defining a road segment location in the x(I=1), y(I=2) plane.

X3V(I) - A point defining the receiver location in the x(I=1), y(I=2) plane.

X4V(I), X5V(I) - Points defining a barrier or ground strip location in the x,y plane. See Output Parameters.

Output Parameters

LOC A logic parameter indicating the relative alignment of the line segment (X4V, X5V) with the line segments (X1V, X3V) and (X2V, X3V). LOC = 0 or 3 or 5.

SUBROUTINE DEGEN (X1V, X2V, X3V, X4V, X5V, LOC) Continued

LOC = 0 indicates that both point X4V and point X5V are colinear with the line segments (X1V, X3V) or (X2V, X3V).

LOC = 3 indicates that point X4V is colinear with (X1V, X3V) and that point X5V is colinear with (X2V, X3V) or that point X4V is colinear with (X2V, X3V) and that point X5V is colinear with (X1V, X3V). That is, the line segment (X4V, X5V) exactly blocks the (x, y) plane line-of-sight from the receiver X3V to the roadway (X1V, X2V).

LOC = 5 indicates that either point X4V or X5V was determined to be colinear with one of the segments (X1V, X3V) or (X2V, X3V) or neither point X4V or X5V was colinear with one of the segments (X1V, X3V) or (X2V, X3V). If either X4V or X5V was determined to be colinear, the point is relocated by subroutine MOVE2 decreasing the length of the segment (X4V, X5V) by 1 foot.

X4V(I), X5V(I) - If LOC = 5, either X4V(I) or X5V(I) may be relocated as indicated above so that X4V(I) or X5V(I) is not collinear with the segments (X1V, X3V) or (X2V, X3V).

RESTRICTIONS: This subroutine should be used only as a preprocessor for subroutine BLOCN. See listing of subroutine GEOMRY for usage.

If an error occurs in subroutine MOVE2, the following message is printed: "ERROR IN MOVE2". This error will

SUBROUTINE DEGEN (X1V, X2V, X3V, X4V, X5V, LOC) Concluded

not be, quite likely, fatal but the user should check results closely.

ACCURACY: See RESTRICTIONS.

SIZE: 1684

REFERENCES: None.

SUBROUTINE DEGEN: LISTING

```
C     DEGEN         03/78    SAI MOD
      SUBROUTINE DEGEN(X1V,X2V,X3V,X4V,X5V,LOC)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/INOU/INPT,IOUT
      DIMENSION X1V(2),X2V(2),X3V(2),X4V(2),X5V(2)
      LOC=5
      IF(IAREA(X4V,X1V,X3V).EQ.0) GO TO 10
      IF(IAREA(X4V,X2V,X3V).EQ.0) GO TO 40
      IF(IAREA(X5V,X1V,X3V).EQ.0) GO TO 45
      IF(IAREA(X5V,X2V,X3V).EQ.0) GO TO 45
      RETURN
   10 IAREA1=IAREA(X5V,X2V,X3V)
      IF(IAREA1.EQ.0) GO TO 30
      IAREA2=IAREA(X5V,X3V,X1V)
      IAREA3=IAREA(X5V,X1V,X2V)
      IF(IAREA1.EQ.IAREA2.AND.IAREA1.EQ.IAREA3) GO TO 55
   20 LOC=0
      RETURN
 30   LOC=3
      RETURN
   40 IAREA1=IAREA(X5V,X3V,X1V)
      IF(IAREA1.EQ.0) GO TO 30
      IAREA2=IAREA(X5V,X1V,X2V)
      IAREA3=IAREA(X5V,X2V,X3V)
      IF(IAREA1.EQ.IAREA2.AND.IAREA1.EQ.IAREA3) GO TO 55
      GO TO 20
   45 IAREA1=IAREA(X4V,X3V,X1V)
      IAREA2=IAREA(X4V,X1V,X2V)
      IAREA3=IAREA(X4V,X2V,X3V)
      IF(IAREA1.EQ.IAREA2.AND.IAREA1.EQ.IAREA3) GO TO 60
      GO TO 20
   55 CALL MOVE2(X4V,X4V,X5V,-1.0,IERR)
      IF(IERR.EQ.4) WRITE(IOUT,1000)
      RETURN
   60 CALL MOVE2(X5V,X5V,X4V,-1.0,IERR)
      IF(IERR.EQ.4) WRITE(IOUT,1000)
      RETURN
 1000 FORMAT(1H ,14HERROR IN MOVE2)
      END
```

E.7 SUBROUTINE BLOCN (X1V, X2V, X3V, X4V, X5V, X6V, LOC) Continued

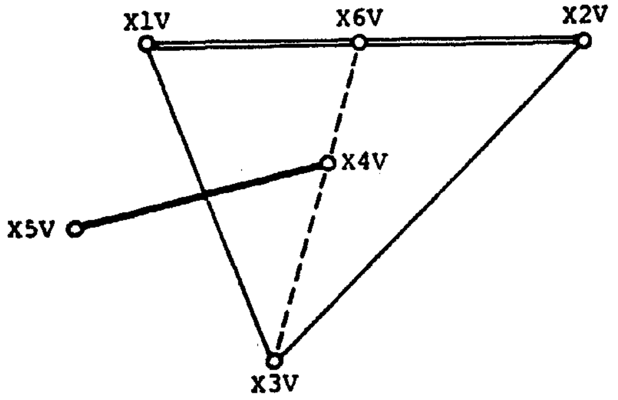
PURPOSE: This subroutine calculates the alignments in the x-y plane, of one line segment relative to the alignment of another line segment and a point. Physically, the line segment defined by the x(I = 1), y(I = 2) coordinates of the points X1V(I) and X2V(I) represents a road segment, the point X3V(I) represents a receiver, and the line segment defined by the points X4V(I) and X5V(I) represent either a barrier or an absorptive ground strip.

The subroutine output is a point X6V(I) in the x-y plane and a configuration index, LOC. See Figure E-2.
If LOC = 0, the line segment defined by X4V, X5V is outside the triangle formed by X1V, X2V, X3V. In this case, the subroutine assigns no values to X6V.

If LOC = 1, this line segment defined by X4V, X5V intersects the line segment defined by X1V, X3V. In this case, the subroutine assigns X6V as the intersection point (in the x-y plane) of the line segment X1V, X2V and the line defined by the points X3V, X4V or X3V, X5V.

If LOC =2, the line segment defined by X4V, X5V intersects the line segment defined by X2V, X3V. In this case, the subroutine assigns X6V as the intersection point (in the x-y plane) of the line segment X1V, X2V and the line defined by the points X3V, X4V or X3V, X5V.

If LOC = 3, the line segment defined by X4V, X5V intersects both line segments defined by X1V, X3V and X2V, X3V (ie, the road segment, as viewed from point X3V, is completely covered by the line segment X4V, X5V). In this case, the subroutine assigns no values to X6V.



LOC = 0 denotes that the line X4V, X5V is outside the triangle X1V, X2V, X3V.

LOC = 1 denotes that the line X4V, X5V intersects the line X1V, X3V.

LOC = 2 denotes that the line X4V, X5V intersects the line X2V, X3V.

LOC = 3 denotes that the line X4V, X5V intersects both lines X1V, X3V and X2V, X3V.

LOC = 4 denotes that the line X4V, X5V is completely inside the triangle X1V, X2V, X3V.

FIGURE E-2. SUBROUTINE BLOCN: RELATIVE GEOMETRY

SUBROUTINE BLOCN (X1V, X2V, X3V, X4V, X5V, X6V, LOC) Continued

If LOC = 4, the line segment defined by X4V, X5V is interior to the triangle defined by the points X1V, X2V, X3V. In this case, the subroutine assigns X6V as the intersection point on the line segment X1V, X2V of the line from X3V to either X4V or X5V that is closest to the point X1V. SEE RESTRICTIONS

SUBPROGRAMS USED: KCUT(X1, X2, X3, X4), TRI(X1, X2, X3, X4, X5, KTRI) INTCPT(X1, X2, X3, X4, X5), SEE RESTRICTIONS, SEE SUBROUTINE DEGEN

VARIABLES: Input parameters

X1V(I), X2V(I) - points defining a road segment locatio in the x(I=1), y(I=2) plane.

X3V(I) - a point defining the receiver location in the x(I = 1), y(I = 2) plane.

X4V(I), X5V(I) - points defining a line segment location in the x(I = 1), y(I = 2) plane.

Output parameters

X6V(I) - a point on the line segment defined by X1V(I), X2V(I) that represents the intersection of the line defined by either the points X3V, X4V or X3V, X5V. (SEE PURPOSE)

LOC - a parameter describing the configuration (SEE PURPOSE).

Subprogram parameters

KTRI - A parameter assigned by subprogram TRI.

KTRI = 0 if X4V is either exterior to the triangle X1V, X2V, X3V or lies on a line segment X1V, X2V; X1V, X3V; or X2V, X3V.

KTRI = 1 if X4V is interior to the triangle X1V, X2V, X3V.

SUBROUTINE BLOCN (X1V, X2V, X3V, X4V, X5V, X6V, LOC) Concluded

XAV(I) - a point on the line segment defined by X1V(I), X2V(I) that represents the intersection of the line defined by X3V, X4V.

XBV(I) - a point on the line segment defined by X1V(I), X2V(I) that represents the intersection of the line defined by X3V, X5V.

RESTRICTIONS: The subprogram BLOCN is used by the subprograms ENDPT and GEOMRY to establish the basic geometric relationship between a roadway segment (X1V, X2V); a receiver location, X3V; and a potentially intervening barrier or ground strip segment (X4V, X5V). Geometric configurations between the five points defined by X1V, X2V, X3V, X4V, and X5V can arise that may either produce erroneous results or program failure. To check for these potential problems and to avoid the possibility of calculating erroneous results, the subprogram DEGEN is used. The problem geometrical configurations are associated with colinearity of source-receiver points X1, X2, X3 with barrier and/or ground strip points X4V, X5V or if the points X4V and/or X5V lie on the boundary of the triangle formed by the points X1V, X2V, X3V. See Figure E-2.

ACCURACY: SEE RESTRICTIONS.

SIZE: 958

REFERENCES: None.

```
   SUBROUTINE BLOCN(X1V,X2V,X3V,X4V,X5V,X6V,LOC)
C FIND RELATIVE LOCATION OF BARRIER
   IMPLICIT REAL*8 (A-H,O-Z)
   DIMENSION X1V(2),X2V(2),X3V(2),X4V(2),X5V(2),X6V(2),XAV(2),XBV(2)
   LOC=KCUT(X1V,X3V,X4V,X5V)
   LOC=LOC+KCUT(X2V,X3V,X4V,X5V)*2
   IF(LOC.EQ.3)RETURN
   CALL TRI(X1V,X2V,X3V,X4V,XAV,KTRI)
   IF(LOC.EQ.0)GO TO 4
   IF(KTRI.EQ.1)GO TO 6
  2 CALL INTCPT(X1V,X2V,X3V,X5V,XBV)
   IF(LOC.EQ.4)GO TO 5
  3 X6V(1)=XBV(1)
   X6V(2)=XBV(2)
   RETURN
  4 IF(KTRI.EQ.0)RETURN
   LOC=4
   GO TO 2
  5 IF(KPOS(X1V,XAV,XBV).EQ.1)GO TO 3
  6 X6V(1)=XAV(1)
   X6V(2)=XAV(2)
   RETURN
   END
```

SUBROUTINE BLOCN: LISTING

E.8 SUBROUTINE MOVE (X1V, X2V, X3V, DELTA, IERR) Continued

PURPOSE: To calculate the coordinates of the point X2V that lies on a line passing through the points X1V, X3V and is a specified distance, DELTA, from the point X1V in (x, y, z) coordinate space. (See VARIABLES, DELTA).

SUBPROGRAMS USED: AMAG (X1, X2)

VARIABLES: Input Parameters

X1V(I), X3V(I) - Points in (x, y, z) coordinate space defining a line.

x - coordinate I = 1
y - coordinate I = 2
z - coordinate I = 3

DELTA - The distance from the point X1V at which one desires the point X2V to be located on the line X1V, X3V. If DELTA is positive, X2V will be located along the line defined by X1V, X3V in the direction from X3V to X1V. If DELTA is negative, X2V will be located along the line defined by X1V, X3V in the direction from X1V to X3V. If DELTA is zero, X2V will coincide with X1V.

Subprogram Parameters

TEMP - The length of the line segment defined by the points X1V, X3V.

FCTR - The ratio of DELTA to TEMP

Output Parameters

X2V(I) - The x, y, z coordinates of the point X2V.

IERR - An error indicator. If TEMP is greater than zero (i.e., X1V and X3V do not coincide) then IERR = 0. If TEMP is equal to zero (i.e., X1V and X3V coincide) then IERR = 4 and the point X2V(I) is not calculated when control is returned to the calling program.

RESTRICTIONS: See description of variable IERR.

ACCURACY: Not applicable.

SIZE: 582

REFERENCES: The point X2V is calculated using the vector relation

$$\vec{R}_2 = \vec{R}_1 + \text{DELTA}\ \vec{r}_{31}$$

$$\vec{r}_{31} = \vec{R}_{31} / \sqrt{\vec{R}_{31} \cdot \vec{R}_{31}}$$

```
      SUBROUTINE MOVE(X1V,X2V,X3V,DELTA,IERR)
C MOVE ENDPOINT OF ROAD
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3)
      IERR=0
      TEMP=AMAG(X1V,X3V)
      IF(TEMP.EQ.0.) GO TO 3
      FCTR=DELTA/TEMP
      DO 2 I=1,3
      X2V(I)=X1V(I)+(X1V(I)-X3V(I))*FCTR
    2 CONTINUE
      RETURN
    3 IERR=4
      RETURN
      END
```

SUBROUTINE MOVE: LISTING

E.9 SUBROUTINE MOVE2 (X1V, X2V, X3V, DELTA, IERR) Continued

PURPOSE: To calculate, in the x-y plane, the coordinates of the point X2V that lies on a line passing through the points X1V, X3V and is a specified distance, DELTA, from the point X1V. This is the x-y plane analogue of subroutine MOVE.

SUBPROGRAMS USED: SQRT(X)

VARIABLES: Input Parameters

X1V(I), X3V(I) - Points in the x-y plane defining a line.

x - coordinate I = 1
y - coordinate I = 2

DELTA - The distance from the point X1V at which one desires to locate the point X2V on the line defined by the points X1V, X3V. If DELTA is positive, X2V will be located on the line defined by X1V, X3V in the direction from X3V to X1V. If DELTA is negative, X2V will be located along the line defined by X1V, X3V in the direction from X1V to X3V. If DELTA is zero, X2V coincides with X1V.

Subprogram Parameters

TEMP - The length of the line segment defined by the points X1V, X3V.

FCTR - The ratio of DELTA to TEMP.

Output Parameters

X2V(I) - The x,y coordinates of the point X2V.

SUBROUTINE MOVE2 (X1V, X2V, X3V, DELTA, IERR) Concluded

IERR - An error indicator. If TEMP is greater than zero (i.e., X1V and X3V do not coincide), then IERR = 0 and the coordinates, X2V(I) are calculated. If TEMP is zero (i.e., X1V and X3V coincide), then IERR = 4 and the coordinates, X2V(I), are not calculated.

RESTRICTIONS: See description of variable IERR.

ACCURACY: Not applicable.

REFERENCES: See Subroutine MOVE.

SIZE: 596

```
      SUBROUTINE MOVE2(X1V,X2V,X3V,DELTA,IERR)
C MOVE AN ENDPOINT(2-DIMENSION)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2)
      IERR=0
      TEMP=DSQRT((X1V(1)-X3V(1))**2+(X1V(2)-X3V(2))**2)
      IF(TEMP.EQ.0.0) GO TO 3
      FCTR=DELTA/TEMP
      DO 2 I=1,2
      X2V(I)=X1V(I)+(X1V(I)-X3V(I))*FCTR
    2 CONTINUE
      RETURN
    3 IERR=4
      RETURN
      END
```

SUBROUTINE MOVE2: LISTING

E.10 SUBROUTINE TRI (X1V, X2V, X3V, X4V, X5V, KTRI) Continued

PURPOSE: To calculate a logic number, KTRI, that indicates whether or not the point X4V lies within or on the boundaries of a triangle in the x-y plane formed by the points X1V, X2V, and X3V. (See VARIABLES and RESTRICTIONS).

SUBPROGRAMS USED: INTCPT (X1, X2, X3, X4, X5); KPOS (X1, X2, X3)

VARIABLES: Input Parameters

X1V(I), X2V(I), X3V(I) - The coordinates of three points in the x-y plane. The x-coordinate is denoted by I = 1; the y-coordinate by I = 2.

X4V(I) - A point in the x-y plane whose location relative to the triangle formed by the points X1V, X2V, X3V is to be determined.

Output Parameters

X5V(I) - The intersection point of the lines through X1V, X2V and X3V, X4V.

KTRI - A logic number that indicates the location of X4V relative to the triangle formed by the points X1V, X2V, X3V.

KTRI = 1 If the point X4V lies interior to or on the boundary of (excluding the point X3V) the triangle formed by the points X1V, X2V, X3V.

KTRI = 0 If the point X4V coincides with the point X3V or lies exterior to the triangle formed by the points X4V, X2V, X3V.

SUBROUTINE TRI (X1V, X2V, X3V, X4V, X5V, KTRI) Concluded

RESTRICTIONS: The intersection point X5V is always calculated and returned to the calling program. If KTRI = 1 the point X5V lies on the line segment defined by the end points X1V, X2V including the end points. If KTRI = 0 and X4V does not coincide with X3V, the point X5V lies on the line passing through the points X1V, X2V. If the points X3V and X4V coincide KTRI = 0 and X5V is projected to a point beyond $2 \cdot 10^{14}$ miles from the point X1V. (See Subprogram INTCPT). Usage of this subroutine should recognize these restrictions.

ACCURACY: That of subprograms.

SIZE: 594

REFERENCES: None.

```
      SUBROUTINE TRI(X1V,X2V,X3V,X4V,X5V,KTRI)
C FIND IF POINT IN TRIANGLE AND LOCATE INTERCEPT
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2),X4V(2),X5V(2)
      CALL INTCPT(X1V,X2V,X3V,X4V,X5V)
      KTRI=0
      IF(KPOS(X1V,X2V,X5V).EQ.0)RETURN
      IF(KPOS(X3V,X5V,X4V).EQ.1)KTRI=1
      RETURN
      END
```

SUBROUTINE TRI: LISTING

E.11 SUBROUTINE INTCPT (X1V, X2V, X3V, X4V, X5V) Continued

PURPOSE: To calculate the x-y plane intersection point, X5V(I), of two lines defined by the points (X1V(I)), and (X2V(I)), and (X3V(I)), (X4V(I)). The subscript I = 1 for x-coordinates and I = 2 for y-coordinates.

SUBPROGRAMS USED: None.

VARIABLES: Input parameters

X1V(I), X2V(I) - Points in the x-y plane defining a line.

X3V(I), X4V(I) - Points in the x-y plane defining a line.

Subprogram parameters

AX, AY - x-component and y-component respectively, of the line segment defined by (X1V, X2V).

BX, BY - x-component and y-component respectively of the line segment defined by (X3V, X4V).

C1, C2 - Algebraic expressions arising in the derivation of the algorithm.

D - The value of the 2X2 determinant formed by the x,y components of the two line segments.

Output parameters

X5V(I) - The (x,y) coordinate (I = 1, I = 2, respectively) of the intersection point.

RESTRICTIONS: If either line segment has zero length, then D = 0 and a division by zero will occur. If the two line segments are parallel or coincide, D = 0 and a division by zero will occur. If $D^2 < 10^{-6}$ ft^2, the subroutine, projects the point X5V out in the x-y plane somewhere beyond a radius of 2×10^{14} miles from the point X1V. Usage should recognize these restrictions.

ACCURACY: See Restrictions.

SIZE: 738

SUBROUTINE INTCPT (X1V, X2V, X3V, X4V, X5V) Concluded

REFERENCES: The algorithm used to calculate the point X5V, is derived by writing the vector equation for lines passing through the points (X1V, X2V) and (X3V, X4V) and solving for their common point.

```
      SUBROUTINE INTCPT(X1V,X2V,X3V,X4V,X5V)
C FIND INTERCEPT OF TWO LINES IN A PLANE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2),X4V(2),X5V(2)
      AX=X2V(1)-X1V(1)
      AY=X2V(2)-X1V(2)
      BX=X4V(1)-X3V(1)
      BY=X4V(2)-X3V(2)
      C1=AY*X2V(1)-AX*X2V(2)
      C2=BY*X4V(1)-BX*X4V(2)
      D=AX*BY-AY*BX
      IF(D**2.LT.1.E-6)GO TO 2
      X5V(1)=(AX*C2-BX*C1)/D
      X5V(2)=(AY*C2-BY*C1)/D
      RETURN
    2 D=DSQRT(AX**2+AY**2)
      X5V(1)=X1V(1)+(AX/D)*1.E+15
      X5V(2)=X1V(2)+(AY/D)*1.E+15
      RETURN
      END
```

SUBROUTINE INTCPT: LISTING

E.12 SUBROUTINE NRPT (X1V, X2V, X3V, X4V, DIST) Continued

PURPOSE: To compute the point X4V on a line defined by the points X1V, X2V that is nearest to the point X3V. The length of the line segment (X3V, X4V) is the distance, DIST, from the point X3V to the line defined by X1V, X2V. If DIST =0, then DIST is set equal to 1 foot prior to returning to the calling program.

SUBPROGRAMS USED: DSQR (X1,X2); AMAG (X1, X2)

VARIABLES: Input Parameters

X1V(I), X2V(I) - Points in x, y, z coordinate space defining a line.

X3V(I) - A point in the x, y, z coordinate space.

Subprogram Parameters

I - Subscript denoting coordinate

x - coordinate, I = 1
y - coordinate, I = 2
z - coordinate, I = 3

AV(I) - Components of vector $\vec{R}_{21}$

BV(I) - Components of vector $\vec{R}_{31}$

AX, AY, AZ - Values of AV(1), AV(2), AV(3); respectively.

BX, BY, BZ - Values of BV(1), BV(2), BV(3); respectively.

