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16. Abstract

Research Report 140-1, "Documentation of Input for Single Vehicle Accident Computer Program," Young, R. D., et al., was written in 1969 to document the input requirements of the Texas Transportation Institute's version (V-3 modified slightly) of the Highway-Vehicle-Object-Simulation-Model. Since that time, several additional changes have been incorporated in the model by TTI researchers. This document was therefore written to amplify the information contained in Research Report 140-1. This report will supersede Research Report 140-1.

Values of vehicle parameters are included where available. Comments regarding some of the input parameters are included to help reduce the time needed for setting up the data. Sample problems are given which illustrate how the input is determined and how the corresponding output is presented.

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HVOSM USER'S MANUAL

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Research Report 140-9

Evaluation of the Roadway Environment by
Dynamic Analysis of the Interaction
Between the Vehicle, Passenger,
and the Roadway

Research Study No. 2-10-69-140

Sponsored by

The Texas Highway Department
in cooperation with the
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TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

KEY WORDS

Documentation, Computer Program, HVOSM, Math Model, Automobile Dynamics, Highway Safety, User Manual.

FOREWORD

The information contained herein was developed on Research Study 2-5-69-140 entitled "Evaluation of the Roadside Environment by Dynamic Analysis of the Interaction Between the Vehicle, Passenger, and Roadway." It is a cooperative research study sponsored jointly by the Texas Highway Department and the U.S. Department of Transportation, Federal Highway Administration.

The basic objective of the study is to develop criteria to aid in the design of a safe highway. This is being accomplished through the application of mathematical simulation techniques and crash tests to determine the dynamic behavior of automobiles and their occupants when in collision with roadside objects or when traversing highway geometric features such as ditches, sloping culvert grates, etc. The study began in September, 1968.

Several significant findings have resulted from the study and these are documented in the following reports:

1. "Documentation of Input for Single Vehicle Accident Computer Program," Young, R. D., et al., TTI Research Report 140-1, July 1969.

2. "A Three-Dimensional Mathematical Model of an Automobile Passenger," Young, R. D., TTI Research Report 140-2, August 1970.

3. "Criteria for the Design of Safe Sloping Culvert Grates," Ross, H. E., Jr., and Post, E. R., TTI Research Report 140-3, August 1971.

4. "Criteria for Guardrail Need and Location on Embankments," Ross, H. E., Jr., and Post, E. R., TTI Research Report 140-4, April 1972.

5. "Simulation of Vehicle Impact with the Texas Concrete Median Barrier," Young, R. D., et al., TTI Research Report 140-5, June 1972.

6. "Comparison of Full-Scale Embankment Tests with Computer Simulations," Ross, H. E., Jr., and Post, E. R., TTI Research Report 140-7, December 1972.

7. "Impact Performance and a Selection Criterion for Texas Median Barriers," Ross, H. E., Jr., TTI Research Report 140-8, April 1974.

SUMMARY

Research Report 140-1 was written in 1969 to document the input requirements of the Texas Transportation Institute's version (V-3 modified slightly) of the Highway-Vehicle-Object-Simulation-Model. Since that time, several additional changes have been incorporated in the model by TTI researchers. This document was therefore written to amplify the information contained in Report 140-1. This report will supersede Report 140-1.

Values of vehicle parameters are included where available. Comments regarding some of the input parameters are included to help reduce the time needed for setting up the data. Sample problems are given which illustrate how the input is determined and how the corresponding output is presented.

IMPLEMENTATION STATEMENT

This report will facilitate the application of the HVOSM computer program by both researchers and highway officials. The information in the report on input requirements will minimize the time needed to set up the program.

Several applications of the HVOSM in Study 140 have been made and the results have been implemented. These have included studies related to roadside, guardrail, median barriers, and sloping culvert grates.

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I. INTRODUCTION

To facilitate the design and evaluation of a roadway and its near environment, it is beneficial to know the effects that various design features have on the dynamic response of the vehicle and passenger. Roadway alignment of horizontal curves, superelevation, and ramps are determined, to a large degree, by the ability of a vehicle to negotiate these features. This ability is dependent upon the dynamic interaction between the vehicle and the roadway surface. Design of the roadway subgrade, pavement, and bridges is dependent upon static and dynamic loads imposed by vehicular traffic. From the safety aspect it is advantageous to know the effects of vehicle collisions with various roadside obstacles, such as guardrails, bridge rails, median barriers, sign posts, and others. In the areas adjacent to the traveled way it is important to know the effects that shoulders, side slopes, and back slopes have on a vehicle's motion.

It is felt that the problems mentioned above can be studied and evaluated satisfactorily with the use of mathematical simulation techniques. If these problems were studied using full-scale tests, the expense would likely be prohibitive and the number of variables that could be studied would be limited.

This research report was written to revise and amplify the information contained in TTI Report 140-1. Sample problems are included which illustrate how the input data is determined and how the output is presented.

1.1 Purpose and Scope

Since Research Report 140-1 was written several additional changes have been incorporated in TTI's version of the HVOSM program. These changes along with more detailed input illustrations and sample problems have been included as an aid to the researcher. This research report supersedes Research Report 140-1.

1.2 Additions and Modifications to Research Report 140-1

a. In order to provide more flexibility to the curb impact section (17th card series), the maximum permitted number of curb faces was increased from two to six. The last curb face is extended at the same slope without calling "CRIMBP", i.e., without undue expense.

b. The 24th series of cards was added to permit the researcher to input a predetermined path (Logarithmic Spiral) for the vehicle to follow. The steering angle is estimated by pointing the front wheels in the direction of the "Target Point" on the desired path some distance ahead of the vehicle. This is achieved using a rod of constant length (called the "Steering Pointer"), one end of which is fixed at a point midway between the front wheels. The steering pointer, which has no physical restraint capabilities, is rotated in a horizontal plane until its free and coincides with the prescribed path of the vehicle. This method of estimating the steering angle is similar to that employed by an actual driver when he estimates the steering angle of his vehicle by looking some distance down the roadway. The driver depends on his experience in handling his car to estimate the turn of the steering wheel, whereas the success of this steering mechanism is dependent on the length of the steering pointer. TTI has found that a steering pointer length of 20 ft produces good tracking for curvatures from 100 to 2,000 ft and speeds from 30 to 80 mph.

c. Additional comments and illustrative examples have been added to the cards and card series in order to clarify the input.

d. Two sample problems, illustrating the total data input, are contained in Chapter III. The first problem involves a vehicle negotiating a sloping culvert grate and its surrounding terrain, while the second considers a vehicle impacting a highway curb and its surrounding terrain.

1.3 General Input Requirements

All input data needed to complete one event, e.g., a vehicle striking a guardrail, is defined herein as a *data group*. As a matter of convenience, the data group is divided into two sections. The first section pertains to the computations and the second section provides the information necessary for CAL-COMP plot generations. Any number of data groups may be submitted together, and as such constitute a *computer run*.

Section 1. The first two cards of this section are title cards, and their contents will be printed at the top of each output page. Both cards must always be included in each data group. If the standard plot option (described in Part 2.2 of this report) is chosen, the contents of the first card are also printed out on each plot. The 3rd card, 16th series of cards, and the final card must always be included in each data group.

The remaining input cards in Section 1, needed for specific events, are described in Part 2.1 and Appendix B. Not all of this input is necessarily required for a given event. The user should refer to References 1, 2, and 3 for the input needed for a particular event.

As mentioned in Part 1.2, provisions have been made to reduce the amount of input data. The characteristics of a *typical* vehicle are available to the program (in Subroutine STAN) and will be used unless otherwise specified. Input supplied are the contents of cards 4 through 9, 12, 13, and card series 14, 19, and 23. If other data are required, the card or cards of this group which are appropriate and their ICARD number should be input. The ICARD number is used as an identification code by the program in storing the data.

In some cases recommended values are given in the report for certain variables. The value of these variables supplied by STAN are in agreement with the recommended values.

Note that the input is referred to by card number up through Card 12 and by series of cards thereafter. This is done since the exact number of input cards is variable after the first 13 and depends on the event simulated. Also, note that the format listed for the input parameters can and in many cases must be overridden.

Section 2. In addition to the digital output, three options are available to the user for plotting the output. One may choose a standard set of plots, a specified number of plots, or no plots. A description of the input requirements for each of these options is given in Part 2.2.

Termination Card. Part 2.3 of this report describes the input needed to terminate a computer run.

1.4 Typical Program Uses

The HVOSM program, at the state of development documented in this report, can be used to investigate the following situations:

(a) Handling response, i.e., observing the vehicle's response for lane change maneuvers or any such maneuver for which the steering angle (ψ_f) is known as a function of time (Part 2.1, 15th series of cards).

(b) Ride response, i.e., observing the vehicle's response while traveling over arbitrary terrain (roadway, ditches, ramps, side slopes, earth berms, etc.).

(c) Simultaneous handling and ride response which involves a combination of (a) and (b) above.

It is noted that the mathematical model has the capability of allowing the steering angle of the tires to be determined by the interactive forces between the tires and the terrain. The condition, called a *steer degree of freedom*, is used to simulate the case of a vehicle in which the driver has lost contact with the steering wheel, thus having no control over its direction. The steer degree of freedom is activated by setting INDCRB = 1.0 on the 3rd card (Part 2.1).

TTI has used the steer degree of freedom in studies of side slopes and earth berms.

(d) Skid response, i.e., observing the vehicle's response during a skid.

A skid can be generated by a proper combination of steering angles and applied torques (Part 2.1, 15th series of cards).

(e) Curb impact, i.e., observing the vehicle's response during interaction with a curb or bridge rail (Part 2.1, 17th series of cards). During curb impact it is recommended that the more accurate tire model (the radial-spring tire model) be activated, which is accomplished by setting INDCRB = 1.0 on the third card of Part 2.1.

(f) Barrier impact, i.e., observing the vehicle's response during collision with a barrier.

Four types of barriers can be studied:

1) rigid barrier with a finite vertical dimension,
2) rigid barrier with an infinite vertical dimension,
3) deformable barrier with a finite vertical dimension,
4) deformable barrier with an infinite vertical dimension.

The input information for a vehicle-barrier collision is described in Part 1.2 of this report (20th, 21st, and 22nd series of cards).

These are just typical uses available to the roadway designer. Any combination of these could conceivably be used in an effort to simulate the designer's particular problem.

II. GENERAL INPUT REQUIREMENTS

2.1 Primary Data

1st and 2nd Cards (always included)

Format (18A4)

As stated above, these are title cards containing alphameric information in columns 1-72, for the purpose of identification.

3rd Card

Program Control Parameters (always included)

Format (9F8.0,I8)

Col. Nos.	Program Variable	*Report Variable	Definition	Units
1-8	TO	NONE	Start time of event	sec
9-16	T1	NONE	End time of event	sec
17-24	DTCOMP	NONE	Increment of integration	
25-32	DTCMP1	NONE	= 0.0, program computes initial position of vehicle to rest on terrain. = 1.0, user provides all initial vehicle position data.	
33-40	DTPRNT	NONE	Output interval	sec
41-48	THMAX	NONE	Value of THETA at which we shift planes usually = 70°	
49-56	UVWMIN	NONE	See comments	
57-64	PQRMIN	NONE	See comments	
65-72	INDCRB	NONE	See comments	

*"Report" is taken to mean either this report or any of the CAL reports referenced herein.

3rd Card (Continued)

Col. Nos.	Program Variable	*Report Variable	Definition	Units
80	ICARD	NONE	=1	

Comments on 3rd Card

TO - Usually 0.0, however, an event can start at any desired time.

DTCOMP - CAL uses 0.005-0.01 seconds depending on the character of the run. TTI has not used larger than 0.005; and runs made with 0.001 produced essentially the same results as with 0.005.

DTCMP1 - See comments for 10th and 11th cards.

DTPRNT - TTI prints the output every other increment of integration; for example, if DTCOMP = 0.005, DTPRNT = 0.01.

UVWMIN & PQRMIN - Absolute value of the resultant translational velocity (in./sec.) and angular velocity (deg./sec.), respectively, of the vehicle center of gravity at which the program will terminate computations. Both the translational velocity and the angular velocity of the vehicle must be equal to or less than these values before termination occurs. TTI uses 0.0 for both values.

INDCRB - Three values are used and their function is as follows:

(1) 0.0 - allows steering angles to be read in tabular form (15th series of cards); or allows a specified path (logarithmic spiral) to be used (24th series of cards); or if neither of the previous two are used, the initial steering angle (PSIFIO) of the 10th card is maintained throughout the computations, i.e., from the start to the end of the event.

(2) 1.0 - activates the steer degree of freedom and the radial tire model. In this case the curb input (17th series of cards) must be included.

(3) -1.0 - activates the steer degree of freedom only.

4th Card*

METHOD OF INTEGRATION

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	MODE	NONE	Mode of integration = 0.0 Variable Adams-Moulton = 1.0 Runge-Kutta = 2.0 Fixed Adams-Moulton	
9-16	EBAR	NONE	Applicable only if	
17-24	EM	"	Mode = 0.0	
25-32	AAA	"	See	
33-40	HMAX	"	PINT1	
41-48	HMIN	"	Subroutine	
49-72			blank	
80	ICARD		= 2	

Comment on 4th Card

MODE - TTI has used MODE = 1.0, exclusively (Runge-Kutta).

*If the 4th card is omitted, the program will automatically select MODE = 1.0.

5th Card*

INERTIAL DATA

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	XMS	M_S	= sprung mass	$Lb\text{-}Sec^2/In.$
9-16	XMUF	M_{UF}	= front unsprung mass (both sides,)	$Lb\text{-}Sec^2/In.$
17-24	XMUR	M_{UR}	= rear unsprung mass	$Lb\text{-}Sec^2/In.$
25-32	G	g	= 386.4	In/Sec^2
33-40	XIX	I_X	See comments below	$Lb\text{-}in.\text{-}sec^2$
41-48	XIY	I_Y	See comments below	$Lb\text{-}in.\text{-}sec^2$
49-56	XIZ	I_Z	See comments below	$Lb\text{-}in.\text{-}sec^2$
57-64	XIXZ	I_{XZ}	See comments below	$Lb\text{-}in.\text{-}sec^2$
65-72	XIR	I_R	See comments below	$Lb\text{-}in.\text{-}sec^2$
80	ICARD		= 3	

Comment on 5th Card

I_X, I_Y, I_Z, I_{XZ} = moments and product of inertia of sprung mass, $lb\text{-}sec^2\text{-}in.$

I_R = rear unsprung mass moment of inertia about a line through its center of gravity and parallel to the X axis, $lb\text{-}sec^2\text{-}in.$

Typical values of inertial data are shown in Table 2-1, (from reference 1).

*If the 5th card is omitted, the program will automatically select the inertial properties of a 1963 Ford Galaxie given in Table 2-1.

TABLE 2-1. INERTIAL DATA

	Typical Standard Size Sedan	Typical 1958 Production Car**	1953 Buick*	1963 Ford Galaxie Four-door Sedan***
M_S	8.280-9.8450	10.2530	10.6720	10.8180
M_{UF}	0.540-0.5910	0.5000	0.7240	0.6080
M_{UR}	0.8860-0.9700	0.8070	1.1720	0.9450
I_X	4340.0-5160.0	6288.0	5592.0	6000.0
I_Y	23800.0-28300.0	30492.00	33600.0	30000.0
I_Z	25500.0-30320.0	36600.00	37068.0	36000.0
I_{XZ}	(-11.30)-(-13.40)	-14.500	-14.760	-192.0
I_R	613.00-670.00	508.00	733.00	600.0

* - See description on page 18, Fig. 3.2, Ref. 1

** - See description on page 27, Fig. 3.7, Ref. 1

*** - See reference 2 on page 64.

6th Card*

PHYSICAL DIMENSIONS

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	A	a	See comments below	Inches
9-16	B	b	See comments below	Inches
17-24	TF	T_F	See comments below	Inches
25-32	TR	T_R	See comments below	Inches
33-40	ZF	Z_F	See comments below	Inches
41-48	ZR	Z_R	See comments below	Inches
49-56	RHO	ρ	See comments below	Inches
57-64	RW	R_W	Undeflected radius of wheels	Inches
65-72	AO	A_O	See comments below	
80	ICARD		= 4	

Comments on 6th Card

a = distance along the vehicle-fixed X axis from the sprung mass center of gravity to the centerline of the front wheels.

b = distance along the vehicle-fixed X axis from the sprung mass center of gravity to the centerline of the rear wheels.

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*If the 6th card is omitted, the program will automatically select the physical dimensions of a 1963 Ford Galaxie given in Table 2-2.

Comments on 6th Card (continued)

T_F , T_R = tread at front and rear suspensions, respectively.

Z_F = static distance along the Z axis between the center of gravity (C.G.) of the sprung mass and the C.G. of the front unsprung masses (C.G. of the individual front masses assumed to coincide with the wheel centers).

Z_R = static distance along the Z axis between the C.G. of the sprung mass and the roll center of the rear axle.

ρ = distance between center of gravity of rear axle and rear axle roll center, positive for roll center above C.G.

A_0 = coefficients in the functional relationships fitted to tire side-force data (see Ref. 2).

(1) A_0 = 4400.0 (recommended value, see Reference 2).

(2) Vehicle dimensions shown in Table 2-2 (from References 1 & 2).

TABLE 2-2. TYPICAL DIMENSIONS

	Typical Standard Size Sedan	Typical 1958 Production Car	1953 Buick	1963 Ford Galaxie Four-door Sedan
a	51.600	50.04	62.610	54.517
b	66.400	67.44	62.890	64.483
T_F	60.300	58.80	59.000	61.0
T_R	59.300	58.80	62.200	60.0
Z_F	13.1845	10.8750	13.190	10.138
Z_R	15.0191	12.7030	15.520	12.088
ρ	-2.000	-2.000	-2.270	-2.00
R_W	14.000	13.500	14.40	15.00

7th Card*

FRONT SUSPENSION DATA

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKF	K_F	See comments below	Lb/In.
9-16	XLAMF**	λ_F	Multiple of K_F, for use in suspension deflection stops (see Fig. 4.6, Ref. 1).	
25-32	CF	C_F	See comments below	Lb-Sec/In.
33-40	CFP	C'_F	Coulomb damping for a single wheel, effective at the wheel for front suspension.	Lbs
41-48	EPSF	ε_F	See comments below	In/Sec
49-56	RF	R_F	See comments below	Lb-In/Rad
57-64			Blank	
65-72			Blank	
80	ICARD		= 5	

Comments on 7th Card

K_F = suspension load - deflection rate for a single wheel, effective at the wheel in the quasi-linear range about the design position, for front suspensions.

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*If the 7th card is omitted, the program will automatically select the front suspension data of a 1963 Ford Galaxie given in Table 2-3.

**For new definition, see Sect. 1.4 of CAL Report No. VJ-2251-V-4, March, 1969, pp. 22-28.

C_F = viscous damping coefficient for a single wheel, effective at the wheel, for front suspension.

ε_F = friction lag in front suspension, to prevent extraneous oscillations induced by round-off error in suspension velocities.

R_F = auxiliary roll stiffnes (i.e., roll stiffness in excess of that corresponding to the wheel rates in ride motions) at the front suspension.

TABLE 2-3. TYPICAL FRONT SUSPENSION DATA

	Typical Standard Size Sedan	Typical 1958 Production Car	1953 Buick	1963 Ford Galaxie Four-Door Sedan
K_F	105.00	154.10	100.0	131.0
λ_F	6.0-25.0	3.00	3.00	0.5
C_F	5.0	6.80	4.00	3.5
C_F'	30.0	42.00	30.0	55.0
ε_F	0.001	0.001	0.001	0.001
R_F	98500.0	95800.0	106600.0	266000.0

8th Card*

REAR SUSPENSION DATA

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKR	K_R	See comments below	Lb/In.
9-16	XLAMR**	λ_R	Multiple of K_R, for use in suspension deflection stops (see Fig. 4.6, Ref. 1).	
25-32	CR	C_R	See comments below	Lb-Sec/In.
33-40	CRP	C_R'	Coulomb damping for a single wheel, effective at the wheel for rear suspension.	Lbs
41-48	EPSR	ε_R	See comments below	In/Sec
49-56	RR	R_R	See comments below	Lb-In/Rad
57-64	TS	T_S	Distance between spring connections for solid rear axle.	Inches
65-72	AKRS	K_{RS}	Rear axle roll-steer coefficient (+ for roll under-steer).	
80	ICARD		= 6	

Comments on 8th Card

K_R = suspension load - deflection rate for a single wheel, effective at the wheel in the quasi-linear range about the design position, for rear suspension.

*If the 8th card is omitted, the program will automatically select the rear suspension data of a 1963 Ford Galaxie given in Table 2-4.

**For new definition, see Sect. 1.4 of CAL Report No. VJ-2251-V-4, March 1969, pp. 22-28.

Comments on 8th Card (continued)

C_R = viscous damping coefficient for a single wheel, effective at the wheel, for rear suspension.

R_R = auxiliary roll stiffness (i.e., roll stiffness in excess of that corresponding to the wheel rates in ride motions) at the rear suspension.

ε_R = friction lag in rear suspensions, to prevent extraneous oscillations induced by round-off error in suspension velocities.

TABLE 2-4. TYPICAL REAR SUSPENSION DATA

	Typical Standard Size Sedan	Typical 1958 Production Car	1953 Buick	1963 Ford Galaxie Four Door Sedan
K_R	110.0	106.25	110.00	192.0
λ_R	6.0-25.0	3.00	3.00	0.5
C_R	5.00	5.70	4.00	3.90
C'_R	18.00	4.000	18.00	50.0
ε_R	0.001	0.001	0.001	0.001
R_R	32500.0	23500.0	0.0	61900.0
T_S	45.0	38.28	50.00	46.5
K_{RS}	0.071	0.0	0.016	0.070

9th Card*

TIRE DATA

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKT	K_T	Radial tire rate in quasi-linear range for a single tire.	Lb/In.
9-16	SIGT	σ_T	Maximum radial tire deflection for quasi-linear load-deflection characteristic (see Figure 4.9, Ref. 1).	Inches
17-24	XLAMT	λ_T	Multiple of K_T for use in nonlinear range (i.e., travel limit) (see Figure 4.9, Ref. 1).	
25-32	A1	A_1	See comments below.	
33-40	A2	A_2	See comments below.	
41-48	A3	A_3	See comments below.	
49-56	AMU	μ	Tire-to-ground friction coefficient. This is the basic ground surface coefficient of friction.	
57-64	OMEGT	Ω_T	See comments below.	
65-72	A4	A_4	See comments below.	
80	ICARD		= 7	

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*If the 9th card is omitted, the program will automatically use the tire data of the radial-spring tire model, which is given in Ref. 2 as:

K_T = 1098.0

σ_T = 3.00

λ_T = 10.00

A_1 = 8.276

A_2 = 2900.0

A_3 = 1.78

μ = 0.30 to 0.80

Ω_T = 1.00

A_4 = 3900.0

Comments on 9th Card

A_1, A_2 , A_3 , A_4 = coefficients in the functional relationships fitted to tire side-force data (see Ref. 2).

Ω_T = decimal portion of A_2 at which the assumed parabolic variation of side force with tire loading is abandoned to preclude reversal in the sign of the side load under conditions of excessive tire loading (see Figure 4.13, Ref. 1).

10th Card

INITIAL CONDITIONS (always included)

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	PHIO	ϕ_o	Initial value of ϕ (Euler angular coordinates of sprung mass relative to space-fixed system).	Degrees
9-16	THETAO	θ_o	Initial value of θ (Euler angular coordinates of sprung mass relative to space-fixed system).	Degrees
17-24	PSIO	ψ_o	Initial value of ψ (Euler angular coordinates of sprung mass relative to space-fixed system).	Degrees
25-32	PO	P_o	See comments below.	Deg/Sec
33-40	QO	Q_o	See comments below.	Deg/Sec
41-48	RO	R_o	See comments below.	Deg/Sec
49-56	PSIFIO	ψ_{Fo}	See comments below.	Degrees
57-64	PSIFDO	$\dot{\psi}_{Fo}$	Initial value of steering angular velocity (first time derivative of ψ_F).	Rad/Sec
65-72			Blank	
80	ICARD		= 8	

Comments on 10th Card

PHIO and THETAO are included only if DTCMP1 = 1.0 on 3rd card.

If DTCMP1 = 0.0, PHIO and THETAO are left blank.

P_o, Q_o, R_o = initial values of P, Q, R (scalar components of sprung mass angular velocity, taken along X, Y, Z axes, respectively. See page 111, Ref. 1).

ψ_{FO} = initial value of ψ_F (steer angle of front wheels relative to vehicle coordinate axes system, positive for CW steer as viewed from above vehicle).

11th Card

INITIAL CONDITIONS (always included)

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	XCOP	X'_{co}	See comments below.	Inches
9-16	YCOP	Y'_{co}	See comments below.	Inches
17-24	ZCOP	Z'_{co}	See comments below.	Inches
25-32	UO	U_o	See comments below.	In/Sec
33-40	VO	V_o	See comments below.	In/Sec
41-48	WO	W_o	See comments below.	In/Sec
49-72			Blank	
80	ICARD		= 9	

Comments on 11th Card

(1) ZCOP is included only if DTCMP1 = 1.0 on 3rd card. If DTCMP1 = 0.0, ZCOP is left blank.

(2) XCOP, YCOP, ZCOP, must never coincide to a template point, as described in 16th series of cards (Terrain Input).

(3) X'_{co}, Y'_{co}, Z'_{co} = initial values of X'_c, Y'_c, Z'_c (coordinates of the spring mass center of gravity relative to the space-fixed coordinate axes system).

(4) U_o, V_o, W_o = initial values of U, V, W (scalar components of linear velocity of spring mass, taken along X, Y, Z axes).

12th Card*

INITIAL CONDITIONS

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	DEL10	δ_{10}	See comments below.	Inches
9-16	DEL20	δ_{20}	See comments below.	Inches
17-24	DEL30	δ_{30}	See comments below.	Inches
25-32	PHILRO	ϕ_{RO}	See comments below.	Degrees
33-40	DEL1OD	$\dot{\delta}_{10}$	See comments below.	In/Sec
41-48	DEL2OD	$\dot{\delta}_{20}$	See comments below.	In/Sec
49-56	DEL3OD	$\dot{\delta}_{30}$	See comments below.	In/Sec
57-64	PHIROD	$\dot{\phi}_{RO}$	Initial value of angular velocity of rear axle (first derivative of ϕ_R, see page 111, Ref. 1).	Deg/Sec
65-72			Blank	
79-80	ICARD		= 10	

*If the 12th card is omitted, the program will automatically set each variable on this card equal to zero.

Comments on 12th Card

δ_{10}, δ_{20}, δ_{30} = initial values of δ_1, δ_2, δ_3 (suspension deflections relative to the vehicle from the positions of static equilibrium, at the right front wheel center, left front wheel center, and rear axle roll center, respectively). See Ref. 1, page 111.

ϕ_{RO} = initial value of ϕ_R (angular displacement of the rear axle relative to the vehicle about a line parallel to the X-axis through the rear axle roll center, positive when clockwise, viewed from the rear). See page 111, Ref. 1.

$\dot{\delta}_{10}$, $\dot{\delta}_{20}$, $\dot{\delta}_{30}$ = initial values of suspension velocities (first time derivatives of δ_1, δ_2, δ_3, respectively). See page 111, Ref. 1.

13th Card*

ACCELEROMETER POSITIONS

Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	X1	X_1	See comments below.	Inches
9-16	Y1	Y_1	See comments below.	Inches
17-25	Z1	Z_1	See comments below.	Inches
26-32	X2	X_2	See comments below.	Inches
33-40	Y2	Y_2	See comments below.	Inches
41-48	Z2	Z_2	See comments below.	Inches
49-72			Blank	
79-80	ICARD		= 11	

Comments on 13th Card

This card is optional, however, its use is recommended. For the the case where no accelerometer positions are being considered, use (0,0,0) for the points (X_1, Y_1, Z_1) and X_2, Y_2, Z_2).

X_1, Y_1, Z_1, X_2, Y_2, Z_2 = coordinates of accelerometer positions on the sprung mass, at which acceleration components are to be calculated and printed out, (with reference to the vehicle fixed axes).

---

*If the 13th card is omitted, the program will automatically select the following values:

X_1 = -34.480 X_2 = -5.983

Y_1 = 0.000 Y_2 = -16.500

Z_1 = 4.000 Z_2 = 3.138

14th Series of Cards*

FRONT WHEEL CAMBER (ϕ_c) vs. SUSPENSION DEFLECTION (δ_f)

a. 1st card of series, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	DELB	NONE	Initial Value for δ_f	Inches
9-16	DELE	NONE	Final Value for δ_f	Inches
17-25	DDEL	NONE	Increment for δ_f	Inches
26-78			Blank	
79-80	ICARD		= 12	

(DELE must be > DELB and [DELE - DELB/DDEL] $\leq$ 49.)

b. The second card and succeeding cards contain the PHIC (ϕ_c) Table (see reference 1). It consists of [DELE - DELB/DDEL] + 1 entries, 13 to a card [Format (13F6.3)]. The units must be "degrees".

Comments on 14th Series

A typical set of values for ϕ_c vs. δ_f is shown in Table 2-5.

---

*If the 14th series of cards is omitted, the program will automatically select the data given in Table 2-6.

TABLE 2-5. TYPICAL ϕ_c vs. δ_f VALUES

δ_f (inches)	ϕ_c (degrees)
-5.00	-3.55
-4.00	-2.55
-3.00	-1.80
-2.00	-1.30
-1.00	-0.95
0.00	-0.55
1.00	-0.30
2.00	-0.30
3.00	-0.40
4.00	-0.55
5.00	-0.80

For this set of data, the 14th series of cards is as shown in Table 2-6.

TABLE 2-6. SAMPLE INPUT FOR 14th SERIES

1st Card

Col. Nos.	Information
1-8	-5.00
9-16	5.00
17-24	1.00
25-72	blank
79-80	12

2nd Card

Col. Nos.	Information
1-6	-3.55
7-12	-2.55
13-18	-1.80
19-24	-1.30
25-30	-0.95
31-36	-0.55
37-42	-0.30
43-48	-0.30
49-54	-0.40
55-60	-0.50
61-66	-0.80
67-72	blank
73-78	blank

Had there been more than 13 entries for ϕ_c, one or more additional cards similar to the 2nd card would have been required.

15th Series of Cards

DRIVER CONTROL INPUTS

General Comments: The response of a simulated vehicle may be determined if the steering angle is known as a function of time. If steering inputs are required, then set INDCRB = 0.0 on the third data card (ICARD = 1). If no steering inputs are required, then the initial steering angle read in the 10th card is maintained throughout the event, provided a specified path (logarithmic spiral) is not used in the 24th series.

a. 1st card of series, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	TB	NONE	Initial time for driver control inputs.	sec
9-16	TE	NONE	Final time for driver control inputs.	sec
17-24	TINCR	NONE	Increment time for driver control inputs.	sec
25-32	NTBL1	NONE	= 0.0, read ψ_f table. = 1.0, do not read ψ_f table.	
33-40	NTBL2	NONE	= 0.0, read TQ_F table. = 1.0, do not read TQ_F table.	
41-48	NTBL3	NONE	= 0.0, read TQ_R table. = 1.0, do not read TQ_R table.	
49-72			Blank	
79-80	ICARD	NONE	= 13	

(TE must be > TB and [TE-TB/TINCR] $\leq$ 49)

b. The second card and succeeding cards contain tables of steering angles (PSIF, ψ_f), front wheel torque (TQF, TQ_F), and rear wheel torque (TQR, TQ_R), in that order, depending on the value of NTBL1, NTBL2, and NTBL3, respectively: For each variable with a 0.0 value there must follow a table with [TE-TB/TINCR] + 1 entries, 13 to a card (Format (13F6.3)) containing data relative to that variable. For each non-zero value, the respective table is omitted.

Comments on 15th Series

The units are PSIF (degrees) and TQF and TQR (lb-ft). See the 13th card series for complete definition of (PSIF, ψ_f), (TQF, TQ_F), and (TQR, TQ_R).

If no steering inputs are required, i.e., the vehicle follows a straight line path (per the initial steering angle (ψ_{FO}) read in the 10th card) into the target area, or the logarithmic spiral may be used in the 24th series in which case this series is omitted.

16th SERIES OF CARDS

TERRAIN INPUT (always include)

GENERAL COMMENTS

A given terrain may be simulated by specifying templates (cross sections of terrain) at consecutive intervals such that each template is perpendicular to the X' coordinate axis. Each template is assigned the same number of points (Y' and Z' coordinates) which define the terrain within a given template. Adjacent template points are connected by straight lines to form the desired surface. See Figure 2-1.

a. 1st card of series, Format (3F8.0, 48X, I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	NBX	None	Total No. of templates	None
9-16	NBY	None	Total No. of points used to define each template	None
17-24	NMUXY	None	No. of variable coefficient friction patches	None
79-80	ICARD	None	= 14	None

Comments for Card a.