TEMP - Square of length of line segment defined by X1V, X2V.

SUBROUTINE NRPT (X1V, X2V, X3V, X4V, DIST) Concluded

RATIO - An expression developed in the derivation of the point X4V(I) in terms of X1V(I), X2V(I) and X3V(I).

Output Parameters

X4V(I) - A point on the line defined by X1V(I), X2V(I) that is nearest to the point X3V(I). See RESTRICTIONS.

DIST - The distance from the point X3V(I) to the line defined by X1V(I), X2V(I). If DIST = 0, the subprogram sets DIST = 1 prior to returning control to the calling program. See RESTRICTIONS.

RESTRICTIONS:	If the points X1V and X2V coincide, X4V coincides with X1V and DIST is the distance between X3V and X4V. If X3V is on the line defined by X1V, X2V then X4V and X3V coincide and DIST = 1.
REFERENCES:	None.
SIZE:	796

```
      SUBROUTINE NRPT(X1V,X2V,X3V,X4V,DIST)
C FIND NEAREST POINT TO LINE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3),AV(3),BV(3)
      EQUIVALENCE (AV(1),AX),(AV(2),AY),(AV(3),AZ),(BV(1),BX),(BV(2),BY
     1),(BV(3),BZ)
      DO 5 I=1,3
      AV(I)=X2V(I)-X1V(I)
      BV(I)=X3V(I)-X1V(I)
    5 CONTINUE
      RATIO=0.
      TEMP=DSQR(X2V,X1V)
      IF(TEMP.NE.0.)RATIO=(AX*BX+AY*BY+AZ*BZ)/TEMP
      DO 10 I=1,3
      X4V(I)=X1V(I)+RATIO*AV(I)
   10 CONTINUE
      DIST=AMAG(X4V,X3V)
      IF(DIST.EQ.0.)DIST=1.
      RETURN
      END
```

SUBROUTINE NRPT: LISTING

E.13 SUBROUTINE NR1 (X1V, X2V, X3V, X4V, DIST, X5V, DN1)

PURPOSE: To calculate the point, X5V, on the line segment (X1V, X2V) that is nearest to the point X3V and to calculate the distance between the points X3V and X5V.

SUBPROGRAMS USED: KPOS (X1, X2, X3), REPLACE (X1, X2), AMAG (X1, X2)

VARIABLES: Input Parameters

X1V(I), X2V(I) - Points in (x, y, z) coordinate space defining a line segment and a line.

X3V(I) - A point in (x, y, z) coordinate space.

X4V(I) - The point on the line passing through the points X1V, X2V that is nearest to the point X3V.

DIST - The distance from the point X3V to the line passing through the points X1V, X2V.

Output Parameters

X5V(I) - A point on the line segment (X1V, X2V) that is nearest to the point X3V.

DN1 - The length of the line segment (X3V, X5V).

RESTRICTIONS: See Subprogram NRPT.

ACCURACY: Not Applicable.

SIZE: 736

REFERENCES: None.

```
      SUBROUTINE NR1(X1V,X2V,X3V,X4V,DIST,X5V,DN1)
C FIND NEAREST POINT TO LINE SEGMENT
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3),X5V(3)
      IF(KPOS(X4V,X2V,X1V).EQ.1)GO TO 2
      IF(KPOS(X1V,X4V,X2V).EQ.1)GO TO 4
      CALL REPLCE(X4V,X5V)
      DN1=DIST
      RETURN
    2 CALL REPLCE(X1V,X5V)
      GO TO 6
    4 CALL REPLCE(X2V,X5V)
    6 DN1=AMAG(X5V,X3V)
      RETURN
      END
```

SUBROUTINE NR1: LISTING

E.14 SUBROUTINE ENDPT (X1V, X2V, X3V, X4V, X5V, X6V, KTRIG, IERR) Continued

PURPOSE: To calculate the (x, y, z) coordinates of points on a roadway segment for which sound propagation may or may not be affected at a receiver location by an intervening barrier or ground strip. (See RESTRICTIONS).

The input values of the points X1V, X2V define the initial roadway segment. The point X3V defines the observer location and the points X4V, X5V define the location of a barrier on ground strip.

The subroutine calculates the index KTRIG and,as necessary, the point X6V on the line segment defined by the input values of X1V, X2V so that if KTRIG = 0, the line segment defined by the output values of X1V, X2V represent a road segment with a clear line of sight to the receiver X3V. If KTRIG = 0, the output values of X6V have no physical significance. If KTRIG = 1, the line segment defined by the output values of X1V, X6V represent a road segment with an obstructed (in the x-y plane) line-of-sight to the receiver at X3V and the line segment defined by the output values of X6V, X2V represent a roadway segment with a clear line-of-sight to the receiver at X3V.

The subroutine does not alter the input values of X1V, X3V, X4V, and X5V, but it may alter the input value of X2V. Also, the points X2V and X6V may coincide. (see VARIABLES and RESTRICTIONS).

SUBPROGRAMS USED: REPLCE (X1V, X2V); ZCOR (X1V, X2V, X3V); BLOCN (X1V, X2V, X3V, X4V, X5V, X6V, LOC); MOVE (X1V, X2V, X3V, DELTA, IERR).

SUBROUTINE ENDPT (X1V, X2V, X3V, X4V, X5V, X6V, DTRIG, IERR) Continued

VARIABLES: <u>Input parameters</u>

X1V(I), X2V(I) - Points in x, y, z coordinate space defining the alignment of the roadway segment.

X3V(I) - A point in x, y, z coordinate space defining the receiver location.

X4V(I), X5V(I) - Points in x, y, z coordinate space defining a barrier or a ground strip.

<u>Subprogram parameters</u>

ITRIG - An index, internal to the subprogram, that indicates whether or not the input value of the point X1V and the point X6V initially calculated on the line segment (X1V, X2V) are so close that the significance of the segment (X1V, X6V) can be ignored in judging the effect of the strip (X4V, X5V). The subroutine considers "close" to be a distance of 0.51 feet.

LOC An index generated by the subroutine BLOCN that indicates the relative location of the roadway segment and the receiver to the barrier or ground strip.

DELTA - A distance defined as either -0.50 or -0.51 feet and used by subroutine MOVE to shift points.

XDUM(I)- A dummy point initially set equal to X4V(I).

<u>Output parameters</u>

KTRIG - An index of whether or not the sound from a road segment may be attenuated by a barrier or ground strip. If KTRIG = 0, the segment (X1V, X2V) is unaffected by the strip X4V, X5V (see Output parameter X2V(I)). If KTRIG = 1, the line segment (X1V, X6V) is totally affected by the strip

(X4V, X5V) and the segment (X6V, X2V) is unaffected by the strip (X4V, X5V) (See Output parameter,X6V(I)).

IERR - An error code set by subroutine MOVE. If IERR = 0, the subroutine MOVE has been successful and output from ENDPT can be used. If IERR = 4, the subroutine MOVE has not been successful and output from ENDPT are probably in error. (See Subroutine MOVE).

X1V(I) - One end point of the roadway segment. The input values of X1V(I) are not altered by the subprogram.

X2V(I) - One end point of the roadway segment. The input values of X2V(I) to ENDPT may be altered by ENDPT so that when KTRIG = 0, the roadway segment defined by (X1V, X2V) is <u>not</u> affected by the barrier or ground strip defined by (X4V, X5V). If KTRIG = 1, the input values of X2V(I) to ENDPT are not altered by the subroutine. Hence, the output values of X2V(I) always represent an end point of a roadway segment that is unaffected by the intervening barrier or ground strip.

X3V(I) - Input values of the receiver location. Not altered by the subprogram.

X4V(I), X5V(I) - Input values of the barrier or ground strip location. Not altered by the subprogram.

X6V(I) - If KTRIG = 0, the point X6V has no significance. If KTRIG = 1, the point X6V is a point on the roadway segment (X1V, X2V) that defines a totally affected segment (X1V, X6V) and a totally unaffected segment (X6V, X2V). The point X6V may coincide with the point X2V.

SUBROUTINE ENDPT (X1V, X2V, X3V, X4V, X5V, X6V, DTRIG, IERR) Concluded

RESTRICTIONS: The subroutine ENDPT determines whether or not the roadway segment defined by the input values of (X1V, X2V) is affected by the barrier or ground strip (X4V, X5V) using x-y coordinate geometry. Hence, the subroutine ENDPT does make an absolute judgement as to no effect if KTRI = 0 on the segment (X1V, X2V) or if KTRI = 1 on the segment (X6V, X2V). However, if KTRI = 1, the subroutine does not consider the elevations of source, barrier, and receiver for the roadway segment (X1V, X6V). The usage should recognize this fact.

ACCURACY: That of subprograms.

SIZE: 1152

REFERENCES: None.

```
      SUBROUTINE ENDPT(X1V,X2V,X3V,X4V,X5V,X6V,KTRIG,IERR)
C FIND NEW ENDPOINT
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/INOU/INPT,IOUT
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3),X5V(3),X6V(3),XDUM(3)
      IERR=0
      KTRIG=0
      ITRIG=1
      CALL REPLCE(X1V,XDUM)
    1 CALL BLOCN(XDUM,X2V,X3V,X4V,X5V,X6V,LOC)
      IF(LOC.EQ.0) RETURN
      IF(LOC.NE.3) GO TO 2
      CALL REPLCE(X2V,X6V)
      GO TO 4
    2 X6V(3)=ZCOR(X1V,X2V,X6V)
      IF(ITRIG.EQ.0) GO TO 5
      IF(AMAG(X1V,X6V).GT.0.51) GO TO 5
      ITRIG=0
      DELTA=-0.51
      CALL MOVE(XDUM,XDUM,X2V,DELTA,IERR)
      GO TO 1
    5 DELTA=-0.5
      IF(LOC.EQ.1) GO TO 3
      CALL MOVE(X6V,X2V,X1V,DELTA,IERR)
      RETURN
    3 CALL MOVE(X6V,X6V,X1V,DELTA,IERR)
    4 KTRIG=1
      IF (IERR.EQ.4) WRITE(IOUT,1000)
 1000 FORMAT(14H ERROR IN MOVE)
      RETURN
      END
```

SUBROUTINE ENDPT: LISTING

PURPOSE:	Calculates the (x, y, z) coordinates of the points X6V(I) and X7V(I). The point X6V(I) is on the line passing through the points X4V, X5V intersecting the vertical (z - coordinate) plane defined by the (x-y) coordinates of the points X1V, X3V. The point X7V is on the line passing through the points X4V, X5V intersecting the vertical (z - coordinate) plane defined by the (x-y) coordinates of the points X2V, X3V. (See RESTRICTIONS and Figure E-3).
SUBPROGRAMS USED:	INTCPT (X1, X2, X3, X4, X5), ZCOR (X1, X2, X3)
VARIABLES:	<u>Input Parameters</u> X1V(I), X2V(I), X3V(I) - Points in (x, y, z) coordinate space defining <u>lines</u> passing through the points X1V, X3V and X2V, X3V. X4V(I), X5V(I) - Points in the (x, y, z) coordinate space defining a <u>line</u> passing through the points X4V, X5V. <u>Output Parameters</u> X6V(I), X7V(I) - Points on the line passing through the points X4V, X5V that lie in the vertical plane defined by the x-y components of the lines passing through the points X1V, X3V and X2V, X3V, respectively.
RESTRICTIONS:	The subprogram does not check to see if the points X6V and X7V lie on the line segment (X4V, X5V). Usage of this subprogram must recognize this restriction.
ACCURACY:	See Subprogram INTCPT.

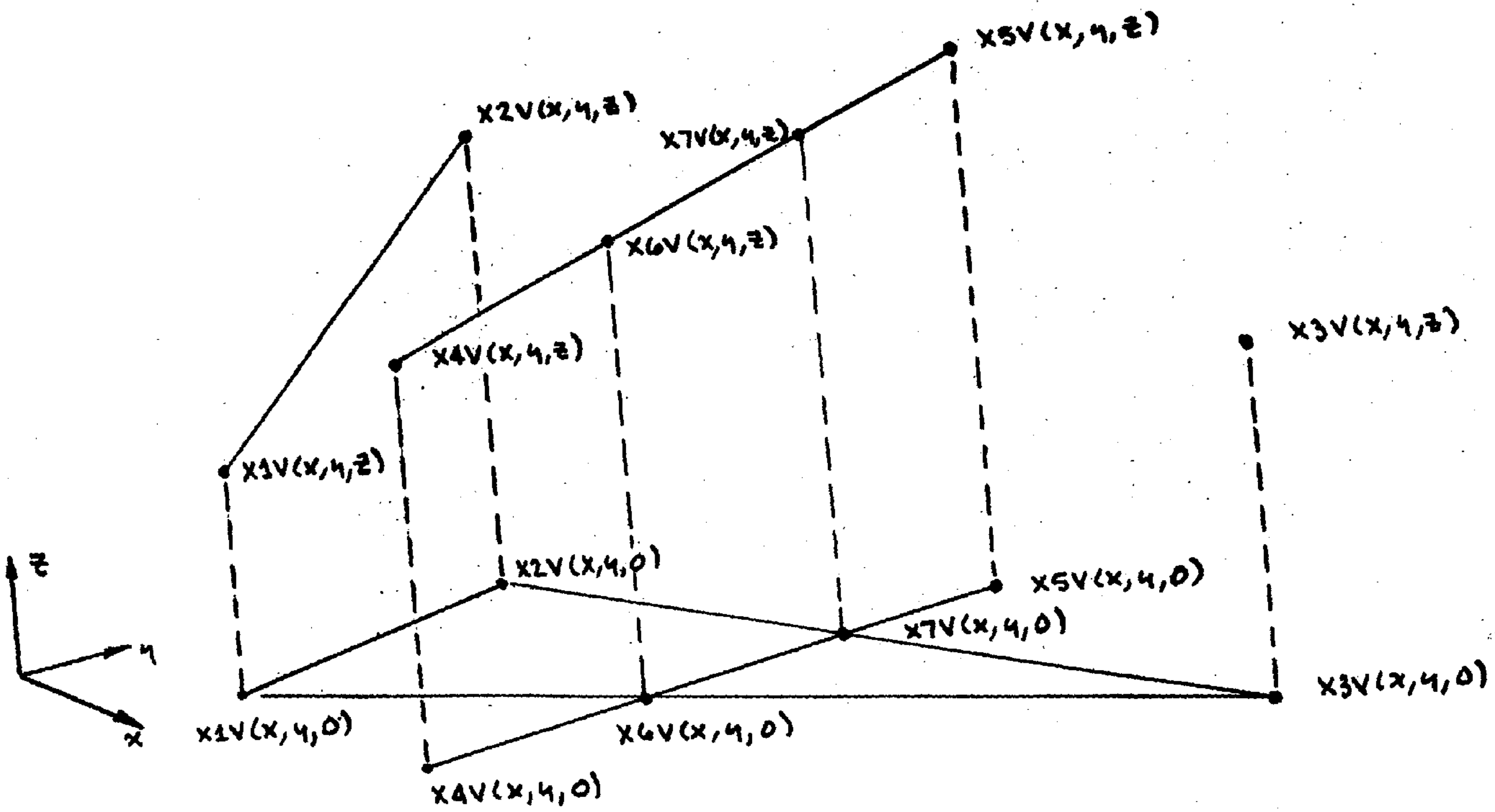


FIGURE E-3. SUBROUTINE SECTN: NOMENCLATURE

SUBROUTINE SECTN (X1V, X2V, X3V, X4V, X5V, X6V, X7V) Concluded

SIZE: 634

REFERENCES: None.

```
      SUBROUTINE SECTN(X1V,X2V,X3V,X4V,X5V,X6V,X7V)
C FIND EFFECTIVE BARRIER SECTION
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3),X5V(3),X6V(3),X7V(3)
      CALL INTCPT(X1V,X3V,X4V,X5V,X6V)
      X6V(3)=ZCOR(X4V,X5V,X6V)
      CALL INTCPT(X2V,X3V,X4V,X5V,X7V)
      X7V(3)=ZCOR(X4V,X5V,X7V)
      RETURN
      END
```

SUBROUTINE SECTN: LISTING

E.16 SUBROUTINE IMAGE(X1V, X2V, X3V, X4V) Continued

PURPOSE: To calculate the (x, y, z) (I = 1,2,3) location of an image receiver at the point X4V(I) relative to a receiver at the point X3V(I) and a reflector defined by the end points X1V(I) and X2V(I). All calculations are conducted in the x-y plane with the z coordinate, X4V(3), of the image receiver set equal to the z coordinate X3V(3) of the receiver.

SUBPROGRAMS USED: None.

VARIABLES:

Input parameter

X1V(I), X2V(I) - The x, y, z coordinates of the reflector.

X3V(I) - The x, y, z coordinates of the receiver.

Subprogram parameters

AX - The x-component of the directed line segment (X1V, X2V)

AY - The y-component of the directed line segment (X1V, X2V).

AXY - The square of the distance of the x-y plane projection of the line segment (X1V, X2V).

RATIO - The ratio of the x-y plane projections of the distance of point X3V from the line defined by X1V, X2V to the length of the line segment (X1V, X2V).

Output parameters

X4V(I) - The (x, y, z) coordinates of the image receiver.

RESTRICTIONS: The subroutine does not utilize the z coordinates defining the reflector and, hence, cannot judge whether or not a reflection would in fact occur. Usage should recognize this restriction.

ACCURACY: Not applicable.

SUBROUTINE IMAGE(X1V, X2V, X3V, X4V) Concluded

SIZE: 532

REFERENCES: See Figure E-4 for nomenclative.

```
      SUBROUTINE IMAGE(X1V,X2V,X3V,X4V)
C FIND IMAGE POINT
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3)
      AX=X2V(1)-X1V(1)
      AY=X2V(2)-X1V(2)
      AXY=AX**2+AY**2
      RATIO=0.
      IF(AXY.EQ.0.)GO TO 10
      RATIO=(((X3V(2)-X2V(2))*AX-(X3V(1)-X2V(1))*AY)*2.0)/AXY
   10 X4V(1)=X3V(1)+AY*RATIO
      X4V(2)=X3V(2)-AX*RATIO
      X4V(3)=X3V(3)
      RETURN
      END
```

SUBROUTINE IMAGE: LISTING

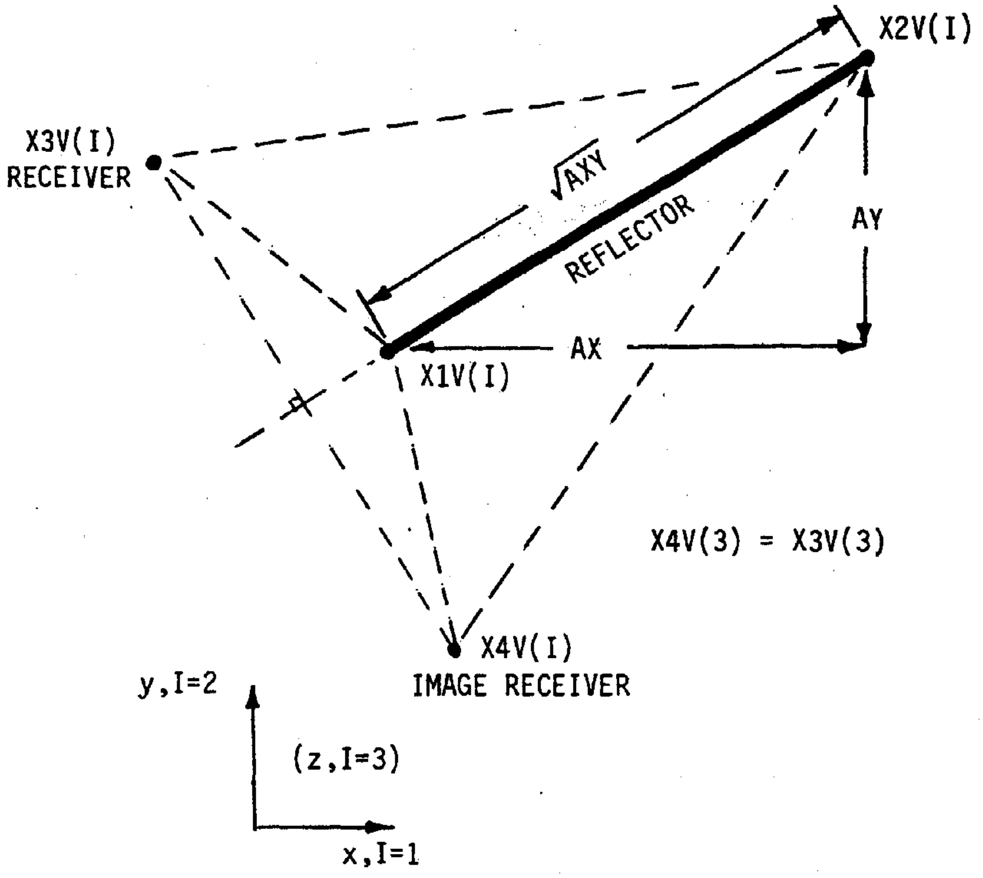


FIGURE E-4. SUBROUTINE IMAGE: NOMENCLATURE

E.17 SUBROUTINE MIDP (X1V, X2V, X3V)

PURPOSE: To calculate the midpoint, X3V, of a line segment defined by the points (X1V, X2V) in x, y, z coordinate space.

SUBPROGRAMS USED: None.

VARIABLES: <u>Input parameters</u>

X1V(I), X2V(I) - Points in x, y, z coordinate space defining the line segment.

I - Subscript defining the
x - component I = 1
y - component I = 2
z - component I = 3
of the points X1V(I), X2V(I), X3V(I).

<u>Output parameter</u>

X3V(I) - Point in x, y, z coordinate spece defining the midpoint of the line segment (X1V, X2V).

RESTRICTIONS: None

ACCURACY: Not applicable

SIZE: 402

REFERENCES: None

```
      SUBROUTINE MIDP (X1V, X2V, X3V)
C     FIND CENTER POINT
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3), X2V(3), X3V(3)
      DO 10 I=1,3
   10 X3V(I) = (X1V(I)+X2V(I))/2.
      RETURN
      END
```

SUBROUTINE MIDP: LISTING

E.18 SUBROUTINE REPLCE (X1V, X2V)

PURPOSE: To assign the coordinates of a point or the components of a vector, X1V(I), to the coordinates of a point or the components of a vector X2V(I). The values of X1V(I) are unchanged.

SUBPROGRAMS USED: None.

VARIABLES: Input/Output Parameters

X1V(I), X2V(I) - The components of two vectors or the coordinates of two points in (x, y, z) coordinate space.

x - component or coordinate I = 1
y - component or coordinate I = 2
z - component or coordinate I = 3

RESTRICTIONS: None.

ACCURACY: Not applicable.

SIZE: 310

REFERENCES: None.

```
      SUBROUTINE REPLCE(X1V,X2V)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3)
      X2V(1)=X1V(1)
      X2V(2)=X1V(2)
      X2V(3)=X1V(3)
      RETURN
      END
```

SUBROUTINE REPLCE: LISTING

E.19 FUNCTION AMAG (X1V, X2V)

PURPOSE: To compute the length, AMAG, of a line segment defined by the end points X1V(I) and X2V(I), for an (x, y, z) coordinate system.

SUBPROGRAMS LISTED: DSQR (X1V, X2V); SQRT (X).

VARIABLES: <u>Input Parameters</u>

X1V(I), X2V(I) - Points defined by their x(I=1), y(I=2), z(I=3) coordinates.

RESTRICTIONS: None.

ACCURACY: Not Applicable.

SIZE: 370

REFERENCES: Calculates the length of a line vector, $\vec{R}_{12}$, as AMAG = $(\vec{R}_{12} \cdot \vec{R}_{12})^{\frac{1}{2}}$.

```
      FUNCTION AMAG(X1V,X2V)
C FIND MAGNITUDE OF VECTOR
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3)
      AMAG=DSQRT(DSQR(X1V,X2V))
      RETURN
      END
```

FUNCTION AMAG: LISTING

E.20 FUNCTION ANGLE (X1V, X2V, X3V)

PURPOSE: To compute the angle between the two line segments defined by the points (X1V, X3V) and (X2V, X3V) for an (x, y, z) coordinate system.

SUBPROGRAMS LISTED: DSQR (X1, X2), SQRT (X), ARCOS (X).

VARIABLES: Input Parameters

X1V(I), X2V(I), X3V(I) - Points defined by their x(I=1), y(I=2), z(I=3) coordinates.

Subprogram Parameters

D13 - Square of the length of the line segment defined by the points X1V(I) and X3V(I).

D12 - Square of the length of the line segment defined by the points X1V(I) and X2V(I).

D23 - Square of the length of the line segment defined by the points X2V(I) and X3V(I).

RESTRICTIONS: If point X3V coincides with either X1V or X2V, ANGLE = $\pi/2$.

ACCURACY: That of subprograms.

SIZE: 624_8

REFERENCES: COS (ANGLE) is calculated using the "Law of Cosines." ANGLE is calculated as $\cos^{-1}$ (COS(ANGLE)).

FUNCTION ANGLE: LISTING

```
      FUNCTION ANGLE(X1V,X2V,X3V)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3)
      D13=DSQR(X1V,X3V)
      D23=DSQR(X2V,X3V)
      ANGLE=1.5708
      IF(D13*D23.EQ.0.)RETURN
      D12=DSQR(X1V,X2V)
      ANGLE=DARCOS((D23+D13-D12)/(DSQRT(D13*D23)*2.))
      RETURN
      END
```

E.21 FUNCTION BARFAC (KF, DELP) Continued

PURPOSE: To compute the attenuation of acoustic intensity for a propagation path over a barrier between a source point and a receiver point for a given path length difference, DELP, and octave band center frequency, denoted by the index KF.

SUBPROGRAMS LISTES: SQRT(X), TAN(X), TANH(X), ABS(X).

VARIABLES: Input parameters

KF - Interger index, n, for octave band center frequency (see derivation below) or A-weighted sound level, (KF = 1).

Subprogram parameters

DELP - Path length difference, δ, between the diffracted ray and the direct ray between source and receiver.

IP - Variable internal to subprogram equal to KF.

A - 2 πN, where N is the Fresnel Number (see derivation below).

RESTRICTION: Theory based upon Fresnel diffraction using an analytical approximation to the experimental measurements of Maekawa. (See Section A.6, Appendix A).

If KF=1, the A-weighted sound level is being utilized. This subprogram evaluates A-weighted sound level attenuation by calculating the attenuation at the octave-band center frequency of 500 Hz. (IP=5).

Speed of sound, c, is assumed to be 1120 ft/sec.

ACCURACY: That of subprograms.

SIZE: 856

FUNCTION BARFAC (KF, DELP) Continued.

REFERENCES: Maekawa, Z.: "Noise Reduction by Screens; Applied Acoustics, Vol. 1, 1968, pp 157-173.

Kurze, U.J., and Anderson, G.S.; "Sound Attenuation by Barriers", Applied Acoustics, Vol. 4, 1971, pp 35-53.

Kurze, U.J.; "Noise Reduction by Barriers", J. Acoustical Society of America, Vol. 55, No. 3, March 1974, pp 504-518.

DERIVATION: Development of the relationship for calculating the barrier factor (attenuation) as a function of Fresnel Number is presented in Section

For an octave band center frequency, f_c; a path length difference, δ; and a speed of sound, c; the Fresnel Number is defined as

$$N = 2f_c\,\delta/c$$

for $f_c = 2^n \cdot 10^3/64$; $n = 2,3,\ldots.9$, $c = 1120$ ft/sec.

$$N = 2f_c\,\delta/1120 = f_c\,\delta/560$$

$$N = 2^n \cdot 10^3\,\delta/(64 \cdot 560) = 2^n\,\delta/(35.84)$$

$$A = 2\pi N = 2^n\,\delta/(35.84/2\pi) = 2^n\,\delta/5.7$$

$$\text{BARFAC} = 10^{-D_b/10}$$

for $N \leq -0.2$; $A \leq -1.257$; $D_b=0$; BARFAC=1.0

for $-0.2 \leq N \leq 0$ $-1.257 \leq A \leq 0$

$$D_b = 20 \cdot \log\ (\sqrt{|A|}/\text{TAN}(\sqrt{|A|})) + 5 = 20\log(R) + 5$$

$$\text{BARFAC} = 10^{-(20\log(R)+5)/10} = (10^{0.5}R^2)^{-1}$$

$$\text{BARFAC} = (3.1623\ R^2)^{-1} = (\text{TAN}(\sqrt{|A|})/\sqrt{|A|})^2/3.16$$

for $N=0$; $A=0$; $D_b=5$; BARFAC $= 10^{-5/10} = 0.31623$

for $0 \leq N \leq 5.03$; $0 \leq A \leq 31.6$;

$$D_b = 20 \cdot \log\ (\sqrt{A}/\text{TAN H}(\sqrt{A})) + 5 = 20\log(R) + 5$$

FUNCTION BARFAC (KF, DELP) Concluded

$$\text{BARFAC} = 10^{-(20\cdot\log(R) + 5)/10}$$

$$= (3.1623\ R^2)^{-1} = (\text{TANH}(\sqrt{A}))^2/3.16A$$

for $N > 5.03$; $A > 31.6$ $D_b = 20$*

$$\text{BARFAC} = 10^{-20/10} = 10^{-2} = 0.0100$$

* Note:Previous versions of this subroutine placed an upper limit of $D_b = 24$ dB on barrier attenuation (ie, $\text{BARFAC} = 4 \cdot 10^{-3}$). The upper limit has been reduced to 20 dB based upon field experience.

```
      FUNCTION BARFAC(KF,DELP)
      IMPLICIT REAL*8 (A-H,O-Z)
C FIND BARRIER FACTOR
      IF(DELP.EQ.-0.2)GO TO 3
      IF(DELP.GE.5.65)GO TO 4
      IP=KF
      IF(KF.EQ 1)IP=5
      A=DELP*(2.**IP)/5.7
      IF(A.GE.31.6)GO TO 4
      IF(A.GT.0.) GO TO 5
      IF(A.EQ.0.)GO TO 6
      IF(A.GT.-1.25.AND.A.LT.0.)GO TO 7
    3 BARFAC=1.0
      RETURN
    4 BARFAC=0.01
      RETURN
    5 BARFAC=(DTANH(DSQRT(A))**2)/A/3.16
      RETURN
    6 BARFAC=.316
      RETURN
    7 A1=DABS(A)
      BARFAC=(DTAN(DSQRT(A1)))**2/A1/3.16
      RETURN
      END
```

FUNCTION BARFAC: LISTING

E.22 FUNCTION DEL (X1V, X2V, X3V, X4V, HDIFF, DN1) Continued

PURPOSE: To calculate the path length difference, DEL, between the ray from the source point, X1V(I), diffracted over a barrier defined by a line segment defined by the points (X3V(I), X4V(I)) towards a receiver location at the point X2V(I). Points and line segments are defined in an x(I = 1), y(I =2), z(I = 3) coordinate system.

SUBPROGRAMS USED: NRPT (X1, X2, X3, X4, DIST), DSQR (X1, X3), SQRT (X).

VARIABLES: <u>Input parameters</u>

X1V(I) - Source point at x(I = 1), y(I = 2), z(I = 3)

X2V(I) - Receiver point at x(I = 1), y(I = 2), z(I = 3)

X3V(I) - End point of line segment at x(I = 1), y(I = 2), z(I = 3) defining barrier.

X4V(I) - End point of line segment at x(I = 1), y(I = 2), z(I = 3) defining barrier.

HDIFF - Height difference between source-receiver ray and top of barrier. (See function HEIGHT).

DN1 - Distance between source-receiver.

<u>Subprogram parameters</u>

DISTA - Distance from source to point XA(I).

DISTB - Distance from receiver to point XB(I).

DISTC - Square of distance between points XA(I) and XB(I).

XA(I) - Point on <u>line</u> defined by the line segment (X3V, X4V) that is nearest to the source point X1V(I).

XB(I) - Point on <u>line</u> defined by the line segment (X3V, X4V) that is nearest to the receiver point X2V(I).

<u>Output parameters</u>

DEL - Path length difference. Positive if HDIFF is less than zero. Negative if HDIFF is greater than zero.

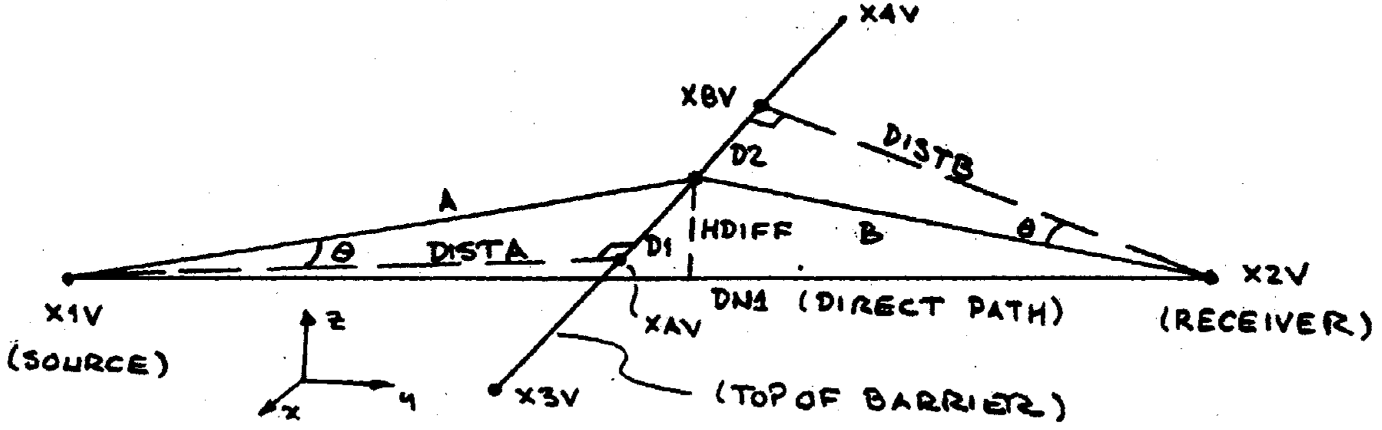
FUNCTION DEL (X1V, X2V, X3V, X4V, HDIFF, DN1) Concluded

RESTRICTIONS:	The subprogram does not check to see if the direct path from the source to the receiver intersects the barrier. Hence, it is possible to define input to the subroutine that yields a positive value of DEL when in fact DEL should be zero. Usage of this subroutine should recognize this restriction.
ACCURACY:	That of subprograms.
SIZE:	672
REFERENCES:	See Figure E-5 for derivation of algorithm.

```
      FUNCTION DEL(X1V,X2V,X3V,X4V,HDIFF,DN1)
C FIND PATH LENGTH DIFFERENCE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3),XAV(3),XBV(3)
      CALL NRPT(X3V,X4V,X1V,XAV,DISTA)
      CALL NRPT(X3V,X4V,X2V,XBV,DISTB)
      DISTC=DSQR(XBV,XAV)
      DEL=DSQRT((DISTA+DISTB)**2+DISTC)-DN1
      IF(HDIFF.GT.0.)DEL=-DEL
      RETURN
      END
```

FUNCTION DEL: LISTING

FUNCTION DEL (X1V,X2V,X3V,X4V,HDIFF,DN1)



Basic Relationship: $\mathrm{DEL} = A + B - \mathrm{DN1}$

Basic Geometry:

$$\mathrm{DISTA} = A \cos\theta \qquad \mathrm{D1} = A \sin\theta$$

$$\mathrm{DISTB} = B \cos\theta \qquad \mathrm{D2} = B \sin\theta$$

$$A^2 = \mathrm{DISTA}^2 + \mathrm{D1}^2 \qquad B^2 = \mathrm{DISTB}^2 + \mathrm{D2}^2$$

$$\mathrm{DISTA} \bullet \mathrm{DISTB} + \mathrm{D1} \bullet \mathrm{D2} = AB \cos^2\theta + AB \sin^2\theta = AB$$

$$(A + B)^2 = A^2 + B^2 + 2AB$$

$$(A + B)^2 = \mathrm{DISTA}^2 + \mathrm{D1}^2 + \mathrm{DISTB}^2 + \mathrm{D2}^2 + 2\,(\mathrm{DISTA} \bullet \mathrm{DISTB} + \mathrm{D1} \bullet \mathrm{D2})$$

$$(A + B)^2 = (\mathrm{DISTA} + \mathrm{DISTB})^2 + (\mathrm{D1} + \mathrm{D2})^2$$

$$\mathrm{DISTC} = (\mathrm{D1} + \mathrm{D2})^2$$

$$\therefore A + B - \mathrm{DN1} = \mathrm{SQRT}((\mathrm{DISTA} + \mathrm{DISTB})^2 + \mathrm{DISTC}) - \mathrm{DN1}$$

FIGURE E-5. FUNCTION DEL: DERIVATION

E.23 FUNCTION DSQR (X1V, X2V)

PURPOSE: To calculate the square of the distance between two points X1V(I), X2V(I) in x(I = 1), y(I = 2), z(I = 3) space.

SUBPROGRAMS USED: None.

VARIABLES: Input parameters

X1V(I), X2V(I) - Points defining a line segment by their x, y, z coordinates.

Output parameters

DSQR - The square of the distance between the points X1V(I), X2V(I).

RESTRICTIONS: None.

ACCURACY: Not applicable.

SIZE: 392

REFERENCES: DSQR is the scalar ("dot") product of the vector between points X1V and X2V.

DSQR = $\vec{R}_{12} \cdot \vec{R}_{12} = \vec{R}_{21} \cdot \vec{R}_{21}$

FUNCTION DSQR: LISTING

```
      FUNCTION DSQR(X1V,X2V)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3)
      DSQR=0.0
      DO 10 I=1,3
   10 DSQR=(X1V(I)-X2V(I))**2+DSQR
      RETURN
      END
```

E.24 FUNCTION HEIGHT (X1V, X2V, X3V, X4V)

PURPOSE: To calculate the difference in elevation (z coordinates) between the lines defined by the points (X1V, X2V) and (X3V, X4V) at the x-y plane intersection point of the x-y plane projections of the lines (X1V, X2V) and (X3V, X4V).

SUBPROGRAMS USED: INTCPT (X1, X2, X3, X4, X5) ZCOR (X1, X2, X3).

VARIABLES: Input parameters

X1V(I), X2V(I) - Two points defining a line in x(I = 1), y(I = 2), z(I = 3) coordinates.

X3V(I), X4V(I) - Two points defining a line in x(I = 1), y(I = 2), z(I = 3) coordinates.

Subprogram parameters

XI(I) - The x-y plane intersection point of the x-y plane projections of lines defined by the points (X1V, X2V) and (X3V, X4V). Note XI(3) is never assigned a value.

Output parameters

HEIGHT - Difference in elevation between lines defined by (X1V, X2V) and (X3V, X4V) at intersection point.

RESTRICTIONS: That of subprograms used. Hence, HEIGHT can be an elevation difference at a location not on the line segment defined by (X1V, X2V) and (X3V, X4V). See Subprograms INTCPT and ZCOR.

ACCURACY: If the x-y plane projections of the lines (X1V, X2V) and (X3V, X4V) are parallel on collinear HEIGHT will be a very large number. See Subprograms INTCPT and ZCOR.

SIZE: 518

REFERENCES: See Subprograms INTCPT and ZCOR.

```
      FUNCTION HEIGHT(X1V,X2V,X3V,X4V)
C FIND HEIGHT DIFFERENCE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3),XI(3)
      CALL INTCPT(X1V,X2V,X3V,X4V,XI)
      HEIGHT=ZCOOR(X1V,X2V,XI)-ZCOOR(X3V,X4V,XI)
      RETURN
      END
```

FUNCTION HEIGHT: LISTING

E.25 FUNCTION IAREA (X1V, X2V, X3V) Continued

PURPOSE: To calculate an index, IAREA, that indicates the relative spacing (area enclosed) of the three points X1V, X2V, X3V in the x-y plane.

SUBPROGRAMS USED: DABS(X)

VARIABLES: <u>Input Parameters</u>

X1V(I), X2V(I), X3V(I) - Points defined in the x-y plant.
x - coordinate I = 1
y - coordinate I = 2

<u>Subprogram Parameters</u>

TERM 1, TERM 2, TERM 3 - The three terms resulting from calculating the vector ("cross") product of the vectors R_{31} and R_{32}.

AREA - A number equal to twice the area of the triangle formed by the points X1V, X2V, X3V. If AREA is zero, the points X1V, X2V, X3V, are colinear. (See REFERENCES).

<u>Output Parameters</u>

IAREA: IAREA = 1 if the area of the triangle formed by X1V, X2V, X3V is greater than 1 square foot, or if AREA is negative.

IAREA = 0 if the area of the triangle formed by X1V, X2V, X3V is equal to or greater than zero square feet but less than or equal to 1 square foot.

FUNCTION IAREA (X1V, X2V, X3V) Concluded

RESTRICTIONS: None.

ACCURACY: Not applicable.

SIZE: 486

REFERENCES: The variable AREA is the magnitude of the vector formed by the vector product of the vectors $\vec{R}_{31}$ and $\vec{R}_{32}$ in the x-y plane.

```
C  IAREA          03/78   SAI MOD
      FUNCTION IAREA(X1V,X2V,X3V)
C FIND AREA OF TRIANGLE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2)
      IAREA=1
      TERM1=X1V(1)*(X2V(2)-X3V(2))
      TERM2=X2V(1)*(X3V(2)-X1V(2))
      TERM3=X3V(1)*(X1V(2)-X2V(2))
      AREA=TERM1+TERM2+TERM3
      IF (DABS(.5*AREA).LE.1.) IAREA=0
      RETURN
      END
```

FUNCTION IAREA: LISTING

E.26 FUNCTION IEPS (X1V, X2V, X3V, X4V, DEL1) Continued

PURPOSE: The decision parameter IEPS represents a comparison of two path length differences, DEL1 and DEL2, to decide whether or not the path length differences are sufficiently similar so that the condition of uniform sound intensity from a roadway segment to a receiver via a diffracted path over a barrier exists. If IEPS = 0, the condition of uniform sound intensity at the receiver is satisfied and DEL2 is considered similar to DEL1. If IEPS = 1, DEL2 is not sufficiently similar to DEL1 for uniform sound intensity at the receiver to be assumed.

SUBPROGRAMS USED: AMAG(X1, X2); HEIGHT(X1, X2, X3, X4); (DEL(X1, X2, X3, X4), (HDIFF, DIST); ABS(X).

VARIABLES: Input parameters

X1V(I) - A point in (x, y, z) coordinate space that represents the source.

X2V(I) - A point in (x, y, z) coordinate space that represents the receiver.

X3V(I), X4V(I) - Two points in (x, y, z) coordinate space that define a line representing the top of a barrier.

DEL1 - A number representing a path length difference for an acoustic propagation path diffracting over a barrier.

Subprogram parameters

DIST - The distance between the source point X1V(I) and the receiver point X2V(I).

HDIFF - The elevation difference (difference in z coordinates) between points on the lines defined by the points X1V, X2V and X3V, X4V at the x-y plane intersection point of these lines (See RESTRICTIONS).

FUNCTION IEPS (X1V, X2V, X3V, X4V, DEL1) Concluded

DEL2 - The path length difference defined by the source location, X1V; the receiver location, X2V; and the top of a barrier defined by the line through the points X3V, X4V. (See RESTRICTIONS and Subprogram DEL).

DELM - The arithemetic average of the values of DEL1 and DEL2.

Output parameter

IEPS - IEPS = 0 if the values of DEL1 and DEL2 satisfy the cirterion presented under REFERENCES. (See PURPOSE) IEPS = 1 if the values of DEL1 and DEL2 do not satisfy the criterion presented under REFERENCES. (See PURPOSE).

RESTRICTION: Neither the subprogram IEPS nor any of the subprograms utilized by IEPS checks to see if the line segment (X1V, X2V) intersects the line segment (X3V, X4V). For proper utilization this subprogram must receive input data such that the above line segments do intersect and that the variable DEL1 corresponds to a path length difference associated with the input data geometry. Usage should recognize this restriction. (See Subprogram DEL).

ACCURACY: That of subprograms used and the criterion specified. (See REFERENCES).