This card gives the necessary information to describe the template to be used to input the terrain information. Each template must have NBY points. The templates are assumed to be normal to the X' axis. A maximum of 21 templates (NBX) and 21 points (NBY) per template may be used. The template information is entered on cards that immediately follow the first card of this series. If no terrain is to be input, set NBX = NBY = 0 and do not include template cards (this assumes flat level terrain with Z' = 0). NMUXY is the number of terrain patches which will have coefficients of friction different from the coefficient of friction (AMU) read in the 9th card (ICARD = 7). There are a total of (NBX) x (NBY) patches with a maximum of 21 x 21 = 441.

b. Terrain Template Cards (include if NBX and NBY are greater than 0)

The following cards will describe the template.

Format (I3,F7.0,(10F7.0))

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-3	ITEMP(I)	None	Template No. (i.e., 1,2,3,...21)	None
4-10	XTEMP(I)	X'	X' value of template ITEMP(I)	ft
11-17	YGP(I,J)	Y'	Y' value of point J=1 in template ITEMP(I)	ft
18-24	ZGP(I)	Z'	Z' value of point J=1 in template ITEMP(I)	ft
25-31	YGP(I,J+1)	Y'	Y' value of point J=2 in template ITEMP(I)	ft
32-38	ZGP(I,J+2)	Z'	Z' value of point J=2 in template ITEMP(I)	ft

Continue with input of Y's and Z's (10F7.0) through Column 80 and on successive cards until J=NBY points for each template ITEMP(I) have been entered. On all continuation cards enter these values starting in column 1 (there will be a maximum of four continuation cards per template). Start a new card for each template (part b is repeated for each template).

The following rules should be observed in developing a surface:

(1) the templates are always normal to the X' axis,

(2) the values of XTEMP(I), YGP(I,J) and ZGP(I,J) are referenced to the X', Y', Z' axis, respectively,

(3) points on each template are numbered consecutively,

(4) the point YGP (I,1) is always zero,

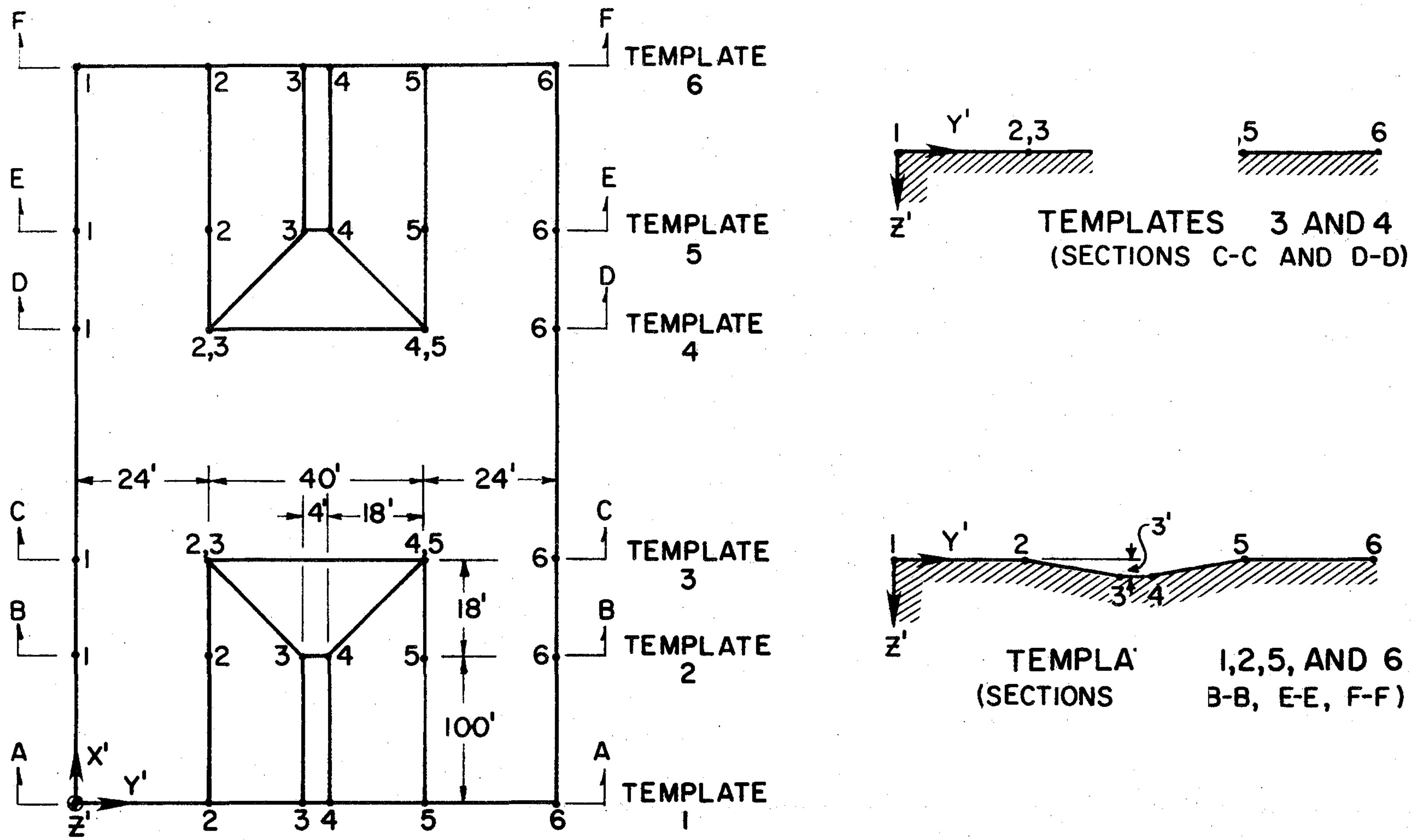


FIGURE 2-1 MEDIAN CROSSOVER AND AJACENT DITCH SECTIONS (PLAN VIEW)

(5) Each template must have the same number of points (Y' and Z' coordinates) defining its particular cross section. If 2 or more boundary lines converge at a point within a given template, then that point must be treated as 2 or more points and each of these common points must be read in separately. For example, in Figure 2-1, template 2 has 4 distinct points (2, 3, 4, and 5) which in template 3 converge to 2 actual points (2, 3, and 3, 4) although these 2 actual points must be treated as 4 points when reading in the data for template 3.

(6) The area outside the limits described by the terrain template is assumed to be horizontal (plane X'-Y') with Z' = 0.

(7) The developed surface must be in the first (positive) quadrant of the coordinate axes.

An example problem demonstrating the input of this section follows paragraph c.

c. Variable Coefficient of Friction Card (include if NMUXY > 0).

The following cards will describe the terrain patches on which it is desired to change the coefficient of friction from the AMU value read in the 9th card (I card = 7). A terrain patch I, J, is defined as the surface enclosed between two consecutive templates (I, I+1) and two consecutive points (J, J+1) on the templates (I, I+1) (c.f. Figure 2-1).

Format (2I2,F6.0)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-2	I	None	Template No. (i.e., 1, 2, 3, ...21)	None
3-4	J	None	Point number within any template	None
5-10	AMUXY(I,J)	None	Friction Coeff. For Patch I, J	None

An example problem demonstrating the input of this section is given on the next page.

EXAMPLE: Develop the surface shown in Figure 2-1 from X'=0 to X'=118' and change the coefficient of friction on the terrain patch 1, 3 (bounded by templates 1 ar nes 3-3 and 4-4) to AMUXY = 0.70

DATA CARD COLUMN NUMBER

Data Card No.	1-8	9-16	17-24	79	80
1	3.0	6.0	0.0	1	4

DATA CARD COLUMN NUMBER

Data Card No.	1	2	3	4-10	11-17	18-24	25-31	32-38	39-45	46-52	53-59	60-66	67-73	74-80	* 1-7	* 8-14
2			1	0.0	0.0	0.0	24.0	0.0	42.0	3.0	46.0	3.0	64.0	0.0		
3															88.0	0.0
4			2	100.0	0.0	0.0	24.0	0.0	42.0	3.0	46.0	3.0	64.0	0.0		
5															88.0	0.0
6			3	118.0	0.0	0.0	24.0	0.0	24.0	0.0	64.0	0.0	.0	0.0		
7															88.0	0.0

DATA CARD COLUMN NUMBER

Data Card No.	1	2	3	4	5	6	7	8	9	10
8	0	1	0	3			0	.	7	0

*Continuation card.

17th Series of Cards

CURB IMPACT INPUT

a. 1st card of series, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
---	NCRBSL	-----	No. curb faces	-----
---	AMUC	μ_c	Tire-curb friction	-----
---	DELTC	Δt_c	Increment of integration	-----
---	ICARD	-----	ICARD = 15	-----

b. 2nd card of series, Format (6F10.0)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-10	YC1P	Y'_{c1}	Fixed Y-Coordinate,	Inches
11-20	YC2P	Y'_{c2}	(See figure 2-2 on next	Inches
21-30	YC3P	Y'_{c3}	page), Also see	Inches
31-40	YC4P	Y'_{c4}	comments on 17th series	Inches
41-50	YC5P	Y'_{c5}	of cards on the fol-	Inches
51-60	YC6P	Y'_{c6}	lowing page.	Inches

c. 3rd card of series, Format (6F10.0)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-10	ZC2P	Z'_{c2}	Fixed Z-Coordinate,	Inches
11-20	ZC3P	Z'_{c3}	(See comments on	Inches
21-30	ZC4P	Z'_{c4}	17th series of cards	Inches
31-40	ZC5P	Z'_{c5}	on the following	Inches
41-50	ZC6P	Z'_{c6}	page).	Inches

d. 4th card of series, Format (6F10.0)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-10	PHIC1	ϕ_{c1}	Fixed Phi-Coor-	Degrees
11-20	PHIC2	ϕ_{c2}	dinate, (see	Degrees
21-30	PHIC3	ϕ_{c3}	comments on 17th	Degrees
31-40	PHIC4	ϕ_{c4}	series of cards	Degrees
41-50	PHIC5	ϕ_{c5}	below and on the	Degrees
51-60	PHIC6	ϕ_{c6}	following page.)	Degrees

Comments on 17th Series of Cards

(1) The Z'_{c1} coordinate (in the 3rd card of this series) must always be zero, (see Figure 2-2), therefore it has been omitted and the required input begins with Z'_{c2}.

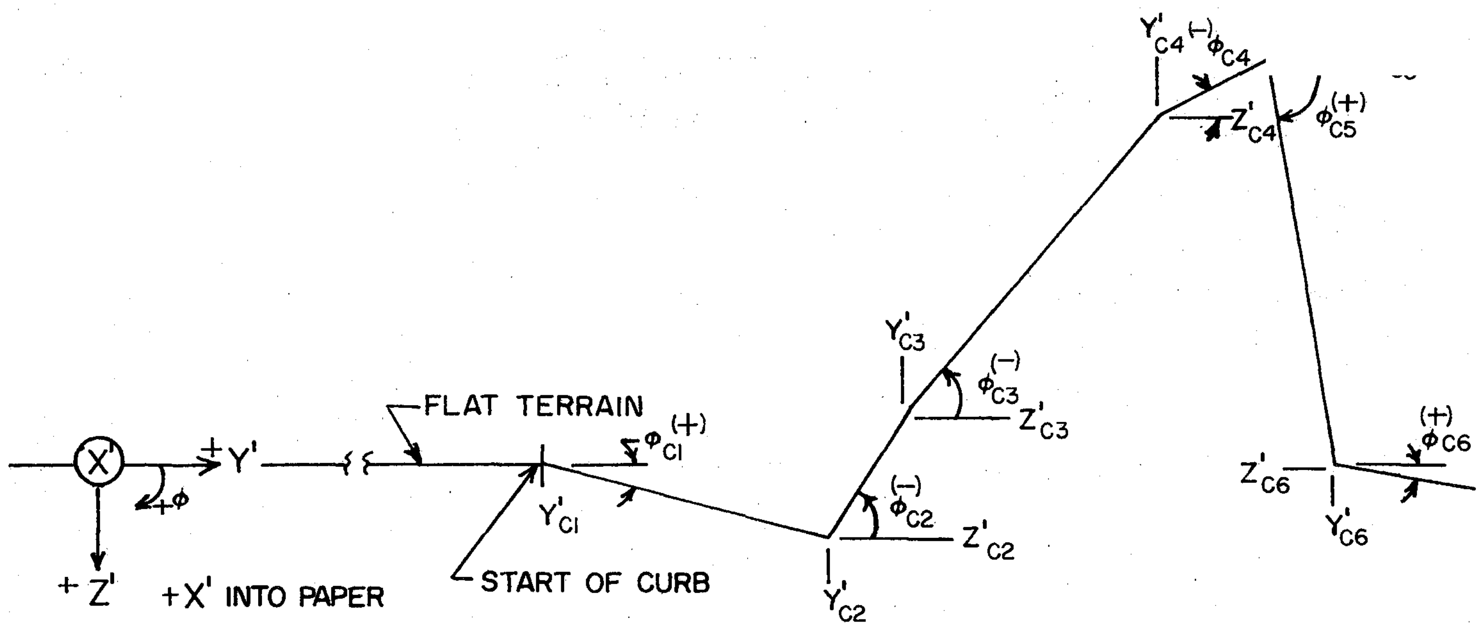
(2) The maximum number of permitted curb faces is six.

(3) The last actual curb face is extended at the same slope but without calling "CRIMBP", i.e., without undue expense.

(4) The first curb point (Y'_{c1}, $Z'_{c1} = 0$) cannot be located at the origin of the X', Y', Z' coordinate system.

(5) +X' in Figure 2-2 is into the plane of the paper.

(6) Y'_{c1} = initial boundary of curb to be encountered by vehicle, (first slope change).



MAXIMUM NO. CURB FACE = 6

FIGURE 2-2 CURB COORDINATE SYSTEM

Comments on 17th Series of Cards (continued)

(7) Y'_{c2} = boundary of second slope of curb.

(8) Z'_{c2} = elevation of curb profile at Y'_{c2}.

(9) ϕ_{c1}, ϕ_{c2} = first and second curb slopes encountered by the vehicle.

(10) μ_c = tire-to-curb friction coefficient.

18th Series of Cards

PARAMETERS NEEDED FOR GENERATING THE FJP (F'_j) TABLE

One card, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	RWHJB	NONE	Initial value of $R_W - h'_j$ for F'_j table.	Inches
9-16	RWHJE	NONE	Final value of $R_W - h'_j$ for F'_j table.	Inches
17-24	DRWHJ	NONE	Increment value of $R_W - h'_j$ for F'_j table.	
25-72			Blank	
79-80	ICARD		= 16	

Comments on 18th Series

(1) This series is included when INDCRB = 1.0 (curb impact).

(2) The F'_j table is generated in subroutine "WHEEL".

(3) ([RWHJE - RWHJB/DRWHJ] + 1) must be $\leq$ 35. Typical values are RWHJB = 0.0, RWHJE = 6.0, and DRWHJ = 0.25.

(4) R_W = undeflected radius of wheels.

(5) h'_j = rolling radius of wheel j.

(6) F'_j = the forces exerted by the individual radial springs when curb impact occurs. The spring model is shown diagrammatically in Figure 4.8, page 121, of the CAL Report VJ-2251-V-1 and the computation employing F'_j is on page 193 of the same reference. F'_j is derived from the radial load-deflection characteristics of the tires on flat terrain which is shown in the graph on page 122.

19th Series of Cards*

INERTAIL PROPERTIES OF STEERING SYSTEM

One Card, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	XIPS	I_ψ	Moment of inertia of steering system, effective at front wheels (both sides included).	$Lb\text{-}Sec^2\text{-}In.$
9-16	CPSP	C'_ψ	Coulomb resistance in steering system, effective at the wheels (both sides included).	Lb-in.
17-24	OMGPS	Ω_ψ	Angular deflection of the steering system at which elastic stops are encountered.	Radians
25-32	AKPS	K_ψ	Load-deflection of the elastic stops in the steering system, effective at the wheels (both sides included).	Lb-In/Rad
33-40	EPSPS	ε_ψ	Friction lag in steering system.	Rad/Sec
41-48	XPS	$\overline{PT}$	Pneumatic trail of front tires.	Inches
49-72			Blank	
ICARD			= 17	

---

*If the 19th series is omitted, the program will automatically select the steering inertial properties of a 1963 Ford Galaxie which are given as typical values on the following page.

Comments on 19th Series

(1) This card is included whenever the steer mode degree of freedom is to be activated (INDCRB = 1 or -1, third card).

(2) Typical values (standard size sedan):

$$I_\psi = 492.0$$

$$C'_\psi = 600.0$$

$$\Omega_\psi = 0.40$$

$$K_\psi = 5000.0$$

$$\varepsilon_\psi = 0.075$$

$$\overline{PT} = 1.50$$

20th Series of Cards

VEHICLE AND BARRIER DIMENSIONS

One card, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	YBPO	$(Y'_B)_o$	See Fig. 2.3 & 2.4.	Inches
9-16	DELYBP	$\Delta Y'_B$	"	Inches
17-24	ZBTP	Z'_{BT}	"	Inches
25-32	ZBBP	Z'_{BB}	"	Inches
33-40	XVF	X_{VF}	"	Inches
41-48	XVR	X_{VR}	"	Inches
49-56	YV	Y_V	"	Inches
57-64	ZVT	Z_{VT}	"	Inches
65-72	ZVB	Z_{VB}	"	Inches
79-80	ICARD		= 18	

Comments on 20th Series

(1) In Figure 2-3, the quantities Z_{VT}, X_{VR} are negative.

(2) In Figure 2-4, the plane containing the barrier (cross-hatched) and and the X'-Z' plane are parallel and separated by a distance of $(Y'_B)_o$. The bottom of the barrier is located a distance Z'_{BB} above the X'-Y' plane. The elevation of the top of the barrier relative to the X'-Y' plane is Z'_{BT}. It should be noted that for the coordinate system shown, both Z'_{BB} and Z'_{BT} are negative.

$\Delta Y'_B$ = size of incrementing step in establishing force balance between vehicle and barrier. (CAL uses 0.5 inches in Ref. 1., Page 49).

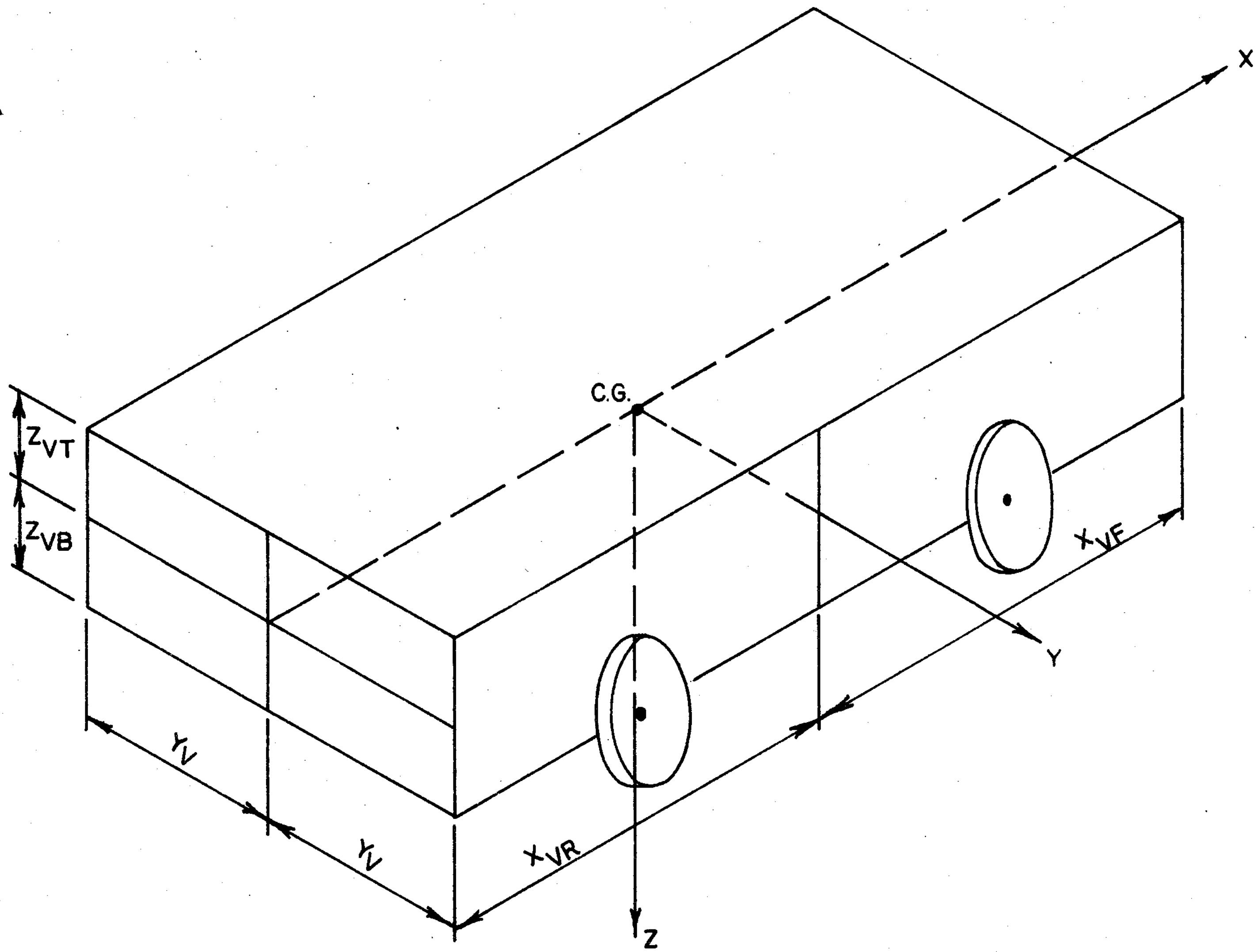


FIGURE 2-3

VEHICLE DIMENSIONS FOR BARRIER IMPACT

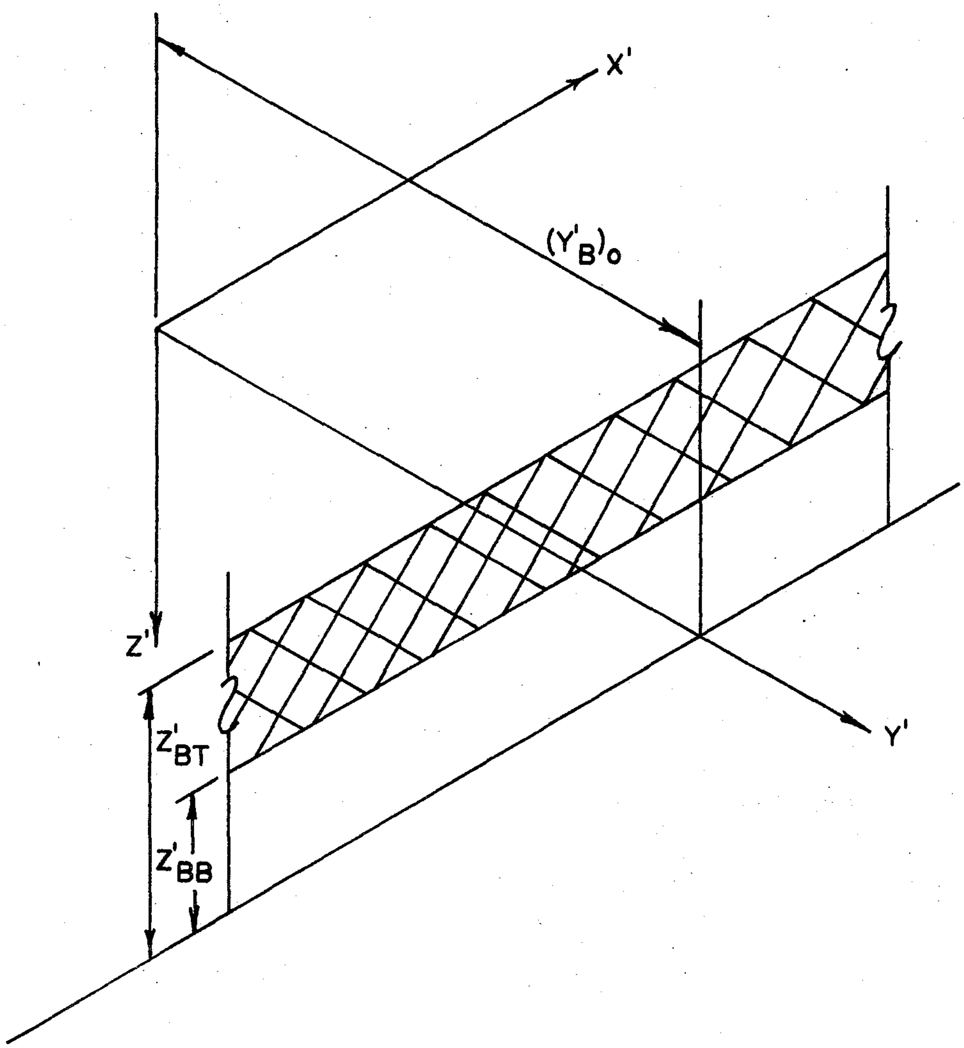


FIGURE 2-4

BARRIER DIMENSIONS AND POSITION

21st Series of Cards

VEHICLE-BARRIER PROPERTIES

One card, Format (9F8.0,I8)

Col Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKV	K_V	Load-deflection characteristic of vehicle structure.	Lb/In.^{3}
9-16	SET	$\overline{SET}$	Ratio of permanent deflection to maximum energy absorbed by barrier.	
17-24	CONS	$\overline{CONS}$	Ratio of conserved energy to maximum energy absorbed by barrier.	
25-32	AMUB	μ_B	Sprung mass-to-barrier friction coefficient.	
33-40	EPSV	ε_V	Friction lag in vehicle-to-barrier friction force.	In./Sec
41-48	EPSB	ε_B	Acceptable error in force balance between vehicle structure and barrier.	Lbs
49-56	DELTB		Increment of integration during barrier collision.	Sec
57-64	INDB		= 1.0 rigid barrier finite vertical dim. = 2.0 rigid barrier infinite vertical dim. = 3.0 deformable barrier finite vertical dim. = 4.0 deformable barrier infinite vertical dim.	
65-72			Blank	
79-80	ICARD		= 19	

Comment on 21st Series

Typical Values:

K_V = 4.0 (2.0 used by TTI)

$\overline{SET}$ = 0.122 (deformable barrier)

$\overline{CONS}$ = 0.56 (deformable barrier)

μ_B = 0.2

ε_V = 1.0

ε_B = 500.0

DELTB = 0.002 (used by TTI)

22nd Series of Cards

2 cards, Format (9F8.0,I8) and (2F8.0)

These two cards contain 11 values of σ_R; 9 on the first card and 2 on the second with 8 columns per entry. ICARD = 20, and is punched in columns 79-80 of the first card.

These first six coefficients define the barrier force-deflection curve in the form of a fifth degree polynomial.

$$F = \sigma_{R0} + \sigma_{R1}\delta + \sigma_{R2}\delta^2 + \sigma_{R3}\delta^3 + \sigma_{R4}\delta^4 + \sigma_{R5}\delta^5$$

The last five coefficients define a barrier force versus deflection velocity curve in the form of a fifth order polynomial.

$$F = \sigma_{R6}\dot{\delta} + \sigma_{R7}\dot{\delta}^2 + \sigma_{R8}\dot{\delta}^3 + \sigma_{R9}\dot{\delta}^4 + \sigma_{R10}\dot{\delta}^5$$

The total force is meant to be

$$F_B = F + F'$$

However, for the present simulation F' = 0 and the last five coefficients are zero.

23rd Series of Cards**

VEHICLE MONITOR AND TERRAIN CONTACT

a. 1st card of series, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	NVP		See comments below.	-----
9-16	SSTIFF		Stiffness of ground surface.	Lb/In.
17-24	XJ		Soil damping constant.	Sec/In.
25-32	FRFAC		Coefficient of friction between vehicle and terrain.	-----
79-80	ICARD		= 23	-----

Note: NVP cannot be greater than 28.

b. 2nd card (to be used if NVP > 0.0), Format (12F6.0)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-6	XVP(I)*	x_{vp}.	See comments below.	Inches
7-12	YVP(I)	y_{vp}.	See comments below.	Inches
13-18	ZVP(I)	z_{vp}.	See comments below.	Inches

* I = 1, NVP

Continue with same format on succeeding cards, twelve entries (four points) per card, six columns per entry (Format (12F6.0)). The maximum number of cards of this type is seven.

**The user omits the 23rd series of cards unless he wishes to monitor more points or different points than those shown in Table 2-7. By including the 23rd series, the preset values are overridden.

Comments on 23rd Series of Cards

(1) NVP (number of vehicle points to be monitored) is to be punched as a floating point number, i.e., if 10 points are desired, then NVP is punched as 10.0. These points also are the points on the vehicle to which the soil restoring forces are applied if contact is made with the ground surface.

(2) Subroutine STAN presets only four vehicle monitor points to represent the four lower corners of the vehicle (four bumper points). In vehicle-fixed coordinates, for the 1963 Ford, TTI has decided to use the coordinate values shown in Table 2.7 for bumper points.

(3) XVP(I), YVP(I), ZVP(I) = coordinates of points on vehicle which are to be monitored referenced to the vehicle fixed axes. There can be a maximum of twenty-eight points (coordinates in inches).

(4) SSTIFF = 4000., is based on a soil subgrade modulus of 40 $lb/in.^3$ and a contact area of 100 $in.^2$. These preset values of SSTIFF, XJ, and FRFAC are not necessarily recommended values since these change for any given soil.

TABLE 2-7. BUMPER POINTS IN VEHICLE COORDINATES (INCHES)

I	XVP(I)	YVP(I)	ZVP(I)
1	81.517	39.5	12.138
2	81.517	-39.5	12.138
3	-117.483	39.0	8.138
4	-117.483	-39.0	8.138

(5) See Figures 2-5 and 2-6 for more vehicle dimensions.