SIZE: 700

REFERENCES: The criterion used to judge similarity of two path length differences is that

$$|\delta_2 - \delta_1| - \frac{(\delta_2 + \delta_1)}{100}(1 + (\delta_2 + \delta_1)/2) \leq 0.10$$

Where δ_1 = DEL1, δ_2 = DEL2. See description of barrier diffraction under Prediction Model in main text of report.

```
      FUNCTION IEPS (X1V, X2V, X3V, X4V, DEL1)
C     CHECK ON PATH LENGTH DIFFERENCE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3),X4V(3)
      IEPS =0
      DIST = AMAG (X1V,X2V)
      HDIFF = HEIGHT (X1V,X2V,X3V,X4V)
      DEL2 = DEL (X1V, X2V, X3V, X4V, HDIFF, DIST)
      DELM= (DEL1+DEL2)/2.
      IF ((DABS(DEL2-DEL1)-0.1-DELM/50.*(1.+DELM)) .GT.0.) IEPS=1
      RETURN
      END
```

FUNCTION IEPS: LISTING

E.27 FUNCTION KCUT (X1V, X2V, X3V, X4V)

PURPOSE: To calcualte a logic number, KCUT, that indicates whether or not two line segments intersect in the x-y plane. The line segments are defined by the end points (X1V, X2V) and (X3V, X4V). If the line segments intersect (including end points) KCUT = 1. Otherwise, KCUT = 0.

SUBPROGRAMS USED: INTCPT (X1, X2, X3, X4, X5), KPOS (X1, X2, X3).

VARIABLES: <u>Input parameters</u>

X1V(I), X2V(I) - Points in the x-y plane defining a line segment. The subscript I = 1 for x-coordinates; I = 2 for y-coordinates.

X3V(I), X4V(I) - Points in the x-y plane defining a line segment. The subscript I = 1 for x-coordinates; I = 2 for y-coordinates.

<u>Output parameters</u>

KCUT = 1 - if the line segments intersect in an oblique sense including end points.

KCUT = 0 - if the line segments do not intersect or are collinear.

RESTRICTIONS: If the line segments are collinear, KCUT = 0. See Subprogram INTCPT. Usage should recognize this restriction.

ACCURACY: Not applicable.

SIZE: 544

REFERENCES: None.

FUNCTION KCUT: LISTING

```
      FUNCTION KCUT(X1V,X2V,X3V,X4V)
C DETERMINE IF TWO LINE SEGMENTS CROSS
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2),X4V(2),X5V(2)
      KCUT=0
      CALL INTCPT(X1V,X2V,X3V,X4V,X5V)
      IF(KPOS(X1V,X2V,X5V).NE.1)RETURN
      IF(KPOS(X3V,X4V,X5V).EQ.1)KCUT=1
      RETURN
      END
```

E.28 FUNCTION KPOS (X1V, X2V, X3V)

PURPOSE: To calculate a logic number, KPOS, indicating whether the point X3V, in the x-y plane lies on a line segment defined by the points X1V, X2V in the x-y plane. If X3V lies on the line segment (including the end points) KPOS = 1. If X3V does not lie on the line segment KPOS = 0. (See RESTRICTIONS).

SUBPROGRAMS USED: None.

VARIABLES: Input parameters

X3V(I) - A point in the x-y plane defined by the x-coordinate (I = 1) and the y-coordinate (I = 2).

X1V(I), X2V(I) - Points in the x-y plane defined by the x-coordinate (I = 1) and the y-coordinate (I = 2).

Output parameters (SEE RESTRICTIONS)

KPOS = 1 - If X3V lies on the line segment X1V, X2V.

KPOS = 0 - If X3V does not lie on the line segment X1V, X2V.

RESTRICTIONS: The criteria used to judge if X3V is on the line is $\vec{R}_{12} \cdot \vec{R}_{23} > 0$. Hence, it is possible for X3V to lie off the line segment and still obtain KPOS = 1. Usage should recognize this fact.

ACCURACY: See RESTRICTIONS.

SIZE: 390

REFERENCES: None.

```
      FUNCTION KPOS(X1V,X2V,X3V)
C FIND POSITION OF POINT ON LINE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(2),X2V(2),X3V(2)
      KPOS=1
      IF(((X3V(1)-X1V(1))*(X3V(1)-X2V(1))+(X3V(2)-X1V(2))*(X3V(2)-X2V(2)
     1)).GT.0.)KPOS=0
      RETURN
      END
```

FUNCTION KPOS: LISTING

E.29 FUNCTION ZCOR (X1V, X2V, X3V)

PURPOSE:	To calculate the z - coordinate, X3V(3), of a point X3V(I) on a line defined by the points X1V(I) and X2V(I).
SUBPROGRAMS USED:	ABS(X)
VARIABLES:	<u>Input Parameters</u> X1V(I), X2V(I) - Points in (x, y, z) coordinate space defining a line. X3V(1), X3V(2) - The x-coordinate and the y-coordinate of the point X3V. (See RESTRICTIONS). <u>Output Parameter</u> X3V(3) - The z-coordinate of the point X3V. (See RESTRICTIONS).
RESTRICTIONS:	The subroutine does not check to see if the x-y coordinates of X3V fall on the x-y plane projection of the line through the points X1V, X2V. Usage of the subroutine should reflect this restriction. The points X1V, X2V must neither coincide nor define a line parallel to the z-axis.
ACCURACY:	Not applicable.
SIZE:	490
REFERENCES:	None.

```
      FUNCTION ZCOR(X1V,X2V,X3V)
C FIND Z COORDINATE
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1V(3),X2V(3),X3V(3)
      TEM1=X2V(1)-X1V(1)
      TEM2=X2V(2)-X1V(2)
      TEM3=X2V(3)-X1V(3)
      IF (DABS(TEM1).GT.DABS(TEM2)) GO TO 10
      ZCOR=X1V(3)+(X3V(2)-X1V(2))*TEM3/TEM2
      RETURN
   10 ZCOR=X1V(3)+(X3V(1)-X1V(1))*TEM3/TEM1
      RETURN
      END
```

FUNCTION ZCOR: LISTING

E.30 SUBROUTINE GEOMRY(XR, YR, ZR, XR10, XR20, IERR, MR)

PURPOSE

This subroutine conducts the bulk of the calculation effort of the highway traffic noise prediction code. Basically, subroutine GEOMRY considers a receiver location defined by the coordinates XR, YR, ZR and a straight line roadway segment defined for roadway number MR with end points XR10 and XR20. This defines the basic roadway/receiver geometry and traffic flow conditions as indicated in Figure A-1, Appendix A. The error code, IERR, is generated in subroutines MOVE and MOVE2 (IERR=4) or if too many reflections have occurred (IDXR greater than 11, IERR = 3).

Using the basic assumption of uniform reception of acoustic intensity at the receiver location, subroutine GEOMRY considers attenuation by barrier diffraction or ground absorption or amplification by reflection from barriers. It is an understatement to say that the subroutine is complex. Subroutine GEOMRY considers all site-related geometric and acoustic parameters to estimate the normalized acoustic intensity (Equation A-9) and the normalized value of the cumulant, κ_2^* (Equation A-11) at a receiver for a straight line roadway segment. Subroutine GEOMRY is called by the MAIN PROGRAM for all segments defining a roadway and for all roadways for each receiver location (See Figure D-2). The summation of acoustic intensity and calculation of the cumulant at each receiver is accomplished by the call statement to GEOMRY from the MAIN PROGRAM and branching internal to GEOMRY. Consideration of vehicle types and spectra calculations defined by the user are conducted internally in subroutine GEOMRY. The vast bulk of data utilized by GEOMRY is transferred through the various COMMON data blocks (See Appendix C).

The basic organization of subroutine GEOMRY is illustrated in Figure E-6. For the basic roadway/receiver geometry (a plane triangle defined by the end points of the roadway segment and the receiver),

AN OVERVIEW OF SUBROUTINE GEOMRY

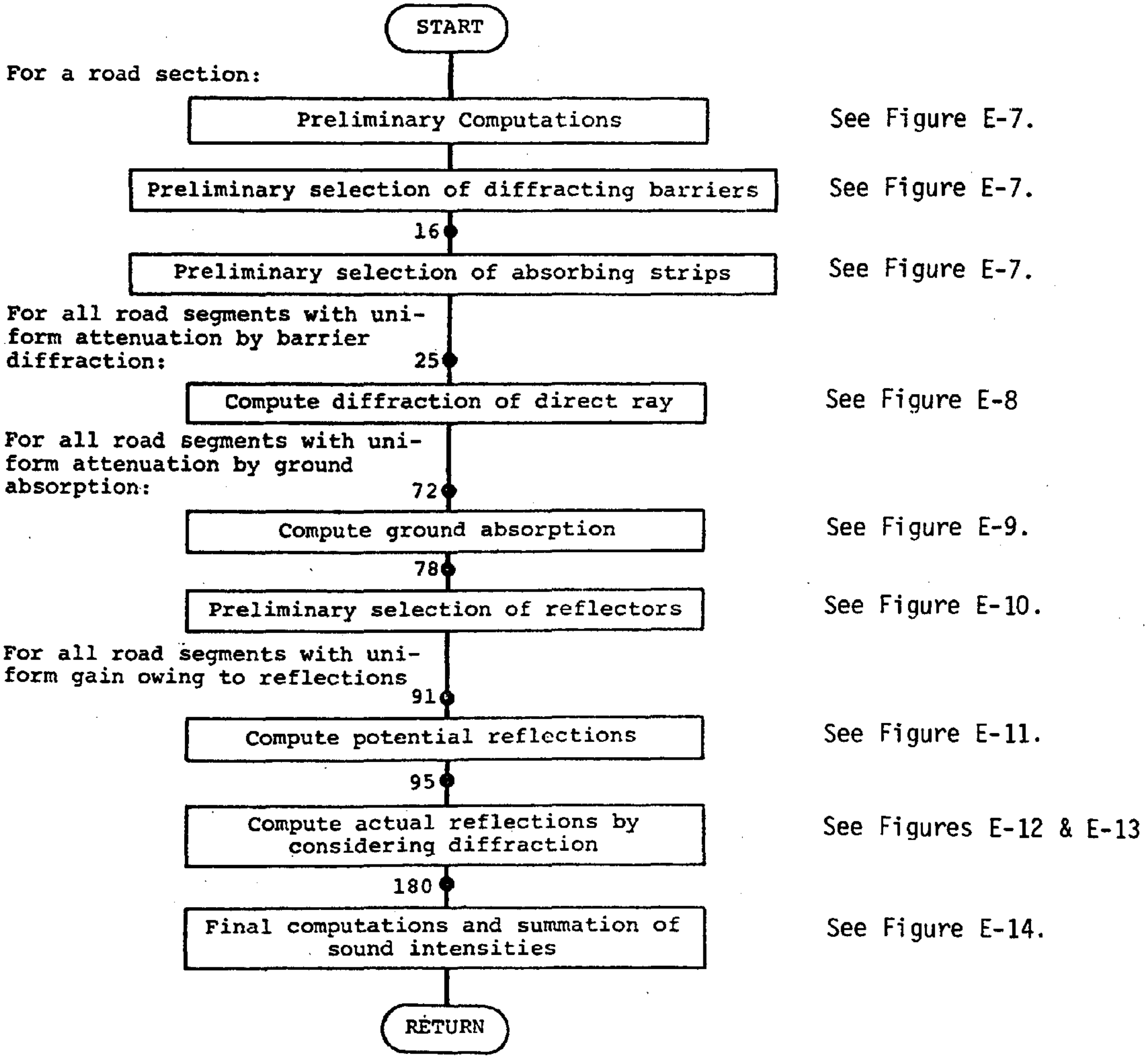


FIGURE E-6. SUBROUTINE GEOMRY: OVERVIEW

GEOMRY checks during the preliminary calculations to see if barrier segments and/or ground strip segments lie interior to the x-y plane projection of the roadway/receiver triangle. Using only x-y plane geometry, segments or portions of segments of barriers and/or ground strips are identified as "potential" diffractions or ground strips, respectively, which are stored for a more detailed analysis.

The detailed consideration of diffraction or ground strip attenuation is accomplished by GEOMRY using a sequential subdivision of the straight line roadway segment into subsegments, beginning at point XR10. If no barriers, ground strips, or reflectors have been encountered, no subdivision of the segment XR10, XR20 occurs and the acoustic intensity is calculated from the roadway segment. (Equation (A-3))

If a potential diffraction or ground strip has been encountered, the segment (XR10,XR20) is subdivided as indicated in Figure A-1 (c) as an example. For each subsegment potentially affected by a barrier, GEOMRY further subdivides the roadway segment using three-dimensional geometry to determine whether or not the diffraction is significant. For significant diffractions (See Equation(A-21))the roadway subdivision continues until uniform acoustic intensity at the receiver can be assumed. If a diffraction is encountered, GEOMRY ignores attenuation potentially resulting from absorptive ground strips for subsegment geometry. For each diffraction calculation, GEOMRY retains only the maximum path length difference calculated for each vehicle type (including source height adjustment) to estimate attenuation resulting from diffraction.

Subroutine GEOMRY checks first for diffraction, then for absorptive ground strips, and finally for reflections to establish the subdivision of a roadway segment. Hence, a roadway segment as defined by the user may be subdivided several times internaly by GEOMRY prior to returning to the MAIN PROGRAM.

Flow diagrams are presented in Figures E-7 through E-14 illustrating the detail operations and branches of the internal calculations utilized by

GEOMRY for each major consideration presented in Figure E-6. These flow diagrams are presented at the end of the subroutine description so as not to interrupt the flow of text. Statement numbers are shown so that the user may refer to blocks of code in the subroutine listing. The subroutine listing is presented following the flow diagrams.

Figure E-7 illustrates the preliminary calculations performed by GEOMRY. First, GEOMRY calls subroutine COLIN to insure that the receiver point and the roadway segment are not colinear. Next, GEOMRY calculates the distance, DIST, and the point on the line through the roadway segment end points, XNPT, using subroutine NRPT. The angle, ANG1 , between the normal from the receiver point to the roadway line and the line from the receiver point to the roadway end point, XR10, is calculated using subroutine ANGLE.

As indicated in Figure E-7, the preliminary selection of barriers is accomplished by calling subroutines DEGEN and BLOCN to determine if barrier segments occurr internally to the x-y plane triangle formed by the roadway segment and receivers. (See Figure E-2) If a potential barrier is encountered, barrier data is stored internally to GEOMRY. Otherwise, the barrier segment is ignored. All barrier segments are checked for each call to subroutine GEOMRY. The preliminary selection of absorptive ground strips is analogous to the procedure described for barriers.

Following the preliminary selection of barriers and ground strips, GEOMRY then begins the detail calculation of barrier diffraction. The flow diagram for these considerations is presented in Figure E-8. During this step in the computation the roadway segment being analyzed is subdivided to ensure that uniform reception of acoustic intensity at the receiver occurs (See Equation (A-21)). The path length difference is initialized to ensure that barrier attention is zero (DELPO=-0.2). This initialization corresponds to an octave band center frequency of 500 Hz. The subsegment of roadway being analyzed is carried internally as (XR1,XK).

GEOMRY bases the selection of significant barrier diffraction using the source height adjustment specified for automobiles and light trucks. Once the subdivision of the roadway has proceeded so that the criteria of Equation(A-21)has been satisfied, the path length difference for each vehicle type is computed. These values are compared with the maximum values of path length difference stored in array DELPO to ensure that the maximum value for the path length difference is retained. Hence, barrier attenuation is calculated by vehicle type using the maximum value of the path length difference encountered between the roadway subsegment and the receiver. This procedure allows consideration of only the most effective barrier in multi-barrier configurations (See Section A.6, Appendix A). The reader should be aware that the maximum path length difference may not correspond to the highest barrier but depends upon source location, barrier elevation, and receiver location.

Figure E-9 presents the flow diagram for the calculation of sound level attenuation resulting from ground absorption. If significant diffraction has been encountered for the roadway subsegment under analysis, GEOMRY disregards the attenuation resulting from a ground strip and proceeds to the consideration of reflections. Further, if the direct ray path from the source roadway subsegment to the receiver passes above the top of the ground strip (10 feet above ground elevation for shrubbery, 30 feet for trees) the attenuation due to the ground strip is disregarded. If GEOMRY determines that ground strip attenuation is significant, the attenuation is calculated as described in Section A.7, Appendix A.

Figure E-10 presents the flow diagram for the preliminary selection of reflectors in GEOMRY. By the introduction of an image receiver location, the reflection problem becomes similar to the diffraction problem. A reflector in the path from the road segment to an image receiver is effective whenever a barrier in the path from the road segment to a receiver strongly diffracts the sound.

Also, the intensity of the direct (or diffracted) sound from the road segment considered is compared to the potential maximum contribution of each reflection. This check assures that only essential reflectors are considered. Since a reflector might not be high enough or reflections might be strongly attenuated by diffraction at additional barriers in the ray path, the reflectors found at this stage are considered "potential" reflectors.

During the preliminary selection of reflectors GEOMRY also conducts the preliminary selection of barriers which can possibly diffract the reflected sound. The check performed is based on the length and orientation of a barrier section and on the distance from the image receiver relative to the respective parameters of the road section and the receiver considered.

Figure E-11 is the flow diagram for the block of code in GEOMRY that considers barrier elevation as related to potential reflection of sound. If the height difference above the reflector of a sound ray from the nearest point on the road segment leads to the acceptance or rejection of the reflector, no further check is made for other source points on the road segment.

Since diffraction of the reflected ray is not yet checked, a reflection is still called a potential one and the end point of the road segment is preliminary. As the final step in the reflector problem, GEOMRY considers possible diffraction both before reflection and after reflection.

Figure E-12 presents the flow diagram for consideration of diffraction before reflection. Checks for barriers in the area defined by projections of the four points XR1, XR2, XRB3, and XRB4 into the x-y plane are made by considering first the triangle containing image rays and then the triangle formed by the road segment and the image receiver.

If a barrier is found to be high enough for possible diffraction, the reflector is checked again to determine whether or not it is high enough to reflect the diffracted rays (which now come from an effective source that might by considerably higher than the roadway).

Calculation of the path length difference between diffracted and direct rays from only the near point of the road segment implies that the diffraction of sound rays from other source points is about the same.

Very strongly diffracted reflections are neglected. The decision is made on the basis of the diffraction of sound from trucks, since rays from cars are even more strongly diffracted.

Figure E-13 presents the flow diagram for the consideration of diffraction after reflection. Checks are made for diffracting barriers in the triangle defined by projections of the reflector segment (XRB3, XRB4) and the receiver XRC onto the x-y plane.

After a barrier has been found which is high enough for possible diffraction, the reflector is checked to determine whether or not it is high enough to reflect sound towards the top line of the diffracting barrier, which might be considerably higher than the receiver.

Calculation of the path length difference implies simplifying assumptions similar to those for the problem of diffraction before reflection.

Reflections are neglected in the case of diffraction before and after reflection and in the case of very strong diffraction after reflection.

Figure E-14 presents the flow diagram representing the block of code in GEOMRY that performs the final computations and accumulation of sound intensities at the receiver. These calculations consider barrier diffraction, reflections (gain of direct sound), atmospheric absorption, and ground absorption. The calculations are directly related to the expression given in Appendix A, Equation (A-9) for the acoustic intensity. For the octave band center frequency of 500 Hz, the cumulant, κ_2^*, of the acoustic intensity is calculated (See Equation A-11) and accumulated.

After the calculation and accumulation of acoustic intensity, GEOMRY checks to see if the subsegment end point XR2 is within a prescribed distance to the end points of the subsegments defining the segment end point XR20, or the subsegment end point XR2G corresponding to a ground strip, or a subsegment end point XR2D corresponding to a diffraction. GEOMRY branches internally to continue the roadway segment analysis until the point XR2 is within 1 foot of the segment end point XR20. When this criteria is satisfied, GEOMRY returns control to the MAIN program.

SUBPROGRAMS REQUIRED

See Figure D-1, page D-2.

VARIABLES

Due to the lengthly and complex nature of subroutine GEOMRY, variables are listed in alphabetical order.