(6) The following values are also preset by subroutine STAN:

NVP = 4.0 SSTIFF = 4.000

XJ = 0.001 FRFAC = 0.25

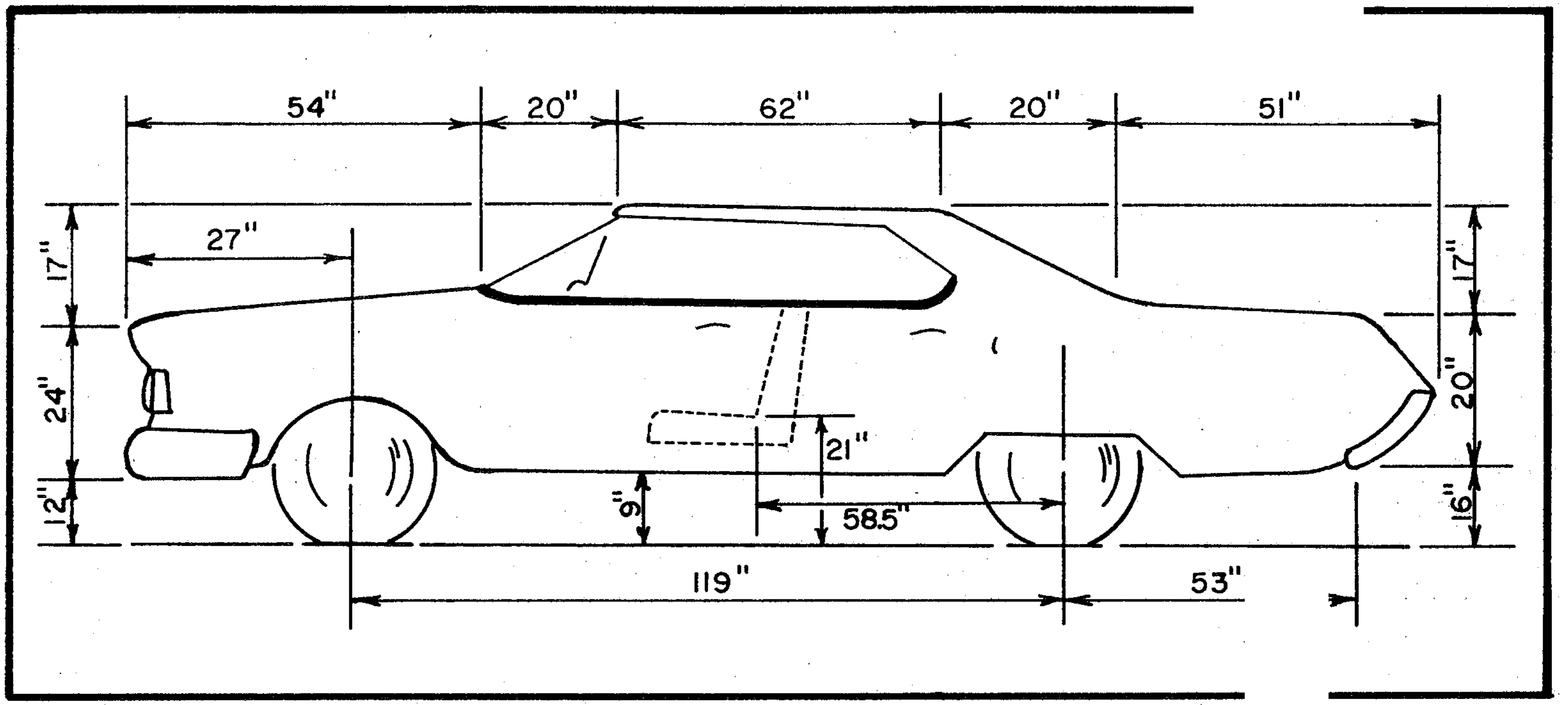


FIGURE 2-5 APPROXIMATE BODY-DIMENSIONS OF THE 1963 FORD, PART I

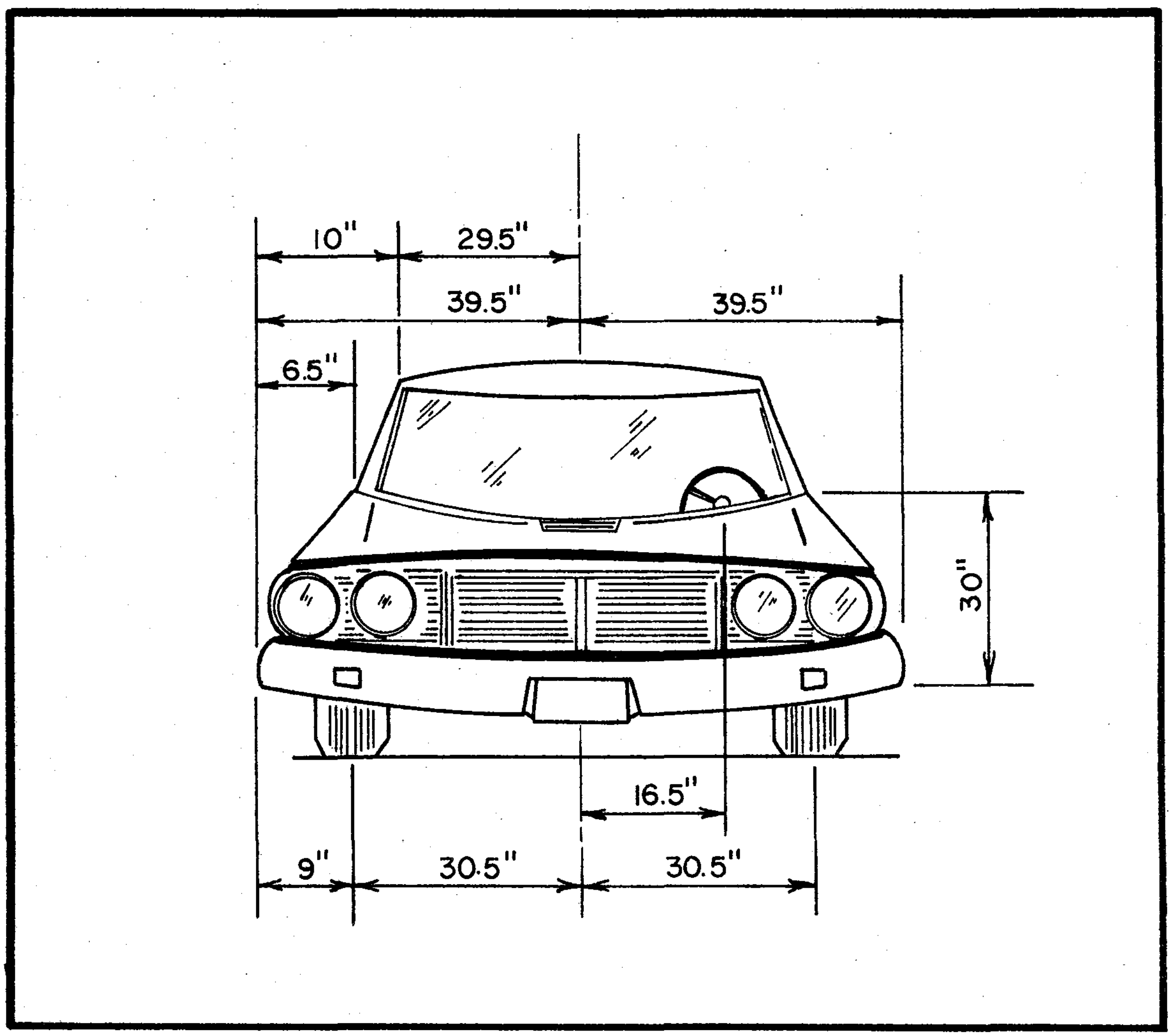


FIGURE 2-6 APPROXIMATE BODY DIMENSIONS OF THE 1963 FORD, PART II

24th Series of Cards

General Comments

This series of cards defines the path (Logarithmic Spiral) along which the simulated vehicle travels and the initial coordinates and orientation as shown in Figures 2-7 and 2-8.

The steering angle is estimated by pointing the front wheels in the direction of the "Target Point" on the desired path some distance ahead of the vehicle. This is achieved using a rod of constant length (called the "Steering Pointer") one end of which is fixed at a point midway between the front wheels. The steering pointer, which has no physical restraint capabilities, is rotated in a horizontal plane until its free end coincides with the prescribed path of the vehicle. This method of estimating the steering angle is similar to that employed by an actual driver when he estimates the steering angle of his vehicle by looking some distance down the roadway. The driver depends on his experience in handling his car to estimate the turn of the steering wheel, whereas the success of this steering mechanism is dependent on the length of the steering pointer. TTI has found that a steering pointer length of 20 ft produces good tracking for curvatures from 100 to 2,000 ft and speeds from 30 to 80 mph.

One Card, Format (9F8.0, I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	WT	None	length of wagon tongue	Inches
9-16	C	None	$r=ce^{BM\theta}$	Inches
17-24	BM	None	$r=ce^{BM\theta}$	
25-32	JWT	None	=1.0	

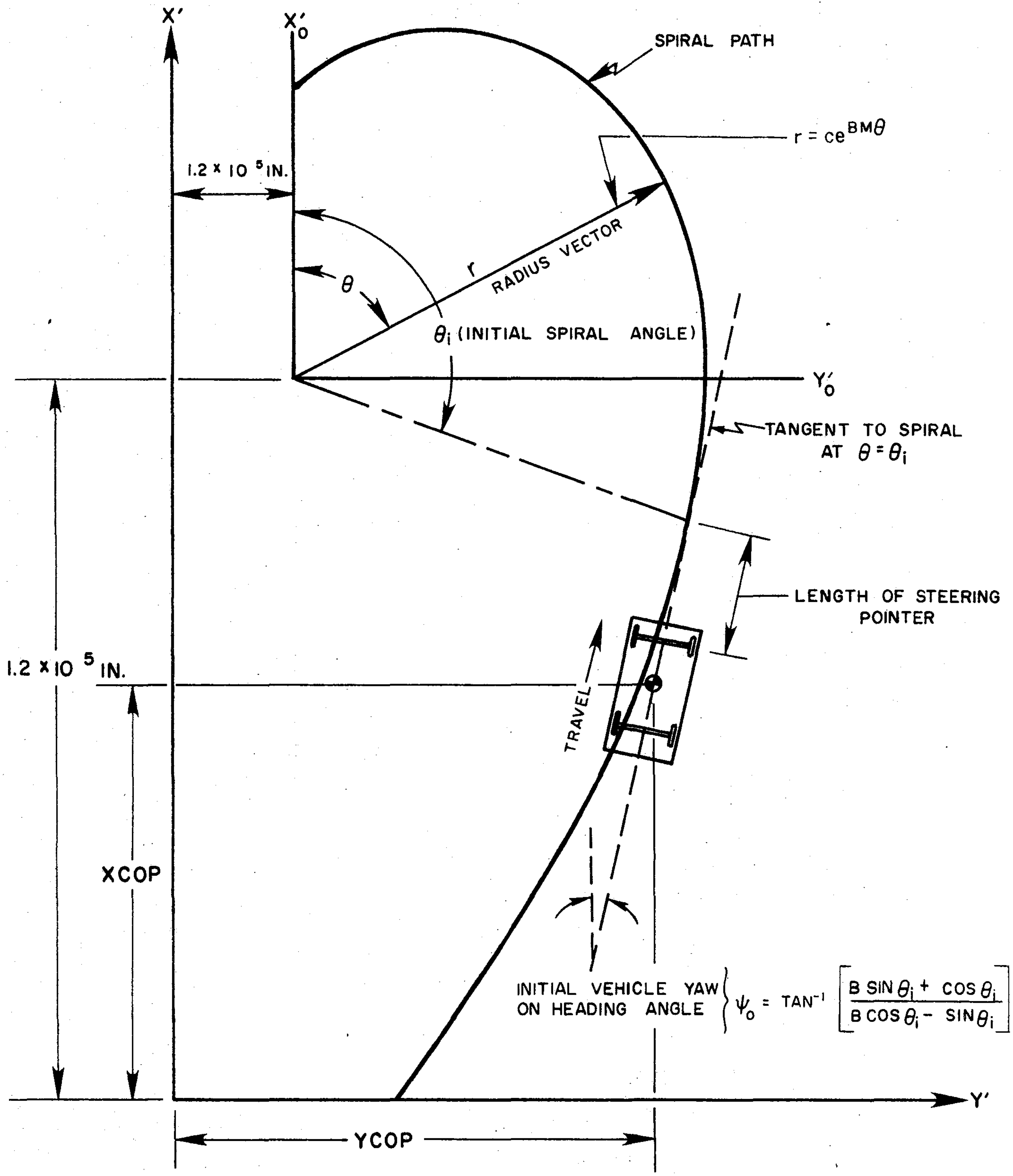
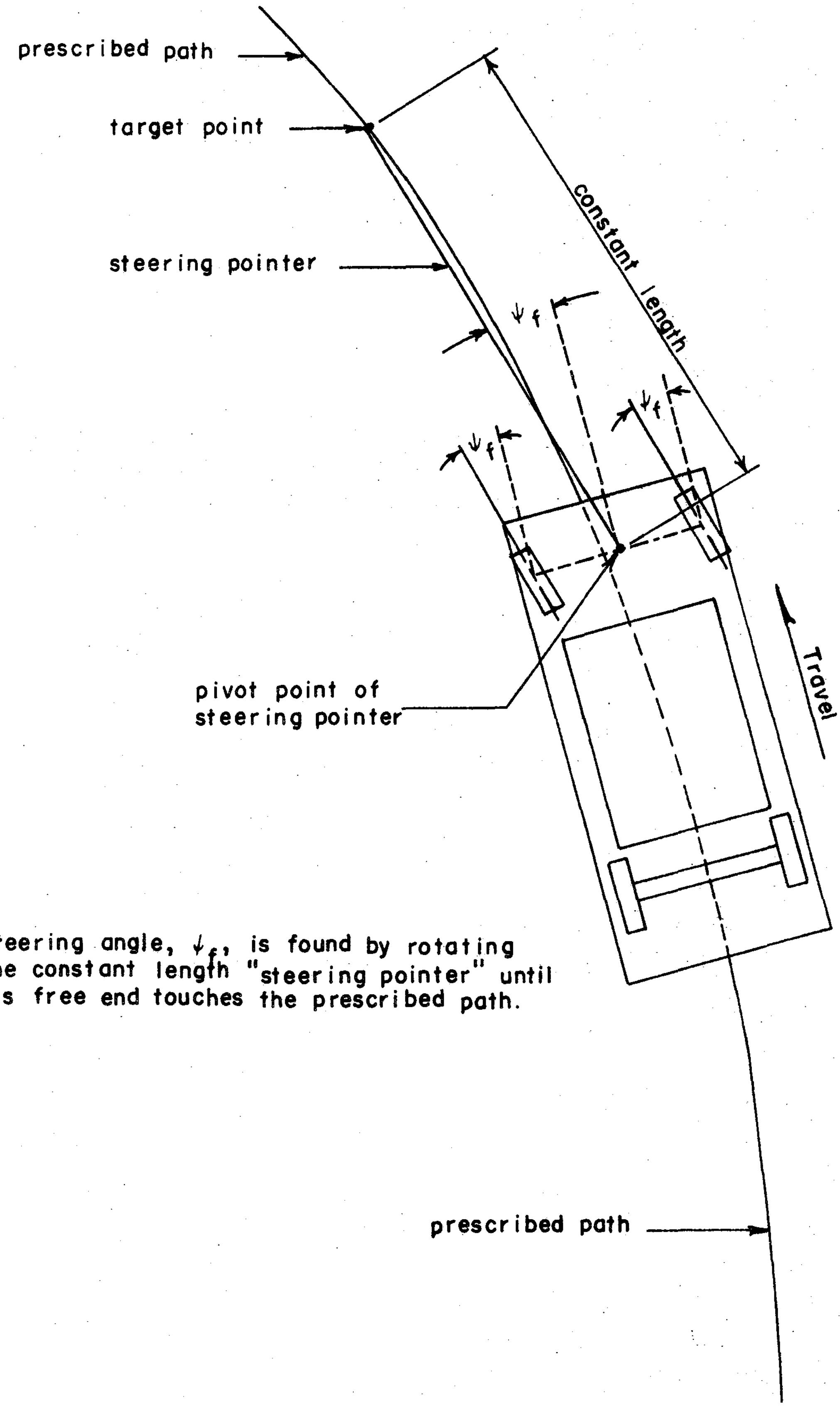


FIGURE 2-7 LOGARITHMIC SPIRAL AND INITIAL VEHICLE POSITION



Note: Steering angle, ψ_f, is found by rotating the constant length "steering pointer" until its free end touches the prescribed path.

FIGURE 2-8 SCHEMATIC OF STEERING MECHANISM FOR FOLLOWING PRESCRIBED PATH

One Card, Format (9F8.0, I8) (cont'd)

Col. Nos.	Program Variable	Report Variable	Definition	Units
33-78		None	leave blank	
79-80	ICARD	None	=24	

Comments on 24th Series

1. This series is left out unless the logarithmic spiral path is desired.
2. Whenever this series is included, the following must be done:
   a. Set INDCRB=0.0 on third card (ICARD=1)
   b. Compute PSIO=(BM $\sin\theta_i$ + $\cos\theta_i$)/(BM $\cos\theta_i$ - $\sin\theta_i$) as shown in Figure 2-7, and enter on tenth card (ICARD=8)
   c. Set PSIFIO=0.0 and PSIFDO=0.0 on tenth card (ICARD=8)
   d. Compute XCOP and YCOP as shown in Figure 2-7, and enter these on eleventh card (ICARD=9)
   e. Put in large enough terrain template in sixteenth series of cards (ICARD=14)

25th Series of Cards

This series of cards provides the input for the calculation of friction developed during the interaction of a tire with a surface which is dependent on the vertical tire load and vehicle speed as well as the surface characteristics. Include this card series only when this correction is desired, otherwise friction remains constant at the value read in as AMU(μ) on the 9th card (ICARD=7)

One Card, Format(9F8.0, I8)

Col. No.	Program Variable	Report Variable	Definition	Units
1-8	ALPHA	α	slope of $K_{V,L}$ vs load curve	1/lb mph
9-16	XKVTH	$K_{V,1000}$	slope $f_{V,1000}$ vs speed curve	1/mph
17-24	XKL	K_L	slope of $f_{40,L}$ vs load curve	1/lb
25-78			leave blank	
79-80			ICARD = 25	

Comments

(1) Note that $f_{40,1000}$ is read as AMU(μ) on 9th card (ICARD=7)

(2) See Figure 2-9 for Graphical Description of $K_{V,1000}$

(3) See Figure 2-10 for Graphical Description of α

(4) See Figure 2-11 for Graphical Description of K_L

(5) Due to the number of different types of tires and road surfaces, typical values will not be given in this card series. See TTI Report 628-2.

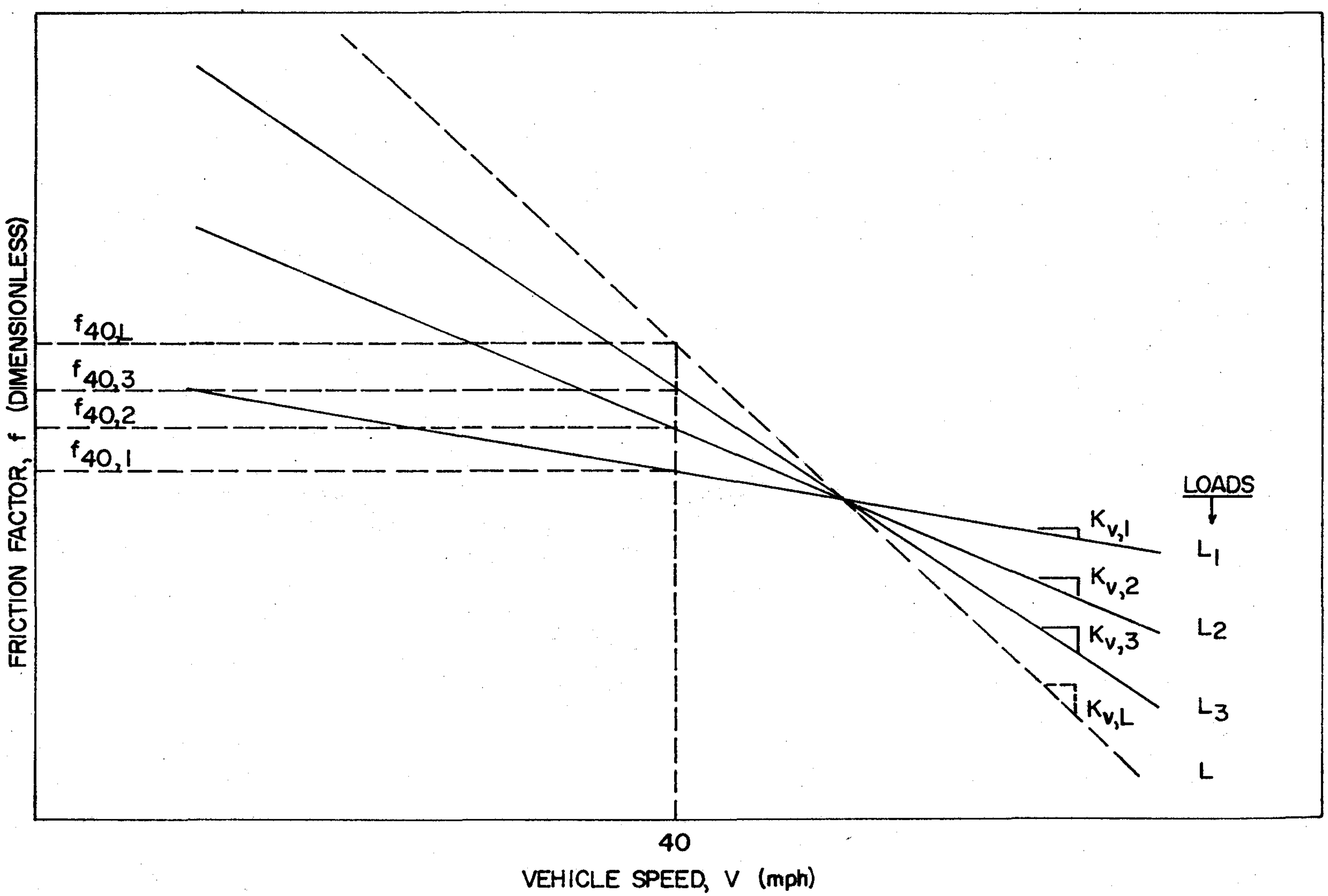


FIGURE 2-9 FRICTION FACTOR VERSUS VEHICLE SPEED

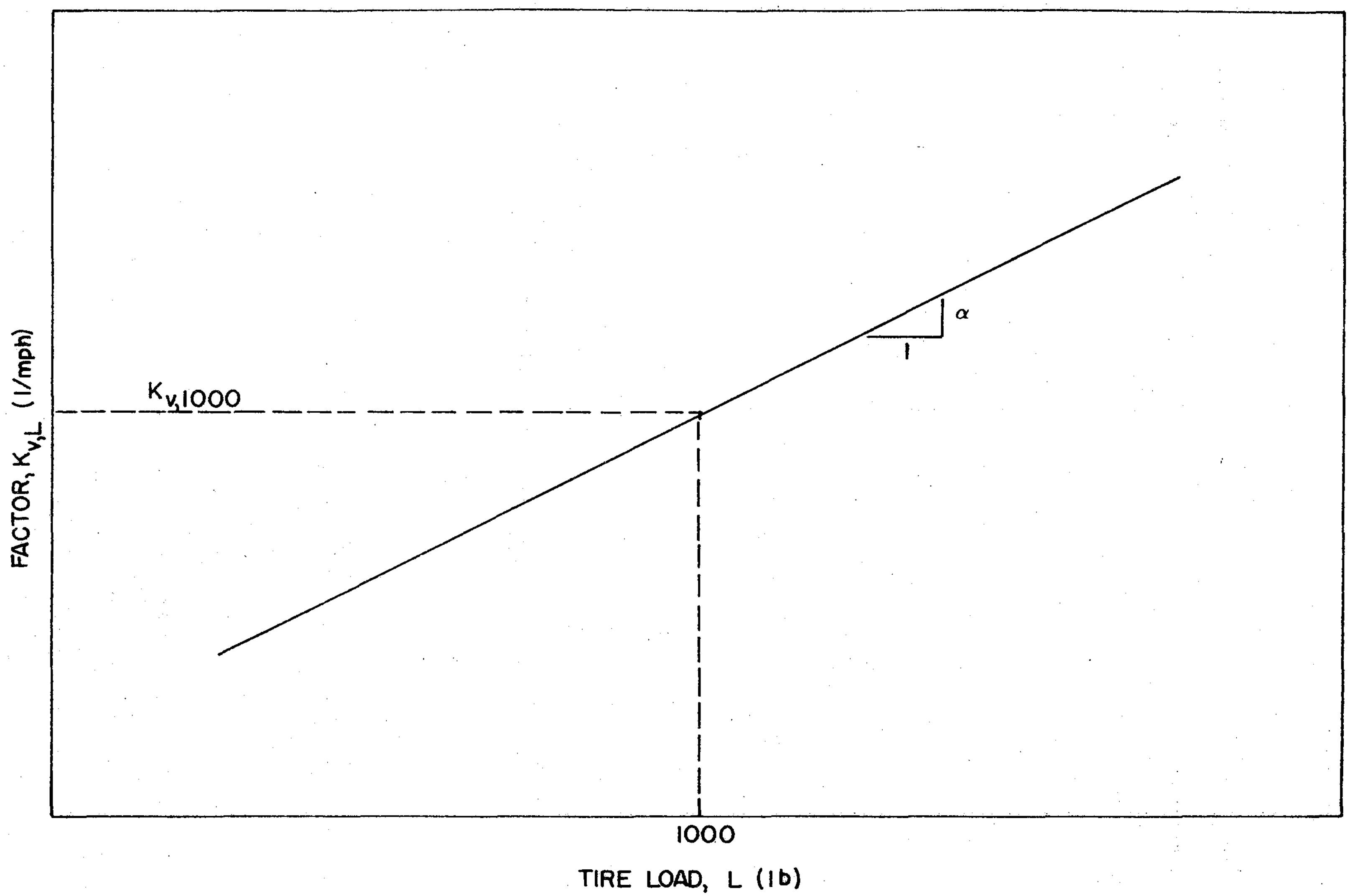


FIGURE 2-10 SPEED SLOPE VERSUS TIRE LOAD

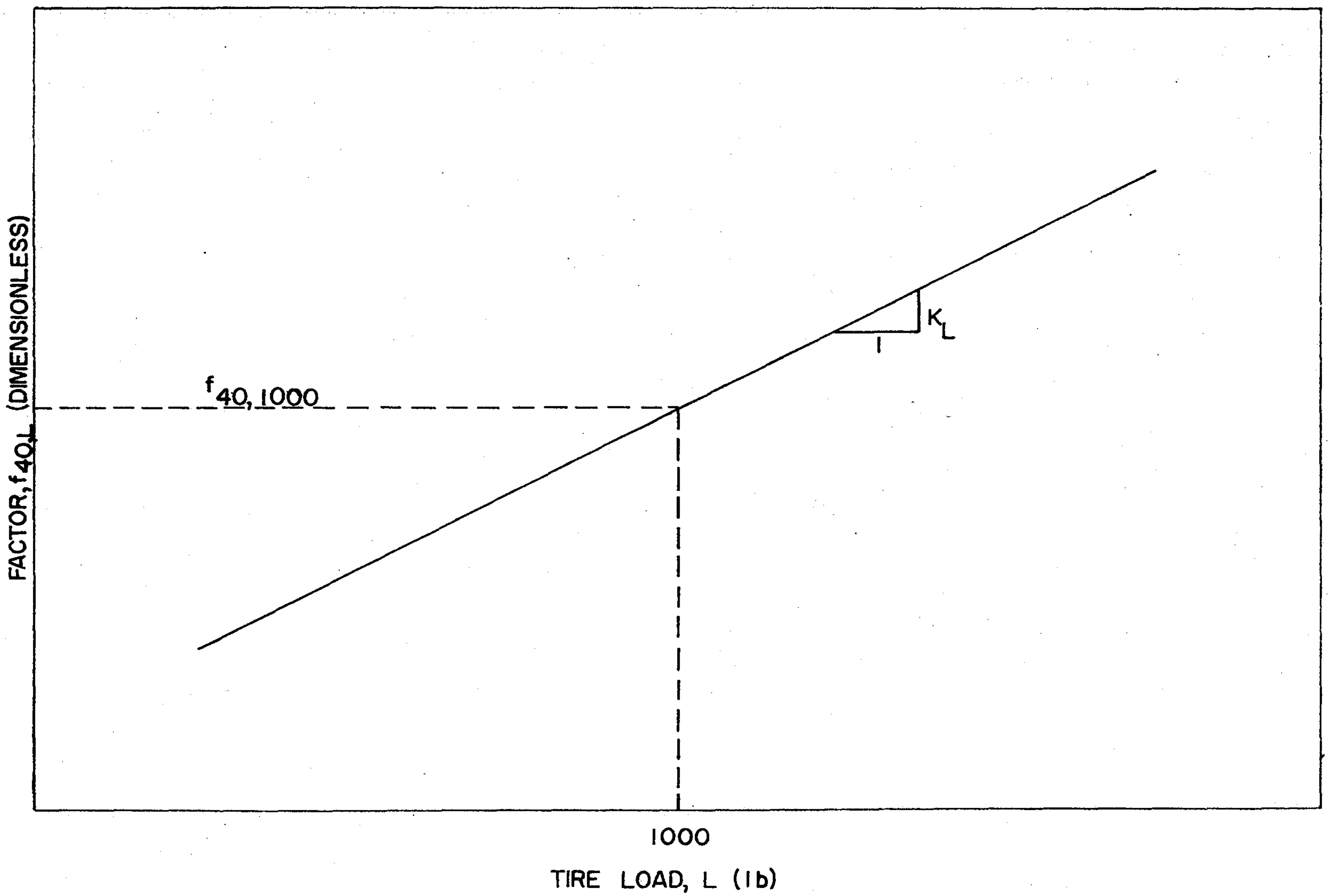


FIGURE 2-11 FRICTION FACTOR VER:)

26th Series of Cards**

FRONT WHEELS' NONLINEAR SUSPENSION BUMPER DATA (always included)

One Card, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKFC	K_{FC}	*	Lb/in.
9-16	AKFCP	K'_{FC}	*	$Lb/in.^3$
17-24	OMEGFC	Ω_{FC}	*	Inches
25-32	AKFE	K_{FE}	*	Lb/in.
33-40	AKFEP	K'_{FE}	*	$Lb/in.^3$
41-48	OMEGFE	Ω_{FE}	*	Inches
49-78			Leave blank	
79-80	ICARD		= 26	

*Refer to Section 1.4 of Cornell Aeronautical Laboratory Report No. VJ-2251-V-4, March, 1969, pp. 22-28.

**If the 26th card series is omitted, the program will automatically select the following values:

AKFC = 300.0	AKFE = 300.0
AKFCP = 2.0	AKFEP = 2.0
OMEGFC = -3.0	OMEGFE = 3.0
ICARD = 26	

27th Series of Cards**

REAR WHEELS' NONLINEAR SUSPENSION BUMPER DATA (always included)

One Card, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	AKRC	K_{RC}	*	Lb/in.
9-16	AKRCP	K'_{RC}	*	$Lb/in.^3$
17-24	OMEGRC	Ω_{RC}	*	Inches
25-32	AKRE	K_{RE}	*	Lb/in.
33-40	AKREP	K'_{RE}	*	$Lb/in.^3$
41-48	OMEGRE	Ω_{RE}	*	Inches
49-78			Leave blank	
79-80	ICARD		= 27	

---

*Refer to Section 1.4 of Cornell Aeronautical Laboratory Report No. VJ-2251-V-4, March, 1969, pp. 22-28.

**If the 27th card series is omitted, the program will automatically select the following values:

AKRC	= 300.0	AKREP	= 2.0
AKRCP	= 2.0	OMEGRE	= 4.0
OMEGRC	= -4.0	ICARD	= 27
AKRE	= 300.0		

28th Series of Cards

LOCATION AND STIFFNESS OF STRUCTURAL HARDPOINTS

a. 1st card of 28th series, Format (9F8.0,I8)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-8	NHP		No. of hardpoints, (≤ 3.0)*	
9-78			Blank	
79-80	ICARD		= 28	

b. 2nd thru 4th card of 28th series, Format (I4, T10, 4F10.3)

Col. Nos.	Program Variable	Report Variable	Definition	Units
1-4	J		Hardpoint number	
5-9			Blank	
10-19	XSTIO(J)		See comments below.	Inches
20-29	YSTIO(J)		See comments below.	Inches
30-39	ZSTIO(J)		See comments below.	Inches
40-49	AKST(J)		Stiffness of hard-point no. J, omni-directional.	Lbs/in.
50-80			Blank	

Comments on 28th Series of Cards

(1) Friction on hardpoints is the same as that of sheet metal (AMUB of 21st series).

(2) XSTIO(J), YSTIO(J), ZSTIO(J) = coordinates of hardpoint no. J, in vehicle-fixed coordinates.

---

*Input NHP as a real number.

Final Card of Section 2.1

(always included)

Col. Nos.	Information
1-76	Blank
77-80	9999

NOTE: This card signifies the end of data in Section 1.

2.2 PLOTTING DATA

Four options are available for use in displaying the output generated by the HVOSM program. The CAL-COMP plot routines are utilized for this purpose. A brief description of each option follows.

(1) Option 1 - A group of 19 plots will be generated under this option. Table 2-8 lists the plots which are printed. Two types of identification are printed on each plot. The first is a Figure number which corresponds to those given in Table 2-8. The second is general information related to the data group in the first card of Section 1.

(2) Option 2 - Any number of plots, up to a total of 19, may be generated by choosing this option. Table 2-9 lists the variables available for plotting. The type of identification appearing in the plots is to be inputted according to subsequent instructions.

(3) Option 3 - If no plots are needed, this option is used.

(4) Option 4 - Put data on disk or other storage medium and omit Section 2.2.

For a given data group only one of these options may be selected. If another data group is submitted in the computer run, follow the cards required for the chosen plot option by the first card of Section 1 of the next data group, etc.

Description of each option input follows:

<u>Option 1 - Standard Plots</u>. One card required. Format (A4).

Col. No.	Information
1-4	STAN

<u>Option 2 - N Plots</u>. Three series of input cards are needed in this option: (a), (b), and (c).

(a) <u>Plot Control Cards</u>

Format (2A4)

TABLE 2-8. STANDARD PLOTS

Figure	Description*		
1	XTRK	versus	YTRK
2	XPOS	"	AVER
3	YPOS	"	ZPOS
4	YPOS	"	AVER
5	YPOS	"	ALON
6	YPOS	"	ALAT
7	TIME	"	XPOS
8	TIME	"	YPOS
9	TIME	"	ZPOS
10	TIME	"	ALON
11	TIME	"	ACX2
12	TIME	"	ALAT
13	TIME	"	ACY2
14	TIME	"	AVER
15	TIME	"	ACZ2
16	TIME	"	ROLL
17	TIME	"	PTCH
18	TIME	"	YAWW
19	TIME	"	SANG

* See Table 2-9.

TABLE 2-9. ALPHAMERIC VARIABLE NAMES

SEQUENCE NO.	NAME	PROGRAM VARIABLE	DESCRIPTION	OT UNITS
1	TIME	TM	Time in seconds.	
2	XPOS	XPO	X, Y, and Z coordinate, respectively, of sprung mass relative to space-fixed coordinate system.	Inches
3	YPOS	YPO		"
4	ZPOS	ZPO		"
5	ALON	ACLON	Sprung mass longitudinal acceleration.	G-units
6	ALAT	ACLAT	Sprung mass lateral acceleration.	"
7	AVER	ACVER	Sprung mass vertical acceleration.	"
8	ROLL	PHIO	Roll, pitch, yaw angles, respectively, of vehicle.	Degrees
9	PTCH	THTAO		"
10	YAWW	PSIO		"
11	ACX1	AX1	Acceleration components in X, Y, and Z directions, respectively, at accelerometer position No. 1, relative to ve- fixed coordinate system.	G-units
12	ACY1	AY1		"
13	ACZ1	AZ1		"
14	ACX2	AX2	Acceleration components in X, Y, and directions, respectively, at accelerometer position No. 2, relative to ve- fixed coordinate system.	G-units
15	ACY2	AY2		"
16	ACZ2	AZ2		"
17	VDFO	DEFO	Vehicle deformation.	Inches
18	BDFL	DELBO	Barrier deflection.	Inches
19	SANG	PSIFO	Steering angle.	Degrees
20	XTRK	XTRK	X-position of vehicle wheel centers.	Inches
21	YTRK	YTRK	Y-position of vehicle wheel centers.	Inches

Col. Nos.	Variable Name to be Punched	Program Variable	Definition
1-4	*	See Table 2-9	Y (abcissa)
5-8	**	See Table 2-9	X (ordinate)

* Time is usually specified as the first variable, however, it can be any variable in the *NAME* column of Table 2-9. The variable to be entered here must have a figure number less than the variable to be entered in cols. 5-8.