A	Atmospheric attenuation factor, ground absorption parameter
ADST	ANG/DIST
ANG	Angle subtended at receiver by road segment
ANG1	Angle α_1 in Fig. A-1
ANG2	Angle α_2 in Fig. A-1
ANGI	Angle subtended at image receiver by road segment
ANGIMG	Angle subtended at image receiver by barrier section
B1	End point of barrier section
BGS	Width of absorptive ground strip
BGT	Width of absorptive ground strip
BX	x-coordinate of barrier point
BY	y-coordinate of barrier point
BZ	z-coordinate of barrier point
CA1	$\cos(\alpha_1)$

CA2	$\cos(\alpha_2)$
CPREV	Angular function C_{n-1}
CQ	Factor accounting for standard deviation of reference level
DELM	Mean path length difference
DELP	Path length difference
DELP0	Maximum path length difference for diffraction of direct ray
DELP1	Maximum path length difference for diffraction before reflection
DELP2	Maximum path length difference for diffraction after reflection
DELPA	Path length difference for diffraction of direct ray
DELR	Path length difference for reflected ray
DELTA	Distance along the roadway
DIST	Distance from the receiver to the source line
DISTI	Distance from the image receiver to the source line
DISTJ	Distance from the image receiver to the diffracting barrier
DL	Mean path length over an absorptive ground strip
DN1	Distance from the receiver to the nearest point of the road segment
DN1I	Distance from the image receiver to the nearest point of the road segment
DN2	Distance from the image receiver to the nearest point of the diffracting barrier
DR1	Distance from the receiver to the initial point of the road segment
DRK	Distance from the receiver to the preliminary end point of the road segment
FB	Attenuation factor accounting for diffraction and reflections
FCTR	Weighting factor for reflections

FG	Ground attenuation factor
HDIFA	Height of ray from source point XR1 to receiver XRC above barrier
HDIFF	Height of ray above barrier, reflector, or ground strip
HGA	Data for effective height of ground cover
I	Index
IA	Alphanumeric "A"
IBAR	Barrier number
IBLAST	Barrier type
ICODE	Number for intermediate printout
IDUM	Index for kind of absorptive ground cover
IDXR	Number of reflections
IERR	Error index
IGRA	Ground strip number
IF	Index for frequency bands
II	Index
IK	Frequency band number
IKIN	Index for kind of absorptive ground cover
IP	Frequency band number
IQ	Index
IR	Alphanumeric "R"
ISEG	Barrier section number
IT3	2N - 1
ITRIG	Trigger
KAR	Alphanumeric indicator for type of barrier
KBAR	Total number of barrier sections; index for barriers
KBAR1	Reflector number in storage
KBAR2	Diffractor number in storage

KBCODE	Indicator for relative location of barrier
KCD	Indicator for relative location of barrier
KDIFF	Barrier number in storage
KF	Index for frequency bands
KGA	Number of ground strips stored
KGCODE	Indicator for relative location of ground strip
KIMG	Reflection number
KNUMB	Total number of relevant barrier sections
KREF	Reflector number stored
KRDNUM	Total number of barrier sections relevant to reflection
KRFDF	Barrier number stored
KRNUM	Total number of relevant reflector sections
KTRIG	Indicator for intersection of barrier or ground strip
LOC	Indicator for relative location of barrier or ground strip
MDIFF	Indicator for diffraction before reflection
MODD	Indicator for diffraction of direct ray
MR	Roadway number
N	Cumulant numbers
NB	Number of barriers
NBSEC	Number of barrier sections
NBSM1	Number of sections for one barrier
NDIFF	Number of barriers stored
NF	Number of frequency bands
NG	Number of absorptive ground strips
NIMG	Number of reflections
NLIM	Number of points defining one barrier
NQ	Number of vehicle types

NQQ	Number of groups within one vehicle type
NQS	Vector notation for number of vehicle groups
NR	Number of roadways
NREF	Number of reflectors stored
NRFDF	Number of barriers stored
PP	Frequency band number
R1	End point of potential reflector
RATIO	Weighting factor for reflected rays
RB1	End point of barrier in path of reflected ray
RDIN	Vector notation for initialization parameters
SA1	$\sin(\alpha_1)$
SA2	$\sin(\alpha_2)$
T1	Temporary variable
T2	Temporary variable
T3	Temporary variable
TA1	End point on center line of absorptive ground strip
VEXPH	Vehicles per foot
XB1	Initial point of barrier stored
XB2	End point of barrier stored
XDB1	Initial point of barrier stored
XDB2	End point of barrier stored
XDB3	Initial point of effective barrier segment
XDB4	End point of effective barrier segment
XG1	Initial point of center line of absorptive ground strip
XG2	End point of center line of absorptive ground strip
XG3	Initial point of effective ground strip segment
XG4	End point of effective ground strip segment
XIMG	Vector of image receivers for all reflections

XJ	Preliminary end point of effective reflector segment
XK	Preliminary end point of road segment
XKA	Cumulant of the A-weighted sound intensity
XKI	Preliminary end point of image road segment
XLA	A-weighted intensity in frequency bands
XLE	Mean intensity
XLREF	Vector notation for reference intensities
XN1	Point on road segment nearest to receiver
XN1I	Point on road segment nearest to image receiver; point on image road segment nearest receiver
XN2	Point on barrier segment nearest to image receiver
XNPT	Point on source line nearest to receiver
XNPTI	Point on source line nearest to image receiver
XNPTJ	Point on image source line nearest receiver
XR	X-coordinate of receiver
XR1	Initial point of road segment
XR10	Initial point of road section
XR1I	Initial point of image road segment
XR2	End point of road segment
XR20	End point of road section
XR2D	End point of road segment with constant attenuation by diffraction
XR2G	End point of road segment with constant attenuation by ground absorption
XR2I	End point of image road segment
XRB1	Initial point of reflector stored
XRB2	End point of reflector stored
XRB3	Initial point of effective reflector segment
XRB4	End point of effective reflector segment

XRC	Receiver point
XRCI	Image receiver point
XXG1	X-coordinate of point on ground strip center line
YR	Y-coordinate of receiver
YYG1	Y-coordinate of point on ground strip center line
ZN10	Z-coordinate of XN1 or XN1I
ZR	Z-coordinate of receiver
ZS	Height adjustment for vehicles
ZZG1	Z-coordinate of point on ground strip center line

RESTRICTIONS

Due to the complex nature of subroutine GEOMRY, the user should use caution in attempting modifications. Changes in the direct calculation schemes related to the acoustic models assumed are found in the following lines of code:

Calculation of Ground Absorption: Lines 160 to 173
Calculation of Barrier Attenuation: Lines 326 to 338
Calculation of Reflection Gain: Lines 340 to 352
Calculation of Normalized Mean Intensity and Dispersion of Mean Intensity: Lines 356 to 381
Calculation of Atmospheric Absorption: Line 364.

Note: If the user desires to modify the barrier model described in this manual, he is warned to check subroutine GEOMRY thoroughly as several important criteria required for decisions concerning the accumulation of uniform acoustic intensity at a receiver are affected. Similarly, the user should not attempt to blindly alter the code for dimensions in metric units without appropriate modification of GEOMRY and other subprograms.

ACCURACY

Dependent upon the acoustic models utilized in the problem formulation.

SIZE

17624_8

REFERENCES

See Appendix A of this manual.

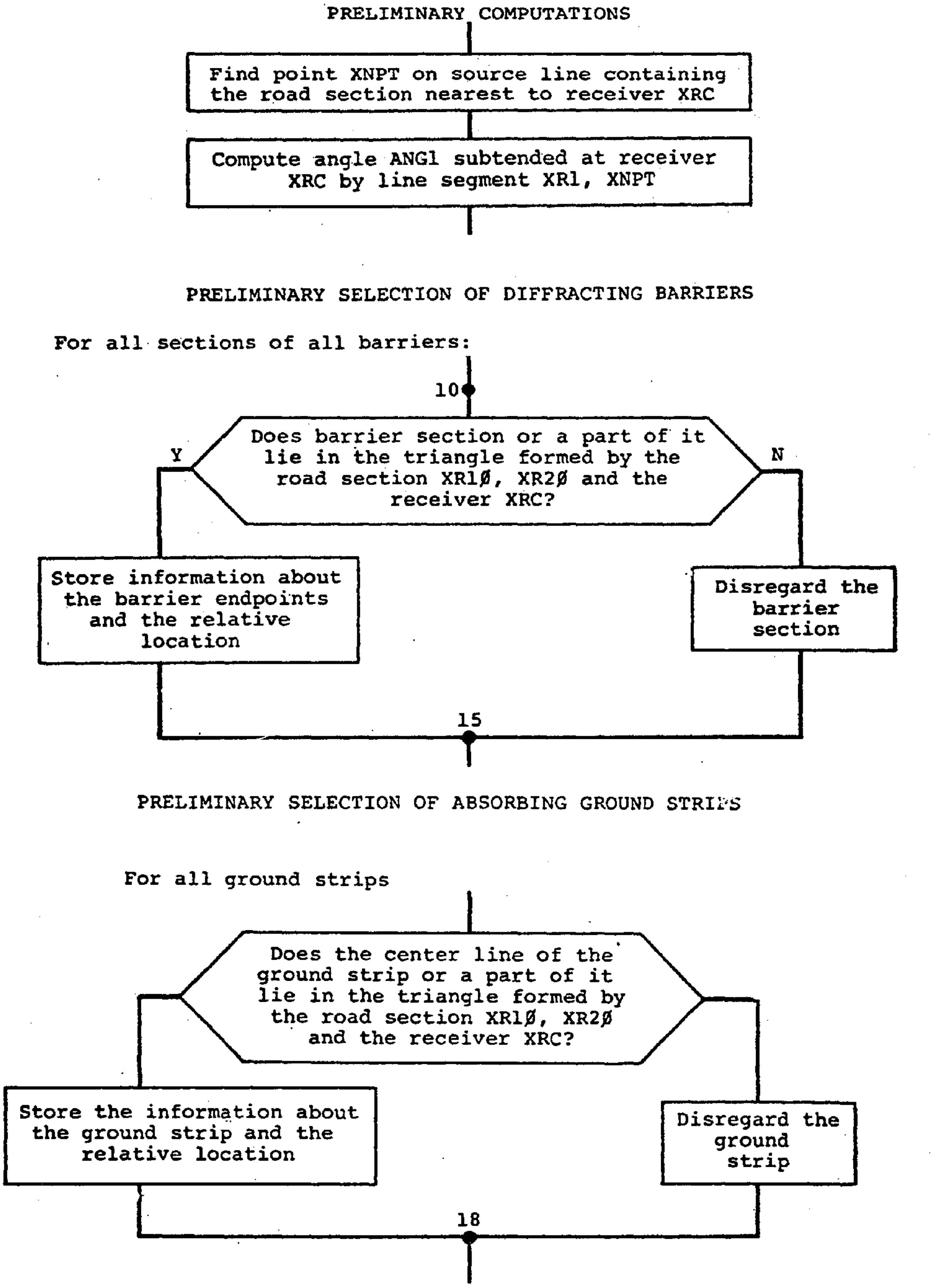


FIGURE E-7. SUBROUTINE GEOMRY: FLOW DIAGRAM OF PRELIMINARY OPERATIONS

DIFFRACTION OF DIRECT RAY

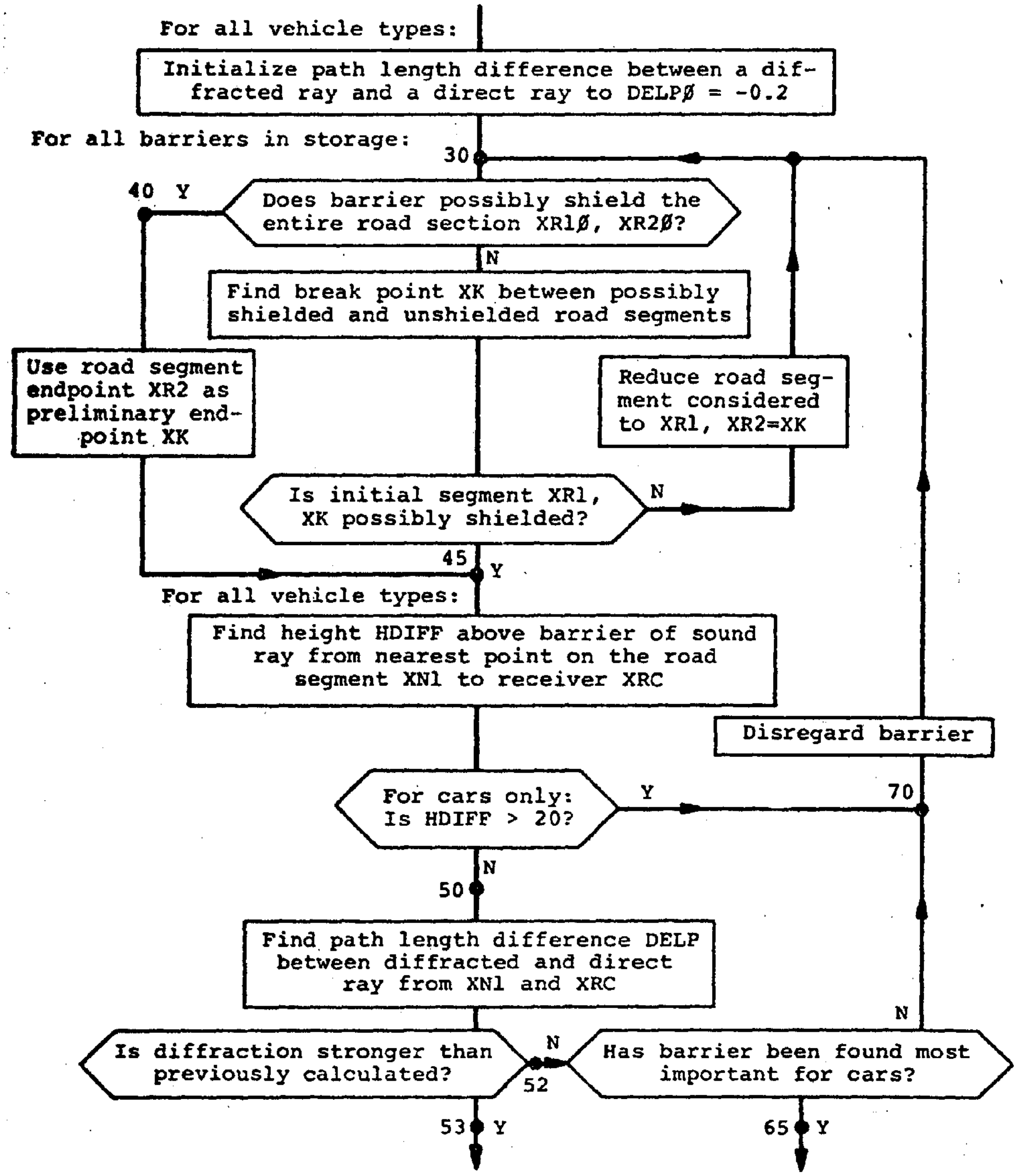


FIGURE E-8. SUBROUTINE GEOMRY: FLOW DIAGRAM OF BARRIER DIFFRACTION CONSIDERATIONS FOR THE DIRECT RAY

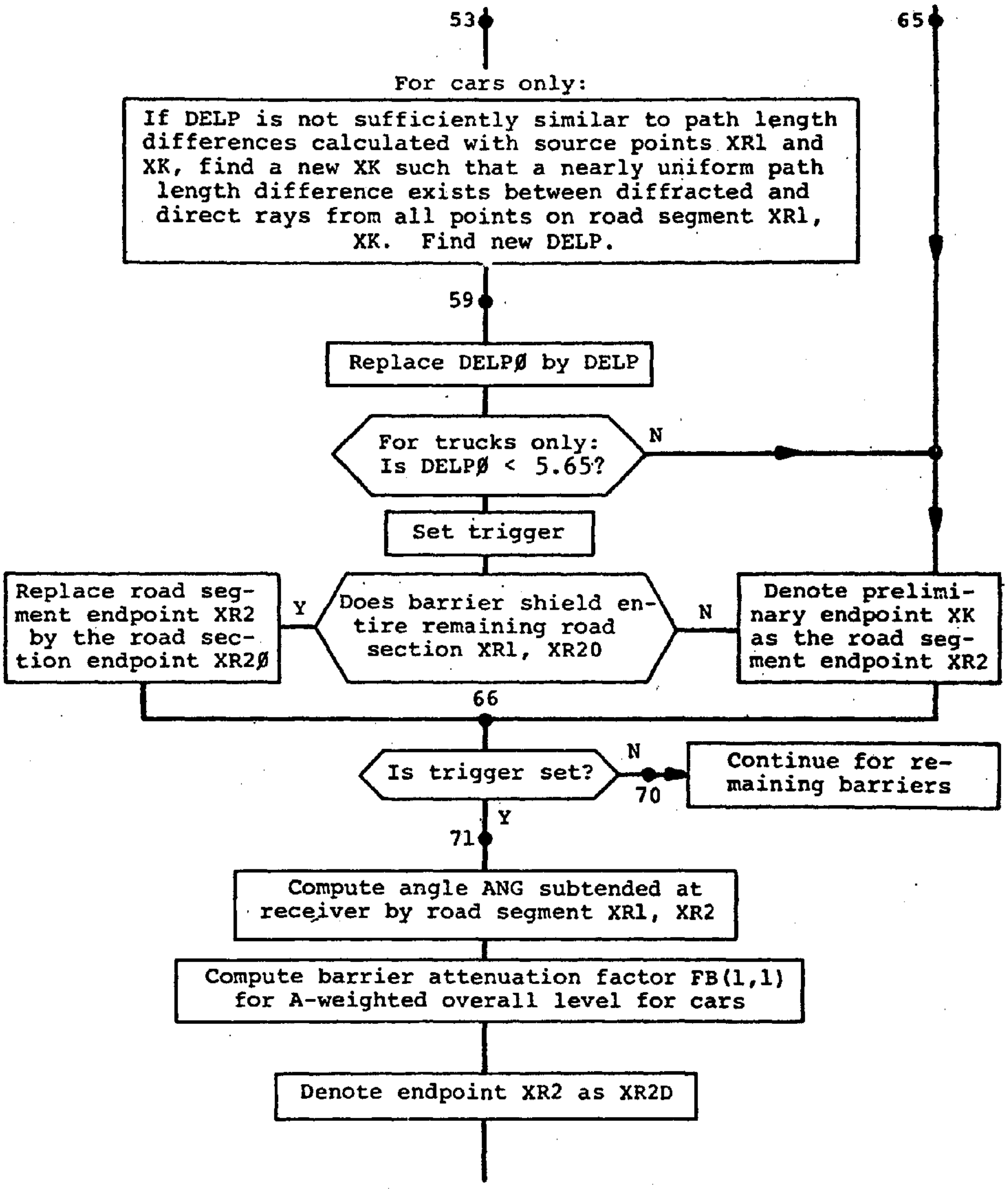


FIGURE E-8. (Concluded)