**Any other desired variable in the *NAME* column from Table 2-9. The figure number of this variable must be greater than the figure number of the variable in cols. 1-4.

NOTE: (1) One card is needed per plot. A maximum of 19 plots can be generated for each data group.

(2) XTRK YTRK can only be plotted against each other.

(b) XXXX Card

Format (A4)

Col No.	Information	Definition
1-4	XXXX	Signifies end of plot control cards.

(c) Plot Identification Cards

Format (20A4)

Col No.	Identification to be Punched
1-70	(whatever desired)

NOTE: (1) Two plot identification cards are required for each plot control card of series (a) and their order of input must follow that of the plot control cards. For example, if 10 plots are specified, 20 plot identification cards are required.

(2) The information on each of these two cards is printed below each respective plot.

Option 3 - One card required. Format (A4).

Col. No.	Information
1-4	NONE

Option 4 - One card required. Format (A4).

Col. No.	Information
1-4	SAVE

2.3 TERMINATION DATA

In order to signify the end of a computer run, a termination card must always be included. Its contents are as follows:

Format (A4)

Col. No.	Information
1-4	FINI

III. SAMPLE PROBLEMS

3.1 Sloping Culvert Grate and Surrounding Terrain

This example problem investigates the dynamic behavior of a 1963 Ford Galaxie (4-door sedan) as it leaves the road and traverses the path shown in Figure 3-1.

The necessary primary input data (described in Chapter II, Section 2.1) for this example problem is shown in Figure 3-2.

The primary input data as printed out by TTI's version of HVOSM is shown in Figures 3-3 and 3-4. Figure 3-3 shows the card images of the necessary data while Figure 3-4 shows the same data in a more convenient form.

The printed output for the time period between 0.510 seconds and 1.013 seconds is given in Figure 3-5.

Assume no output plotting is required, then, the necessary plotting data (described in Chapter II, Section 2.2) for this example problem is:

Column Number	Information
1-4	None

The necessary termination data is given as:

Column Number	Information
1-4	Fini

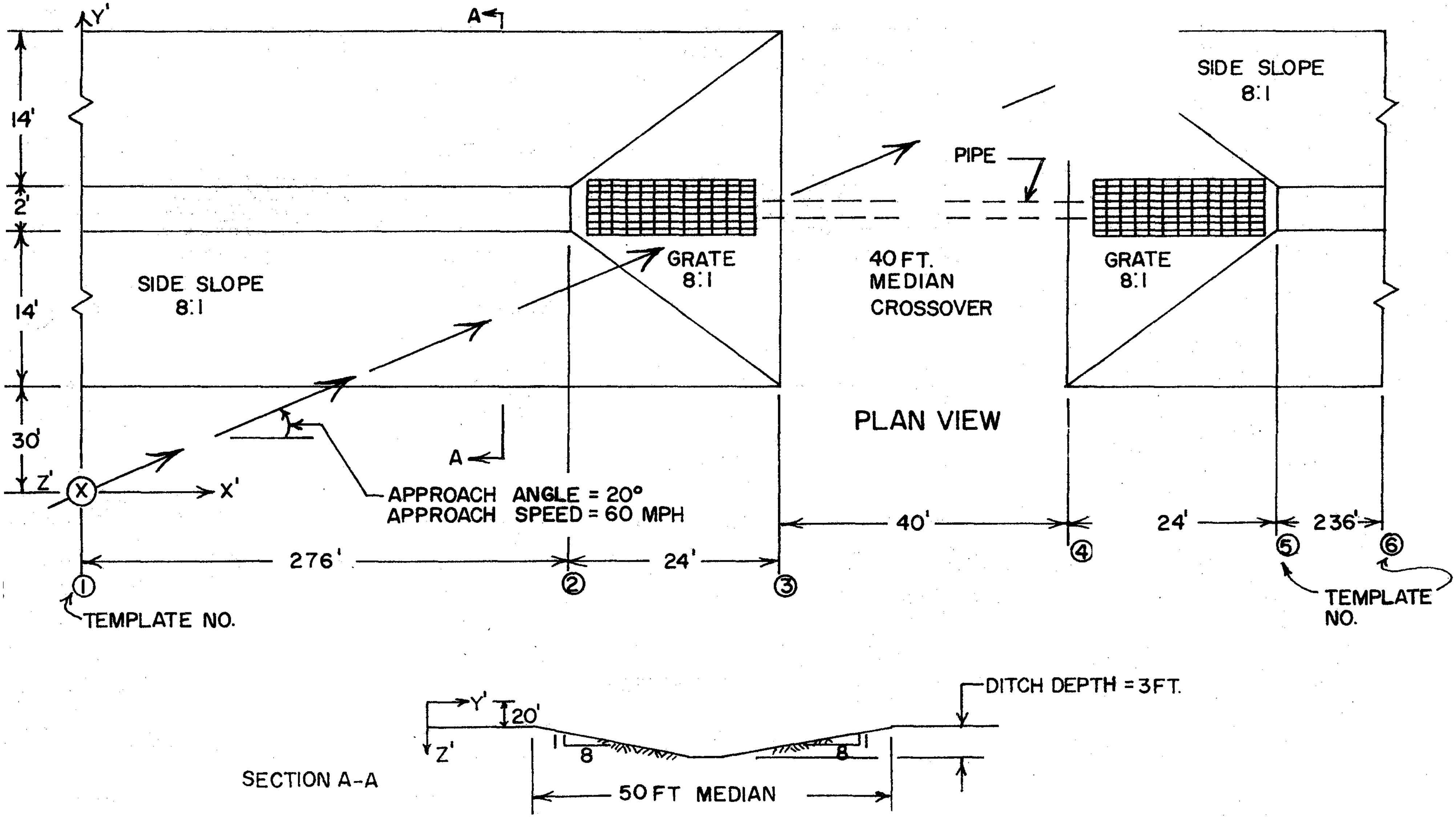


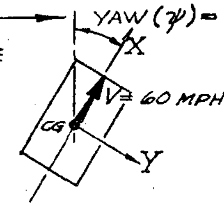
FIGURE 3-1 SIMULATED MEDIAN TERRAIN CONFIGURATION AND AUTOMOBILE PATH

```
PROG 140-2 B   FILL,YAW=20DEG, V=60MPH, 8:1GRATE SLOPE, 8:1 ...E
2.60 SEC RUN DSN = 3G522

0.0      2.60    0.005    0.0      0.01     70.0     0.0      0.0     ...      1

0.0      0.0     -20.0    0.0      0.0      0.0      0.0      0.0              8

2484.0   1044.0  -24.138  1056.0   0.0      0.0                                9

6.0      6.0     0.0                                                          14

   1 0.0     0.0         20.0        30.0        20.0        54.0        23.0        56.0
23.0         80.0        20.0        120.0       20.0

   2 276.0   0.0         20.0        30.0        20.0        54.0        23.0        56.0
23.0         80.0        20.0        120.0       20.0

   3 300.0   0.0         20.0        30.0        20.0        30.0        20.0        80.0
20.0         80.0        20.0        120.0       20.0

   4 340.0   0.0         20.0        30.0        20.0        30.0        2c          80.0
20.0         80.0        20.0        120.0       20.0

   5 364.0   0.0         20.0        30.0        20.0        54.0        23          56.0
23.0         80.0        20.0        120.0       20.0

   6 600.0   0.0         20.0        30.0        20.0        54.0        23.0        56.0
23.0         80.0        20.0        120.0       20.0
```

FIGURE 3-2. PRIMARY INPUT DATA FOR EXAMPLE 3.1

YAW (ψ) = +20 DEG. RULE)

PROG 140-2 B' FILL, YAW=20DEG, V=60MPH, 8:1 GRATE SLOPE, 8:1 SIDE SLOPE
2.60 SEC RUN DSN = SGS22



INPUT PRESET IN SUBROUTINE STD (ON DISK)

									(ICARD)
1									2
10.818	0.608	0.945	386.400	6000.000	30000.000	36000.000	-192.000	600.000	3
54.517	64.483	61.000	60.000	10.138	12.088	-2.000	14.000	4400.000	4
131.000	0.500	3.000	3.500	55.000	0.001	266000.000			5
192.000	0.500	4.000	3.900	50.000	0.001	61900.000	46.500	0.070	6
1098.000	3.000	10.000	8.276	2900.000	1.780	0.800	1.000	3900.000	7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		10
-34.480	0.0	4.000	-5.983	-16.500	3.138				11
-5.000	5.000	1.000							12 (FIRST CARD)

PHIC(I),I=1,11

-3.550	-2.550	-1.800	-1.300	-0.950	-0.550	-0.300	-0.300	-0.400	-0.550	-0.800	12 (SECOND CARD)
492.000	600.000	0.400	5000.000	0.075	1.500						17
4	4000.000	0.001	0.250								23

XVP(I),YVP(I),ZVP(I),I=1,4

81.517	39.500	12.138	VEHICLE MONITOR POINTS OF BUMPERS (2ND SET OF CARDS OF ICARD 23)
81.517	-39.500	12.138	
-117.483	39.000	8.138	
-117.483	-39.000	8.138	

300.000	2.000	-3.000	300.000	2.000	3.000	SEE APPENDIX	26
300.000	2.000	-4.000	300.000	2.000	4.000		27

INPUT READ BY CALSVA (READ IN BY CARDS)

									(ICARD)
0.0	2.60	.005	0.0	.01	70.	0.0	0.0	-1.0	1
0.0	0.0	-20.0	0.0	0.0	0.0	0.0	0.0		8
2484.0	1044.0	-24.138	1056.	0.0	0.0				9
300.0	2.00	-3.00	300.0	2.00	5.00	SEE APPENDIX			26
300.0	2.00	-4.00	300.0	2.00	4.50				27
6.0	6.0	0.0							14

THESE CARDS WILL ... [illegible] ...ALENT AND/OR
CARDS PRESENTED ... ...RIDE THOSE SAME
WHICH ARE ON DISK ... SUBROUTINE STD. (SHOWN)

XGP(I,J),YGP(I,J),ZGP(I,J),I=1, 6 J=1, 6

0.0	0.0	20.000	30.000	20.000	54.000	23.000	56.000	23.000	80.000	20.000
120.000	20.000									
276.000	0.0	20.000	30.000	20.000	54.000	23.000	56.000	23.000	80.000	20.000
120.000	20.000									
300.000	0.0	20.000	30.000	20.000	30.000	20.000	80.000	20.000	80.000	
120.000	20.000									
340.000	0.0	20.000	30.000	20.000	30.000	20.000	80.000	20.000	80.000	
120.000	20.000									
364.000	0.0	20.000	30.000	20.000	54.000	23.000	56.000	23.000	80.000	
120.000	20.000									
600.000	0.0	20.000	30.000	20.000	54.000	23.000	56.000	23.000	80.000	20.000
120.000	20.000									

← TERRAIN DATA (ICARD 14a)

FIGURE 3-3. PRIMARY INPUT DATA REPRODUCED

```
PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SI
2.60 SEC RUN DSN = SG522

     INERTIAL DATA (ICARD 3)              DIMENSIONS (ICARD 4)                                      SUSPI               'CARDS 7 and 8)

MS    = 10.8180 LB.-SEC.**2/IN      A     = 54.5170 INCHES      KF       = 131.000 LB./IN.        L'                 00
MUF   =  0.6080        ''           B     = 64.4830   ''        KR       = 192.000 LB./IN.        L'                 00
MUR   =  0.9450        ''           TF    = 61.0000   ''        CF'      =  55.000 LBS.           O'                 00 INCHES
                                    TR    = 60.0000   ''        CR'      =  50.000 LBS.           O'                 00 INCHES
IX    =  6000.0 LB.-SEC.**2-IN      ZF    = 10.1380   ''        EPSILONF=   0.001 IN./SEC.       T'                 00 INCHES
IY    = 30000.0        ''           ZR    = 12.0880   ''        EPSILONR=   0.001 IN./SEC.       RF                 .0 LB-IN/RAD
IZ    = 36000.0        ''           RHO   = -2.0000   ''        CF       =   3.500 LB-SEC/IN      RF       =266000.0 LB-IN/RAD
IXZ   =-192.000        ''           RW    = 14.0000   ''        CR       =   3.900 LB-SEC/IN      KRS      =    0.070 ROLL STEER COEFF.
IR    =  600.00        ''
G     = 386.400 IN/SEC.**2                                    ( AKFC   = 300.000 LB/IN          AKRC    = 300.000 LB/IN  )
                                                              ( AKFCP  =   2.000 LB/IN3         AKRCP   =   2.000 LB/IN3 )
                                                    ICARD     { OMEGFC=   -3.000 IN             OMEGRC  =  -4.000 IN     } ICARD 27
                                                     26       ( AKFE   = 300.000 LB/IN          AKRE    = 300.000 LB/IN  ) SEE APPENDIX
                                                SEE APPENDIX  ( AKFEP  =   2.000 LB/IN3         AKREP   =   2.000 LB/IN3 )
                                                              ( OMEGFE=    5.000 IN             OMEGRE  =   4.500 IN     )

                                        INITIAL CONDITIONS (ICARDS 8, 9 and 10)                                       ACCELEROMETER POSITIONS
                                                                                                                           (ICARD 11)
PHIO   =   0.0    DEGREES   XCO'  =2484.000INCHES   PO     =  0.0   DEG/SEC   UO    =1056.000 IN/SEC          X1  = -34.480 INCHES
THETAO=    0.0      ''      YCO'  =1044.000  ''     QO     =  0.0     ''      VO    =   0.0      ''           Y1  =   0.0     ''
PSIO   = -20.000    ''      ZCO'  = 215.862  ''     RO     =  0.0     ''      WO    =   0.0      ''           Z1  =   4.000   ''
PHIRO  =   0.0      ''      DELTA1=    0.0   ''  D(PHIR)/DT=  0.0     ''  D(DEL1)/DT=   0.0      ''           X2  =  -5.983   ''
PSIFIO=    0.0      ''      DELTA2=    0.0   ''  D(PSIF)/DT=  0.0   RAD/SC D(DEL2)/DT=  0.0      ''           Y2  = -16.500   ''
                            DELTA3=    0.0   ''                               D(DEL3)/DT=   0.0      ''           Z2  =   3.138   ''

                                               DRIVER CONTROL TABLES (NOT APPLICABLE)

   T      PSIF     TQF     TQR       T      PSIF     TQF     TQR       T      PSIF     TQF     TQR       T      ;IF     TQF     TQR
  SEC     DEG     LB/FT   LB/FT     SEC     DEG     LB/FT   LB/FT     SEC     DEG     LB/FT   LB/FT     SE      )EG    LB/FT   LB/FT

  0.0     0.0     0.0     0.0

    TIRE DATA               TERRAIN TABLE ARGUMENTS                      PROGRAM CONTROL DATA (ICARD 1)
   (ICARD 7)
KT          1098.000 LB/IN                                      START TIME                  =   0.0    SEC
SIGMAT  =      3.000                                            END TIME                    =   2.600
LAMBDAT =     10.000                                            INCR FOR INTEGRATION        =   0.0050 ''
A0      =4400.000   ICARD ( SOIL DAMPING= 0.001 SPI             PRINT INTERVAL              =   0.010  ''
A1      =    8.276   23   { SOIL FRICT. = 0.250                 THETA MAX (TO SWITCH)=         70.000 DEG
A2      =2900.000         ( SSTIFF   =    4000. LB/IN           UVWMIN(STOP)                =   0.0
A3      =    1.780  ICARD ( NO.X TEMPS. =  6                    PQRMIN(STOP)                =   0.0
A4      =3900.000    14   { NO.Y TEMPS. =  6                    INDCRB                      =  -1  (=0.NO CURB,=1 CURB,=-1 STEER DEG.OF FREEDOM)
AMU     =    0.800        ( NO. VAR AMU =  0                    MODE OF INTEGRATION         =   1  (=0 VAR.ADAMS-MOULT.,=1 RUNGE-KUTTA,=2FIX.AM)
OMEGT   =    1.000          TABLES                              DTCMP1                      =  0.  (=1.0 SUPPLY INITIAL POSITION)
                                                                                                   (=0.0 CAR RESTS ON TERRAIN)


COEFF. OF TIRE FRICTION      )
        VS.                  }  NOT APPLICABLE
(SPEED AND  LOAD) DATA       )
ALPHA= 0.0        1/(LB-MPH) )
```

FIGURE 3-4. PRIMARY INPUT DATA REPRODUCED
IN MORE CONVENIENT FORM

```
XKVTH= 0.0        1/ MPH
XXL=   0.0        1/LB
```
} NOT APPLICABLE

VEHICLE MONITOR POINTS (BUMPERS) ICARD 23

	X (IN.)	Y (IN.)	Z (IN.)
POINT 1	81.517	39.500	12.138
POINT 2	81.517	-39.500	12.138
POINT 3	-117.483	39.000	8.138
POINT 4	-117.483	-39.000	8.138

FRONT WHEEL CAMBER VS SUSPENSION DEFLECTION

DELTAF (Inches)	PHIC (Degrees)
-5.00	-3.55
-4.00	-2.55
-3.00	-1.80
-2.00	-1.30
-1.00	-0.95
0.00	-0.55
1.00	-0.30
2.00	-0.30
3.00	-0.40
4.00	-0.55
5.00	-0.80

This data on front wheel camber versus suspension deflection will be printed out on later programs

FIGURE 3-4. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE S
2.60 SEC RUN DSN = SGS22

**** CURB AND BARRIER DAT
(NOT APPLICABLE TO THIS STUDY.

CURB IMPACT DATA

YCI'	=	0.0	INCHES
YC2'	=	0.0	"
ZC2'	=	0.0	"
DELTC	=	0.0	SEC(INTEG.INCR.)
PHIC1	=	0.0	DEGREES
PHIC2	=	0.0	"
AMUC	=	0.0	
IPSI	=	492.000	LB-SEC**2-IN
CPSI'	=	600.000	LB-IN
OMEGA PSI	=	0.400	RAD
KPSI	=	5000.000	LB-IN/RAD
EPSILON PSI	=	0.075	RAD/SEC
TRAIL.FRONT(PT)=		1.500	INCHES

BARRIER DIMENSIONS

(YB')0	=	0.0	INCHES
DELYB'	=	0.0	"
ZBT'	=	0.0	"
ZBB'	=	0.0	"

VEHICLE DIMENSIONS

XVF	=	0.0	INCHES
XVR	=	0.0	"
YV	=	0.0	"
ZVT	=	0.0	"
ZVB	=	0.0	"

INDB = 0 (=1 RIGID BARRIER, FINITE VERT. DIM.)
=2 " " INFINITE " ")
=3 DEFORM.BARRIER,FINITE " ")
=4 " " INFINITE " ")

SPRUNG MASS-BARRIER IMPACT DATA

KV	=	0.0	LB/IN**3
SET	=	0.0	DEFL.RATIO
CONS	=	0.0	ENERGY RATIO
MUB	=	0.0	
EPSILON V=		0.0	IN/SEC
EPSILON B=		0.0	LB
DELTB	=	0.0	SEC (INTEG.INCR)

BARRIER LOAD DEFLECT.

SIGMAR 0	=	0.0
SIGMAR 1	=	0.0
SIGMAR 2	=	0.0
SIGMAR 3	=	0.0
SIGMAR 4	=	0.0
SIGMAR 5	=	0.0
SIGMAR 6	=	0.0
SIGMAR 7	=	0.0
SIGMAR 8	=	0.0
SIGMAR 9	=	0.0
SIGMAR10	=	0.0

STRUCTURAL HARDPOINTS RELATIVE TO C. G.

	X	Y (INCHES)	Z	STIFFNESS LB/IN
POINT 1	0.0	0.0	0.	0.0
POINT 2	0.0	0.0	0.	0.0
POINT 3	0.0	0.0	0.	0.0

WHEEL RADIUS-RADIAL SPRING FOR TABLE (NOT APPLICABLE)

RWHJB(BEGIN)	=	0.0	INCHES
RWHJE(END)	=	0.0	"
DRWHJ(INCRE.)	=	0.0	"

ANTI-PITCH TABLES FOR CIRCUMFERENTIAL TIRE FORCE (NOT APPLICABLE)

APF=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
APR=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

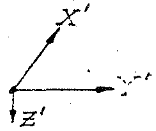
FIGURE 3-4. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLOPE
2.60 SEC RUN DSN = SGS22

TIME SEC.	STEERING INPUT DEG.	TORQUE INPUTS POUND-FEET FRONT	REAR	SPRUNG MASS CG ACCEL. G-UNITS LONG.	LAT.	VERT.	ANGULAR DEG. ROLL	P	W	FORWARD SPEED FT./SEC.
0.5100	0.76	0.0	0.0	0.037	-0.063	0.406	-11.76	-	.36	88.33
0.5200	0.77	0.0	0.0	0.037	-0.046	0.421	-8.73	-4.57	0.57	88.34
0.5300	0.77	0.0	0.0	0.037	-0.025	0.408	-5.56	-3.93	0.78	88.35
0.5400	0.77	0.0	0.0	0.037	-0.003	0.393	-2.51	-3.28	0.92	88.36
0.5500	0.76	0.0	0.0	0.037	0.008	0.350	0.36	-2.61	1.03	88.37
0.5600	0.75	0.0	0.0	0.037	0.018	0.329	2.88	-2.02	1.11	88.39
0.5700	0.72	0.0	0.0	0.037	0.022	0.304	5.25	-1.41	1.18	88.40
0.5800	0.69	0.0	0.0	0.037	0.023	0.277	7.47	-0.79	1.24	88.41
0.5900	0.65	0.0	0.0	0.038	0.023	0.247	9.54	-0.21	1.31	88.42
0.6000	0.61	0.0	0.0	0.038	0.024	0.215	11.49	0.31	1.38	88.43
0.6100	0.56	0.0	0.0	0.039	0.028	0.182	13.29	0.75	1.45	88.45
0.6200	0.51	0.0	0.0	0.040	0.034	0.149	14.94	1.10	1.50	88.46
0.6300	0.47	0.0	0.0	0.040	0.041	0.115	16.43	1.38	1.54	88.47
0.6400	0.42	0.0	0.0	0.041	0.047	0.082	17.74	1.60	1.55	88.48
0.6500	0.36	0.0	0.0	0.041	0.051	0.050	18.86	1.78	1.54	88.50
0.6600	0.31	0.0	0.0	0.041	0.052	0.020	19.79	1.93	1.52	88.51
0.6700	0.26	0.0	0.0	0.041	0.051	-0.009	20.52	2.05	1.48	88.52
0.6800	0.20	0.0	0.0	0.041	0.047	-0.037	21.07	2.16	1.44	88.53
0.6900	0.14	0.0	0.0	0.042	0.042	-0.064	21.43	2.23	1.40	88.54
0.7000	0.08	0.0	0.0	0.042	0.038	-0.092	21.61	2.25	1.36	88.56
0.7100	0.02	0.0	0.0	0.043	0.035	-0.121	21.62	2.22	1.32	88.57
0.7200	-0.04	0.0	0.0	0.043	0.033	-0.150	21.46	2.12	1.26	88.58
0.7300	-0.10	0.0	0.0	0.044	0.032	-0.180	21.17	1.98	1.19	88.60
0.7400	-0.16	0.0	0.0	0.044	0.030	-0.209	20.71	1.76	1.10	88.61
0.7500	-0.22	0.0	0.0	0.044	0.027	-0.236	20.11	1.48	0.99	88.62
0.7600	-0.28	0.0	0.0	0.044	0.021	-0.261	19.38	1.17	0.86	88.64
0.7700	-0.33	0.0	0.0	0.044	0.014	-0.281	18.55	0.83	0.73	88.65
0.7800	-0.39	0.0	0.0	0.020	0.007	-0.300	17.59	0.44	0.65	88.66
0.7900	-0.44	0.0	0.0	0.019	-0.001	-0.315	16.52	0.04	0.58	88.66
0.8000	-0.49	0.0	0.0	-0.014	-0.009	-0.328	15.32	-0.40	0.47	88.66
0.8100	-0.53	0.0	0.0	-0.014	-0.015	-0.341	14.03	-0.86	0.34	88.66
0.8200	-0.57	0.0	0.0	-0.035	-0.019	-0.351	12.69	-1.33	0.21	88.65
0.8300	-0.61	0.0	0.0	-0.095	-0.006	-0.389	11.37	-1.84	0.01	88.63
0.8400	-0.66	0.0	0.0	-0.293	0.083	-0.602	10.88	-2.18	-0.27	88.55
0.8510	-0.70	0.0	0.0	-0.381	0.210	-3.513	24.72	2.45	-0.31	88.47
0.8610	-0.75	0.0	0.0	-1.208	0.307	-1.879	51.42	11.78	-0.59	88.24
0.8710	-0.79	0.0	0.0	-1.483	0.305	-6.471	76.38	24.69	-1.77	87.78
0.8810	-0.85	0.0	0.0	-2.010	0.491	-8.486	97.11	55.43	-3.59	87.25
0.8910	-0.91	0.0	0.0	-2.169	0.085	-6.984	115.07	83.45	-4.38	86.60
0.9010	-0.97	0.0	0.0	-1.536	-0.174	-8.631	97.80	114.52	-5.40	86.08
0.9110	-1.01	0.0	0.0	-0.836	-0.110	-4.261	71.24	139.28	-6.02	85.85
0.9210	-1.04	0.0	0.0	-0.357	-0.180	-2.726	41.74	152.20	-7.17	85.81
0.9300	-1.07	0.0	0.0	-0.249	-0.124	-1.334	22.22	156.74	-8.06	85.82
0.9430	-1.10	0.0	0.0	-0.180	-0.314	-1.541	8.50	155.16	.22	85.81
0.9530	-1.12	0.0	0.0	-0.032	-0.706	-2.897	-10.92	142.59	.45	85.74
0.9630	-1.13	0.0	0.0	0.058	-0.377	-3.614	-38.29	122.72	.55	85.64
0.9730	-1.14	0.0	0.0	-0.505	0.026	-2.155	-55.58	107.13	.46	85.50
0.9830	-1.15	0.0	0.0	-0.568	-0.250	-6.470	-67.72	80.28	.41	85.27
0.9930	-1.16	0.0	0.0	-0.101	-0.150	-1.036	-76.92	58.73	.21	85.09
1.0030	-1.17	0.0	0.0	0.417	-0.099	-0.910	-77.57	52.91	.00	85.15
1.0130	-1.18	0.0	0.0	0.030	0.079	-4.868	-72.51	35.75	.10	85.18

HIGHEST ACCELERATIONS MEASURED AND AVERAGED OVER 50 MILLISECONDS

FIGURE 3-5. PROGRAM OUTPUT



PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLO
2.60 SEC RUN DSN = SGS22

ROLL (FIG. 15) — PITCH (FIG. 15) — YAW (FIG. 15)

TIME SEC.	SPACE-FIXED COORDINATES POSITION (INCHES) FIG A16 X'	Y'	Z'	SPRUNG MASS CG ORIENTATION (DEGREES) PHI (φ)	THETA (ψ)	PSI (ψ)	VELOCITY (FT /SEC.) LAT.	VERT.	T RF		ON A\ GCP (SEE FIGURE 15)) RR	LR
0.5100	2989.85	857.89	225.81	-10.29	-2.39	-19.86	-1.10	0.70	250.88		45.98	252.98
0.5200	2999.77	854.19	226.37	-10.39	-2.44	-19.85	-1.13	0.76	251.34		46.44	253.45
0.5300	3009.69	850.49	226.94	-10.47	-2.48	-19.83	-1.15	0.82	251.80		46.91	253.91
0.5400	3019.61	846.78	227.53	-10.51	-2.52	-19.82	-1.17	0.90	252.26	259.42	247.38	254.38
0.5500	3029.53	843.09	228.13	-10.52	-2.54	-19.80	-1.18	0.97	252.73	259.88	247.85	254.85
0.5600	3039.45	839.39	228.75	-10.50	-2.56	-19.79	-1.19	1.05	253.19	260.35	248.31	255.32
0.5700	3049.38	835.69	229.38	-10.46	-2.58	-19.77	-1.21	1.12	253.66	260.81	248.78	255.79
0.5800	3059.30	832.00	230.02	-10.40	-2.59	-19.76	-1.22	1.20	254.13	261.28	249.25	256.26
0.5900	3069.23	828.31	230.68	-10.32	-2.59	-19.75	-1.23	1.28	254.60	261.75	249.72	256.72
0.6000	3079.16	824.62	231.34	-10.21	-2.59	-19.73	-1.24	1.36	255.07	262.22	250.18	257.19
0.6100	3089.10	820.94	232.01	-10.09	-2.58	-19.72	-1.25	1.43	255.54	262.69	250.65	257.66
0.6200	3099.03	817.25	232.68	-9.95	-2.57	-19.71	-1.26	1.50	256.01	263.16	251.13	258.13
0.6300	3108.97	813.57	233.36	-9.79	-2.55	-19.70	-1.26	1.57	256.49	263.64	251.60	258.61
0.6400	3118.90	809.89	234.05	-9.62	-2.54	-19.69	-1.27	1.63	256.96	264.11	252.07	259.08
0.6500	3128.84	806.21	234.74	-9.44	-2.52	-19.67	-1.27	1.68	257.43	264.58	252.55	259.55
0.6600	3138.79	802.53	235.43	-9.24	-2.50	-19.66	-1.27	1.72	257.91	265.05	253.02	260.03
0.6700	3148.73	798.86	236.12	-9.04	-2.47	-19.65	-1.27	1.76	258.38	265.53	253.49	260.50
0.6800	3158.68	795.18	236.81	-8.84	-2.45	-19.63	-1.27	1.79	258.85	266.00	253.97	260.97
0.6900	3168.63	791.51	237.50	-8.62	-2.43	-19.62	-1.27	1.81	259.32	266.48	254.44	261.44
0.7000	3178.58	787.84	238.18	-8.41	-2.40	-19.61	-1.27	1.83	259.80	266.95	254.91	261.91
0.7100	3188.53	784.16	238.87	-8.19	-2.38	-19.60	-1.28	1.83	260.27	267.42	255.38	262.38
0.7200	3198.49	780.49	239.54	-7.98	-2.35	-19.59	-1.28	1.83	260.74	267.89	255.85	262.85
0.7300	3208.44	776.82	240.22	-7.76	-2.33	-19.58	-1.28	1.81	261.21	268.37	256.32	263.32
0.7400	3218.40	773.14	240.88	-7.56	-2.31	-19.58	-1.28	1.78	261.68	268.84	256.79	263.79
0.7500	3228.36	769.47	241.54	-7.35	-2.30	-19.57	-1.28	1.74	262.14	269.31	257.26	264.26
0.7600	3238.33	765.79	242.19	-7.15	-2.28	-19.56	-1.28	1.68	262.61	269.78	257.73	264.73
0.7700	3248.29	762.12	242.82	-6.96	-2.27	-19.55	-1.28	1.62	263.08	2	258.20	265.20
0.7800	3258.26	758.44	243.45	-6.78	-2.26	-19.55	-1.29	1.54	263.51	2	258.66	265.67
0.7900	3268.22	754.76	244.07	-6.61	-2.26	-19.54	-1.29	1.45	263.97	2	259.13	266.14
0.8000	3278.19	751.08	244.67	-6.45	-2.26	-19.54	-1.30	1.34	264.44	2	259.59	266.60
0.8100	3288.16	747.40	245.26	-6.31	-2.27	-19.53	-1.30	1.23	264.90	2	260.06	267.07
0.8200	3298.12	743.71	245.84	-6.17	-2.28	-19.53	-1.31	1.10	265.37	2	260.53	267.53
0.8300	3308.09	740.03	246.40	-6.05	-2.29	-19.52	-1.32	0.96	265.83	2	260.99	268.00
0.8400	3318.05	736.34	246.95	-5.95	-2.31	-19.52	-1.29	0.78	266.29	2	261.46	268.46
0.8510	3328.99	732.29	247.52	-5.78	-2.32	-19.53	-1.25	0.24	265.96	2	261.97	268.98
0.8610	3338.93	728.61	247.93	-5.38	-2.25	-19.54	-1.17	-0.52	264.74	267.35	262.44	269.45
0.8710	3348.83	724.94	248.23	-4.75	-2.08	-19.56	-1.05	-1.47	263.48	266.13	262.91	269.92
0.8810	3358.68	721.29	248.29	-3.87	-1.67	-19.62	-0.95	-3.39	262.27	264.91	263.38	270.39
0.8910	3368.47	717.65	248.06	-2.77	-0.99	-19.70	-0.87	-4.71	261.07	263.69	263.82	270.87
0.9010	3378.18	714.02	247.52	-1.69	0.01	-19.79	-0.90	-5.80	259.85	262.48	264.28	271.34
0.9110	3387.83	710.41	246.69	-0.84	1.28	-19.87	-0.94	-5.96	258.64	261.27	264.75	271.74
0.9210	3397.44	706.80	245.67	-0.26	2.74	-19.95	-0.96	-4.98	257.42	260.06	265.21	272.21
0.9300	3406.07	703.55	244.66	0.01	4.13	-20.02	-0.93	-3.47	256.33	258.96	265.63	272.63
0.9430	3418.52	698.85	243.12	0.20	6.17	-20.13	-0.84	-0.81	254.76	257.39	266.23	271.18
0.9530	3428.08	695.23	241.89	0.19	7.67	-20.20	-0.88	0.88	253.55	256.17	266.72	269.97
0.9630	3437.61	691.60	240.58	-0.06	9.00	-20.25	-0.93	2.09	252.33	25	66.22	268.77
0.9730	3447.12	687.97	239.17	-0.57	10.14	-20.29	-0.91	3.09	251.12	25	65.01	267.57
0.9830	3456.60	684.36	237.66	-1.18	11.10	-20.33	-0.95	2.95	249.91	25	63.81	266.36
0.9930	3466.01	680.75	235.95	-1.92	11.76	-20.36	-1.04	2.74	248.70	25	62.60	265.15
1.0030	3475.41	677.14	234.18	-2.70	12.32	-20.37	-1.13	3.35	247.48	25(	61.40	263.93
1.0130	3484.80	673.52	232.36	-3.46	12.78	-20.39	-1.20	3.18	246.26	24	60.21	262.75

FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLOPE
2.60 SEC RUN DSN = SGS22

TIME			UNSPRUNG MASSES						RONT WHEEL	
SEC.	DEFLECTIONS (IN. AND DEG.)				VELOCITIES (IN./SEC. , DEG./SEC.)				MBER (DEG.)	
	DELTA 1	DELTA 2	DELTA 3	PHI R	D(DEL1)/DT	D(DEL2)/DT	D(DEL3)/DT	D(PHIR	1	PHI 2
0.5100	4.97	1.92	3.08	2.72	-0.67	-17.11	-5.68	7.65	-0.79	0.29
0.5200	4.96	1.76	3.03	2.85	-2.87	-14.23	-5.36	16.71	-0.79	0.28
0.5300	4.91	1.63	2.98	3.04	-7.19	-12.29	-5.12	21.10	-0.77	0.27
0.5400	4.81	1.51	2.93	3.25	-12.46	-11.93	-5.00	19.13	-0.74	0.27
0.5500	4.66	1.39	2.87	3.40	-17.35	-13.04	-5.53	11.32	-0.70	0.27
0.5600	4.47	1.25	2.82	3.47	-20.74	-15.02	-6.05	1.95	-0.65	0.28
0.5700	4.25	1.09	2.75	3.44	-22.30	-16.77	-7.95	-8.29	-0.60	0.29
0.5800	4.03	0.92	2.65	3.31	-22.32	-17.51	-11.04	-16.46	-0.56	0.32
0.5900	3.81	0.74	2.52	3.12	-21.58	-16.87	-14.81	-20.56	-0.52	0.35
0.6000	3.59	0.58	2.36	2.92	-20.98	-15.05	-18.57	-20.15	-0.48	0.39
0.6100	3.38	0.44	2.15	2.73	-21.19	-12.70	-21.65	-16.36	-0.45	0.42
0.6200	3.17	0.33	1.93	2.59	-22.43	-10.59	-23.58	-11.31	-0.42	0.45
0.6300	2.93	0.23	1.69	2.50	-24.44	-9.37	-24.19	-7.37	-0.39	0.48
0.6400	2.68	0.14	1.45	2.44	-26.64	-9.27	-23.61	-6.21	-0.36	0.51
0.6500	2.40	0.04	1.22	2.37	-28.42	-10.06	-22.26	-8.35	-0.33	0.54
0.6600	2.11	-0.07	1.00	2.26	-29.35	-11.20	-20.65	-13.06	-0.31	0.58
0.6700	1.82	-0.18	0.80	2.10	-29.34	-12.06	-19.29	-18.72	-0.28	0.63
0.6800	1.53	-0.31	0.62	1.89	-28.59	-12.16	-18.57	-23.49	-0.27	0.68
0.6900	1.25	-0.42	0.43	1.64	-27.52	-11.37	-18.60	-25.93	-0.28	0.73
0.7000	0.98	-0.53	0.24	1.38	-26.54	-9.92	-19.27	-25.53	-0.30	0.77
0.7100	0.72	-0.62	0.04	1.14	-25.90	-8.29	-20.28	-22.74	-0.36	0.80
0.7200	0.46	-0.70	-0.16	0.93	-25.66	-6.96	-21.21	-18.74	-0.42	0.83
0.7300	0.20	-0.76	-0.38	0.76	-25.68	-6.29	-21.90	-15.38	-0.49	0.86
0.7400	-0.06	-0.83	-0.60	0.62	-25.66	-6.35	-21.60	-12.90	0.57	0.88
0.7500	-0.31	-0.89	-0.81	0.50	-25.35	-6.92	-20.46	-12.29	0.68	0.91
0.7600	-0.56	-0.96	-1.00	0.37	-24.61	-7.59	-18.60	-13.39	0.78	0.94
0.7700	-0.80	-1.04	-1.18	0.22	-23.45	-7.97	-16.28	-15.42	0.87	0.96
0.7800	-1.04	-1.12	-1.33	0.06	-23.20	-7.87	-13.80	-17.32	0.96	0.98
0.7900	-1.26	-1.20	-1.46	-0.12	-22.34	-7.26	-11.53	-18.17	1.03	1.01
0.8000	-1.48	-1.27	-1.56	-0.30	-20.74	-7.35	-9.64	-17.45	1.10	1.03
0.8100	-1.68	-1.34	-1.65	-0.46	-18.63	-7.59	-8.23	-15.22	1.17	1.05
0.8200	-1.85	-1.42	-1.73	-0.60	-16.38	-7.31	-7.24	-12.03	1.24	1.08
0.8300	-2.01	-1.60	-1.80	-0.70	-14.45	-36.69	-6.42	-8.75	-1.30	1.14
0.8400	-2.14	-2.83	-1.86	-0.78	-13.90	-235.91	-5.41	-6.91	-1.36	1.69
0.8510	-2.32	-5.66	-1.91	-0.89	-22.98	-159.12	-5.64	-19.17	-1.43	3.55
0.8610	-2.88	-5.59	-1.98	-1.22	-126.20	46.08	-6.73	-42.52	-1.73	3.55
0.8710	-5.08	-6.01	-2.04	-1.75	-244.50	-108.25	-6.91	-64.44	-3.55	3.55
0.8810	-5.76	-6.47	-2.13	-2.49	59.14	-9.32	-9.86	-82.03	-3.55	3.55
0.8910	-5.85	-6.31	-2.23	-3.41	-75.01	15.91	-10.59	-97.38	-3.55	3.55
0.9010	-6.33	-6.16	-2.35	-4.32	-19.72	6.95	-11.59	-80.37	-3.55	3.55
0.9110	-6.16	-5.58	-2.46	-5.00	34.45	119.87	-10.61	-54.17	-3.55	3.55
0.9210	-6.01	-4.21	-2.54	-5.41	62.44	129.28	-5.68	-24.48	-3.55	2.74
0.9300	-5.22	-3.26	-2.57	-5.54	100.70	81.96	0.28	-6.26	5	1.97
0.9430	-3.96	-2.51	-2.57	-5.44	87.16	41.24	-4.59	31.56	1	1.52
0.9530	-3.22	-2.12	-2.85	-4.29	63.07	42.21	-64.14	234.67	4	1.35
0.9630	-2.61	-1.61	-3.79	-1.25	62.66	57.22	-122.36	269.10	8	1.15
0.9730	-1.88	-0.96	-5.48	-0.20	87.29	76.94	-201.55	-43.70	5	0.94
0.9830	-0.83	-0.10	-6.66	-0.66	121.51	93.65	20.21	5.20	9	0.59
0.9930	0.52	0.90	-5.41	-0.24	146.24	107.55	146.88	21.75	0	0.32
1.0030	2.06	2.06	-5.14	-0.12	160.26	123.57	-101.87	36.77	0	0.30
1.0130	3.68	3.35	-6.42	0.66	159.55	131.50	-70.54	69.68	0	0.45

FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SL
2.60 SEC RUN DSN = SGS22

TIME SEC.	CAMBER , STEER ANGLES RELATIVE TO GROUND PLANES PHI CG (DEG.) RF	LF	RR	LR	PSI' (DEG.) RF	LF	RR	LR	FORCES ...DS) RF		RR	LR
0.5100	-4.38	-3.30	-0.87	-0.87	0.75	0.75	0.19	0.19	320.4		150.7	725.1
0.5200	-4.48	-3.42	-0.85	-0.85	0.76	0.77	0.20	0.20	320.(		32.6	761.4
0.5300	-4.54	-3.50	-0.73	-0.73	0.77	0.77	0.21	0.21	335.1		15.4	797.1
0.5400	-4.55	-3.54	-0.56	-0.56	0.77	0.77	0.23	0.23	365.4		6.7	824.0
0.5500	-4.52	-3.55	-0.42	-0.42	0.76	0.76	0.24	0.24	404.(		115.5	839.5
0.5600	-4.46	-3.53	-0.33	-0.33	0.74	0.74	0.24	0.24	444.8	1306.9	136.3	844.5
0.5700	-4.36	-3.47	-0.32	-0.32	0.72	0.72	0.24	0.24	482.7	1329.9	176.4	845.7
0.5800	-4.25	-3.38	-0.39	-0.39	0.69	0.69	0.23	0.23	515.8	1351.4	232.3	850.1
0.5900	-4.13	-3.26	-0.49	-0.49	0.65	0.65	0.22	0.22	545.3	1368.4	297.4	864.0
0.6000	-3.99	-3.12	-0.59	-0.59	0.60	0.61	0.20	0.20	574.8	1379.4	364.4	890.4
0.6100	-3.84	-2.96	-0.65	-0.65	0.56	0.56	0.19	0.19	608.1	1384.3	427.9	928.6
0.6200	-3.66	-2.79	-0.65	-0.65	0.51	0.51	0.18	0.18	648.2	1384.8	485.0	973.7
0.6300	-3.48	-2.61	-0.58	-0.58	0.46	0.47	0.18	0.18	695.5	1383.8	536.5	1019.1
0.6400	-3.27	-2.41	-0.48	-0.48	0.42	0.42	0.17	0.17	748.3	1383.9	585.0	1058.2
0.6500	-3.06	-2.19	-0.36	-0.36	0.36	0.36	0.17	0.17	803.5	1386.4	634.4	1086.5
0.6600	-2.84	-1.96	-0.28	-0.28	0.31	0.31	0.16	0.16	857.9	1391.2	687.4	1103.3
0.6700	-2.62	-1.71	-0.23	-0.23	0.26	0.26	0.15	0.15	909.0	1396.9	745.4	1111.2
0.6800	-2.40	-1.45	-0.24	-0.24	0.20	0.20	0.13	0.13	956.5	1401.1	807.8	1115.6
0.6900	-2.19	-1.19	-0.27	-0.27	0.14	0.14	0.11	0.11	1001.1	1402.3	872.6	1122.2
0.7000	-2.00	-0.93	-0.32	-0.32	0.08	0.08	0.10	0.10	1044.7	1399.5	937.2	1135.5
0.7100	-1.84	-0.68	-0.35	-0.35	0.02	0.02	0.08	0.08	1089.0	1393.5	999.2	1157.2
0.7200	-1.68	-0.43	-0.34	-0.34	-0.04	-0.04	0.07	0.07	1134.9	1385.8	1057.4	1186.0
0.7300	-1.54	-0.19	-0.29	-0.29	-0.10	-0.10	0.05	0.05	1182.2	1378.4	1113.2	1218.3
0.7400	-1.42	0.04	-0.22	-0.22	-0.16	-0.16	0.04	0.04	1229.6	1373.0	1164.2	1248.8
0.7500	-1.32	0.27	-0.14	-0.14	-0.22	-0.22	0.03	0.03	1275.5	1370.1	1211.9	1273.3
0.7600	-1.22	0.49	-0.07	-0.07	-0.28	-0.28	0.03	0.03	1318.4	1369.2	1256.8	1289.0
0.7700	-1.13	0.71	-0.03	-0.03	-0.33	-0.33	0.02	0.02	1357.5	1369.2	1299.1	1295.8
0.7800	0.60	0.91	-0.01	-0.01	-0.39	-0.39	0.00	0.00	1398.1	1368.3	1337.9	1295.3
0.7900	0.74	1.11	-0.02	-0.02	-0.44	-0.44	-0.01	-0.01	1435.9		1372.7	1291.3
0.8000	0.86	3.47	-0.04	-0.04	-0.49	-0.48	-0.02	-0.02	1469.0		1402.6	1287.2
0.8100	0.97	3.68	-0.06	-0.06	-0.53	-0.53	-0.03	-0.03	1496.1		1427.3	1285.7
0.8200	1.07	-2.57	-0.06	-0.06	-0.57	-0.56	-0.04	-0.04	1518.4		1447.0	1287.8
0.8300	1.16	-2.38	-0.04	-0.04	-0.61	-0.61	-0.05	-0.05	1530.1		1462.2	1292.5
0.8400	1.25	-1.72	-0.01	-0.01	-0.65	-0.65	-0.05	-0.05	1468.5		1474.4	1295.2
0.8510	-4.64	0.28	0.04	0.04	-0.69	-0.69	-0.06	-0.06	1333.6	1	1516.8	1176.4
0.8610	-4.52	0.69	0.11	0.11	-0.73	-0.74	-0.09	-0.09	1812.7		1604.4	1122.6
0.8710	-5.70	1.32	0.22	0.22	-0.78	-0.78	-0.12	-0.12	8674.4	1	1705.7	1048.0
0.8810	-4.83	2.20	0.35	0.35	-0.84	-0.84	-0.17	-0.17	8288.6	28334.7	1836.6	973.5
0.8910	-3.75	3.29	2.15	0.51	-0.90	-0.90	-0.24	-0.24	16899.2	13266.3	1977.0	878.0
0.9010	-2.69	4.37	2.35	0.68	-0.96	-0.96	-0.30	-0.30	25169.2	11792.8	2097.0	838.9
0.9110	-1.86	5.21	2.55	3.03	-1.01	-1.00	-0.35	-0.35	11769.1	6858.2	2326.7	829.7
0.9210	-1.31	4.97	2.74	3.22	-1.04	-1.04	-0.38	-0.38	10409.1	1766.1	2563.6	831.6
0.9300	-1.05	4.46	2.91	3.39	-1.07	-1.06	-0.39	-0.39	5162.4	1120.9	2633.6	829.0
0.9430	0.15	4.18	3.24	-2.79	-1.10	-1.09	-0.38	-0.38	1800.0	1159.0	2434.7	1018.4
0.9530	0.68	3.97	4.42	-1.65	-1.12	-1.11	-0.30	-0.30	1392.5	1128.2	2072.3	1743.3
0.9630	0.78	3.50	1.15	1.15	-1.13	-1.13	-0.09	-0.09	1272.2	1016.8	2019.1	2511.9
0.9730	0.59	2.77	1.70	1.70	-1.14	-1.14	-0.01	-0.01	1082.9	869.4	5690.2	4827.3
0.9830	0.32	1.80	0.63	0.63	-1.15	-1.15	-0.05	-0.05	813.4		18075.4	10958.2
0.9930	0.06	0.77	0.32	0.32	-1.16	-1.16	-0.02	-0.02	524.9		3893.6	3148.3
1.0030	-0.63	-0.02	-0.33	-0.33	-1.16	-1.16	-0.01	-0.01	246.6		3713.9	3549.5
1.0130	-1.59	-0.65	-0.30	-0.30	-1.17	-1.17	0.05	0.05	13.7		8988.3	15211.7

FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLOPE
2.60 SEC RUN DSN = SGS22

TIME SEC.	HUB VELOCITY PARALLEL TO GROUND PLANES (FT./SEC.) LONGITUDINAL				LATERAL				VERT :ES			
	RF	LF	RR	LR	RF	LF	RR	LR	RF			LR
0.5100	88.20	88.25	88.20	88.25	-0.55	-0.63	-0.82	-0.82	-397.4	-12[illegible]	[illegible]	-985.0
0.5200	88.21	88.28	88.22	88.29	-0.68	-0.75	-1.13	-1.13	-472.0	-1308.2	0.0	-957.1
0.5300	88.23	88.32	88.23	88.32	-0.84	-0.87	-1.36	-1.36	-541.1	-1369.8	-51.2	-899.8
0.5400	88.25	88.35	88.25	88.35	-0.99	-0.99	-1.47	-1.47	-586.5	-1437.7	-190.1	-843.7
0.5500	88.27	88.38	88.27	88.38	-1.13	-1.11	-1.46	-1.46	-602.7	-1493.9	-336.2	-821.7
0.5600	88.30	88.40	88.29	88.40	-1.25	-1.22	-1.42	-1.42	-597.7	-1525.4	-465.5	-852.6
0.5700	88.32	88.43	88.32	88.43	-1.35	-1.32	-1.35	-1.35	-587.7	-1530.0	-559.0	-935.5
0.5800	88.34	88.45	88.34	88.45	-1.43	-1.40	-1.33	-1.33	-589.7	-1513.6	-604.9	-1052.8
0.5900	88.36	88.48	88.36	88.47	-1.50	-1.48	-1.37	-1.37	-614.8	-1489.5	-608.9	-1175.1
0.6000	88.38	88.50	88.38	88.50	-1.57	-1.54	-1.47	-1.47	-664.9	-1472.3	-590.2	-1272.7
0.6100	88.40	88.52	88.40	88.52	-1.64	-1.59	-1.62	-1.62	-733.0	-1471.9	-572.6	-1324.8
0.6200	88.41	88.54	88.41	88.54	-1.70	-1.64	-1.78	-1.78	-806.8	-1489.9	-576.6	-1325.8
0.6300	88.43	88.56	88.43	88.56	-1.76	-1.69	-1.90	-1.90	-874.2	-1520.2	-612.7	-1286.9
0.6400	88.44	88.58	88.44	88.58	-1.81	-1.74	-1.96	-1.96	-928.2	-1551.7	-679.5	-1231.4
0.6500	88.46	88.59	88.46	88.59	-1.85	-1.78	-1.95	-1.95	-968.0	-1573.0	-766.5	-1187.7
0.6600	88.47	88.60	88.48	88.60	-1.88	-1.81	-1.89	-1.89	-998.6	-1577.7	-859.1	-1178.5
0.6700	88.49	88.62	88.49	88.61	-1.90	-1.84	-1.81	-1.81	-1027.8	-1565.1	-944.1	-1213.9
0.6800	88.50	88.63	88.51	88.62	-1.91	-1.86	-1.74	-1.74	-1062.6	-1540.9	-1014.4	-1288.1
0.6900	88.52	88.64	88.52	88.64	-1.91	-1.87	-1.71	-1.71	-1107.6	-1515.0	-1069.2	-1394.4
0.7000	88.53	88.65	88.53	88.65	-1.91	-1.87	-1.71	-1.71	-1161.7	-1496.6	-1113.6	-1478.9
0.7100	88.55	88.66	88.55	88.66	-1.91	-1.87	-1.75	-1.75	-1221.4	-1490.4	-1154.4	-1549.9
0.7200	88.56	88.67	88.56	88.67	-1.90	-1.86	-1.80	-1.80	-1279.6	-1496.2	-1197.8	-1584.1
0.7300	88.57	88.68	88.57	88.67	-1.89	-1.86	-1.84	-1.84	-1332.5	-1509.4	-1245.4	-1580.8
0.7400	88.59	88.68	88.59	88.68	-1.88	-1.85	-1.85	-1.85	-1377.1	-1521.6	-1293.8	-1549.7
0.7500	88.60	88.69	88.60	88.68	-1.86	-1.84	-1.82	-1.82	-1413.2	-1526.9	[illegible]3.3	-1508.0
0.7600	88.61	88.69	88.61	88.69	-1.84	-1.83	-1.77	-1.77	-1444.3	-1521.5	[illegible]9.7	-1474.1
0.7700	88.63	88.69	88.63	88.69	-1.82	-1.81	-1.69	-1.69	-1473.8	-1507.1	[illegible]0.0	-1461.7
0.7800	88.36	88.69	88.63	88.69	-1.80	-1.79	-1.63	-1.63	-1546.7	-1488.3	[illegible]3.3	-1476.1
0.7900	88.36	88.69	88.64	88.69	-1.77	-1.76	-1.58	-1.58	-1562.4	-1470.4	[illegible]1.4	-1513.5
0.8000	88.35	88.22	88.64	88.68	-1.74	-1.74	-1.55	-1.55	-1576.2	-1515.6	[illegible]7.2	-1562.1
0.8100	88.33	88.20	88.63	88.66	-1.72	-1.71	-1.53	-1.53	-1594.4	-1494.4	[illegible]2.8	-1607.8
0.8200	88.31	87.55	88.63	88.65	-1.69	-1.68	-1.54	-1.54	-1619.3	-1559.7	[illegible]0.4	-1638.3
0.8300	88.27	87.90	88.61	88.61	-1.67	-1.78	-1.53	-1.53	-1650.0	-3334.0	[illegible]7.5	-1646.5
0.8400	88.29	90.43	88.54	88.51	-1.65	-2.77	-1.49	-1.49	-1677.1	-9160.1	[illegible]0.3	-1631.2
0.8510	87.53	89.62	88.51	88.49	-2.02	-2.68	-1.67	-1.67	-2508.5	-2834.0	-1640.9	-1594.7
0.8610	88.82	87.21	88.40	88.37	-3.13	-2.28	-2.01	-2.01	-9195.3	-14395.8	-1660.3	-1530.6
0.8710	90.11	89.25	88.11	88.02	-3.78	-3.32	-2.19	-2.19	-3899.8	-21219.3	-1685.0	-1436.1
0.8810	86.60	88.34	87.96	87.84	-3.24	-3.39	-2.30	-2.30	-11723.3	-21008.3	-1727.4	-1323.1
0.8910	88.19	88.12	87.24	87.59	-3.57	-3.52	-2.61	-2.53	-20962.9	-20099.4	-1841.0	-1204.6
0.9010	87.77	88.10	86.99	87.57	-3.06	-3.09	-2.52	-2.39	-19253.0	-12403.2	-1942.4	-1095.7
0.9110	87.56	87.09	87.00	87.38	-2.53	-2.73	-2.47	-2.46	-17016.4	-4670.1	-2074.1	-1094.2
0.9210	87.52	87.16	87.23	87.66	-2.04	-2.20	-2.40	-2.42	-9086.7	-3255.7	-2249.3	-1064.2
0.9330	87.50	87.40	87.56	87.93	-1.79	-1.73	-2.39	-2.44	-5630.4	-2769.8	-2447.0	-1083.8
0.9430	87.61	87.25	88.02	87.68	-1.47	-1.28	-2.86	-1.42	-2906.0	-1372.4	[illegible]3	-3219.6
0.9530	87.35	86.99	88.40	87.40	-0.82	-0.73	-5.22	-3.51	-2109.4	-208.7	[illegible]	-11200.5
0.9630	86.95	86.85	87.33	86.35	0.04	0.03	-3.10	-3.10	-1107.0	0.0	[illegible]	-2958.0
0.9730	86.75	86.83	85.72	85.97	0.62	0.57	1.41	1.41	-204.6	0.0	[illegible]	-1951.2
0.9830	86.44	86.69	86.16	86.54	1.15	1.14	0.32	0.32	0.0	0.0	[illegible]	-2098.0
0.9930	86.26	86.64	86.74	87.20	1.66	1.67	0.15	0.15	0.0	0.0	[illegible]	-9315.1
1.0030	86.52	86.99	84.88	85.33	1.93	1.94	0.02	0.02	0.0	0.0	[illegible]	-16331.8
1.0130	86.47	86.99	84.92	85.00	1.99	1.99	-0.66	-0.66	0.0	-279.3	[illegible]	-3036.5

FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLOP
2.60 SEC RUN DSN = SGS22

TIME SEC.	CIRCUMFERENTIAL TIRE FORCES (POUNDS) RF	LF	RR	LR	TIRE SIDE (POUND RF	LF		LR
0.5100	0.0	0.0	0.0	0.0	84.65	119.99		99.17
0.5200	0.0	0.0	0.0	0.0	96.95	130.99		130.58
0.5300	0.0	0.0	0.0	0.0	110.56	142.13		153.60
0.5400	0.0	0.0	0.0	0.0	123.47	152.73		164.23
0.5500	0.0	0.0	0.0	0.0	134.16	162.73	------	166.04
0.5600	0.0	0.0	0.0	0.0	141.45	171.55	129.77	166.32
0.5700	0.0	0.0	0.0	0.0	146.30	179.49	135.91	166.17
0.5800	0.0	0.0	0.0	0.0	150.07	186.08	136.75	167.40
0.5900	0.0	0.0	0.0	0.0	154.04	190.69	137.20	171.74
0.6000	0.0	0.0	0.0	0.0	159.14	193.66	140.33	180.55
0.6100	0.0	0.0	0.0	0.0	165.17	195.65	147.03	193.41
0.6200	0.0	0.0	0.0	0.0	171.13	197.02	157.15	207.62
0.6300	0.0	0.0	0.0	0.0	176.14	198.05	169.70	219.05
0.6400	0.0	0.0	0.0	0.0	179.69	198.90	182.43	224.45
0.6500	0.0	0.0	0.0	0.0	181.48	199.68	192.19	223.39
0.6600	0.0	0.0	0.0	0.0	181.63	200.44	196.65	217.99
0.6700	0.0	0.0	0.0	0.0	180.67	200.79	195.88	211.00
0.6800	0.0	0.0	0.0	0.0	178.71	200.25	192.29	204.39
0.6900	0.0	0.0	0.0	0.0	175.83	198.59	189.02	199.52
0.7000	0.0	0.0	0.0	0.0	172.01	195.88	188.36	197.29
0.7100	0.0	0.0	0.0	0.0	166.98	192.42	190.89	198.03
0.7200	0.0	0.0	0.0	0.0	160.89	188.45	195.53	200.98
0.7300	0.0	0.0	0.0	0.0	153.85	184.24	199.69	203.76
0.7400	0.0	0.0	0.0	0.0	145.58	179.62	202.22	205.20
0.7500	0.0	0.0	0.0	0.0	136.25	174.73	201.37	203.21
0.7600	0.0	0.0	0.0	0.0	126.60	169.51	196.75	197.56
0.7700	0.0	0.0	0.0	0.0	116.82	163.81	189.23	189.40
0.7800	0.0	0.0	0.0	0.0	151.43	157.42	181.00	180.97
0.7900	0.0	0.0	0.0	0.0	143.39	151.03	17	173.48
0.8000	0.0	0.0	0.0	0.0	136.02	200.65	16	167.59
0.8100	0.0	0.0	0.0	0.0	129.21	195.46	16	163.80
0.8200	0.0	0.0	0.0	0.0	122.19	23.79	16	162.03
0.8300	0.0	0.0	0.0	0.0	115.35	-10.85	16	160.59
0.8400	0.0	0.0	0.0	0.0	108.10	46.15	15	156.88
0.8510	0.0	0.0	0.0	0.0	-43.41	90.55	17	176.40
0.8610	0.0	0.0	0.0	0.0	-0.57	74.29	20	210.02
0.8710	0.0	0.0	0.0	0.0	1.19	133.08	22	225.75
0.8810	0.0	0.0	0.0	0.0	-5.34	153.17	231.80	229.61
0.8910	0.0	0.0	0.0	0.0	25.65	178.90	297.95	241.38
0.9010	0.0	0.0	0.0	0.0	19.47	175.54	281.42	215.79
0.9110	0.0	0.0	0.0	0.0	7.91	171.53	266.65	259.52
0.9210	0.0	0.0	0.0	0.0	-7.31	137.37	246.59	251.14
0.9300	0.0	0.0	0.0	0.0	-15.77	109.26	226.68	255.76
0.9430	0.0	0.0	0.0	0.0	-7.15	62.83	214.84	-20.56
0.9530	0.0	0.0	0.0	0.0	-70.37	-39.09	318.69	115.62
0.9630	0.0	0.0	0.0	0.0	-171.76	0.0	174.53	172.85
0.9730	0.0	0.0	0.0	0.0	-114.59	0.0	-34.97	-107.32
0.9830	0.0	0.0	0.0	0.0	0.0 *	0.0	-7	-22.59
0.9930	0.0	0.0	0.0	0.0	0.0 *	0.0	-1	-1.40
1.0030	0.0	0.0	0.0	0.0	0.0 *	0.0	-9	-9.51
1.0130	0.0	0.0	0.0	0.0	0.0 *	-185.80	42	30.41

FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLOPE
2.60 SEC RUN DSN = SGS22

ACCELERATION COMPONENTS AT POINTS 1 AND 2 ON SPRUNG MASS
(G-UNITS)

TIME SEC.	AX1	AY1	AZ1	AX2	AY2	
0.5100	0.047	-0.151	0.486	0.060	-0.109	02
0.5200	0.049	-0.138	0.519	0.061	-0.096	0.201
0.5300	0.049	-0.110	0.509	0.059	-0.074	0.193
0.5400	0.049	-0.076	0.497	0.055	-0.048	0.189
0.5500	0.048	-0.053	0.439	0.052	-0.031	0.171
0.5600	0.048	-0.038	0.423	0.051	-0.019	0.162
0.5700	0.048	-0.029	0.400	0.051	-0.012	0.150
0.5800	0.048	-0.026	0.370	0.051	-0.009	0.133
0.5900	0.048	-0.024	0.333	0.051	-0.007	0.112
0.6000	0.047	-0.021	0.290	0.050	-0.003	0.088
0.6100	0.046	-0.013	0.243	0.049	0.004	0.063
0.6200	0.046	-0.002	0.197	0.047	0.013	0.039
0.6300	0.045	0.011	0.152	0.045	0.024	0.016
0.6400	0.044	0.025	0.110	0.043	0.034	-0.005
0.6500	0.044	0.035	0.073	0.041	0.042	-0.024
0.6600	0.044	0.042	0.039	0.040	0.046	-0.040
0.6700	0.044	0.044	0.007	0.039	0.048	-0.055
0.6800	0.043	0.044	-0.025	0.039	0.047	-0.070
0.6900	0.043	0.042	-0.059	0.039	0.045	-0.085
0.7000	0.042	0.041	-0.095	0.039	0.044	-0.100
0.7100	0.042	0.043	-0.133	0.038	0.043	-0.118
0.7200	0.041	0.046	-0.173	0.036	0.044	-0.137
0.7300	0.040	0.051	-0.213	0.034	0.045	-0.157
0.7400	0.040	0.054	-0.251	0.033	0.046	-0.177
0.7500	0.039	0.056	-0.284	0.031	0.044	0.196
0.7600	0.039	0.054	-0.313	0.030	0.041	0.212
0.7700	0.038	0.050	-0.337	0.030	0.035	0.224
0.7800	0.013	0.037	-0.363	0.009	0.028	0.235
0.7900	0.012	0.031	-0.379	0.008	0.021	0.241
0.8000	-0.022	0.034	-0.401	-0.030	0.015	0.248
0.8100	-0.023	0.029	-0.413	-0.030	0.009	0.255
0.8200	-0.044	0.032	-0.430	-0.054	0.007	0.263
0.8300	-0.104	0.050	-0.463	-0.118	0.018	0.317
0.8400	-0.290	0.104	-0.581	-0.310	0.076	-0.682
0.8510	-0.146	-0.478	-1.489	-0.190	-0.311	-5.932
0.8610	-1.117	0.148	-1.138	-1.191	0.170	-2.731
0.8710	-1.022	0.044	-2.652	-1.304	0.018	-7.962
0.8810	-1.334	-0.535	-3.403	-1.651	-0.166	-11.681
0.8910	-1.510	0.247	-2.974	-1.976	0.439	-5.284
0.9010	-0.569	0.443	-3.419	-1.221	0.519	-4.642
0.9110	-0.038	0.026	-1.985	-0.705	0.173	-2.587
0.9210	0.423	0.344	-1.504	-0.305	0.243	-0.452
0.9300	0.461	0.162	-1.056	-0.201	0.096	-0.201
0.9430	0.288	-0.125	-3.242	-0.177	-0.072	49
0.9530	0.088	-0.427	-6.703	-0.065	-0.268	56
0.9630	-0.086	0.353	-8.450	-0.150	0.257	77
0.9730	-0.417	0.046	-4.141	-0.441	0.122	70
0.9830	-1.037	-0.124	-12.059	-0.810	0.025	53
0.9930	-0.149	-0.161	-2.289	-0.054	-0.050	05
1.0030	0.357	-0.066	-2.197	0.413	-0.018	52
1.0130	-0.465	-0.049	-9.452	-0.375	-0.033	46

FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLC
2.60 SEC RUN DSN = SGS22

HORIZONTAL TIRE FORCES (POUNDS)