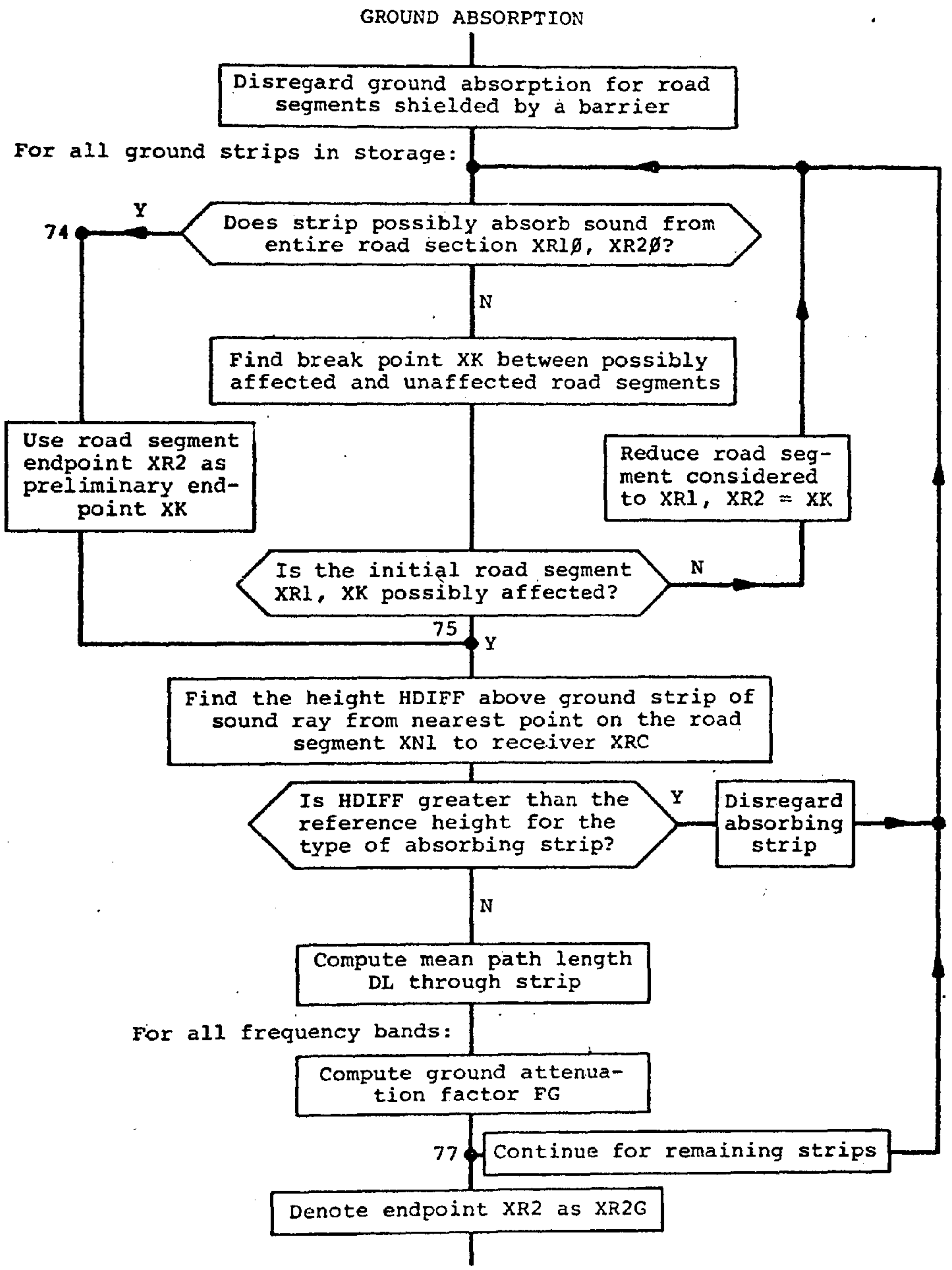


FIGURE E-9. SUBROUTINE GEOMRY: FLOW DIAGRAM OF ABSORPTIVE GROUND STRIP CONSIDERATIONS

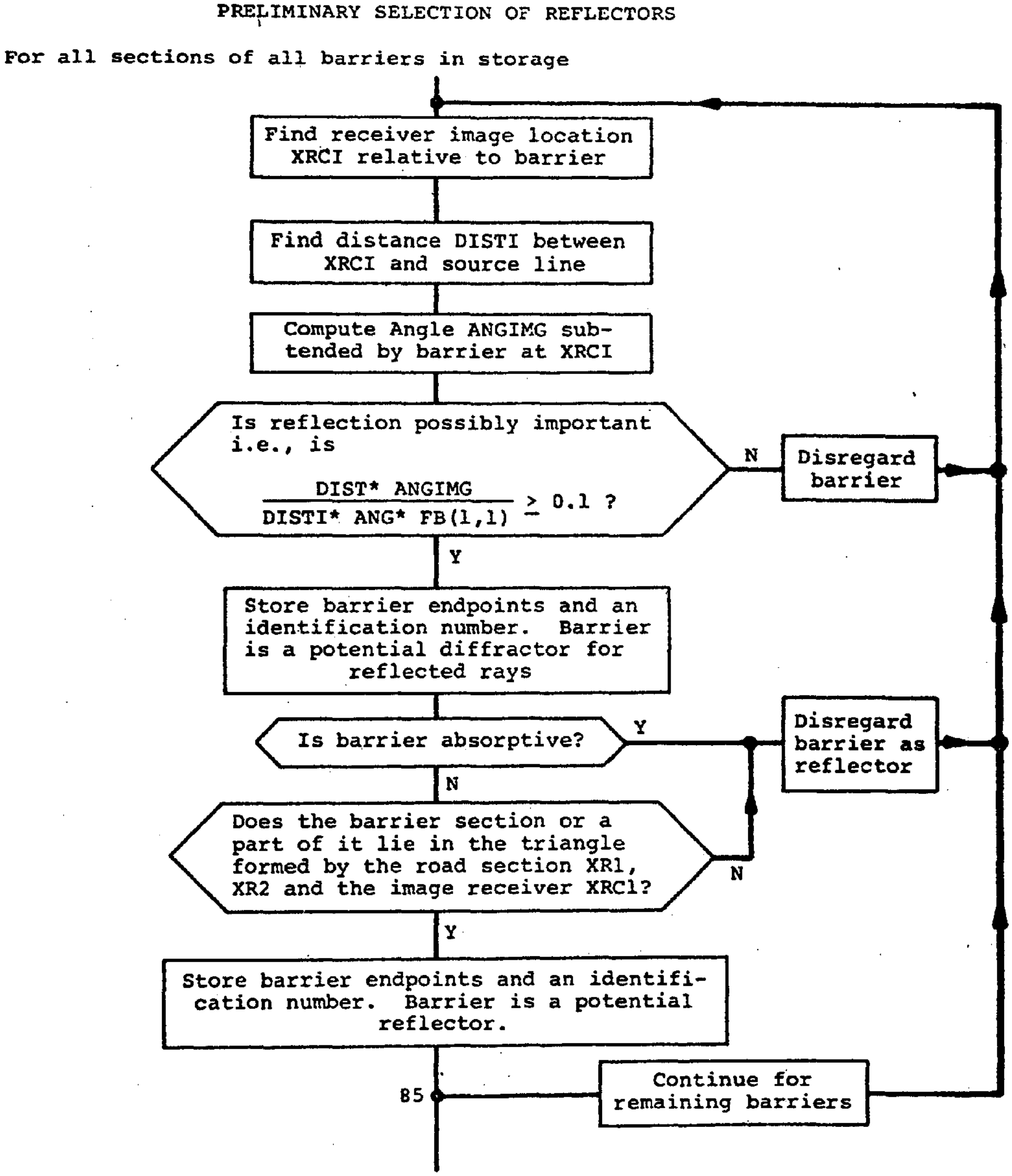


FIGURE E-10. SUBROUTINE GEOMRY: FLOW DIAGRAM FOR THE PRELIMINARY SELECTION OF REFLECTORS

CALCULATION OF POTENTIAL REFLECTIONS

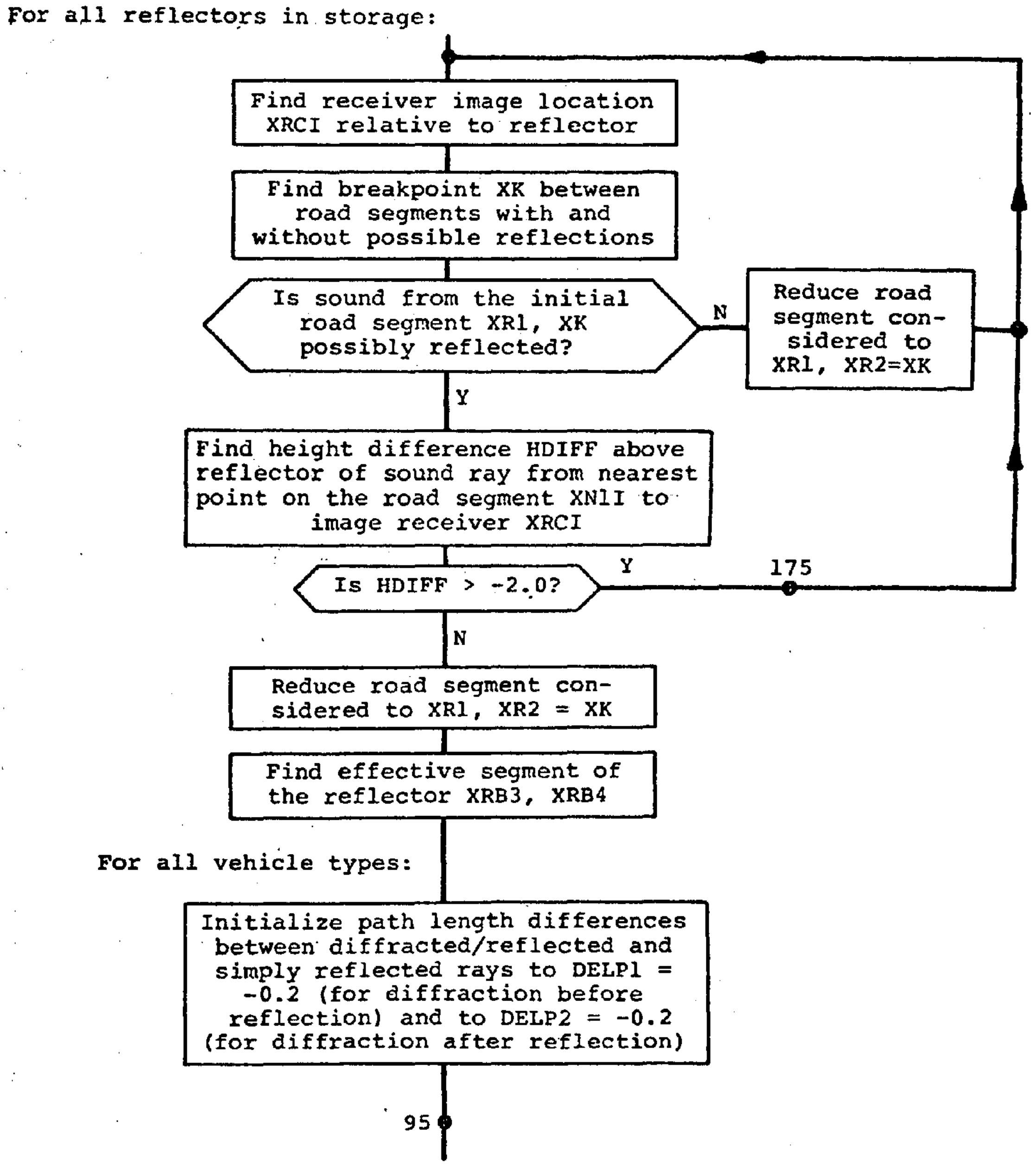


FIGURE E-11. SUBROUTINE GEOMRY: FLOW DIAGRAM FOR CALCULATION OF POTENTIAL REFLECTIONS

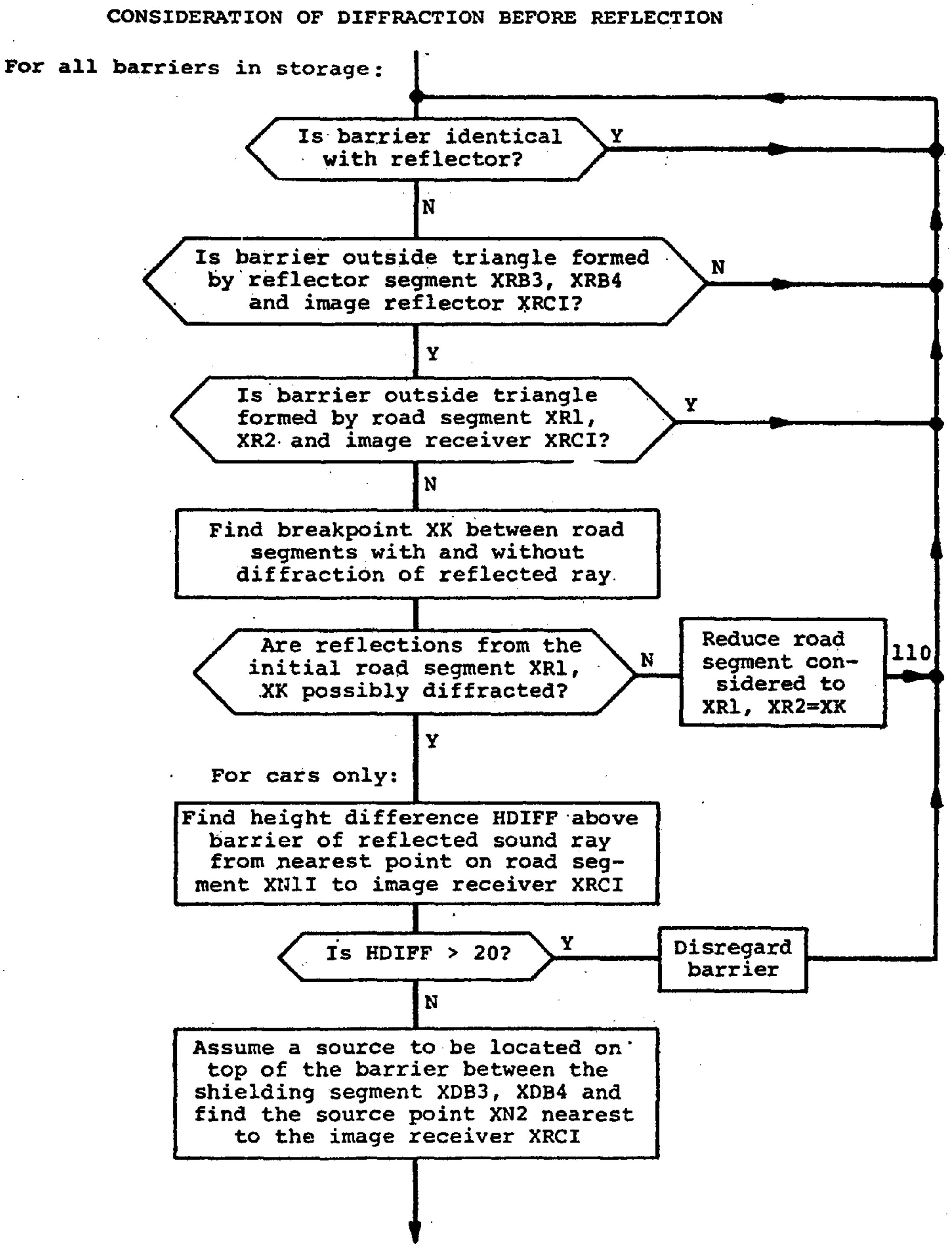


FIGURE E-12. SUBROUTINE GEOMRY: FLOW DIAGRAM FOR CONSIDERATION OF DIFFRACTION BEFORE REFLECTION

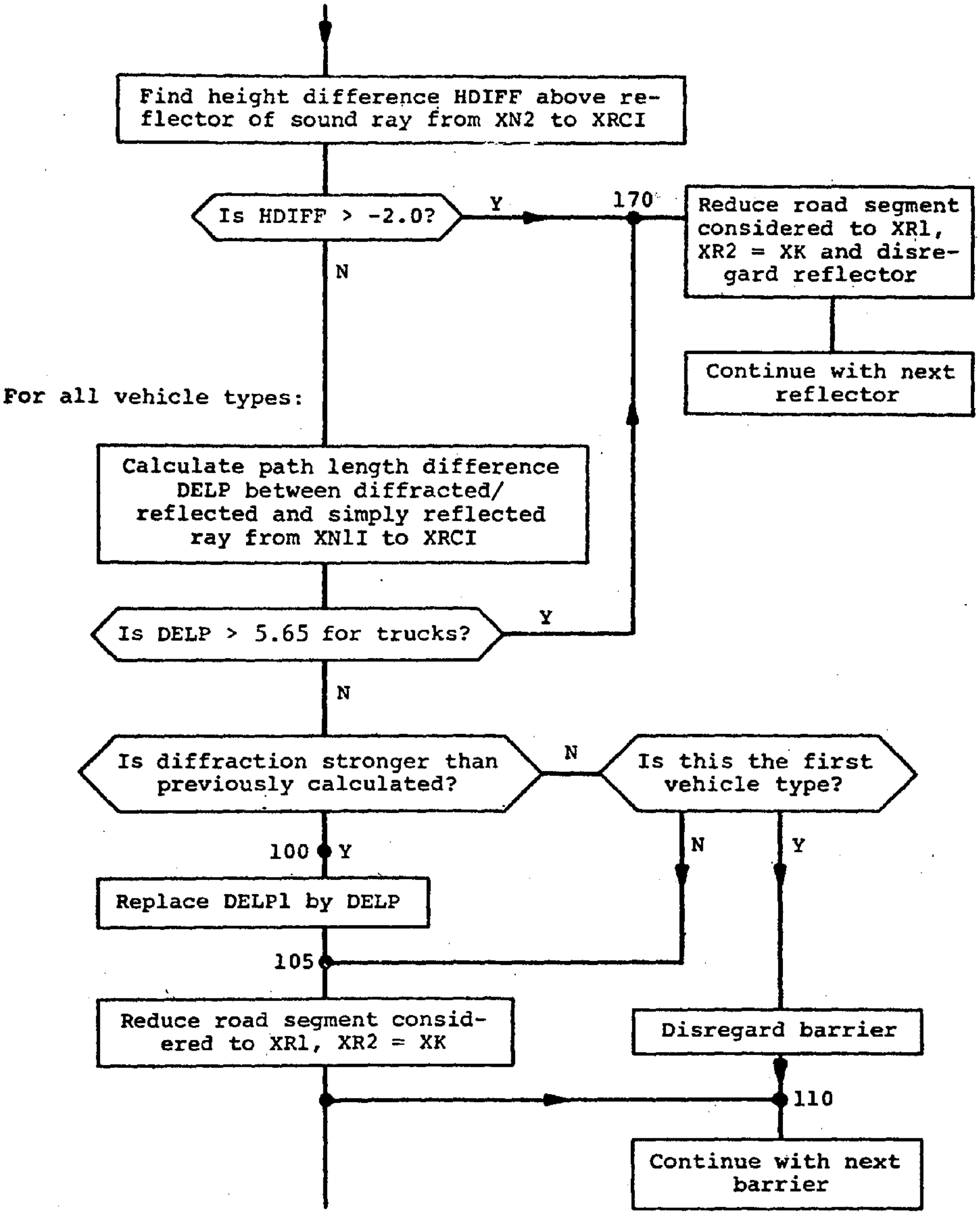


FIGURE E-12. (Concluded)

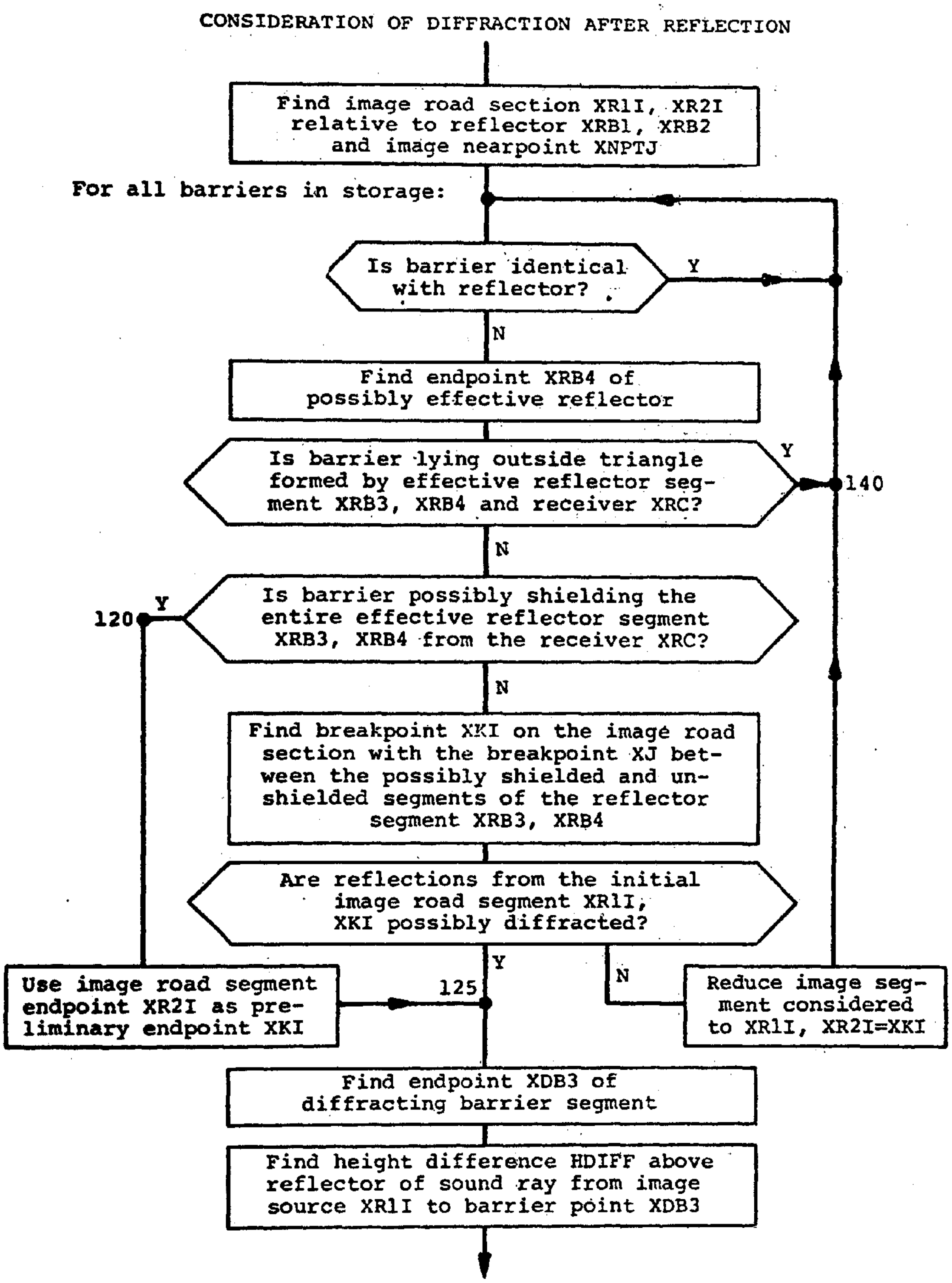


FIGURE E-13. SUBROUTINE GEOMRY: FLOW DIAGRAM FOR CONSIDERATION OF DIFFRACTION AFTER REFLECTION

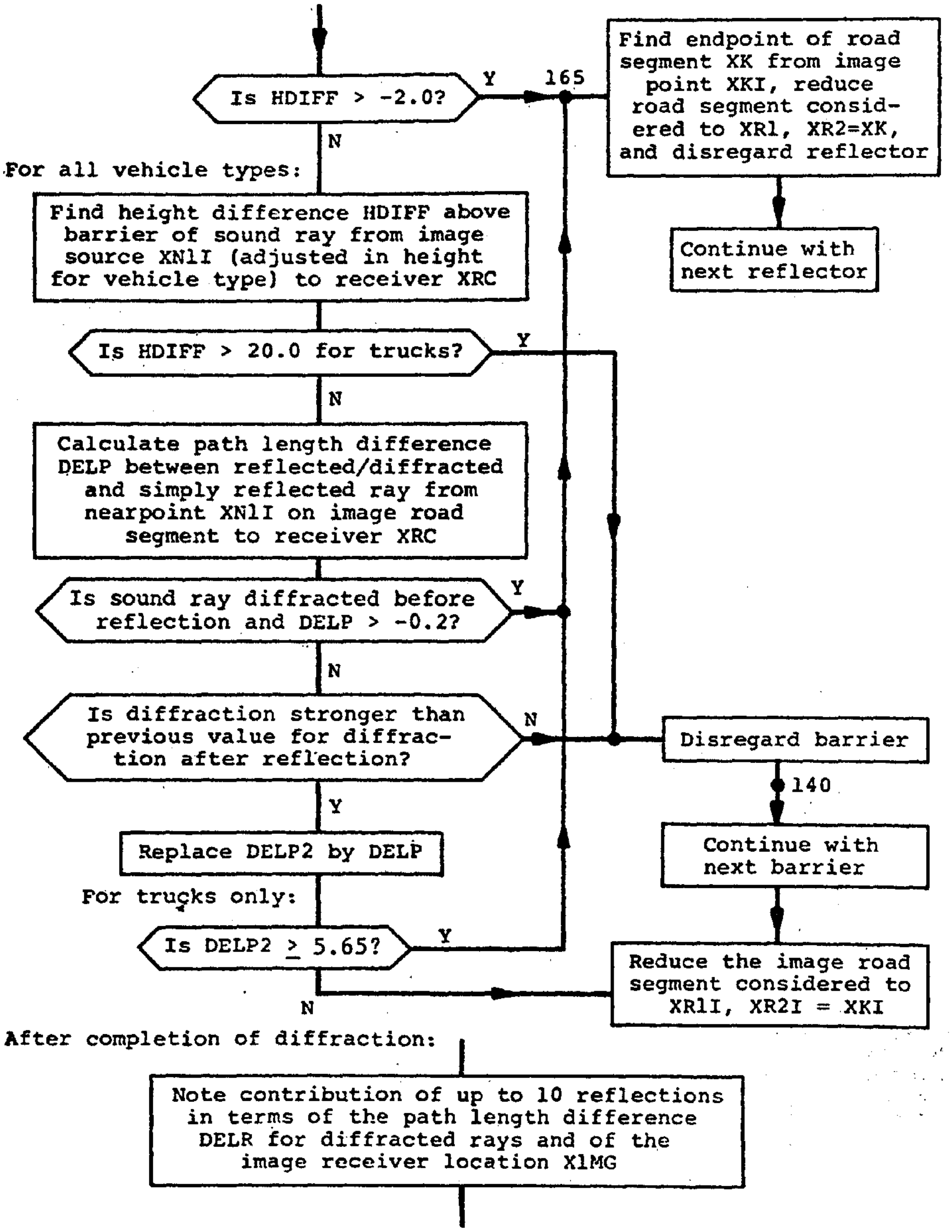


FIGURE E-13. (Concluded)