TIME SEC.	X' DIRECTION RF	LF	RR	LR	Y' RF	LF		LR
0.5100	27.9	39.5	0.0	33.6	30.9	-44.3		-29.1
0.5200	31.9	43.1	0.0	44.2	33.3	-38.9		4.2
0.5300	36.4	46.8	12.7	52.0	37.6	-36.0		33.2
0.5400	40.6	50.2	29.7	55.5	44.2	-34.4		50.3
0.5500	44.1	53.5	38.6	56.0	52.3	-31.9		54.8
0.5600	46.5	56.4	43.8	56.1	59.9	-27.4	64.7	51.2
0.5700	48.2	59.1	45.8	56.0	65.8	-20.4	59.1	40.7
0.5800	49.5	61.3	46.1	56.4	69.1	-12.2	54.1	27.2
0.5900	50.8	62.9	46.2	57.9	69.7	-4.8	54.1	16.1
0.6000	52.6	64.0	47.3	60.8	68.3	0.2	59.4	12.2
0.6100	54.7	64.8	49.5	65.2	65.4	2.1	67.9	17.9
0.6200	56.7	65.3	52.9	69.9	61.9	1.1	77.0	31.3
0.6300	58.5	65.8	57.1	73.8	58.2	-1.8	84.4	47.0
0.6400	59.8	66.2	61.4	75.5	54.7	-4.9	88.2	59.1
0.6500	60.5	66.5	64.7	75.2	51.4	-6.9	86.6	63.5
0.6600	60.6	66.9	66.1	73.3	47.7	-6.8	79.3	59.6
0.6700	60.4	67.2	65.9	70.9	43.1	-4.9	67.9	48.5
0.6800	59.9	67.1	64.7	68.7	36.8	-2.5	55.7	33.0
0.6900	59.1	66.7	63.6	67.1	28.5	-0.9	45.7	16.3
0.7000	57.9	65.9	63.4	66.4	18.0	-1.2	39.6	2.4
0.7100	56.3	64.9	64.2	66.6	5.7	-3.8	36.9	-5.8
0.7200	54.4	63.7	65.8	67.6	-7.4	-8.3	35.8	-7.3
0.7300	52.1	62.5	67.2	68.6	-20.7	-14.0	33.8	-4.2
0.7400	49.5	61.0	68.0	69.0	-34.1	-20.0	30.2	1.0
0.7500	46.4	59.5	67.8	68.4	-47.6	-25.3	23.2	4.3
0.7600	43.2	57.9	66.2	66.5	-60.6	-29.6	13.0	3.2
0.7700	40.0	56.1	63.7	63.7	-73.6	-33.3	0.8	-3.0
0.7800	-74.0	54.0	60.9	60.9	-50.7	-37.0	-11.1	-12.8
0.7900	-80.6	51.9	58.4	58.4	-60.3	-40.9	[illegible]	-24.6
0.8000	-86.8	-96.2	56.5	56.4	-69.0	-0.5	[illegible]	-36.2
0.8100	-93.2	-98.0	55.3	55.2	-77.8	-2.8	[illegible]	-45.6
0.8200	-100.4	-186.5	54.8	54.6	-87.6	22.3	[illegible]	-51.0
0.8300	-108.2	-420.6	54.3	54.1	-98.0	-10.1	[illegible]	-53.4
0.8400	-115.8	-1128.6	52.9	52.9	-108.3	43.2	[illegible]	-55.1
0.8510	-329.4	-322.4	59.4	59.5	-40.5	84.9	[illegible]	-32.0
0.8610	-1149.6	-1773.4	70.7	71.0	-0.5	69.6	[illegible]	7.9
0.8710	-497.0	-2605.7	76.4	76.4	1.1	124.7	[illegible]	34.6
0.8810	-1467.4	-2572.3	78.7	78.0	-5.0	143.6	[illegible]	52.3
0.8910	-2611.0	-2449.7	-49.3	82.3	23.9	167.7	51.6	78.1
0.9010	-2399.5	-1488.8	-66.4	73.7	18.1	164.5	23.1	67.4
0.9110	-2124.2	-523.3	-86.1	-29.8	7.4	160.7	-7.5	108.5
0.9210	-1138.5	-358.1	-112.0	-31.3	-6.8	128.5	-48.4	104.4
0.9300	-709.5	-307.0	-140.1	-33.7	-14.7	102.1	-92.1	106.4
0.9430	-365.8	-148.8	-177.4	-409.7	-6.7	58.6	-141.4	-19.3
0.9530	-289.2	-40.3	-173.1	-1359.7	-65.6	-36.4	-79.6	108.5
0.9630	-200.9	0.0	-1601.5	-309.8	-160.2	0.0	163.9	162.3
0.9730	-67.3	0.0	-1204.1	-281.1	-106.8	0.0	-32.8	-100.8
0.9830	0.0	0.0	-355.7	-270.1	0.0	0.0	[illegible]	-21.2
0.9930	0.0	0.0	-1621.0	-1164.9	0.0	0.0		-1.3
1.0030	0.0	0.0	-1575.5	-2044.7	0.0	0.0		-8.9
1.0130	0.0	-102.3	-321.1	-369.1	0.0	-173.3		28.6

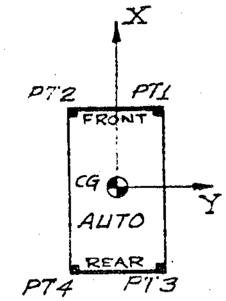
FIGURE 3-5. CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SLOPE
2.60 SEC RUN DSN = SGS22

TIME	STEERING TORQUES		TERRAIN SLOPES							
SEC.	T1PSI	T2PSI	PHIG1	PHIG2	PHIG3	PHIG4	H1		S 3	H4
	LB.-IN.	LB.-IN.	DEGREES	DEGREES	DEGREES	DEGREES	INCHES	IN	HES	INCHES
0.5100	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.7	[illegible]	[illegible]	13.1
0.5200	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.6	12.8	14.0	13.1
0.5300	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.8	14.0	13.2
0.5400	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.7	13.8	13.2
0.5500	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.7	13.7	13.3
0.5600	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.6	13.6	13.2
0.5700	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.6	13.5	13.2
0.5800	0.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.6	13.5	13.1
0.5900	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.5	12.7	13.5	12.9
0.6000	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.4	12.7	13.5	12.9
0.6100	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.4	12.7	13.5	12.8
0.6200	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.3	12.7	13.5	12.8
0.6300	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.2	12.6	13.5	12.8
0.6400	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.2	12.6	13.4	12.9
0.6500	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.1	12.6	13.3	12.9
0.6600	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.1	12.6	13.2	12.9
0.6700	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.1	12.6	13.2	12.9
0.6800	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.1	12.6	13.1	12.8
0.6900	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.0	12.6	13.0	12.8
0.7000	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	13.0	12.7	13.0	12.7
0.7100	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.9	12.7	13.0	12.6
0.7200	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.8	12.6	12.9	12.6
0.7300	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.8	12.6	12.9	12.6
0.7400	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.8	12.6	12.8	12.6
0.7500	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.7	12.6	12.8	12.6
0.7600	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.7	12.6	12.7	12.7
0.7700	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.7	12.6	12.7	12.7
0.7800	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.6	12.6	12.7	12.7
0.7900	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.6	12.7	12.6	12.6
0.8000	-600.0	0.0	-7.1	-7.1	-7.1	-7.1	12.6	12.6	12.6	12.6
0.8100	0.0	0.0	-7.1	-7.1	-7.1	-7.1	12.5	12.6	12.6	12.5
0.8200	0.0	0.0	-7.1	0.0	-7.1	-7.1	12.5	12.6	12.6	12.5
0.8300	0.0	0.0	-7.1	0.0	-7.1	-7.1	12.5	11.0	12.6	12.5
0.8400	0.0	0.0	-7.1	0.0	-7.1	-7.1	12.5	10.5	12.5	12.5
0.8510	0.0	0.0	0.0	0.0	-7.1	-7.1	11.7	11.4	12.5	12.6
0.8610	-600.0	0.0	0.0	0.0	-7.1	-7.1	10.5	10.0	12.5	12.6
0.8710	-600.0	0.0	0.0	0.0	-7.1	-7.1	10.9	9.4	12.5	12.7
0.8810	-600.0	0.0	0.0	0.0	-7.1	-7.1	10.2	9.4	12.4	12.8
0.8910	-600.0	0.0	0.0	0.0	-7.1	-7.1	9.4	9.5	12.3	12.9
0.9010	-600.0	0.0	0.0	0.0	-7.1	-7.1	9.5	10.2	12.2	13.0
0.9110	0.0	0.0	0.0	0.0	-7.1	-7.1	9.7	10.9	12.1	13.0
0.9210	0.0	0.0	0.0	0.0	-7.1	-7.1	10.5	11.0	12.0	13.0
0.9300	0.0	0.0	0.0	0.0	-7.1	-7.1	10.8	11.5	11.8	13.0
0.9430	0.0	0.0	0.0	0.0	-7.1	0.0	11.3	12.7	.5	11.0
0.9530	0.0	0.0	0.0	0.0	-7.1	0.0	12.1	13.8	.2	10.3
0.9630	0.0	0.0	0.0	0.0	0.0	0.0	13.0	14.0	.1	11.3
0.9730	0.0	0.0	0.0	0.0	0.0	0.0	13.8	14.0	.4	12.2
0.9830	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	.4	12.1
0.9930	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	.1	10.4
1.0030	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	.1	9.8
1.0130	0.0	0.0	0.0	0.0	0.0	0.0	14.0	13.7	.5	11.2

FIGURE 3-5 CONTINUED

PROG 140-2 3' FILL, YAW=20DEG, V=60MPH, 8 1 GRATE SLOPE, 8 1 SIDE SL
2.60 SEC RUN DSN = SGS22



WHEEL POSITIONS (INCHES)
(* INDICATES LOSS OF CONTACT)

TIME SEC.	RF WHEEL X'	RF WHEEL Y'	LF WHEEL X'	LF WHEEL Y'	RR WHEEL X'	RR WHEEL Y'	LR WHEEL X'	LR WHEEL Y'	CONTACT URFACE N.)		T3	PT4
0.5100	3051.83	870.29	3030.94	813.44	2939.85*	910.21*	2919.31	854.32			.0	0.0
0.5200	3061.74	866.61	3040.86	809.75	2949.76*	906.52*	2929.23	850.62			.0	0.0
0.5300	3071.65	862.93	3050.78	806.06	2959.67	902.83	2939.14	846.90			.0	0.0
0.5400	3081.56	859.23	3060.70	802.36	2969.58	899.14	2949.06	843.17	0.0	0.0	0.0	0.0
0.5500	3091.47	855.52	3070.62	798.65	2979.49	895.44	2958.97	839.44	0.0	0.0	0.0	0.0
0.5600	3101.38	851.81	3080.54	794.94	2989.40	891.73	2968.89	835.70	0.0	0.0	0.0	0.0
0.5700	3111.29	848.08	3090.47	791.21	2999.30	888.00	2978.81	831.97	0.0	0.0	0.0	0.0
0.5800	3121.21	844.36	3100.40	787.48	3009.20	884.25	2988.73	828.23	0.0	0.0	0.0	0.0
0.5900	3131.12	840.63	3110.32	783.75	3019.11	880.49	2998.64	824.49	0.0	0.0	0.0	0.0
0.6000	3141.04	836.90	3120.25	780.01	3029.01	876.72	3008.57	820.74	0.0	0.0	0.0	0.0
0.6100	3150.96	833.18	3130.19	776.28	3038.92	872.94	3018.49	816.98	0.0	0.0	0.0	0.0
0.6200	3160.88	829.45	3140.12	772.54	3048.82	869.17	3028.41	813.21	0.0	0.0	0.0	0.0
0.6300	3170.80	825.72	3150.06	768.81	3058.73	865.41	3038.33	809.43	0.0	0.0	0.0	0.0
0.6400	3180.72	821.99	3160.00	765.07	3068.64	861.64	3048.26	805.65	0.0	0.0	0.0	0.0
0.6500	3190.65	818.25	3169.94	761.34	3078.56	857.88	3058.19	801.88	0.0	0.0	0.0	0.0
0.6600	3200.57	814.52	3179.89	757.60	3088.47	854.13	3068.12	798.11	0.0	0.0	0.0	0.0
0.6700	3210.50	810.78	3189.83	753.86	3098.39	850.36	3078.05	794.34	0.0	0.0	0.0	0.0
0.6800	3220.43	807.05	3199.78	750.12	3108.31	846.60	3087.99	790.58	0.0	0.0	0.0	0.0
0.6900	3230.37	803.32	3209.73	746.38	3118.23	842.84	3097.93	786.82	0.0	0.0	0.0	0.0
0.7000	3240.30	799.60	3219.68	742.65	3128.15	839.08	3107.87	783.07	0.0	0.0	0.0	0.0
0.7100	3250.24	795.87	3229.63	738.92	3138.08	835.32	3117.81	779.31	0.0	0.0	0.0	0.0
0.7200	3260.18	792.15	3239.59	735.19	3148.01	831.56	3127.75	775.56	0.0	0.0	0.0	0.0
0.7300	3270.13	788.43	3249.54	731.46	3157.94	827.81	3137.70	771.80	0.0	0.0	0.0	0.0
0.7400	3280.07	784.71	3259.50	727.74	3167.88	824.07	3147.65	768.04	0.0	0.0	0.0	0.0
0.7500	3290.02	780.99	3269.46	724.01	3177.82	820.32	3157.60	764.29	0.0	0.0	0.0	0.0
0.7600	3299.97	777.27	3279.42	720.29	3187.76	816.59	3167.55	760.54	0.0	0.0	0.0	0.0
0.7700	3309.93	773.56	3289.38	716.57	3197.71	812.85	3177.50	756.80	0 ^	^ ^	0.0	0.0
0.7800	3319.88	769.84	3299.35	712.84	3207.66	809.12	3187.46	753.06	0		0.0	0.0
0.7900	3329.84	766.13	3309.31	709.12	3217.61	805.39	3197.42	749.33	0		0.0	0.0
0.8000	3339.80	762.41	3319.27	705.40	3227.56	801.66	3207.37	745.60	0		0.0	0.0
0.8100	3349.75	758.70	3329.23	701.69	3237.51	797.94	3217.33	741.88	0		0.0	0.0
0.8200	3359.71	754.99	3339.19	697.97	3247.47	794.22	3227.29	738.16	0		0.0	0.0
0.8300	3369.67	751.28	3349.15	694.24	3257.42	790.51	3237.24	734.44	0		0.0	0.0
0.8400	3379.62	747.58	3359.10	690.40	3267.37	786.80	3247.19	730.73	0		0.0	0.0
0.8510	3390.56	743.49	3370.05	686.01	3278.31	782.72	3258.13	726.64	0		0.0	0.0
0.8610	3400.49	739.71	3379.98	682.27	3288.24	778.99	3268.05	722.89	0	---	0.0	0.0
0.8710	3410.40	735.77	3389.88	678.46	3298.14	775.25	3277.94	719.13	0.0	3.1	0.0	0.0
0.8810	3420.27	731.95	3399.72	674.61	3308.01	771.51	3287.79	715.35	1.2	3.2	0.0	0.0
0.8910	3430.08	728.16	3409.49	670.80	3317.85	767.78	3297.60	711.56	2.0	2.5	0.0	0.0
0.9010	3439.83	724.36	3419.20	666.99	3327.66	764.08	3307.40	707.77	2.0	1.0	0.0	0.0
0.9110	3449.55	720.59	3428.85	663.23	3337.46	760.40	3317.22	704.01	1.2	0.0	0.0	0.0
0.9210	3459.22	716.84	3438.50	659.47	3347.28	756.74	3327.09	700.27	0.0	0.0	0.0	0.0
0.9300	3467.94	713.46	3447.19	656.10	3356.16	753.46	3336.01	696.94	0.0	0.0	0.0	0.0
0.9430	3480.54	708.59	3459.67	651.26	3369.06	748.71	3348.96	692.15	0.0	0.0	0.9	0.0
0.9530	3490.19	704.86	3469.24	647.57	3379.04	745.06	3358.86	688.54	0.0	0.0	2.2	0.0
0.9630	3499.79	701.18	3478.84*	643.90*	3389.05	741.45	3368.49	685.09	0.0	0.0	2.9	0.0
0.9730	3509.38	697.56	3488.48*	640.26*	3398.70	737.91	3378.02	681.59	0.(		.0	0.0
0.9830	3518.99*	693.96*	3498.16*	636.65*	3408.15	734.34	3387.65	677.98	0.(		.5	0.0
0.9930	3528.62*	690.41*	3507.88*	633.09*	3417.98	730.70	3397.56	674.33	0.(		.2	0.0
[illegible].0030	3538.39*	686.89*	3517.66*	629.56*	3427.56	727.11	3407.28	670.71	0.(		.0	0.0
[illegible].0130	3548.01*	683.40*	3527.49	626.04	3436.84	723.57	3416.57	667.17	0.(		.0	0.0

FIGURE 3-5. CONTINUED

3.2 Highway Curb and Surrounding Terrain

This example problem investigates the dynamic behavior of a 1963 Ford Galaxie (4-door sedan) as it leaves the highway (at a speed of 60 mph at 15 degrees) and strikes an 8" curb as shown in Figure 3-6.

The necessary primary input data (described in Chapter II, Section 2.1) for this example problem is shown in Figure 3-6.

The primary input data as printed out by TTI's version of HVOSM is shown in Figures 3-8 and 3-9. Figure 3-8 shows the card images of the necessary primary input data while Figures 3-9 shows the same data in a more convenient form. The printed output for the time period between 0.0 seconds and 0.1 seconds is given in Figure 3-10.

Assuming no output plotting is required, then, the necessary plotting data (described in Chapter II, Section 2.2) for this example is:

Column Number	Information
1-4	None

The necessary termination data is:

Column Number	Information
1-4	None

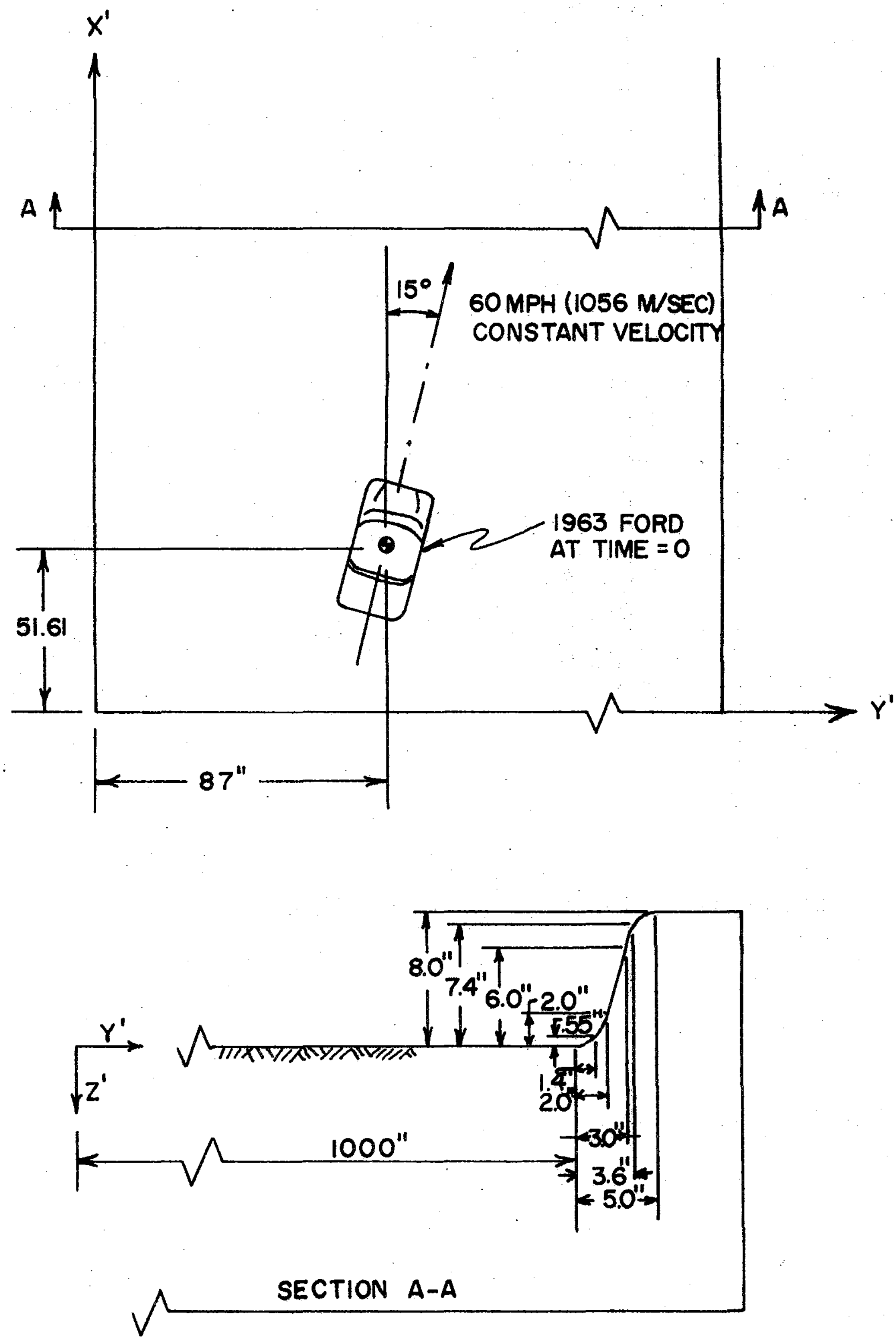


FIGURE 3-6 ROADWAY CURB EXAMPLE PROBLEM

```
THD SPECIAL MEDIAN STUDY-DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28, 1974
0.0     1.0     0.005   0.0     0.002   70.0    0.0     0.0     1.0            1
8.4402  0.5507  0.8952  386.4   6200.0  34400.0 36000.0 -192.0  600.0          3
100.0   0.5     3.0     3.5     30.0    0.001   98500.0                        5
105.0   0.5     4.0     3.9     45.0    0.001   32500.0                        6
0.0     0.0     15.0    0.0     0.0     0.0     0.0     0.0                    8
87.0    51.61           1056.0                                                 9
2.0     2.0     0.0                                                           14
   1 0.0     0.0      0.0     8.333  0.0
   2 500.0   0.0      0.0     8.333  0.0
6.0     0.8     0.002                                                         15
100.0     101.4     102.0     103.0     103.6     105.0
-0.55     -2.0      -6.0      -7.4      -8.0
-21.5     -67.5     -76.0     -66.8     -23.2     0.0
0.0     8.0     0.25                                                          16
300.0   2.0     -3.0  300.0   2.0     5.0
300.0   2.0     -4.0  300.0   2.0     4.5
```

FIG 3-7 PRIMARY INPUT DATA FOR EXAMPLE 3.2

```
THD SPECIAL MEDIAN STUDY - DISTRICT 2, 9 INCH CURB
V = 60 MPH, ANGLE = 15 DEG.,  DSN = M2F6015, MAY 28,1974

INPUT PRESET IN SUBROUTINE STD

          1                                                                                                      2
     10.813       0.608       0.945     386.400    6000.000   30000.000   36000.000   -192.000                   3
     54.517      64.483      61.000      60.000      10.138      12.088      -2.000     14.000    4400.000       4
    131.000       0.500       3.000       3.500      55.000       0.001  266000.000                              5
    192.000       0.500       4.000       3.900      50.000       0.001   61900.000     46.500       0.070       6
   1098.000       3.000      10.000       8.276    2900.000       1.780       0.800      1.000    3900.000       7
      0.0         0.0         0.0         0.0         0.0         0.0         0.0        0.0                    10
    -34.480       0.0         4.000      -5.983     -16.500       3.138                                         11
     -5.000       5.000       1.000                                                                             12

PHIC(I),I=1,11
  -3.550  -2.550  -1.800  -1.300  -0.950  -0.550  -0.300  -0.300  -0.400  -0.550  -0.800
    492.000     600.000       0.400    5000.000       0.075       1.500                                         17
          4    4000.000       0.001       0.250                                                                 23
XVP(I),YVP(I),ZVP(I),I=1,4
     81.517      39.500      12.138
     81.517     -39.500      12.138
   -117.483      39.000       8.138
   -117.483     -39.000       8.138

    300.000       2.000      -3.000     300.000       2.000       3.000                                         26
    300.000       2.000      -4.000     300.000       2.000       4.000                                         27

INPUT READ BY CALSVA

0.0     1.0     0.005   0.0     0.002   70.0    0.0     0.0     1.0           1
8.4402  0.5507  0.8952  386.4   6200.0  34400.0 36000.  -192.0  600.0         3
100.0   0.50    3.0     3.5     30.0    0.001   98500.                        5
105.0   0.5     4.0     3.9     45.0    0.001   32500.  46.5    0.070         6
  0.0     0.0      15.0   0.0     0.0     0.0     0.0     0.0                 8
87.0    51.61           1056.                                                 9
2.0     2.0     0.0                                                          14
XGP(I,J),YGP(I,J),ZGP(I,J),I=1, 2 J=1, 2
    0.0         0.0         0.0         8.333       0.0
  500.000       0.0         0.0         8.333       0.0
6.0     0.9     0.002                                                        15
100.0     101.4     102.0     103.0     103.6     105.0
-0.55     -2.0      -6.0      -7.4      -8.0
-21.5     -67.5     -76.0     -66.8     -23.2     0.0
0.0     8.0     0.25                                                         16

                      WHEEL

300.0   2.00    -3.00   300.0   2.00    5.00                                 26
300.0   2.00    -4.00   300.0   2.00    4.50                                 27
                                                                           9999
```

FIGURE 3-8. PRIMARY INPUT DATA REPRODUCED AS CARD IMAGE

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28,1974

INERTIAL DATA

MS = 8.4402 LB.-SEC.**2/IN
MUF = 0.5537 ''
MUR = 0.8952 ''
IX = 6200.0 LB.-SEC.**2-IN
IY = 34400.0 ''
IZ = 36000.0 ''
IXZ =-192.000 ''
IR = 600.00 ''
G = 386.400 IN/SEC.**2

DIMENSIONS

A = 54.5170 INCHES
B = 64.4830 ''
TF = 61.0000 ''
TR = 60.0000 ''
ZF = 10.1380 ''
ZR = 12.0880 ''
RHO = -2.0000 ''
RW = 14.0000 ''

SUSPENSION

KF = 100.000 LB./IN.
KR = 105.000 LB./IN.
CF' = 30.000 LBS.
CR' = 45.000 LBS.
EPSILONF= 0.001 IN./SEC.
EPSILONR= 0.001 IN./SEC.
CF = 3.500 LB-SEC/IN
CR = 3.900 LB-SEC/IN

AKFC = 300.000 LB/IN
AKFCP = 2.000 LB/IN3
OMEGFC= -3.000 IN
AKFE = 300.000 LB/IN
AKFEP = 2.000 LB/IN3
OMEGFE= 5.000 IN

LAMBDAF
LAMBDAR
OMEGAF [illegible]ES
OMEGAR = 4.000 INCHES
TS = 46.500 INCHES
RR = 32500.0 LB-IN/RAD
RF = 98500.0 LB-IN/RAD
KRS = 0.070 ROLL STEER COEFF.

AKRC = 300.000 LB/IN
AKRCP = 2.000 LB/IN3
OMEGRC = -4.000 IN
AKRE = 300.000 LB/IN
AKREP = 2.000 LB/IN3
OMEGRE = 4.500 IN

INITIAL CONDITIONS

PHIO = 0.0 DEGREES
THETAO= 0.0 ''
PSIO = 15.000 ''
PHIRO = 0.0 ''
PSIFIO= 0.0 ''

XCO' = 87.000INCHES
YCO' = 51.610 ''
ZCO' = -24.138 ''
DELTA1= 0.0 ''
DELTA2= 0.0 ''
DELTA3= 0.0 ''

PO = 0.0 DEG/SEC
QO = 0.0 ''
RO = 0.0 ''
D(PHIR)/DT= 0.0 ''
D(PSIF)/DT= 0.0 RAD/SC

UO =1056.000 IN/SEC
VO = 0.0 ''
WO = 0.0 ''
D(DEL1)/DT= 0.0 ''
D(DEL2)/DT= 0.0 ''
D(DEL3)/DT= 0.0 ''

ACCELEROMETER POSITIONS

X1 = -34.480 INCHES
Y1 = 0.0 ''
Z1 = 4.000 ''
X2 = -5.983 ''
Y2 = -16.500 ''
Z2 = 3.138 ''

DRIVER CONTROL TABLES

T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT	T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT	T SEC	PSIF DEG	TQF LB/FT	TQR LB/FT	T SEC	P	TQF LB/FT	TQR LB/FT
0.0	0.0	0.0	0.0												

TIRE DATA

KT 1098.000 LB/IN
SIGMAT = 3.000
LAMBDAT = 10.000
A0 =4400.000
A1 = 8.276
A2 =2900.000
A3 = 1.780
A4 =3900.000
AMU = 0.800
OMEGT = 1.000

TERRAIN TABLE ARGUMENTS

SOIL DAMPING= 0.001 SPI
SOIL FRICT. = 0.250
SSTIFF = 4000. LB/IN
NO.X TEMPS. = 2
NO.Y TEMPS. = 2
NO. VAR AMU = 0
TABLES

PROGRAM CONTROL DATA

START TIME = 0.0 SEC
END TIME = 1.000
INCR FOR INTEGRATION = 0.0050 ''
PRINT INTERVAL = 0.002 ''
THETA MAX (TO SWITCH)= 70.000 DEG
UVWMIN(STOP) = 0.0
PQRMIN(STOP) = 0.0
INDCRB = 1 (=0.NO CURB,=1 CURB,=-1 STEER DEG.OF FREEDOM)
MODE OF INTEGRATION = 1 (=0 VAR.ADAMS-MOULT.,=1 RUNGE-KUTTA,=2FIX.AM)
DTCMP1 = 0. (=1.0 SUPPLY INITIAL POSITION)
(=0.0 CAR RESTS ON TER

COEFF. OF TIRE FRICTION
VS.
(SPEED AND LOAD) DATA
ALPHA= 0.0 1/(LB-MPH)

FIGURE 3-9. PRIMARY INPUT DATA REPRODUCED IN MORE CONVENIENT FORM

```
XKVTH= 0.0          1/ MPH
XKL=   0.0          1/LB
```

VEHICLE MONITOR POINTS

	X (IN.)	Y (IN.)	Z (IN.)
POINT 1	81.517	39.500	12.138
POINT 2	81.517	-39.500	12.138
POINT 3	-117.483	39.000	8.138
POINT 4	-117.483	-39.000	8.138

FIGURE 3-9. CONTINUED

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THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG.,  DSN = M2F6015, MAY 28,1974

     FRONT WHEEL CAMBER
             VS
    SUSPENSION DEFLECTION

      DELTAF    PHIC
      INCHES    DEGREES

      -5.000     -3.550

     CURB IMPACT DATA                                                        SPRUNG MASS-BARRIER IMPACT DATA
                                       BARRIER DIMENSIONS                                                  BARRIER LOAD DEFLECT.
YC1'            = 100.000 INCHES      (YB')O =    0.0    INCHES     KV         =    0.0   LB/IN**3      SIGMAR 0 =     0.0
YC2'            = 101.400   ''        DELYB' =    0.0      ''       SET        =    0.0   DEFL.RATIO    SIGMAR 1 =     0.0
ZC2'            =  -0.550   ''        ZBT'   =    0.0      ''       CONS       =    0.0   ENERGY RATIO  SIGMAR 2 =     0.0
DELTC           =   0.0020 SEC(INTEG.INCR.)  ZBB'   =    0.0  ''   MUB        =    0.0                 SIGMAR 3 =     0.0
PHIC1           = -21.500 DEGREES      VEHICLE DIMENSIONS           EPSILON V=      0.0   IN/SEC        SIGMAR 4 =     0.0
PHIC2           = -67.500   ''        XVF    =    0.0    INCHES     EPSILON B=      0.0   LB            SIGMAR 5 =     0.0
MUC             =   0.800             XVR    =    0.0      ''       DELTB      =    0.0    SEC          SIGMAR 6 =     0.0
                                      YV     =    0.0      ''                             (INTEG.INCR)  SIGMAR 7 =     0.0
IPSI            = 492.000 LB-SEC**2-IN  ZVT  =    0.0      ''                                           SIGMAR 8 =     0.0
CPSI'           = 600.000 LB-IN       ZVB    =    0.0      ''                                           SIGMAR 9 =     0.0
OMEGA PSI       =   0.400 RAD         INDB =  0 (=1 RIGID BARRIER, FINITE VERT. DIM.)                   SIGMAR10 =     0.0
KPSI            =5000.000 LB-IN/RAD             =2  ''      ''  INFINITE  ''    ''  )
EPSILON PSI     =   0.075 RAD/SEC               =3 DEFORM.BARRIER,FINITE  ''    ''  )
TRAIL.FRONT(PT)=   1.500 INCHES                 =4  ''      ''  INFINITE  ''    ''  )
                                                          STRUCTURAL HARDPOINTS RELATIVE TO C. C
                                                                         X         Y         Z   STIFF
                                                                               (INCHES)           LB/
                                                          POINT   1     0.0       0.0       0.0
                                                          POINT   2     0.0       0.0       0.0
                                                          POINT   3     0.0       0.0       0.0
```

FIGURE 3-9. CONTINUED

```
***** CURB IMPACT DATA *****

VEHICLE-CURB FRICTION COEFFICIENT (AMUC) = 0.800

FIXED SPACE Y-COORDINATES (INCHES)

   YC1P       YC2P       YC3P       YC4P       YC5P       YC6P

 100.000    101.400    102.000    103.000    103.600    105.000

FIXED SPACE Z-COORDINATES (INCHES)