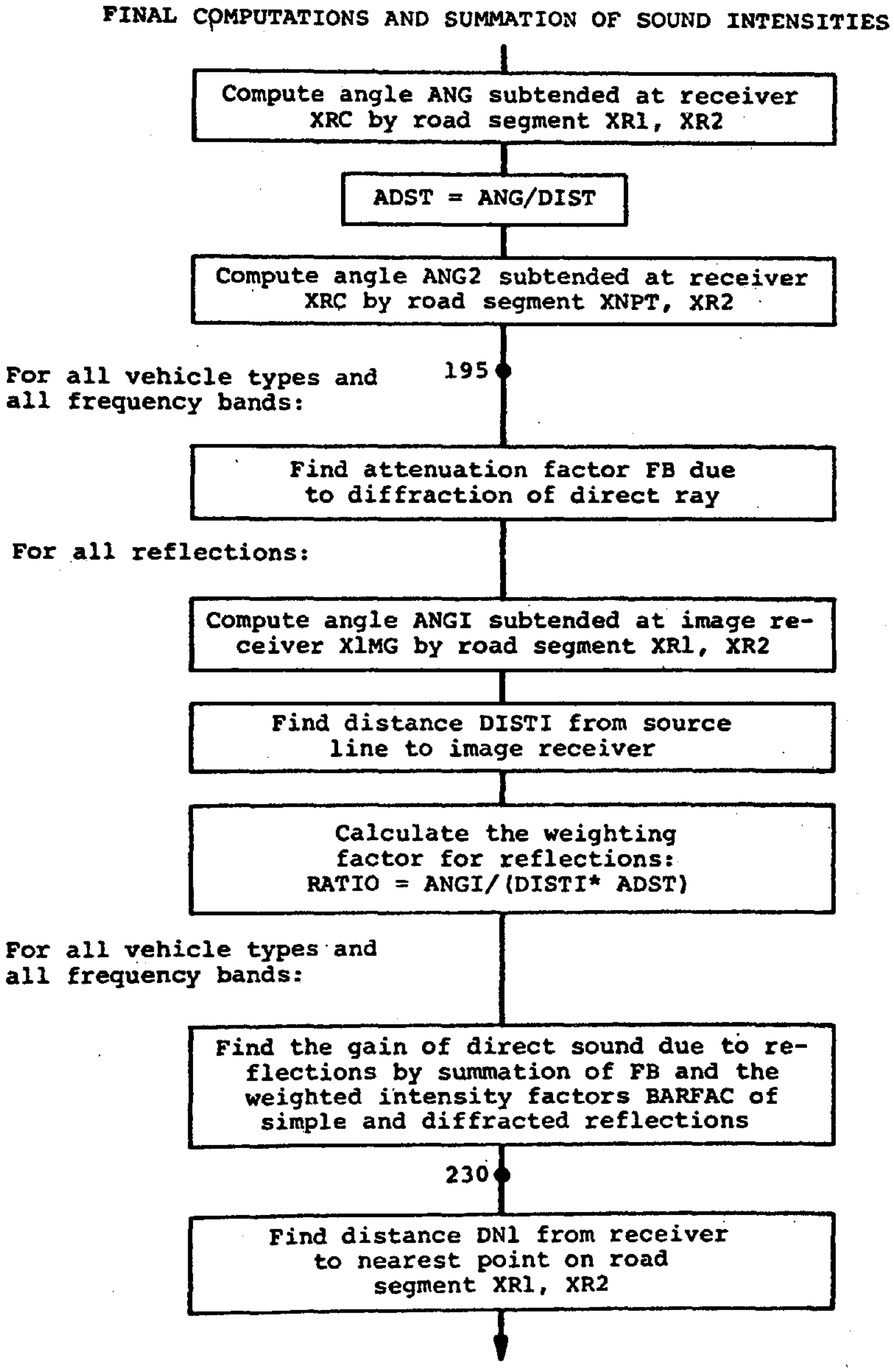


FIGURE E-14. SUBROUTINE GEOMRY: FLOW DIAGRAM FOR FINAL CALCULATION AND SUMMATION OF SOUND INTENSITIES

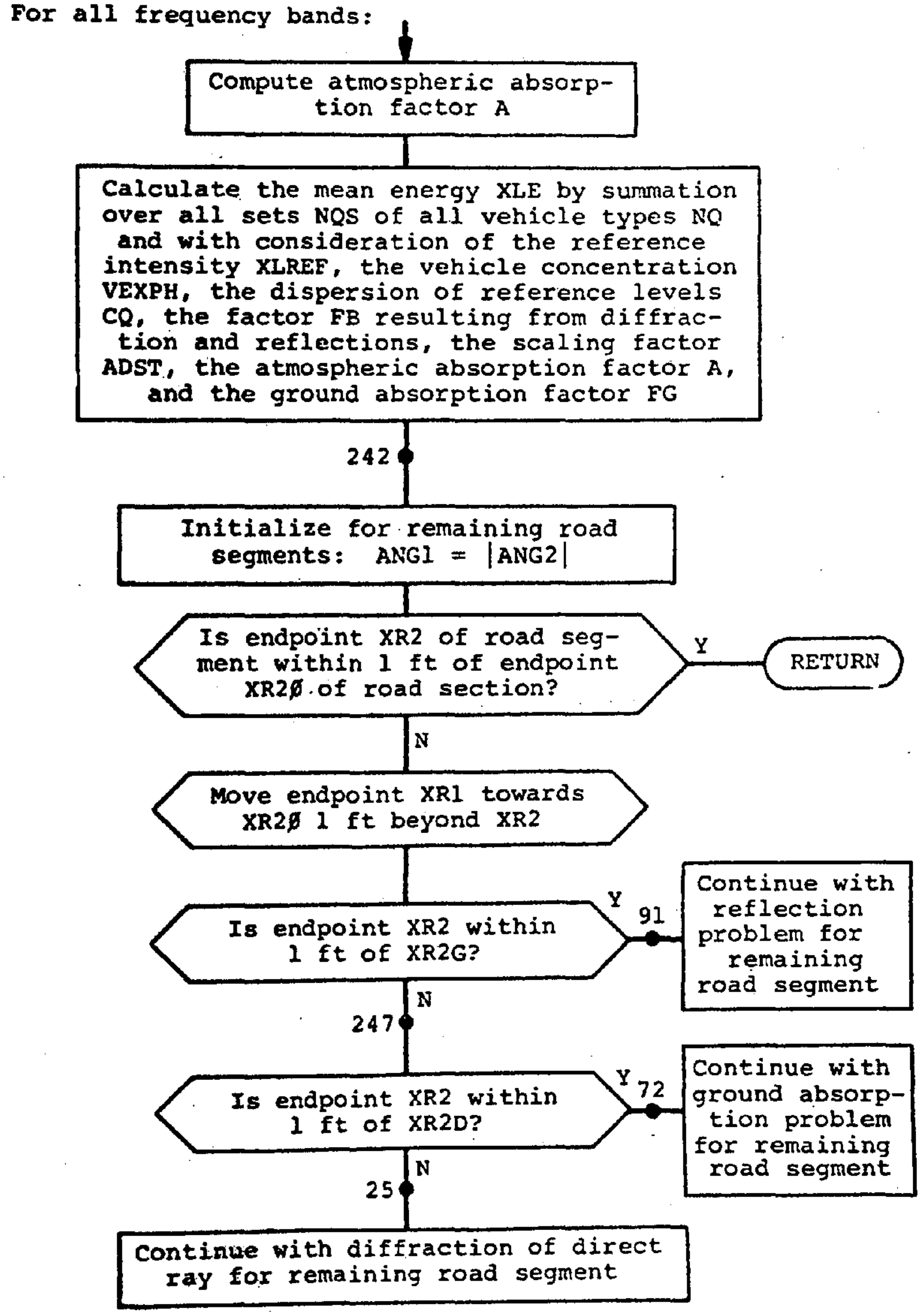


FIGURE E-14. (Concluded)

```
C   GEOMRY         06/79   SAI MOD
      SUBROUTINE GEOMRY(XR,YR,ZR,XR10,XR20,IERR,MR,GAM)
      IMPLICIT REAL*8 (A-H,O-Z)
      EXTERNAL FNC1,FNC2
      DIMENSION XG1(3),XG2(3),XG3(3),XG4(3)
      DIMENSION B1(3,2,20),R1(3,2,20),RB1(3,2,20),TA1(3,2,20)
      DIMENSION KBCODE(220),KNUMB(220),KRNUMB(220),KRDNUM(220)
      DIMENSION KGCODE(10),BGT(10),IKIN(10)
      DIMENSION
     D DELP0(4),DELP1(4),DELP2(4),FB(9,4),DELR(4,10),FG(9),HGA(2),
     X XB1(3),XB2(3),XDB1(3),XDB2(3),XDB3(3),XDB4(3),
     X XRB1(3),XRB2(3),XRB3(3),XRB4(3),XRC(3),XRCI(3),
     X XR1(3),XR2(3),XR1I(3),XR2I(3),XR10(3),XR20(3),
     X XK(3),XKI(3),XJ(3),XNPT(3),XNPTI(3),XNPTJ(3),
     X XN1(3),XN2(3),XN1I(3),XIMG(3,10),XR2D(3),XR2G(3),
     Z ZS(4)
      DIMENSION XH1(3),AUX(20)
      COMMON/INOU/INPT,IOUT
      COMMON/BLK2/NQ
      COMMON /INPT1/RDIN(6),TRDIN(6)
      COMMON/INPT2/NR,NB,NG
      COMMON/DRIV2/NQS(20,4),NF
      COMMON /DRIV3/XLE(9)
      COMMON/DRIV4/CAP2
      COMMON/STORE4/XMPH(20,5,4),VEXPH(20,5,4)
      COMMON/STORE1/BX(20,11),BY(20,11),BZ(20,11),IBLAST(20),NBSM1(20)
      COMMON/STORE2/XXG1(10,2),YYG1(10,2),ZZG1(10,2),BGS(10),IDUM(10)
      COMMON/GEO1/IBAR,ISEG,IGRA
      COMMON /INTER1/XLREF(3600),CQ(3600)
      COMMON /FUNC/XGAM
      COMMON/TIT1/TRC(5,15),BLEV(15),ZZQ,IGOO(20,11),N
      COMMON /OPTION/METIN,METOUT,IREFL
      EQUIVALENCE (RDIN(3),ZS(1))
      DATA   IR/2HR /
      DATA HGA(1),HGA(2)/10.,30./
      XGAM = GAM
      XRC(1)=XR
      XRC(2)=YR
      XRC(3)=ZR
      IERR=0
      CALL COLIN(XR10,XR20,XRC)
      CALL NRPT(XR10,XR20,XRC,XNPT,DIST)
      ANG1=ANGLE(XR10,XNPT,XRC)
C     ICODE=1
C     WRITE(IOUT,1000)ICODE,XR10,XR20,XRC,XNPT
C PRELIMINARY SELECTION OF BARRIERS
      NDIFF=0
      IF(NB.EQ.0) GO TO 16
      KBAR=0
      DO 15 IBAR=1,NB
      KAR=IBLAST(IBAR)
      XB1(1)=BX(IBAR,1)
      XB1(2)=BY(IBAR,1)
      XB1(3)=BZ(IBAR,1)
      NLIM=NBSM1(IBAR)+1
      DO 15 ISEG=2,NLIM
      XB2(1)=BX(IBAR,ISEG)
      XB2(2)=BY(IBAR,ISEG)
      XB2(3)=BZ(IBAR,ISEG)
      KBAR=KBAR+1
```