              ZC2P       ZC3P       ZC4P       ZC5P       ZC6P

             -0.550     -2.000     -6.000     -7.400     -8.000

FIXED SPACE PHI-COORDINATES (DEGREES)

   PHIC1      PHIC2      PHIC3      PHIC4      PHIC5      PHIC6

 -21.500    -67.500    -76.000    -66.800    -23.200      0.0


WHEEL RADIUS-RADIAL SPRING FOR TABLE
RWHJB(BEGIN)   =   0.0    INCHES
RWHJE(END)     =   8.000    "
DRWHJ(INCRE.)  =   0.250    "


ANTI-PITCH TABLES FOR CIRCUMFERENTIAL TIRE FORCE
APF=     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
APR=     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
```

FIGURE 3-9. CONTINUED

PAGE 1

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2F6015, MAY 28,1974

TIME SEC.	STEERING INPUT DEG.	TORQUE INPUTS POUND-FEET FRONT	REAR	SPRUNG MASS CG ACCEL. G-UNITS LONG.	LAT.	VERT.	ANGULAR VELOC DEG./SEC. ROLL	PITCH	YAW	FORWARD SPEED FT./SEC.
0.0	0.0	0.0	0.0	-0.000	0.0	0.000	0.0	0.0	0.0	88.00
0.0050	0.0	0.0	0.0	-0.000	0.000	0.109	-0.00	-0.01	0.00	88.00
0.0070	-0.00	0.0	0.0	-0.000	0.000	0.134	0.00	-0.00	0.00	88.00
0.0090	-0.00	0.0	0.0	0.000	0.000	0.159	0.00	-0.00	0.00	88.00
0.0110	-0.00	0.0	0.0	0.000	0.000	0.183	0.00	-0.00	0.00	88.00
0.0130	-0.00	0.0	0.0	0.000	-0.000	0.205	0.00	-0.01	0.00	88.00
0.0150	-0.00	0.0	0.0	-0.001	-0.000	0.226	0.00	-0.01	0.00	88.00
0.0170	-0.00	0.0	0.0	-0.030	0.014	0.243	-0.00	-0.01	0.00	88.00
0.0190	-0.00	0.0	0.0	-0.295	-0.819	0.253	0.58	-0.06	-0.22	87.99
0.0210	-0.01	0.0	0.0	-0.591	-2.588	0.252	2.55	-0.14	-1.14	87.96
0.0230	-0.05	0.0	0.0	-2.264	-10.557	0.188	10.03	-0.45	-4.97	87.86
0.0250	-0.15	0.0	0.0	-3.049	-11.487	0.077	20.55	-0.94	-10.37	87.69
0.0270	-0.33	0.0	0.0	-3.132	-13.992	-0.086	33.39	-1.43	-17.27	87.49
0.0290	-0.57	0.0	0.0	-2.541	-2.961	-0.281	45.11	-1.75	-24.00	87.31
0.0310	-0.83	0.0	0.0	-1.678	-2.688	-0.483	46.44	-1.79	-25.17	87.17
0.0330	-1.09	0.0	0.0	-0.729	-1.969	-0.692	46.68	-1.48	-26.31	87.10
0.0350	-1.35	0.0	0.0	-0.173	-0.847	-2.215	44.76	-0.67	-27.14	87.08
0.0370	-1.61	0.0	0.0	-0.174	-0.436	-8.308	35.06	2.34	-27.40	87.07
0.0390	-1.87	0.0	0.0	-0.320	-1.039	-17.104	10.83	10.09	-27.86	87.06
0.0410	-2.13	0.0	0.0	-0.196	-0.623	-9.222	-21.38	20.54	-28.45	87.04
0.0430	-2.39	0.0	0.0	-0.165	-0.538	-6.395	-36.61	25.48	-28.71	87.03
0.0450	-2.65	0.0	0.0	-0.116	-0.398	-2.986	-45.76	28.49	-28.86	87.03
0.0470	-2.91	0.0	0.0	-0.075	-0.282	-0.638	-49.48	29.75		87.03
0.0490	-3.17	0.0	0.0	-0.049	-0.224	0.396	-50.12	30.02		87.03
0.0510	-3.43	0.0	0.0	-0.026	-0.218	0.588	-49.67	29.96		87.03
0.0530	-3.68	0.0	0.0	-0.004	-0.217	0.459	-49.09	29.87		87.04
0.0550	-3.94	0.0	0.0	0.016	-0.216	0.295	-48.69	29.86		87.04
0.0570	-4.20	0.0	0.0	0.028	-0.217	0.098	-48.57	29.94		87.05
0.0590	-4.45	0.0	0.0	0.030	-0.220	-0.086	-48.75	30.14		87.06
0.0610	-4.71	0.0	0.0	0.021	-0.234	-0.211	-49.13	30.41		87.06
0.0630	-4.96	0.0	0.0	0.001	-0.258	-0.301	-49.66	30.74		87.07
0.0650	-5.22	0.0	0.0	-0.010	-0.321	-0.474	-50.38	31.12		87.07
0.0670	-5.47	0.0	0.0	-0.026	-0.393	-0.922	-51.54	31.67	-28.90	87.07
0.0690	-5.72	0.0	0.0	-0.045	-0.423	-1.739	-53.83	32.58	-28.97	87.08
0.0710	-5.97	0.0	0.0	-0.063	-0.408	-2.754	-57.93	34.05	-29.02	87.08
0.0730	-6.22	0.0	0.0	-0.083	-0.443	-3.555	-63.87	36.07	-29.06	87.08
0.0750	-6.47	0.0	0.0	-0.057	-0.329	-1.831	-70.14	38.20	-29.09	87.07
0.0770	-6.72	0.0	0.0	-0.058	-0.312	-1.590	-73.47	39.35	-29.04	87.08
0.0790	-6.97	0.0	0.0	-0.054	-0.283	-1.193	-76.22	40.30	-28.96	87.08
0.0810	-7.22	0.0	0.0	-0.049	-0.250	-0.750	-78.21	41.00	-28.86	87.08
0.0830	-7.47	0.0	0.0	-0.044	-0.227	-0.353	-79.44	41.44	-28.73	87.08
0.0850	-7.72	0.0	0.0	-0.041	-0.212	-0.055	-80.04	41.66	-28.69	87.08
0.0870	-7.97	0.0	0.0	-0.040	-0.202	0.133	-80.20	41.74	-	87.08
0.0890	-8.21	0.0	0.0	-0.041	-0.197	0.233	-80.09	41.72	-	87.08
0.0910	-8.46	0.0	0.0	-0.042	-0.196	0.285	-79.86	41.66	-	87.08
0.0930	-8.71	0.0	0.0	-0.046	-0.218	0.307	-79.55	41.58	-	87.09
0.0950	-8.96	0.0	0.0	-0.052	-0.257	0.327	-79.16	41.48	-	87.09
0.0970	-9.20	0.0	0.0	-0.059	-0.295	0.345	-78.69	41.36	-	87.09
0.0990	-9.45	0.0	0.0	-0.066	-0.331	0.362	-78.13	41.23	-	87.08
0.1010	-9.69	0.0	0.0	-0.073	-0.364	0.377	-77.50	41.08	-	87.08
0.1030	-9.94	0.0	0.0	-0.079	-0.392	0.391	-76.81	40.93	-	87.07

FIGURE 3-10. PROGRAM OUTPUT

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28,1974

TIME				SPRUNG MASS CG					TERR		AT GCP	
SEC.	POSITION (INCHES)			ORIENTATION (DEGREES)			VELOCITY (FT /SEC.)					
	X'	Y'	Z'	PHI	THETA	PSI	LAT.	VERT.	RF			LR
0.0	87.00	51.61	-24.14	0.0	0.0	15.00	0.0	0.0	0.0		0	0.0
0.0050	92.10	52.98	-24.14	0.00	-0.00	15.00	0.00	0.01	0.02		0	0.0
0.0070	94.14	53.52	-24.14	-0.00	-0.00	15.00	0.00	0.02	0.02		0	0.0
0.0090	96.18	54.07	-24.14	0.00	-0.00	15.00	0.00	0.03	0.02	0.0	0.0	0.0
0.0110	98.22	54.62	-24.14	0.00	-0.00	15.00	0.00	0.04	-0.01	0.0	0.0	0.0
0.0130	100.26	55.16	-24.14	0.00	-0.00	15.00	0.00	0.05	-0.02	0.0	0.0	0.0
0.0150	102.30	55.71	-24.13	0.00	-0.00	15.00	0.00	0.06	-0.06	0.0	0.0	0.0
0.0170	104.34	56.26	-24.13	0.00	-0.00	15.00	0.00	0.08	-0.42	0.0	0.0	0.0
0.0190	106.38	56.80	-24.13	0.00	-0.00	15.00	-0.03	0.10	-3.05	0.0	0.0	0.0
0.0210	108.42	57.35	-24.13	0.00	-0.00	15.00	-0.13	0.11	-4.26	0.0	0.0	0.0
0.0230	110.46	57.89	-24.12	0.01	-0.00	14.99	-0.56	0.13	-5.26	0.0	0.0	0.0
0.0250	112.50	58.41	-24.12	0.04	-0.00	14.98	-1.18	0.13	-5.62	0.0	0.0	0.0
0.0270	114.54	58.92	-24.12	0.10	-0.00	14.95	-1.95	0.13	-6.03	0.0	0.0	0.0
0.0290	116.58	59.40	-24.12	0.18	-0.01	14.91	-2.69	0.12	-6.49	0.0	0.0	0.0
0.0310	118.62	59.88	-24.11	0.27	-0.01	14.86	-2.80	0.09	-7.02	0.0	0.0	0.0
0.0330	120.66	60.35	-24.11	0.36	-0.01	14.81	-2.87	0.05	-7.50	0.0	0.0	0.0
0.0350	122.70	60.81	-24.11	0.46	-0.02	14.75	-2.89	-0.02	-7.88	0.0	0.0	0.0
0.0370	124.74	61.28	-24.11	0.54	-0.01	14.70	-2.83	-0.33	-7.90	0.0	0.0	0.0
0.0390	126.78	61.74	-24.13	0.59	-0.00	14.64	-2.79	-1.13	-8.00	0.0	0.0	0.0
0.0410	128.82	62.20	-24.17	0.57	0.03	14.59	-2.78	-2.20	-8.00	0.0	0.0	0.0
0.0430	130.85	62.67	-24.23	0.51	0.08	14.53	-2.73	-2.64	-8.00	0.0	0.0	0.0
0.0450	132.89	63.13	-24.30	0.43	0.13	14.47	-2.66	-2.86	-8.00	0.0	0.0	0.0
0.0470	134.93	63.59	-24.38	0.33	0.19	14.42	-2.59	-2.89	-8.00	0.0	0.0	0.0
0.0490	136.97	64.05	-24.46	0.23	0.25	14.36	-2.51	-2.80	-8.00	0.0	0.0	0.0
0.0510	139.01	64.51	-24.53	0.13	0.31	14.30	-2.44	-2.68	-8.00	0.0	0.0	0.0
0.0530	141.04	64.97	-24.61	0.04	0.37	14.24	-2.36	-2.56	-8.00	0.0	0.0	0.0
0.0550	143.08	65.43	-24.68	-0.06	0.43	14.19	-2.28	-2.45	-8.00	0.0	0.0	0.0
0.0570	145.12	65.88	-24.76	-0.16	0.49	14.13	-2.20	-2.35	-8.00	0.	0.0	0.0
0.0590	147.16	66.34	-24.83	-0.26	0.55	14.07	-2.12	-2.26	-8.00	0.	0.0	0.0
0.0610	149.20	66.80	-24.91	-0.36	0.61	14.01	-2.05	-2.18	-8.00	0.	0.0	0.0
0.0630	151.24	67.26	-24.98	-0.46	0.67	13.95	-1.97	-2.11	-8.00	0.	0.0	0.0
0.0650	153.28	67.72	-25.05	-0.56	0.73	13.90	-1.90	-2.04	-8.00	0.	0.0	0.0
0.0670	155.31	68.17	-25.13	-0.66	0.79	13.84	-1.83	-1.99	-8.00	0.	0.0	0.0
0.0690	157.35	68.63	-25.21	-0.77	0.86	13.78	-1.77	-1.98	-8.00	0.	0.0	0.0
0.0710	159.39	69.08	-25.29	-0.88	0.92	13.72	-1.70	-2.03	-8.00	0.	0.0	0.0
0.0730	161.43	69.54	-25.37	-1.00	0.99	13.66	-1.64	-2.13	-8.00	0.	0.0	0.0
0.0750	163.47	69.99	-25.46	-1.14	1.07	13.60	-1.57	-2.24	-8.00	0.	0.0	0.0
0.0770	165.51	70.45	-25.55	-1.28	1.14	13.54	-1.50	-2.24	-8.00	0.0	0.0	0.0
0.0790	167.55	70.90	-25.65	-1.43	1.22	13.48	-1.42	-2.21	-8.00	0.0	0.0	0.0
0.0810	169.59	71.35	-25.75	-1.59	1.30	13.42	-1.35	-2.15	-8.00	0.0	0.0	0.0
0.0830	171.63	71.80	-25.85	-1.75	1.38	13.36	-1.27	-2.07	-8.00	0.0	-0.00	0.0
0.0850	173.67	72.25	-25.95	-1.91	1.46	13.30	-1.19	-1.96	-8.00	0.0	-0.01	0.0
0.0870	175.70	72.70	-26.04	-2.07	1.54	13.24	-1.11	-1.83	-8.00	0.0	-0.02	0.0
0.0890	177.74	73.15	-26.14	-2.23	1.62	13.18	-1.03	-1.69	-8.00	0.0	-0.01	0.0
0.0910	179.78	73.61	-26.24	-2.39	1.71	13.12	-0.96	-1.55	-8.00	0.0	0.00	0.0
0.0930	181.82	74.06	-26.34	-2.55	1.79	13.06	-0.88	-1.41	-8.00	0.0	-0.02	0.0
0.0950	183.86	74.50	-26.44	-2.72	1.87	13.00	-0.81	-1.27	-8.00	0.0	-0.03	0.0
0.0970	185.90	74.95	-26.54	-2.88	1.95	12.94	-0.74	-1.12	-8.00	0.0	04	0.0
0.0990	187.94	75.40	-26.63	-3.03	2.03	12.88	-0.67	-0.97	-8.00	0.0	04	0.0
0.1010	189.98	75.85	-26.73	-3.19	2.11	12.82	-0.60	-0.83	-8.00	0.0	04	0.0
0.1030	192.02	76.30	-26.82	-3.35	2.18	12.76	-0.54	-0.68	-8.00	0.0	04	0.0

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2F6015, MAY 28,1974

TIME SEC.	DEFLECTIONS (IN. AND DEG.) DELTA 1	DELTA 2	DELTA 3	UNSPRUNG MASSES PHI R	VELOCITIES (IN./SEC. , DEG./SEC.) D(DEL1)/DT	D(DEL2)/DT	D(DEL3)/DT	D(PHIR)/DT	PHI 1	WHEEL (DEG.) PHI 2
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.55	0.55
0.0050	0.04	0.04	0.02	0.00	16.55	16.55	9.69	0.00	-0.54	0.54
0.0070	0.09	0.08	0.05	0.00	22.56	22.41	13.29	-0.00	-0.52	0.52
0.0090	0.13	0.13	0.08	-0.00	28.01	27.71	16.73	-0.00	-0.51	0.51
0.0110	0.19	0.19	0.11	-0.00	32.72	32.37	19.91	-0.00	-0.49	0.49
0.0130	0.26	0.26	0.16	-0.00	36.54	36.34	22.80	-0.00	-0.47	0.47
0.0150	0.34	0.34	0.21	-0.00	39.53	39.56	25.39	-0.00	-0.45	0.45
0.0170	0.42	0.42	0.26	-0.00	40.87	41.98	27.63	0.00	-0.43	0.43
0.0190	0.50	0.50	0.32	-0.00	35.19	43.87	29.57	-0.54	-0.41	0.41
0.0210	0.56	0.59	0.38	-0.00	21.60	45.63	31.19	-2.40	-0.39	0.38
0.0230	0.55	0.69	0.44	-0.01	-34.67	49.27	32.71	-9.42	-0.39	0.36
0.0250	0.38	0.79	0.51	-0.04	-147.50	53.49	34.12	-19.24	-0.44	0.34
0.0270	-0.06	0.90	0.58	-0.09	-301.39	58.08	35.22	-31.18	-0.58	0.32
0.0290	-0.84	1.02	0.65	-0.17	-472.63	61.38	35.87	-42.04	-0.89	0.30
0.0310	-1.95	1.14	0.72	-0.25	-634.39	58.66	35.96	-43.08	-1.28	0.28
0.0330	-3.35	1.26	0.79	-0.34	-755.30	54.97	35.45	-43.15	-2.03	0.28
0.0350	-4.92	1.36	0.86	-0.42	-793.97	50.32	34.47	-41.21	-3.46	0.27
0.0370	-6.42	1.46	0.93	-0.50	-675.03	45.69	33.47	-31.85	-3.55	0.27
0.0390	-7.46	1.55	1.00	-0.54	-336.51	43.44	32.98	-8.58	-3.55	0.27
0.0410	-7.64	1.63	1.06	-0.53	124.26	42.56	32.65	22.26	-3.55	0.27
0.0430	-7.16	1.71	1.13	-0.47	341.27	38.15	31.03	36.68	-3.55	0.27
0.0450	-6.34	1.79	1.19	-0.38	468.08	32.76	28.80	45.21	-3.55	0.28
0.0470	-5.35	1.85	1.24	-0.29	511.88	26.70	26.04	48.49	-3.55	0.28
0.0490	-4.32	1.89	1.29	-0.19	502.59	20.56	22.92	48.82		0.29
0.0510	-3.38	1.93	1.33	-0.09	429.45	14.86	19.60	48.12		0.29
0.0530	-2.64	1.95	1.37	0.00	302.32	9.88	16.38	46.98		0.29
0.0550	-2.19	1.97	1.40	0.09	145.31	5.67	13.12	45.98		0.30
0.0570	-2.06	1.98	1.42	0.19	-15.90	2.24	9.85	45.29		0.30
0.0590	-2.24	1.98	1.44	0.28	-155.55	-0.38	6.59	44.93		0.30
0.0610	-2.66	1.97	1.45	0.37	-252.57	-1.90	3.37	44.83		0.30
0.0630	-3.21	1.97	1.45	0.45	-292.59	-2.78	0.23	44.92		0.30
0.0650	-3.80	1.96	1.45	0.55	-293.05	-3.07	-2.80	45.25		0.30
0.0670	-4.38	1.96	1.44	0.64	-278.98	-2.53	-5.67	46.07	[illegible]	0.30
0.0690	-4.90	1.95	1.42	0.73	-242.47	-1.25	-8.32	48.04	-3.44	0.29
0.0710	-5.33	1.95	1.41	0.83	-175.85	0.81	-10.70	51.79	-3.55	0.29
0.0730	-5.59	1.96	1.39	0.94	-81.03	3.33	-12.77	57.35	-3.55	0.29
0.0750	-5.64	1.97	1.35	1.06	18.48	6.43	-14.61	63.27	-3.55	0.30
0.0770	-5.55	1.98	1.32	1.19	75.23	9.44	-16.38	66.39	-3.55	0.30
0.0790	-5.35	2.01	1.29	1.32	123.39	12.82	-17.93	68.99	-3.55	0.30
0.0810	-5.06	2.04	1.25	1.46	160.35	16.50	-19.26	70.90	-3.55	0.30
0.0830	-4.71	2.07	1.21	1.61	186.14	20.33	-20.35	72.13	-3.24	0.30
0.0850	-4.32	2.12	1.17	1.75	202.79	24.00	-21.21	72.71	-2.84	0.31
0.0870	-3.90	2.17	1.13	1.90	213.10	27.52	-21.83	72.86	-2.47	0.31
0.0890	-3.47	2.23	1.08	2.04	219.67	30.93	-22.17	72.81		0.31
0.0910	-3.03	2.29	1.04	2.19	224.35	34.25	-22.19	72.74		0.32
0.0930	-2.58	2.36	1.00	2.34	227.87	37.49	-21.94	72.57		0.32
0.0950	-2.12	2.44	0.95	2.48	229.43	40.69	-21.46	72.24		0.33
0.0970	-1.66	2.53	0.91	2.62	228.93	43.83	-20.75	71.77		0.34
0.0990	-1.20	2.62	0.87	2.77	226.43	46.92	-19.79	71.21		0.35
0.1010	-0.75	2.71	0.83	2.91	222.03	49.95	-18.59	70.62		0.36
0.1030	-0.32	2.82	0.79	3.05	215.82	52.90	-17.17	69.95		0.37

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28,1974

TIME	CAMBER , STEER ANGLES RELATIVE TO GROUND PLANES									S	SS	
SEC.	PHI CG (DEG.)				PSI' (DEG.)							
	RF	LF	RR	LR	RF	LF	RR	LR	RF			LR
0.0	-0.55	0.55	0.0	0.0	0.0	0.0	0.0	0.0	883.6		.0	747.0
0.0050	-0.54	0.54	0.00	0.00	0.0	0.0	0.00	0.00	791.4		.7	661.7
0.0070	-0.52	0.52	-0.00	-0.00	-0.00	-0.00	0.00	0.00	766.5		.2	645.2
0.0090	-0.51	0.51	0.00	0.00	-0.00	-0.00	-0.00	-0.00	742.3	743.5	628.6	628.6
0.0110	-0.49	0.49	0.00	0.00	-0.00	-0.00	-0.00	-0.00	719.7	721.1	612.4	612.4
0.0130	-0.47	0.47	0.00	0.00	-0.00	-0.00	-0.00	-0.00	699.4	700.4	596.6	596.6
0.0150	-0.45	0.45	0.00	0.00	-0.00	-0.00	-0.00	-0.00	681.3	691.5	581.5	581.5
0.0170	29.33	0.43	0.00	0.00	-0.00	-0.00	-0.00	-0.00	668.6	664.8	567.1	567.1
0.0190	62.86	0.41	0.00	0.00	-0.00	-0.00	-0.00	-0.00	680.9	649.4	554.4	552.7
0.0210	69.78	0.39	0.00	0.00	-0.00	-0.01	-0.00	-0.00	723.4	633.5	544.8	536.9
0.0230	69.70	0.38	0.00	0.00	-0.01	-0.05	-0.00	-0.00	983.1	608.8	543.9	512.6
0.0250	62.36	0.38	0.00	0.00	-0.06	-0.16	-0.00	-0.00	1402.7	576.4	548.5	483.0
0.0270	52.47	0.42	0.01	0.01	-0.14	-0.33	-0.01	-0.01	2000.4	534.5	558.5	449.7
0.0290	22.34	0.48	0.01	0.01	-0.49	-0.57	-0.01	-0.01	2700.9	487.2	569.8	418.4
0.0310	21.69	0.56	0.02	0.02	-0.74	-0.83	-0.02	-0.02	3410.7	452.1	568.2	404.2
0.0330	20.96	0.64	0.03	0.03	-1.01	-1.09	-0.02	-0.02	4143.3	413.6	567.6	393.8
0.0350	19.55	0.73	0.03	0.03	-1.27	-1.35	-0.03	-0.03	9154.6	375.0	565.6	388.7
0.0370	-3.01	0.81	0.04	0.04	-1.61	-1.61	-0.03	-0.03	29068.4	339.4	551.7	395.2
0.0390	-2.96	0.86	0.04	0.04	-1.87	-1.87	-0.04	-0.04	57797.3	308.3	512.1	425.6
0.0410	-2.98	0.84	0.05	0.05	-2.13	-2.13	-0.04	-0.04	32113.7	295.8	456.8	469.7
0.0430	-3.04	0.79	0.05	0.05	-2.39	-2.39	-0.03	-0.03	22876.7	313.6	430.4	495.4
0.0450	-3.13	0.70	0.05	0.05	-2.65	-2.65	-0.03	-0.03	11722.9	345.3	414.7	515.8
0.0470	-3.23	0.61	0.05	0.05	-2.90	-2.91	-0.02	-0.02	4016.9	385.3	409.4	531.2
0.0490	-2.63	0.51	0.04	0.04	-3.16	-3.17	-0.01	-0.01	586.4	427.9	410.5	544.1
0.0510	-1.94	0.41	0.04	0.04	-3.42	-3.43	-0.01	-0.01	-97.1	468.3	414.8	556.8
0.0530	-1.58	0.31	0.04	0.04	-3.68	-3.68	0.00	0.00	181.4	502.2	420.2	659.0
0.0550	-1.47	0.20	0.03	0.03	-3.94	-3.94	0.01	0.01	674.3	526.9	426.2	672.1
0.0570	-1.52	0.10	0.03	0.03	-4.20	-4.20	0.01	0.01	1282.6	541	432.7	686.4
0.0590	-1.70	-0.00	0.02	0.02	-4.45	-4.45	0.02	0.02	1793.8	605	439.3	701.7
0.0610	-2.01	-0.11	0.01	0.01	-4.71	-4.71	0.03	0.03	2186.0	600	446.1	718.0
0.0630	-2.45	-0.22	-0.00	-0.00	-4.96	-4.96	0.03	0.03	2465.9	589	452.9	734.9
0.0650	-3.00	-0.33	-0.01	-0.01	-5.21	-5.22	0.04	0.04	3020.6	575	459.5	752.5
0.0670	-3.63	-0.44	-0.02	-0.02	-5.46	-5.47	0.04	0.04	4471.2	558	465.3	770.8
0.0690	-4.29	-0.55	-0.03	-0.03	-5.71	-5.72	0.05	0.05	7132.2	541	468.9	790.9
0.0710	-4.52	-0.67	-0.05	-0.05	-5.95	-5.97	0.06	0.06	10496.8	462	468.7	813.6
0.0730	-4.65	-0.81	-0.06	-0.06	-6.20	-6.22	0.07	0.07	13105.4	446	464.5	838.9
0.0750	-4.80	-0.95	-0.07	-0.07	-6.45	-6.47	0.07	0.07	7475.8	432	458.5	864.9
0.0770	-4.95	-1.11	-0.09	-0.09	-6.70	-6.72	0.08	0.08	6677.7	422.9	456.7	887.2
0.0790	-5.12	-1.27	-0.10	-0.10	-6.94	-6.97	0.09	0.09	5375.0	413.6	454.8	908.4
0.0810	-5.29	-1.44	-0.12	-0.12	-7.19	-7.22	0.10	0.10	3918.1	404.5	453.2	928.1
0.0830	-5.15	-1.61	-0.14	-0.14	-7.44	-7.47	0.11	0.11	2614.6	395.7	451.8	946.3
0.0850	-4.93	-1.78	-0.15	-0.15	-7.69	-7.71	0.12	0.12	1637.2	387.6	450.7	963.0
0.0870	-4.73	-1.95	-0.17	-0.17	-7.94	-7.96	0.13	0.13	1017.1	379.7	449.4	978.1
0.0890	-4.56	-2.13	-0.18	-0.18	-8.19	-8.21	0.14	0.14	685.0	371.9	447.4	992.0
0.0910	-4.43	-2.30	-0.20	-0.20	-8.43	-8.45	0.15	0.15	516.1	363.8	444.3	1004.5
0.0930	-4.35	-2.47	-0.21	-0.21	-8.68	-8.70	0.16	0.16	444.3	355.3	440.3	1015.9
0.0950	-4.32	-2.64	-0.23	-0.23	-8.93	-8.94	0.17	0.17	383.0	346.4	435.6	1026.0
0.0970	-4.31	-2.81	-0.24	-0.24	-9.17	-9.19	0.18	0.18	329.0	336.[illegible]	.1	1034.8
0.0990	-4.33	-2.97	-0.26	-0.26	-9.42	-9.43	0.19	0.19	282.5	326.[illegible]	.6	1042.3
0.1010	-4.36	-3.14	-0.28	-0.28	-9.66	-9.67	0.20	0.20	243.7	315.[illegible]	.1	1048.5
0.1030	-4.39	-3.30	-0.29	-0.29	-9.90	-9.92	0.21	0.21	212.8	303.[illegible]	.7	1053.4

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28,1974

TIME SEC.	HUB VELOCITY PARALLEL TO GROUND PLANES (FT./SEC.) LONGITUDINAL				LATERAL				VERTIC (POUNDS)			
	RF	LF	RR	LR	RF	LF	RR	LR	RF	LF	RR	LR
0.0	88.00	88.00	88.00	88.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0050	88.00	88.00	88.00	88.00	0.00	0.00	0.00	0.00	-23.6	-46.3	0.0	0.0
0.0070	88.00	88.00	88.00	88.00	-0.00	0.00	-0.00	-0.00	-69.2	-89.5	0.0	0.0
0.0090	88.00	88.00	88.00	88.00	-0.00	0.00	-0.00	-0.00	-121.6	-145.3	-31.6	-31.6
0.0110	88.00	88.00	88.00	88.00	-0.00	0.00	-0.00	-0.00	-220.5	-212.3	-72.8	-72.8
0.0130	88.00	88.00	88.00	88.00	-0.00	0.00	-0.00	-0.00	-314.3	-289.1	-120.9	-120.9
0.0150	87.97	88.00	88.00	88.00	0.00	0.00	-0.00	-0.00	-438.3	-374.1	-175.3	-175.3
0.0170	86.42	88.00	88.00	88.00	-1.25	0.00	-0.00	-0.00	-747.6	-465.7	-235.5	-235.5
0.0190	75.19	87.98	88.00	87.98	-2.83	-0.07	-0.02	-0.02	-1958.2	-562.2	-300.6	-300.6
0.0210	72.34	87.91	88.01	87.91	-2.04	-0.31	-0.07	-0.07	-3456.0	-661.6	-370.0	-359.7
0.0230	73.26	87.64	88.07	87.64	1.83	-1.31	-0.29	-0.29	-12358.7	-761.9	-443.0	-442.0
0.0250	81.49	87.21	88.13	87.22	9.16	-2.72	-0.61	-0.61	-19770.5	-861.0	-519.3	-515.1
0.0270	89.50	86.70	88.22	86.72	19.48	-4.50	-0.99	-0.99	-24498.2	-957.0	-598.1	-590.9
0.0290	95.75	86.21	88.33	86.23	10.07	-6.19	-1.33	-1.33	-26047.6	-1047.6	-678.8	-665.4
0.0310	98.37	86.03	88.24	86.05	14.66	-6.45	-1.37	-1.37	-23799.0	-1131.4	-760.1	-739.2
0.0330	96.78	85.91	88.22	85.93	18.11	-6.63	-1.36	-1.36	-16907.4	-1206.0	-840.7	-811.9
0.0350	93.54	95.96	88.25	85.88	19.53	-6.64	-1.26	-1.26	-5323.1	-1269.7	-919.7	-882.7
0.0370	90.15	85.89	88.30	85.91	-5.35	-6.26	-1.00	-1.00	-1968.5	-1321.4	-996.1	-951.2
0.0390	88.33	85.99	88.43	86.01	-4.95	-5.40	-0.45	-0.45	-931.5	-1360.5	-1068.7	-1017.4
0.0410	88.38	86.13	88.61	86.14	-4.59	-4.28	0.26	0.26	-645.2	-1385.9	-1136.1	-1081.3
0.0430	88.45	86.20	88.70	86.21	-4.35	-3.69	0.65	0.65	-1016.5	-1395.2	-1197.8	-1142.0
0.0450	88.54	86.24	88.75	86.25	-4.11	-3.31	0.92	0.92	-1734.6	-1388.6	-1253.3	-1198.3
0.0470	88.64	86.26	88.78	86.27	-3.91	-3.10	1.08	1.08	-2621.6	-1366.7	5	-1249.5
0.0490	88.72	86.27	88.79	86.28	-3.79	-2.99	1.18	1.18	-5851.5	-1330.5	1	-1294.9
0.0510	88.76	86.27	88.80	86.28	-3.65	-2.92	1.26	1.26	-14217.4	-1281.4	7	-1334.1
0.0530	88.76	86.27	88.80	86.29	-3.49	-2.86	1.34	1.34	-20318.1	-1220.9	2	-1367.1
0.0550	88.70	86.27	88.81	86.29	-3.37	-2.79	1.43	1.43	-23252.1	-1150.5	2	-1394.2
0.0570	88.61	86.27	88.82	86.30	-3.29	-2.72	1.51	1.51	-22642.7	-1071.7	3	-1415.2
0.0590	88.49	86.28	88.83	86.31	-3.25	-2.63	1.60	1.60	-18677.2	-986.0	9	-1430.0
0.0610	88.37	86.29	88.84	86.31	-3.22	-2.54	1.70	1.70	-12058.0	-895.5	5	-1438.6
0.0630	88.28	86.29	88.85	86.32	-3.17	-2.44	1.79	1.79	-3877.9	-802.0	7	-1441.1
0.0650	88.23	86.30	88.86	86.33	-3.15	-2.34	1.88	1.88	-2475.1	-706.7	3	-1437.4
0.0670	88.20	86.31	88.88	86.33	-3.08	-2.24	1.98	1.98	-1611.6	-611.1	-1401.0	-1427.7
0.0690	88.19	86.32	88.90	86.34	-2.94	-2.09	2.10	2.10	-809.4	-516.4	-1371.7	-1412.2
0.0710	88.24	86.34	88.92	86.35	-2.77	-1.87	2.26	2.26	-140.3	-423.9	-1336.1	-1391.4
0.0730	88.34	86.38	88.96	86.38	-2.48	-1.58	2.45	2.45	0.0	-334.2	-1294.5	-1365.5
0.0750	88.47	86.41	88.99	86.40	-2.13	-1.27	2.64	2.64	0.0	-248.2	-1247.3	-1335.0
0.0770	88.56	86.44	89.01	86.42	-1.87	-1.05	2.77	2.77	0.0	-166.9	-1195.2	-1300.3