SUBROUTINE GEOMRY: LISTING

```
C     ICODE=2
C     WRITE(IOUT,1001)ICODE,KBAR,XB1,XB2
   10 CALL DEGEN(XR10,XR20,XRC,XB1,XB2,LOC)
      IF (LOC.EQ.5) CALL BLOCN(XR10,XR20,XRC,XB1,XB2,XK,LOC)
   11 IF(LOC.EQ.0)GO TO 12
      NDIFF=NDIFF+1
      KNUMB(NDIFF)=KBAR
      KBCODE(NDIFF)=LOC
      CALL REPLCE(XB1,B1(1,1,NDIFF))
      CALL REPLCE(XB2,B1(1,2,NDIFF))
   12 CALL REPLCE(XB2,XB1)
   15 CONTINUE
C PRELIMINARY SELECTION OF STRIPS
   16 KGA=0
      IF(NG.EQ.0)GO TO 20
      DO 18 IGRA=1,NG
      XG1(1)=XXG1(IGRA,1)
      XG1(2)=YYG1(IGRA,1)
      XG1(3)=ZZG1(IGRA,1)
      XG2(1)=XXG1(IGRA,2)
      XG2(2)=YYG1(IGRA,2)
      XG2(3)=ZZG1(IGRA,2)
C     ICODE=3
C     WRITE(IOUT,1001)ICODE,IGRA,XG1,XG2
   17 CALL DEGEN(XR10,XR20,XRC,XG1,XG2,LOC)
      IF(LOC.EQ.5)CALL BLOCN(XR10,XR20,XRC,XG1,XG2,XK,LOC)
      IF(LOC.EQ.0)GO TO 18
      KGA=KGA+1
      KGCODE(KGA)=LOC
      CALL REPLCE(XG1,TA1(1,1,KGA))
      CALL REPLCE(XG2,TA1(1,2,KGA))
      BGT(KGA)=BGS(IGRA)
      IKIN(KGA)=IDUM(IGRA)
   18 CONTINUE
C DIFFRACTION OF DIRECT RAY
   20 CALL REPLCE(XR10,XR1)
   25 CALL REPLCE(XR20,XR2)
      CALL REPLCE(XR1,XH1)
      DO 30 IQ=1,NQ
      DELPO(IQ)=-.2
   30 CONTINUE
C     ICODE=4
C     WRITE(IOUT,1000)ICODE,XR1,XR2
      IF(NDIFF.EQ.0)GO TO 71
      ITRIG=0
      DO 70 KDIFF=1,NDIFF
      KBAR=KNUMB(KDIFF)
      KCD=KBCODE(KDIFF)
      CALL REPLCE(B1(1,1,KDIFF),XB1)
      CALL REPLCE(B1(1,2,KDIFF),XB2)
C     ICODE=5
C     WRITE(IOUT,1001)ICODE,KBAR,XR1,XR2,XB1,XB2
      IF(KCD.EQ.3)GO TO 40
      CALL ENDPT(XR1,XR2,XRC,XB1,XB2,XK,KTRIG,IERR)
      IF(IERR.EQ.4) RETURN
      IF(KTRIG.EQ.0)GO TO 70
      GO TO 45
   40 CALL REPLCE(XR2,XK)
   45 MODD=0
C     ICODE=6
C     WRITE(IOUT,1001)ICODE,KCD,XR2,XK
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
      DO 60 IQ=1,NQ
      CALL NR1(XR1,XK,XRC,XNPT,DIST,XN1,DN1)
      XN1(3) = XN1(3) + ZS(IQ)
      XH1(3) = XR1(3) + ZS(IQ)
      DN1=AMAG(XRC,XN1)
      HDIFF=HEIGHT(XN1,XRC,XB1,XB2)
      IF(IQ.NE.1)GO TO 50
      IF(HDIFF.GT.20.)GO TO 70
   50 DELP=DEL(XN1,XRC,XB1,XB2,HDIFF,DN1)
      IF(DELP.GT.DELPO(IQ))GO TO 53
   52 IF(MODD.EQ.1)GO TO 65
      GO TO 70
   53 IF (IQ.NE.1) GO TO 59
      DR1 = AMAG(XRC,XH1)
C  ADJUST ELEVATION OF XK
      XK(3) = XK(3) + ZS(IQ)
      IF (DABS(DR1-DN1).LT.1.) GO TO 54
      HDIFA = HEIGHT(XH1,XRC,XB1,XB2)
      DELPA = DEL(XH1,XRC,XB1,XB2,HDIFA,DR1)
      DELM= (DELPA + DELP)/2.
C     ICODE=107
C     WRITE(IOUT,1000)ICODE,DELP,DELPA
      IF ((DABS(DELPA-DELP)-0.1-DELM/50.*(1.+DELM)).LE.0.) GO TO 55
      CALL MIDP(XH1,XN1,XK)
C     ICODE=7
C     WRITE(IOUT,1000)ICODE,XR1,XN1,XK
      DELP = DELPA
   54 IF (IEPS(XK,XRC,XB1,XB2,DELP).EQ.0) GO TO 58
      CALL MIDP(XH1,XK,XK)
C     ICODE=8
C     WRITE(IOUT,1000)ICODE,XR1,XK
      GO TO 54
   55 DRK= AMAG (XRC,XK)
      IF (DABS(DRK-DN1).LT.1.) GO TO 58
   56 IF(IEPS (XK,XRC,XB1,XB2,DELP).EQ.0) GO TO 58
      CALL MIDP(XN1,XK,XK)
      GO TO 56
C  READJUST XK TO GROUND LEVEL
 58   XK(3) = XK(3)-ZS(IQ)
      IF (DELP.LE.DELPO(1)) GO TO 52
   59 DELPO (IQ) = DELP
C     ICODE=10
C     WRITE(IOUT,1000)ICODE,DELPO(1),DELPO(2)
      MODD=1
   60 CONTINUE
      IF(DELPO(2).LT.5.65)GO TO 65
      ITRIG=1
      IF(KCD.NE.3.OR.KCD.NE.2)GO TO 65
      CALL REPLCE(XR20,XR2)
      GO TO 66
   65 CALL REPLCE(XK,XR2)
   66 IF(ITRIG.EQ.1)GO TO 71
   70 CONTINUE
C     ICODE=11
C     WRITE(IOUT,1000)ICODE,XR2
   71 ANG=ANGLE(XR1,XR2,XRC)
      IF (ANG.LT.0.01D-05) WRITE (IOUT,9001) XR1,XR2,XRC
      DELP=DELPO(1)
      FB(1,1)=BARFAC(1,DELP)
C     ICODE=12
C     WRITE(IOUT,1002)ICODE,FB(1,1)
      CALL REPLCE(XR2,XR2D)
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
C GROUND ABSORPTION
   72 DO 73 KF=1,NF
      FG(KF)=1.
   73 CONTINUE
C     ICODE=13
C     WRITE(IOUT,1000)ICODE,XR1,XR2,XR2D
      KTRG=0
      IF(DELPO(1).GT.-0.2)GO TO 78
      IF(KGA.EQ.0)GO TO 78
      DO 77 IGRA=1,KGA
      LOC=KGCODE(IGRA)
      CALL REPLCE(TA1(1,1,IGRA),XG1)
      CALL REPLCE(TA1(1,2,IGRA),XG2)
      BG=BGT(IGRA)
      IKIND=IKIN(IGRA)
C     ICODE=14
C     WRITE(IOUT,1001)ICODE,LOC,XG1,XG2
      IF(LOC.EQ.3)GO TO 74
      CALL ENDPT(XR1,XR2,XRC,XG1,XG2,XK,KTRIG,IERR)
      KTRG=KTRIG
      IF(IERR.EQ.4) RETURN
      IF(KTRIG.EQ.0)GO TO 77
      GO TO 75
   74 CALL REPLCE(XR2,XK)
   75 CALL NR1(XR1,XK,XRC,XNPT,DIST,XN1,DN1)
      HDIFF=HEIGHT(XN1,XRC,XG1,XG2)
      IF(HDIFF.GT.HGA(IKIND))GO TO 77
      CALL SECTN(XR1,XK,XRC,XG1,XG2,XG3,XG4)
      DL=1.57/(1./BG+1./AMAG(XG3,XG4))
      DO 76 IK=1,NF
      PP=IK
      IF(IK.EQ.1)PP=5.
      IF(IKIND.EQ.1)A=(.0016*PP-0.0028)*DL
      IF(IKIND.EQ.2)A=2.**(PP/3.)/1310.*DL
      IF(A.GT.2.)A=2.
      FG(IK)=FG(IK)/10.**A
      IF(FG(IK).LT.1.E-2)FG(IK)=1.E-2
   76 CONTINUE
      KTRG=1
      CALL REPLCE(XK,XR2)
C     ICODE=15
C     WRITE(IOUT,1000)ICODE,FG(1),FG(9)
   77 CONTINUE
   78 CALL REPLCE(XR2,XR2G)
C PRELIMINARY SELECTION OF REFLECTORS
      NREF=0
      IF(NB.EQ.0)GO TO 91
      IF (IREFL.EQ.0) GO TO 91
      NRFDF=0
      KBAR=0
      DO 85 IBAR=1,NB
      KAR=IBLAST(IBAR)
      XRB1(1)=BX(IBAR,1)
      XRB1(2)=BY(IBAR,1)
      XRB1(3)=BZ(IBAR,1)
      NLIM=NBSM1(IBAR)+1
      DO 85 ISEG=2,NLIM
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
      XRB2(1)=BX(IBAR,ISEG)
      XRB2(2)=BY(IBAR,ISEG)
      XRB2(3)=BZ(IBAR,ISEG)
      KBAR=KBAR+1
C     ICODE=16
C     WRITE(IOUT,1001)ICODE,KBAR,XR1,XR2,XRB1,XRB2
      CALL IMAGE(XRB1,XRB2,XRC,XRCI)
      CALL NRPT(XR1,XR2,XRCI,XNPTI,DISTI)
C     ICODE=17
C     WRITE(IOUT,1000)ICODE,XRCI,XNPTI
      ANGIMG=ANGLE(XRB1,XRB2,XRCI)
      FCTR=(DIST*ANGIMG)/DISTI/ANG/FB(1,1)
      IF(FCTR.LT.0.1)GO TO 80
      NRFDF=NRFDF+1
      KRDNUM(NRFDF)=KBAR
      CALL REPLCE(XRB1,RB1(1,1,NRFDF))
      CALL REPLCE(XRB2,RB1(1,2,NRFDF))
C     ICODE=18
C     WRITE(IOUT,1001)ICODE,NRFDF,XRB1,XRB2
      IF(KAR.NE.IR)GO TO 80
      CALL DEGEN(XR1,XR2,XRCI,XRB1,XRB2,LOC)
      IF (LOC.EQ.5) CALL BLOCN(XR1,XR2,XRCI,XRB1,XRB2,XK,LOC)
   79 IF(LOC.EQ.0)GO TO 80
      NREF=NREF+1
      KRNUMB(NREF)=KBAR
      CALL REPLCE(XRB1,R1(1,1,NREF))
      CALL REPLCE(XRB2,R1(1,2,NREF))
C     ICODE=19
C     WRITE(IOUT,1001)ICODE,NREF,XRB1,XRB2
   80 CALL REPLCE(XRB2,XRB1)
   85 CONTINUE
C BEGIN REFLECTOR PROBLEM
   91 IDXR=0
      IF(NREF.EQ.0)GO TO 180
      DO 175 KREF=1,NREF
      KBAR1=KRNUMB(KREF)
      CALL REPLCE(R1(1,1,KREF),XRB1)
      CALL REPLCE(R1(1,2,KREF),XRB2)
C     ICODE=20
C     WRITE(IOUT,1001)ICODE,KBAR1,XRB1,XRB2,XR1,XR2
      CALL IMAGE(XRB1,XRB2,XRC,XRCI)
      CALL ENDPT(XR1,XR2,XRCI,XRB1,XRB2,XK,KTRIG,IERR)
      IF(IERR.EQ.4) RETURN
C     ICODE=21
C     WRITE(IOUT,1001)ICODE,KTRIG,XRCI,XK
      IF(KTRIG.EQ.0)GO TO 175
      CALL NRPT(XR1,XR2,XRCI,XNPTI,DISTI)
      CALL NR1(XR1,XK,XRCI,XNPTI,DISTI,XN1I,DN1I)
C     ICODE=22
C     WRITE(IOUT,1000)ICODE,XNPTI,XN1I
      XN1I(3)=XN1I(3)+ZS(2)
      HDIFF=HEIGHT(XN1I,XRCI,XRB1,XRB2)
      IF(HDIFF.GT.-2.0)GO TO 175
      CALL REPLCE(XK,XR2)
      CALL SECTN(XR1,XR2,XRCI,XRB1,XRB2,XRB3,XRB4)
C     ICODE=23
C     WRITE(IOUT,1000)ICODE,XR1,XR2,XRB3,XRB4
      HDIFF=0
      DO 95 IQ=1,NQ
      DELP1(IQ)=-0.2
      DELP2(IQ)=-0.2
   95 CONTINUE
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
C DIFFRACTION BEFORE REFLECTION
      IF(NRFDF.EQ.0)GO TO 115
      DO 110 KRFDF=1,NRFDF
      KBAR2=KRDNUM(KRFDF)
      CALL REPLCE(RB1(1,1,KRFDF),XDB1)
      CALL REPLCE(RB1(1,2,KRFDF),XDB2)
C     ICODE=24
C     WRITE(IOUT,1001)ICODE,KBAR2,XDB1,XDB2
      IF(KBAR2.EQ.KBAR1)GO TO 110
      CALL DEGEN(XRB3,XRB4,XRCI,XDB1,XDB2,LOC)
      IF (LOC.EQ.5) CALL BLOCN(XRB3,XRB4,XRCI,XDB1,XDB2,XK,LOC)
   96 IF(LOC.NE.0)GO TO 110
      CALL ENDPT(XR1,XR2,XRCI,XDB1,XDB2,XK,KTRIG,IERR)
      IF(IERR.EQ.4) RETURN
C     ICODE=25
C     WRITE(IOUT,1001)ICODE,KTRIG,XK
      IF(KTRIG.EQ.0)GO TO 110
      CALL NR1(XR1,XK,XRCI,XNPTI,DISTI,XN1I,DN1I)
C     ICODE=26
C     WRITE(IOUT,1000)ICODE,XN1I
      ZN10=XN1I(3)
      XN1I(3)=ZN10+ZS(1)
      HDIFF=HEIGHT(XN1I,XRCI,XDB1,XDB2)
      IF(HDIFF.GT.20.0)GO TO 110
      CALL SECTN(XR1,XK,XRCI,XDB1,XDB2,XDB3,XDB4)
C     ICODE=27
C     WRITE(IOUT,1000)ICODE,XDB3,XDB4
      CALL NRPT(XDB3,XDB4,XRCI,XNPTJ,DISTJ)
      CALL NR1(XDB3,XDB4,XRCI,XNPTJ,DISTJ,XN2,DN2)
C     ICODE=127
C     WRITE(IOUT,1000)ICODE,XNPTJ,XN2,DISTJ,DN2
      HDIFF=HEIGHT(XN2,XRCI,XRB1,XRB2)
C     ICODE=227
C     WRITE(IOUT,1002)ICODE,HDIFF
      IF(HDIFF.GT.-2.0)GO TO 170
      DO 105 II=1,NQ
      IQ=NQ+1-II
      DN1I=AMAG(XRCI,XN1I)
      HDIFF=HEIGHT(XN1I,XRCI,XDB1,XDB2)
      DELP=DEL(XN1I,XRCI,XDB1,XDB2,HDIFF,DN1I)
C     ICODE=327
C     WRITE(IOUT,1002)ICODE,DELP
      IF(DELP.GE.5.65.AND.IQ.EQ.2)GO TO 170
      IF(DELP.GT.DELP1(IQ))GO TO 100
      IF(IQ.EQ.1)GO TO 110
      GO TO 105
  100 MDIFF=I
      DELP1(IQ)=DELP
  105 CONTINUE
C     ICODE=28
C     WRITE(IOUT,1000)ICODE,DELP1(1),DELP1(2)
      CALL REPLCE(XK,XR2)
  110 CONTINUE
C     ICODE=29
C     WRITE(IOUT,1000)ICODE,XR2
C DIFFRACTION AFTER REFLECTION
      CALL IMAGE(XRB1,XRB2,XNPTI,XNPTJ)
      CALL IMAGE(XRB1,XRB2,XR1,XR1I)
  115 CALL IMAGE(XRB1,XRB2,XR2,XR2I)
C     ICODE=30
C     WRITE(IOUT,1000)ICODE,XR1I,XR2I,XNPTI
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
      IF(NRFDF.EQ.0)GO TO 145
      DO 140 KRFDF=1,NRFDF
      KBAR2=KRDNUM(KRFDF)
      CALL REPLCE(RB1(1,1,KRFDF),XDB1)
      CALL REPLCE(RB1(1,2,KRFDF),XDB2)
C     ICODE=31
C     WRITE(IOUT,1001)ICODE,KBAR2,XDB1,XDB2
      IF(KBAR2.EQ.KBAR1)GO TO 140
      CALL INTCPT(XRB1,XRB2,XRC,XR2I,XRB4)
      CALL DEGEN(XRB3,XRB4,XRC,XDB1,XDB2,LOC)
      IF (LOC.EQ.5) CALL BLOCN(XRB3,XRB4,XRC,XDB1,XDB2,XJ,LOC)
  117 IF(LOC.EQ.0)GO TO 140
      IF(LOC.EQ.3)GO TO 120
      CALL INTCPT(XR1I,XR2I,XRC,XJ,XKI)
      XKI(3)=ZCOR(XR1I,XR2I,XKI)
      DELTA=-0.5
      CALL MOVE(XKI,XKI,XR1I,DELTA,IERR)
      IF(IERR.EQ.4) RETURN
      IF(LOC.NE.1)GO TO 135
      GO TO 125
  120 CALL REPLCE(XR2I,XKI)
  125 CALL INTCPT(XR1I,XRC,XDB1,XDB2,XDB3)
C     ICODE=32
C     WRITE(IOUT,1001)ICODE,LOC,XJ,XKI,XDB3
      XDB3(3)=ZCOR(XDB1,XDB2,XDB3)
      HDIFF=HEIGHT(XR1I,XDB3,XRB1,XRB2)
      IF(HDIFF.GT.-2.0)GO TO 165
      CALL NR1(XR1I,XKI,XRC,XNPTJ,DISTI,XN1I,DN1I)
      ZN10=XN1I(3)
      DO 130 II=1,NQ
      IQ=NQ+1-II
      XN1I(3)=ZN10+ZS(IQ)
      DN1I=AMAG(XRC,XN1I)
      HDIFF=HEIGHT(XN1I,XRC,XDB1,XDB2)
      IF(HDIFF.GT.20.0.AND.IQ.EQ.2)GO TO 140
      DELP=DEL(XN1I,XRC,XDB1,XDB2,HDIFF,DN1I)
      IF(MDIFF.EQ.1.AND.DELP.GT.-0.2)GO TO 165
      IF(DELP.LE.DELP2(IQ))GO TO 140
      DELP2(IQ)=DELP
  130 CONTINUE
C     ICODE=33
C     WRITE(IOUT,1000)ICODE,DELP2(1),DELP2(2)
      IF(DELP2(2).GE.5.65)GO TO 165
  135 CALL REPLCE(XKI,XR2I)
  140 CONTINUE
  145 CALL REPLCE(XR2I,XKI)
      IDXR=IDXR+1
C     ICODE=34
C     WRITE(IOUT,1001)ICODE,IDXR,XR2I
      IF(IDXR.LT.11)GO TO 150
      IERR=3
      RETURN
  150 DO 155 IQ=1,NQ
      DELR(IQ,IDXR)=DMAX1(DELP1(IQ),DELP2(IQ))
  155 CONTINUE
      DO 160 I=1,3
      XIMG(I,IDXR)=XRCI(I)
  160 CONTINUE
      GO TO 165
  165 CALL IMAGE(XRB1,XRB2,XKI,XK)
  170 CALL REPLCE(XK,XR2)
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
C     ICODE=35
C     WRITE(IOUT,1000)ICODE,XR2
 175  CONTINUE
C     ICODE=36
C     WRITE(IOUT,1000)ICODE,XR1,XR2
C BEGIN BARRIER FACTOR COMPUTATION
 180  NIMG=IOXR
      ANG=ANGLE(XR1,XR2,XRC)
      ADST=ANG/DIST
      IF(KPOS(XNPT,XR2,XR1).EQ.1)GO TO 190
      ANG2=ANG1-ANG
      GO TO 195
 190  ANG2=ANG1+ANG
C CONTRIBUTION FROM DIRECT RAY
 195  DO 205 IQ=1,NQ
      IF(NQS(MR,IQ).EQ.0)GO TO 205
      DELP=DELPO(IQ)
      DO 200 KF=1,NF
      FB(KF,IQ)=BARFAC(KF,DELP)
 200  CONTINUE
C     ICODE=37
C     WRITE(IOUT,1002)ICODE,FB(1,IQ),FB(9,IQ)
 205  CONTINUE
C CONTRIBUTION FROM REFLECTIONS
      IF(NIMG.EQ.0)GO TO 230
      DO 225 KIMG=1,NIMG
      DO 210 I=1,3
      XRCI(I)=XIMG(I,KIMG)
 210  CONTINUE
      ANGI=ANGLE(XR1,XR2,XRCI)
      CALL NRPT(XR1,XR2,XRCI,XNPTI,DISTI)
      RATIO=(ANGI/DISTI)/ADST
      DO 220 IQ=1,NQ
      IF(NQS(MR,IQ).EQ.0)GO TO 220
      DELP=DELR(IQ,KIMG)
      DO 215 KF=1,NF
      FB(KF,IQ)=FB(KF,IQ)+BARFAC(KF,DELP)*RATIO
 215  CONTINUE
 220  CONTINUE
C     ICODE=38
C     WRITE(IOUT,1002)ICODE,FB(1,1),FB(1,2),FB(9,1),FB(9,2)
 225  CONTINUE
C COMPUTE MEAN ENERGY LEVEL
 230  CALL NR1(XR1,XR2,XRC,XNPT,DIST,XN1,DN1)
      INTEG=0
      IF (NDIFF.NE.0.AND.DELPO(1).GT.-0.2) GO TO 232
      IF (KGA.NE.0.AND.KTRG.GT.0) GO TO 232
      IF (GAM.LE.0) GO TO 232
      INTEG=1
      RO = 50.0
      FSS1 = (RO/DIST) ** GAM
      FSS2 = FSS1 ** 2
      CALL DQATR(ANG1,ANG2,0.10,20,FNC1,FSS3,IER,AUX)
      IF (IER.NE.0) GO TO 231
      CALL DQATR(ANG1,ANG2,0.10,20,FNC2,FSS4,IER,AUX)
      IF (IER.NE.0) GO TO 231
```

SUBROUTINE GEOMRY: LISTING (Continued)

```
      TEM1 = DABS(FSS1 * FSS3 / DIST)
      TEM2 = DABS(FSS2 * FSS4 / DIST**3)
      GO TO 234
  231 WRITE(IOUT,2000) XR,YR,ZR,XR10,XR20,IER
      STOP
  232 TT1=2.0*ANG1
      TT2=2.0*ANG2
      TEM1 = ADST
      TEM2=DABS((DSIN(TT2)+TT2-DSIN(TT1)-TT1)/4./DIST**3)
  234 T3=0.0
      DO 242 IF=1,NF
      IP=IF
      IF(IF.NE.1) GO TO 236
      A = 1.0
      IP = 5
      IF (INTEG.EQ.1) GO TO 237
  236 A=10.**(-DN1*5.4E-5*2.35**(IP-5))
  237 T1=0.0
      DO 240 IQ=1,NQ
      IF(NQS(MR,IQ).EQ.0) GO TO 240
      NQQ=NQS(MR,IQ)
      T2=0.0
      T4=0.0
      DO 238 I=1,NQQ
      INDEX=MR+20*(I-1)+20*5*(IF-1)+20*5*9*(IQ-1)
      XTA=XLREF(INDEX)
      IF(IF.EQ.1.AND.IQ.EQ.2.AND.IGOD(MR,N-1).NE.0)XTA=
     1XLREF(INDEX)*GRADE(XR10,XR20)
      T2=T2+VEXPH(MR,I,IQ)*XTA*CQ(INDEX)
      IF(IF.EQ.1) T4=T4+VEXPH(MR,I,IQ)*XTA**2*CQ(INDEX)**4
  238 CONTINUE
      T1 = T1 + FB(IF,IQ)*FG(IF)*T2
      IF (IF.EQ.1) T3=T3+FB(IF,IQ)**2*FG(IF)**2*T4
  240 CONTINUE
      ZQ=TEM1*T1*A
      XLE(IF)=XLE(IF)+ZQ
      IF(IF.EQ.1)ZZQ=ZZQ+ZQ
      IF(IF.EQ.1)CAP2=CAP2+TEM2*T3*A**2
  242 CONTINUE
C     ICODE=39
C     WRITE(IOUT,1002) ICODE,XLE(1),XLE(9),CAP2
      ANG1=DABS(ANG2)
C     ICODE=40
C     WRITE(IOUT,1000) ICODE,XR2,XR2G,XR2D,XR20
      IF(DSQR(XR2,XR20).LT.1.0) RETURN
      DELTA=1.0
      CALL MOVE(XR2,XR1,XR10,DELTA,IERR)
      IF(IERR.EQ.4) RETURN
C     ICODE=41
C     WRITE(IOUT,1000) ICODE,XR1
      IF(DSQR(XR2,XR2G).LT.1.0) GO TO 247
      CALL REPLCE(XR2G,XR2)
      GO TO 91
  247 IF(DSQR(XR2,XR2D).LT.1.0) GO TO 25
      CALL REPLCE(XR2D,XR2)
      GO TO 72
  999 FORMAT(6H CODE=I3)
 1000 FORMAT(6H CODE=I3,6F9.2/7F9.2)
 1001 FORMAT(6H CODE=I3,I4,6F9.2/6F9.2)
 1002 FORMAT(6H CODE=I3,6E13.4)
 2000 FORMAT('ODQATR UNSUCESSFUL - PROGRAM TERMINATED.'/
     1       ' XR=',F10.4,'  YR=',F10.4,'  ZR=',F10.4,
     2       '  XR10=',F10.4,'  XR20=',F10.4,'  IER=',I2)
 9001 FORMAT (5X,'***   ANGLE SUBTENDED AT RECEIVER BY ROAD SEGMENT IS
     *APPROACHING ZERO',//,11X,'INTIAL PT. OF ROAD SEGMENT ',F10.4,/,
     *11X,'END PT. OF ROAD SEGMENT',F10.4,/,11X,'RECEIVER POINT ',F10.4)
      END
```

SUBROUTINE GEOMRY: LISTING (Concluded)

E.31 SUBROUTINE DQATR (XL, XU, EPS, NDIM, FCT, Y, IER, AUX)

PURPOSE: To compute $\int_{XL}^{XU}$ FCT(X)dx by Romberg's method.

SUBPROGRAMS USED: External function FCT(X)

VARIABLES:

XL - lower bound of the interval.
XU - upper bound of the interval.
EPS - upper bound of the absolute error in single precision.
NDIM - dimension of the auxiliary storage array AUX NDIM-1 is the maximum number of bisections of the interval (XL, XU).
FCT - name of external double precision function subprogram used.
Y - resulting approximation for the integral.
IER - resulting error parameter.

RESTRICTIONS:

IER = 0 - it was possible to reach the required accuracy.
IER = 1 - it was impossible to reach the required accuracy because of rounding error.
IER = 2 - it was impossible to reach accuracy because NDIM is less than 5, or the required accuracy could not be reached within NDIM-1 steps. NDIM should be increased.

ACCURACY: Error within EPS as specified.

SIZE: 1276

REFERENCES: Anon.: "System 1360 Scientific Subroutine Package (360A-CM-03X), Version II, Programmer's Manual," H20-0205-1 (2nd Edition), International Business Machines Corporation, 1967.

```
C   DQATR       02/78    SAI NEW
      SUBROUTINE DQATR(XL,XU,EPS,NDIM,FCT,Y,IER,AUX)
      DIMENSION AUX(1)
      DOUBLE PRECISION AUX,XL,XU,X,Y,H,HH,HD,P,Q,SM,FCT
C
C   PREPARATIONS OF ROMBERG-LOOP
      AUX(1) = .5D0 * (FCT(XL) + FCT(XU))
      H = XU - XL
      IF (NDIM-1) 8,8,1
 1    IF (H) 2,10,2
C
C   NDIM IS GREATER THAN 1 AND H IS NOT EQUAL TO 0.
 2    HH = H
      E = EPS / DABS(H)
      DELT2 = 0.
      P = 1.D0
      JJ = 1
      DO 7 I=2,NDIM
      Y = AUX(1)
      DELT1 = DELT2
      HD = HH
      HH = .5D0 * HH
      P = .5D0 * P
      X = XL + HH
      SM = 0.D0
      DO 3 J=1,JJ
      SM = SM + FCT(X)
 3    X = X + HD
      AUX(I) = .5D0 * AUX(I-1) + P * SM
C   A NEW APPROXIMATION OF INTEGRAL VALUE IS COMPUTED BY MEANS OF
C   TRAPEZOIDAL RULE.
C
C   START OF ROMBERGS EXTRAPOLATION METHOD.
      Q = 1.D0
      JI = I - 1
      DO 4 J=1,JI
      II = I - J
      Q = Q + Q
      Q = Q + Q
 4    AUX(II) = AUX(II+1) + (AUX(II+1)-AUX(II)) / (Q-1.D0)
C   END OF ROMBERG-STEP
C
      DELT2 = DABS(Y-AUX(I))
      IF (I-5) 7,5,5
 5    IF (DELT2-E) 10,10,6
 6    IF (DELT2-DELT1) 7,11,11
 7    JJ = JJ + JJ
 8    IER = 2
 9    Y = H * AUX(1)
      RETURN
 10   IER = 0
      GO TO 9
 11   IER = 1
      Y = H * Y
      RETURN
      END
```

SUBROUTINE DQATR: LISTING

E.32 FUNCTION GRADE(DR1,DR2)

PURPOSE: To compute the grade correction to the sound level of type 2 vehicles (heavy trucks) on a given roadway segment.

SUBPROGRAM USED: DSQRT(x), DABS(x)

VARIABLES:

DR1 - xyz - coordinates of endpoint 1 of roadway segment

DR2 - xyz - coordinates of endpoint 2 of roadway segment

X - grade from endpoint 1 to endpoint 2

Y - grade correction of the segment

GRADE - sound intensity level of grade correction i.e., $\text{GRADE} = 10^{Y/10}$

RESTRICTIONS: none

ACCURACY: not applicable

SIZE: 630

REFERENCES: The grade correction is a linear interpolation of the data given in Gorden, C. G., et. al.: "Highway Noise, A Design Guide for Prediction and Control," Highway Research Board, National Academy of Sciences, Report NCH-RP-174, 1976.

```
C   GRADE        02/79   SAI NEW
      DOUBLEPRECISIONFUNCTIONGRADE(DR1,DR2)
      IMPLICITREAL*8(A-H,O-Z)
      DIMENSIONDR1(3),DR2(3)
      X=DABS(DR2(3)-DR1(3))/DSQRT((DR2(1)-DR1(1))**2+
     1(DR2(2)-DR1(2))**2)
      IF(X.LE.2.D-2)Y=0.D0
      IF(X.GT.2.D-2.AND.X.LT.7.D-2)Y=1.D2*X-2.D0
      IF(X.GE.7.D-2)Y=5.D0
      GRADE=1.D1**(Y*1.D-1)
      RETURN
      END
```

FUNCTION GRADE: LISTING

E.33 FUNCTION FNC1(x)

PURPOSE: To calculate $\cos^{\alpha}(x)$ for use in computing the L_{eq} by integration over the roadway segment.

SUBPROGRAM USED: DCOS(x)

VARIABLES:
X - argument of cosine
XGAM - same as α
FNC1 - $\cos^{\alpha}(x)$

RESTRICTIONS: $\alpha \leq -1$

ACCURACY: not applicable

SIZE: 348

REFERENCES: Appendix A

```
C  FNC1         02/78   SAI NEW
      FUNCTION FNC1(X)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /FUNC/XGAM
      FNC1 = DCOS(X) ** XGAM
      RETURN
      END
```

FUNCTION FNC1: LISTING

E.34 FUNCTION FNC2(x)

PURPOSE:	To calculate $\cos^{2(1+\alpha)}(x)$ for use in computing SIGMA
SUBPROGRAM USED:	DCOS(x)
VARIABLES:	X - argument of cosine XGAM - same as α FNC2 - $\cos^{2(1+\alpha)}(x)$
RESTRICTIONS:	$\alpha \geq -1$
ACCURACY:	not applicable
SIZE:	392
REFERENCES:	Appendix A

```
C   FNC2          02/78   SAI NEW
      FUNCTION FNC2(X)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /FUNC/XGAM
      FNC2 = DCOS(X) ** (2.0 * (XGAM + 1.0))
      RETURN
      END
```

FUNCTION FNC2: LISTING

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