0.0790	88.65	86.46	89.02	86.43	-1.60	-0.85	2.89	2.89	0.0	-91.5	-1138.8	-1261.9
0.0810	88.74	86.49	89.03	86.44	-1.35	-0.68	2.99	2.99	0.0	-23.0	-1078.7	-1220.1
0.0830	88.81	86.51	89.02	86.44	-1.12	-0.52	3.08	3.08	0.0	0.0	-1019.4	-1175.5
0.0850	88.89	86.53	89.03	86.44	-0.90	-0.39	3.16	3.16	0.0	0.0	-963.9	-1128.7
0.0870	88.93	86.55	89.03	86.45	-0.69	-0.27	3.22	3.22	0.0	0.0		-1080.2
0.0890	88.93	86.57	89.03	86.45	-0.50	-0.16	3.29	3.29	0.0	0.0		-1030.8
0.0910	89.03	86.60	89.02	86.45	-0.31	-0.05	3.34	3.34	0.0	0.0		-980.8
0.0930	89.07	86.62	89.01	86.45	-0.14	0.05	3.40	3.40	-117.3	0.0		-930.9
0.0950	89.12	86.64	89.01	86.45	0.00	0.15	3.46	3.46	-322.2	0.0		-881.7
0.0970	89.15	86.65	89.01	86.44	0.13	0.25	3.52	3.52	-528.7	0.0		-834.0
0.0990	89.18	86.67	89.01	86.44	0.25	0.34	3.58	3.58	-732.7	0.0		-788.1
0.1010	89.21	86.69	89.01	86.44	0.35	0.43	3.64	3.64	-931.3	0.0		-744.7
0.1030	89.23	86.71	89.01	86.44	0.43	0.51	3.70	3.70	-1121.6	0.0		-704.2

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2F6015, MAY 28,1974

TIME SEC.	CIRCUMFERENTIAL TIRE FORCES (POUNDS)				TIRE SIDE FOR (POUNDS)			
	RF	LF	RR	LR	RF	LF		LR
0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
0.0050	0.0	0.0	0.0	0.0	-0.39	0.75		0.0
0.0070	0.0	0.0	0.0	0.0	-1.08	1.39		0.0
0.0090	0.0	0.0	0.0	0.0	-1.82	2.17	0.00	0.00
0.0110	0.0	0.0	0.0	0.0	-3.10	3.00	0.00	0.00
0.0130	0.0	0.0	0.0	0.0	-4.14	3.85	0.00	0.00
0.0150	0.0	0.0	0.0	0.0	-5.47	4.65	0.00	0.00
0.0170	0.0	0.0	0.0	0.0	313.63	5.32	0.02	0.02
0.0190	0.0	0.0	0.0	0.0	564.86	11.91	1.41	1.41
0.0210	0.0	0.0	0.0	0.0	476.80	34.96	5.91	5.91
0.0230	0.0	0.0	0.0	0.0	251.49	124.63	23.84	23.94
0.0250	0.0	0.0	0.0	0.0	-55.17	240.52	51.80	52.19
0.0270	0.0	0.0	0.0	0.0	-510.61	371.63	86.81	87.81
0.0290	0.0	0.0	0.0	0.0	-110.94	482.45	119.77	121.49
0.0310	0.0	0.0	0.0	0.0	-326.08	491.67	128.07	129.73
0.0330	0.0	0.0	0.0	0.0	-515.07	490.18	130.74	132.35
0.0350	0.0	0.0	0.0	0.0	-620.61	471.49	125.38	126.92
0.0370	0.0	0.0	0.0	0.0	203.24	414.01	101.20	102.54
0.0390	0.0	0.0	0.0	0.0	150.57	302.06	44.21	44.98
0.0410	0.0	0.0	0.0	0.0	74.63	145.66	-34.81	-35.28
0.0430	0.0	0.0	0.0	0.0	4.99	33.03	-77.15	-78.43
0.0450	0.0	0.0	0.0	0.0	-85.84	-61.47	-106.03	-108.01
0.0470	0.0	0.0	0.0	0.0	-123.10	-131.65	-123.10	-125.64
0.0490	0.0	0.0	0.0	0.0	-112.97	-187.49	-133.44	-136.43
0.0510	0.0	0.0	0.0	0.0	-125.38	-235.90	-141.19	-144.56
0.0530	0.0	0.0	0.0	0.0	-145.51	-279.48	-148.97	-152.70
0.0550	0.0	0.0	0.0	0.0	-168.49	-318.34	-157.05	-161.15
0.0570	0.0	0.0	0.0	0.0	-192.54	-351.59	-165.47	-169.90
0.0590	0.0	0.0	0.0	0.0	-217.55	-377.82	-174.26	-179.03
0.0610	0.0	0.0	0.0	0.0	-244.33	-395.44	-183.16	-188.26
0.0630	0.0	0.0	0.0	0.0	-269.87	-403.09	-191.98	-197.42
0.0650	0.0	0.0	0.0	0.0	-451.37	-399.75	-200.70	-206.53
0.0670	0.0	0.0	0.0	0.0	-598.21	-384.73	-209.76	-216.09
0.0690	0.0	0.0	0.0	0.0	-475.33	-358.08	-220.52	-227.54
0.0710	0.0	0.0	0.0	0.0	-112.24 *	-318.68	-234.13	-242.14
0.0730	0.0	0.0	0.0	0.0	0.0 *	-264.52	-250.28	-259.69
0.0750	0.0	0.0	0.0	0.0	0.0 *	-198.54 *	-265.59	-276.83
0.0770	0.0	0.0	0.0	0.0	0.0 *	-133.54 *	-274.04	-287.31
0.0790	0.0	0.0	0.0	0.0	0.0 *	-73.24 *	-280.03	-295.76
0.0810	0.0	0.0	0.0	0.0	0.0 *	-18.43 *	-283.22	-301.88
0.0830	0.0	0.0	0.0	0.0	0.0 *	0.0 *	-284.06	-305.69
0.0850	0.0	0.0	0.0	0.0	0.0 *	0.0 *	-283.24	-307.58
0.0870	0.0	0.0	0.0	0.0	0.0 *	0.0 *	-280.00	-307.92
0.0890	0.0	0.0	0.0	0.0	0.0 *	0.0 *	-272.83	-307.02
0.0910	0.0	0.0	0.0	0.0	0.0 *	0.0 *	-264.12	-305.07
0.0930	0.0	0.0	0.0	0.0	-93.84 *	0.0 *	-258.64	-302.40
0.0950	0.0	0.0	0.0	0.0	-257.75 *	0.0 *	-251.92	-299.12
0.0970	0.0	0.0	0.0	0.0	-422.96 *	0.0 *	-243.42	5.31
0.0990	0.0	0.0	0.0	0.0	-585.46	0.0 *	-231.12	1.07
0.1010	0.0	0.0	0.0	0.0	-737.56	0.0 *	-219.07	6.53
0.1030	0.0	0.0	0.0	0.0	-874.09	0.0 *	-205.90	1.92

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2F6015, MAY 28,1974

ACCELERATION COMPONENTS AT POINTS 1 AND 2 ON SPRUNG MASS
(G-UNITS)

TIME SEC.	AX1	AY1	AZ1	AX2	AY2	AZ2
0.0	0.000	0.0	0.000	0.000	0.0	0.000
0.0050	0.000	0.000	0.111	0.000	0.000	0.109
0.0070	0.000	0.000	0.135	0.000	0.000	0.134
0.0090	-0.000	0.000	0.159	0.000	0.000	0.159
0.0110	-0.000	-0.000	0.182	-0.000	-0.000	0.182
0.0130	-0.000	-0.000	0.203	-0.000	-0.000	0.204
0.0150	-0.001	-0.000	0.224	-0.001	-0.000	0.225
0.0170	-0.031	0.002	0.236	-0.024	0.014	0.250
0.0190	-0.291	-0.577	0.200	-0.450	-0.834	-0.140
0.0210	-0.603	-1.723	0.155	-1.144	-2.603	-0.881
0.0230	-2.304	-6.948	-0.153	-4.517	-10.560	-4.130
0.0250	-3.094	-7.727	-0.328	-5.400	-11.485	-4.432
0.0270	-3.165	-9.287	-0.409	-6.007	-13.917	-5.270
0.0290	-2.545	-2.261	-0.399	-2.961	-2.900	-0.947
0.0310	-1.652	-1.842	-0.356	-2.107	-2.551	-0.776
0.0330	-0.673	-1.127	-0.315	-1.079	-1.761	-0.464
0.0350	-0.024	-0.025	-1.049	-0.267	-0.419	-0.360
0.0370	0.303	1.257	-4.322	0.074	0.775	-1.595
0.0390	0.635	2.307	-9.068	0.190	1.314	-3.809
0.0410	0.353	1.207	-4.812	0.109	0.681	-1.897
0.0430	0.243	0.761	-3.290	0.066	0.397	-1.242
0.0450	0.116	0.261	-1.454	0.020	0.089	-0.442
0.0470	0.034	-0.070	-0.191	-0.006	-0.107	[illegible]
0.0490	0.004	-0.215	0.364	-0.010	-0.190	
0.0510	0.017	-0.247	0.465	0.004	-0.215	
0.0530	0.042	-0.235	0.365	0.027	-0.208	
0.0550	0.070	-0.209	0.273	0.051	-0.190	
0.0570	0.092	-0.180	0.162	0.071	-0.168	
0.0590	0.104	-0.162	0.056	0.081	-0.155	
0.0610	0.101	-0.156	-0.021	0.076	-0.153	
0.0630	0.085	-0.165	-0.080	0.058	-0.167	
0.0650	0.083	-0.182	-0.183	0.043	-0.207	
0.0670	0.091	-0.159	-0.434	0.034	-0.219	-0.228
0.0690	0.117	-0.045	-0.885	0.049	-0.138	-0.422
0.0710	0.156	0.138	-1.441	0.085	0.021	-0.615
0.0730	0.183	0.245	-1.883	0.104	0.103	-0.804
0.0750	0.121	0.025	-0.961	0.095	-0.001	-0.370
0.0770	0.111	-0.007	-0.838	0.096	-0.009	-0.307
0.0790	0.095	-0.057	-0.631	0.095	-0.028	-0.206
0.0810	0.077	-0.112	-0.398	0.093	-0.050	-0.092
0.0830	0.062	-0.163	-0.189	0.089	-0.076	0.006
0.0850	0.048	-0.204	-0.034	0.083	-0.100	0.076
0.0870	0.038	-0.229	0.063	0.077	-0.115	[illegible]
0.0890	0.031	-0.243	0.113	0.072	-0.124	
0.0910	0.027	-0.249	0.138	0.069	-0.129	
0.0930	0.021	-0.268	0.147	0.058	-0.156	
0.0950	0.012	-0.297	0.155	0.041	-0.198	
0.0970	0.004	-0.326	0.163	0.025	-0.240	
0.0990	-0.005	-0.353	0.171	0.008	-0.280	
0.1010	-0.013	-0.377	0.179	-0.008	-0.317	
0.1030	-0.021	-0.398	0.187	-0.022	-0.349	

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2F6015, MAY 23,1974

HORIZONTAL TIRE FORCES (POUNDS)

TIME SEC.	X' DIRECTION RF	LF	RR	LR	Y' DIRE RF	LF		LR
0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
0.0050	0.1	-0.2	0.0	0.0	-0.4	0.7		0.0
0.0070	0.3	-0.4	0.0	0.0	-1.0	1.3		0.0
0.0090	0.5	-0.6	-0.0	-0.0	-1.8	2.1	0.0	0.0
0.0110	0.8	-0.8	-0.0	-0.0	-3.0	2.9	0.0	0.0
0.0130	1.1	-1.0	-0.0	-0.0	-4.0	3.7	0.0	0.0
0.0150	-2.4	-1.2	-0.0	-0.0	-6.3	4.5	0.0	0.0
0.0170	-124.8	-1.4	-0.0	-0.0	16.9	5.1	0.0	0.0
0.0190	-233.6	-3.1	-0.4	-0.4	-3367.5	11.5	1.4	1.4
0.0210	397.0	-9.0	-1.5	-1.5	-10275.8	33.8	5.7	5.7
0.0230	2133.4	-32.1	-6.2	-6.2	-41631.8	120.4	23.0	23.1
0.0250	177.9	-61.5	-13.4	-13.5	-46001.1	232.5	50.0	50.4
0.0270	2345.5	-93.8	-22.4	-22.6	-55382.9	359.6	83.9	84.8
0.0290	-6361.3	-119.5	-30.8	-31.2	-13919.6	467.4	115.7	117.4
0.0310	-3472.6	-119.2	-32.8	-33.2	-11823.3	477.0	123.8	125.4
0.0330	-692.6	-116.3	-33.4	-33.8	-8040.4	476.2	126.4	128.0
0.0350	267.0	-109.3	-31.9	-32.3	-2905.4	458.6	121.3	122.8
0.0370	-112.2	-93.8	-25.6	-26.0	182.7	403.3	97.9	99.2
0.0390	-33.3	-66.8	-11.1	-11.3	146.8	294.6	42.8	43.5
0.0410	-16.1	-31.4	8.7	8.9	72.9	142.2	-33.7	-34.1
0.0430	-1.1	-6.9	19.3	19.6	4.9	32.3	-74.7	-75.9
0.0450	17.6	12.6	26.5	26.9	-84.0	-60.2	-102.7	-104.6
0.0470	24.6	26.3	30.6	31.2	-120.6	-129.0	-119.2	-121.7
0.0490	22.0	36.4	33.1	33.8	-110.8	-183.9	-129.3	-132.2
0.0510	23.7	44.5	34.9	35.7	-123.1	-231.7	-136.8	-140.1
0.0530	26.7	51.2	36.7	37.6	-143.0	-274.7	-144.4	-148.0
0.0550	30.0	56.6	38.5	39.5	-165.8	-313.3	-152.3	-156.2
0.0570	33.2	60.6	40.4	41.5	-189.6	-346.3	-	-164.8
0.0590	36.4	63.1	42.4	43.6	-214.5	-372.5	-	-173.6
0.0610	39.6	63.9	44.4	45.7	-241.1	-390.2	-	-182.6
0.0630	42.3	63.0	46.4	47.7	-266.5	-398.1	-	-191.6
0.0650	68.4	60.3	48.3	49.7	-446.2	-395.2	-	-200.5
0.0670	87.5	56.0	50.3	51.8	-591.8	-380.6	-	-209.8
0.0690	67.1	50.2	52.7	54.4	-470.6	-354.5	-	-220.9
0.0710	15.3	43.0	55.8	57.7	-111.2	-315.8	-	-235.2
0.0730	0.0	34.3	59.4	61.6	0.0	-262.3	-	-252.3
0.0750	0.0	24.7	62.8	65.5	0.0	-197.0	-	-269.0
0.0770	0.0	15.9	64.6	67.7	0.0	-132.6	-266.3	-279.2
0.0790	0.0	9.3	65.7	69.4	0.0	-72.8	-272.2	-287.5
0.0810	0.0	2.0	66.2	70.6	0.0	-18.3	-275.4	-293.5
0.0830	0.0	0.0	69.8	71.2	0.0	0.0	-275.4	-297.3
0.0850	0.0	0.0	68.0	71.4	0.0	0.0	-275.0	-299.2
0.0870	0.0	0.0	64.1	71.3	0.0	0.0	-272.6	-299.6
0.0890	0.0	0.0	60.0	70.9	0.0	0.0	-266.2	-298.7
0.0910	0.0	0.0	60.9	70.1	0.0	0.0	-257.0	-296.9
0.0930	7.3	0.0	60.2	69.2	-93.6	0.0	-251.5	-294.4
0.0950	18.7	0.0	57.7	68.2	-257.1	0.0	-245.2	-291.2
0.0970	28.5	0.0	55.2	67.1	-422.0	0.0	-23	-287.6
0.0990	36.4	0.0	52.4	65.9	-584.3	0.0	-22	-283.5
0.1010	42.0	0.0	49.0	64.6	-736.4	0.0	-21	-279.1
0.1030	45.2	0.0	46.0	63.4	-872.9	0.0	-20	-274.7

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28,1974

TIME	STEERING TORQUES			TERRAIN SLOPES				ROLL		
SEC.	T1PSI LB.-IN.	T2PSI LB.-IN.	PHIG1 DEGREES	PHIG2 DEGREES	PHIG3 DEGREES	PHIG4 DEGREES	H1 INCHES	H2 INCHES	H3 INCHES	H4 INCHES
0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	14.0	14.0
0.0050	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	14.0	14.0
0.0070	0.0	0.0	-0.0	0.0	0.0	0.0	13.9	13.9	14.0	14.0
0.0090	0.0	0.0	-0.0	0.0	0.0	0.0	13.9	13.9	14.0	14.0
0.0110	0.0	0.0	0.0	0.0	0.0	0.0	13.8	13.8	13.9	13.9
0.0130	0.0	0.0	0.0	0.0	0.0	0.0	13.7	13.7	13.9	13.9
0.0150	0.0	0.0	-0.1	0.0	0.0	0.0	13.6	13.7	13.8	13.8
0.0170	0.0	0.0	-22.3	0.0	0.0	0.0	13.3	13.6	13.8	13.8
0.0190	0.0	0.0	-66.8	0.0	0.0	0.0	11.9	13.5	13.7	13.7
0.0210	-600.0	0.0	-73.1	0.0	0.0	0.0	10.9	13.4	13.7	13.7
0.0230	-600.0	0.0	-73.5	0.0	0.0	0.0	9.9	13.3	13.6	13.6
0.0250	-600.0	0.0	-66.7	0.0	0.0	0.0	9.2	13.2	13.5	13.5
0.0270	-600.0	0.0	-65.6	0.0	0.0	0.0	8.8	13.1	13.5	13.5
0.0290	-600.0	0.0	-27.2	0.0	0.0	0.0	8.8	13.0	13.4	13.4
0.0310	-600.0	0.0	-25.5	0.0	0.0	0.0	9.0	13.0	13.3	13.3
0.0330	-600.0	0.0	-23.9	0.0	0.0	0.0	9.7	12.9	13.2	13.3
0.0350	-600.0	0.0	-22.9	0.0	0.0	0.0	10.8	12.8	13.2	13.2
0.0370	-600.0	0.0	-0.4	0.0	0.0	0.0	12.2	12.8	13.1	13.1
0.0390	-600.0	0.0	0.0	0.0	0.0	0.0	13.2	12.8	13.0	13.1
0.0410	-600.0	0.0	0.0	0.0	0.0	0.0	13.4	12.7	13.0	13.0
0.0430	-600.0	0.0	0.0	0.0	0.0	0.0	13.1	12.7	12.9	13.0
0.0450	-600.0	0.0	0.0	0.0	0.0	0.0	12.4	12.7	12.9	12.9
0.0470	-600.0	0.0	0.0	0.0	0.0	0.0	11.6	12.8	- - -	12.9
0.0490	-600.0	0.0	0.0	0.0	0.0	0.0	10.8	12.8		12.8
0.0510	-600.0	0.0	0.0	0.0	0.0	0.0	10.0	12.8		12.8
0.0530	-600.0	0.0	0.0	0.0	0.0	0.0	9.4	12.9		12.8
0.0550	-600.0	0.0	0.0	0.0	0.0	0.0	9.2	13.0		12.7
0.0570	-600.0	0.0	0.0	0.0	0.0	0.0	9.2	13.0		12.7
0.0590	-600.0	0.0	0.0	0.0	0.0	0.0	9.6	13.1		12.7
0.0610	-600.0	0.0	0.0	0.0	0.0	0.0	10.2	13.2		12.7
0.0630	-600.0	0.0	0.0	0.0	0.0	0.0	10.9	13.3		12.7
0.0650	-600.0	0.0	0.0	0.0	0.0	0.0	11.7	13.4		12.7
0.0670	-600.0	0.0	0.0	0.0	0.0	0.0	12.5	13.4	12.7	12.7
0.0690	-600.0	0.0	0.0	0.0	0.0	0.0	13.2	13.5	12.8	12.7
0.0710	-600.0	0.0	0.0	0.0	0.0	0.0	13.9	13.6	12.8	12.7
0.0730	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	13.7	12.8	12.8
0.0750	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	13.8	12.9	12.8
0.0770	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	13.8	12.9	12.8
0.0790	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	13.9	13.0	12.9
0.0810	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	13.0	12.9
0.0830	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	13.1	12.9
0.0850	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	13.1	13.0
0.0870	-600.0	0.0	0.0	0.0	-0.0	0.0	14.0	14.0	- - -	13.0
0.0890	-600.0	0.0	0.0	0.0	-0.0	0.0	14.0	14.0		13.1
0.0910	-600.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0		13.1
0.0930	-600.0	0.0	0.0	0.0	0.0	0.0	13.9	14.0		13.2
0.0950	-600.0	0.0	0.0	0.0	0.0	0.0	13.7	14.0		13.2
0.0970	-600.0	0.0	0.0	0.0	-0.0	0.0	13.5	14.0		13.2
0.0990	-600.0	0.0	0.0	0.0	0.0	0.0	13.3	14.0		13.3
0.1010	-600.0	0.0	0.0	0.0	-0.0	0.0	13.1	14.0		13.3
0.1030	-600.0	0.0	0.0	0.0	-0.0	0.0	12.9	14.0		13.4

FIGURE 3-10. CONTINUED

THD SPECIAL MEDIAN STUDY - DISTRICT 2, 8 INCH CURB
V = 60 MPH, ANGLE = 15 DEG., DSN = M2E6015, MAY 28,1974

TIME SEC.	RF WHEEL X'	RF WHEEL Y'	LF WHEEL X'	LF WHEEL Y'	RR WHEEL X'	RR WHEEL Y'	LR WHEEL X'	LR WHEEL Y'	REFF WITH (PENE D			ACT DE PTA
	WHEEL POSITIONS (INCHES) (* INDICATES LOSS OF CONTACT)											
0.0	131.77*	95.18*	147.55*	36.26*	16.95*	63.90*	32.43*	5.94*	0			0.0
0.0050	136.87	96.55	152.65	37.63	22.05*	65.26*	37.58*	7.31*	0			0.0
0.0070	138.91	97.09	154.69	38.17	24.09*	65.81*	39.62*	7.86*	0.0	0.0	0.0	0.0
0.0090	140.95	97.64	156.73	38.72	26.13	66.36	41.66	8.40	0.0	0.0	0.0	0.0
0.0110	142.99	98.19	158.77	39.27	28.17	66.90	43.70	8.95	0.0	0.0	0.0	0.0
0.0130	145.03	98.73	160.81	39.81	30.21	67.45	45.74	9.50	0.0	0.0	0.0	0.0
0.0150	147.07	99.28	162.85	40.36	32.25	68.00	47.78	10.04	0.0	0.0	0.0	0.0
0.0170	149.11	99.83	164.89	40.91	34.29	68.54	49.82	10.59	0.0	0.0	0.0	0.0
0.0190	151.15	100.37	166.93	41.45	36.33	69.09	51.86	11.14	0.0	0.0	0.0	0.0
0.0210	153.19	100.92	168.97	41.99	38.37	69.64	53.90	11.68	0.0	0.0	0.0	0.0
0.0230	155.23	101.45	171.01	42.53	40.41	70.18	55.93	12.22	0.0	0.0	0.0	0.0
0.0250	157.28	101.96	173.05	43.03	42.46	70.72	57.96	12.76	0.0	0.0	0.0	0.0
0.0270	159.35	102.43	175.09	43.50	44.51	71.25	59.99	13.28	0.0	0.0	0.0	0.0
0.0290	161.42	102.87	177.12	43.92	46.56	71.77	62.00	13.78	0.0	0.0	0.0	0.0
0.0310	163.50	103.30	179.15	44.33	48.62	72.28	64.00	14.29	0.0	0.0	0.0	0.0
0.0330	165.58	103.72	181.18	44.72	50.67	72.79	66.01	14.78	0.0	0.0	0.0	0.0
0.0350	167.66	104.15	183.21	45.11	52.73	73.30	68.01	15.28	0.0	0.0	0.0	0.0
0.0370	169.74	104.58	185.24	45.50	54.78	73.82	70.01	15.78	0.0	0.0	0.0	0.0
0.0390	171.82	105.01	187.26	45.90	56.84	74.34	72.01	16.28	0.0	0.0	0.0	0.0
0.0410	173.90	105.43	189.29	46.31	58.89	74.87	74.01	16.81	0.0	0.0	0.0	0.0
0.0430	175.99	105.84	191.32	46.72	60.95	75.42	76.01	17.34	0.0	0.0	0.0	0.0
0.0450	178.07	106.26	193.35	47.14	63.01	75.97	78.00	17.87	0.0	0.0	0.0	0.0
0.0470	180.16	106.68	195.38	47.56	65.06	76.52	80.00	18.41	0.0	0.0	0.0	0.0
0.0490	182.25	107.10	197.41	47.99	67.12	77.08	82.00	18.95	0.0	0.0	0.0	0.0
0.0510	184.34	107.52	199.44	48.41	69.18	77.63	84.00	19.49	0.0	0.0	0.0	0.0
0.0530	186.43	107.95	201.47	48.83	71.24	78.19	86.00	20.03	0.0	0.0	0.0	0.0
0.0550	188.52	108.38	203.50	49.25	73.30	78.74	88.00	20.57	0.0	(	)	0.0
0.0570	190.60	108.81	205.52	49.67	75.35	79.30	90.00	21.11	0.0	(	)	0.0
0.0590	192.69	109.23	207.55	50.09	77.41	79.85	92.00	21.65	0.0	(	)	0.0
0.0610	194.77	109.66	209.58	50.51	79.47	80.41	94.00	22.19	0.0	(	)	0.0
0.0630	196.85	110.08	211.61	50.93	81.53	80.96	96.00	22.73	0.0	(	)	0.0
0.0650	198.93	110.49	213.64	51.35	83.59	81.52	98.00	23.27	0.0	(	)	0.0
0.0670	201.01	110.91	215.67	51.77	85.65	82.07	100.00	23.81	0.0	(	)	0.0
0.0690	203.08	111.32	217.70	52.19	87.71	82.63	102.00	24.35	0.0	(	)	0.0
0.0710	205.16	111.73	219.73	52.61	89.77	83.18	104.01	24.89	0.0	(	)	0.0
0.0730	207.24*	112.14*	221.76	53.04	91.83	83.74	106.01	25.43	0.0	(	)	0.0
0.0750	209.33*	112.55*	223.79	53.46	93.89	84.30	108.01	25.97	0.0	0.0	0.0	0.0
0.0770	211.41*	112.97*	225.82	53.89	95.96	84.86	110.01	26.52	0.0	0.0	0.0	0.0
0.0790	213.50*	113.39*	227.86	54.31	98.02	85.43	112.01	27.06	0.0	0.0	0.0	0.0
0.0810	215.59*	113.82*	229.89	54.74	100.08	85.99	114.01	27.61	0.0	0.0	0.0	0.0
0.0830	217.67*	114.24*	231.92*	55.17*	102.14	86.56	116.02	28.16	0.0	0.0	0.0	0.0
0.0850	219.76*	114.67*	233.95*	55.60*	104.20	87.12	118.02	28.70	0.0	0.0	0.0	0.0
0.0870	221.95*	115.11*	235.98*	56.03*	106.27	87.68	120.02	29.25	0.0	0.0	0.0	0.0
0.0890	223.94*	115.54*	238.02*	56.47*	108.33	88.25	122.03	29.79	0.0	0.0	0.0	0.0
0.0910	226.04*	115.99*	240.05*	56.90*	110.39	88.81	124.03	30.34	0.0	0.0	0.0	0.0
0.0930	228.13	116.42	242.08*	57.33*	112.45	89.37	126.03	30.88	0.0	0.0	0.0	0.0
0.0950	230.22	116.87	244.12*	57.76*	114.52	89.94	128.04	31.42	0.0	0.		0.0
0.0970	232.31	117.31	246.15*	58.20*	116.58	90.50	130.04	31.96	0.0	0.		0.0
0.0990	234.41	117.76	248.19*	58.63*	118.64	91.06	132.05	32.50	0.0	0.		0.0
0.1010	236.50	118.21	250.22*	59.07*	120.71	91.62	134.05	33.04	0.0	0.		0.0
0.1030	238.59	118.66	252.25*	59.50*	122.77	92.18	136.06	33.58	0.0	0.		0.0

FIGURE 3-10. CONTINUED

REFERENCES

(1) McHenry, R. R., Segal, D. J., "Determination of Physical Criteria for Roadside Energy Conversion Systems," CAL No. VJ-2251-V-1, July, 1967.

(2) McHenry, R. R., "An Analysis of the Dynamics of Automobiles During Simultaneous Cornering and Ride Motions," Institution of Mechanical Engineers Symposium, "Handling of Vehicle Under Emergency Conditions," 8 January, 1969.

(3) McHenry, R. R., and Deleys, N. J., "Vehicle Dynamics in Single Vehicle Accidents: Validation and Extensions of a Computer Simulation", CAL No. VJ-2251-V-3, December, 1968.

APPENDIX A

APPENDIX A

General Abbreviations

CAL		Cornell Aeronautical Laboratory
CAL-COMP-		California Computer Products, Inc.
CALSVA	-	Cornell Aeronautical Laboratory Single Vehicle Accident
HVOSM	-	Highway-Vehicle-Object-Simulation Model
TTI	-	Texas Transportation Institute

APPENDIX B

APPENDIX B - DEFINITIONS OF INPUT PARAMETERS, LISTED ALPHABETICALLY

DESCRIPTION	ICARD
A=DISTANCE ALONG THE VEHICLE-FIXED X-AXIS FROM THE SPRUNG M :R OF GRAVITY TO THE CENTERLINE OF THE FRONT WHEELS	4
AAA=APPLICABLE ONLY IF MODE = 0, SEE PINT1 ROUTINE	2
AKF=SUSPENSION LOAD-DEFLECTION RATE FOR A SINGLE WHEEL, EFFECTIVE AT THE WHEEL IN THE QUASI-LINEAR RANGE ABOUT THE DESIGN POSITION FOR FRONT SUSPENSION	5
AKPS=LOAD-DEFLECTION OF THE ELASTIC STOPS IN THE STEERING SYSTEM, EFFECTIVE AT THE WHEELS (BOTH SIDES INCLUDED)	17
AKRS=REAR AXLE ROLL-STEER COEFFICIENT	6
AKR=SUSPENSION LOAD-DEFLECTION RATE FOR A SINGLE WHEEL, EFFECTIVE AT THE WHEEL IN THE QUASI-LINEAR RANGE ABOUT THE DESIGN POSITION FOR REAR SUSPENSION	6
AKT=RADIAL TIRE RATE IN QUASI-LINEAR RANGE FOR A SINGLE CARD	7
AKV=LOAD-DEFLECTION CHARACTERISTIC OF VEHICLE STRUCTURE	19
AMU=TIRE-TO-GROUND FRICTION COEFFICIENT	7
AMUB=SPRUNG MASS-TO-BARRIER FRICTION COEFFICIENT	19
AMUC=TIRE-TO-CURB FRICTION COEFFICIENT	15
AMUXY=FRICTION COEFFICIENT FOR A PARTICULAR FRICTION PATCH	14
A0=COEFFICIENT IN THE FUNCTIONAL RELATIONSHIPS FITTED TO TIRE S FORCE DATA	7
A1=COEFFICIENT IN THE FUNCTIONAL RELATIONSHIPS FITTED TO TIRE S FORCE DATA	7
A2=COEFFICIENT IN THE FUNCTIONAL RELATIONSHIPS FITTED TO TIRE SIDE FORCE DATA	7
A3=COEFFICIENT IN THE FUNCTIONAL RELATIONSHIPS FITTED TO TIRE SIDE FORCE DATA	7
A4=COEFFICIENT IN THE FUNCTIONAL RELATIONSHIPS FITTED TO TIRE SIDE FORCE DATA	7
B=DISTANCE ALONG THE VEHICLE-FIXED X-AXIS FROM THE SPRUNG MASS :R OF	

GRAVITY TO THE CENTERLINE OF THE REAR WHEELS 4
BET=APPLICABLE ONLY IF MODE = 0, SEE PINT1 ROUTINE 2
CF=VISCOUS DAMPING COEFFICIENT FOR A SINGLE WHEEL, EFFECTI WHEEL,
FOR FRONT SUSPENSION
CFP=COULOMB DAMPING FOR A SINGLE WHEEL, EFFECTIVE AT THE WHEEL, FOR FRONT
SUSPENSION 5
CONS=RATIO OF CONSERVED ENERGY TO MAXIMUM ENERGY ABSORBED BY BARRIER 19
CPSP=COULOMB RESISTANCE IN STEERING SYSTEM, EFFECTIVE AT THE WHEELS,
(BOTH SIDES INCLUDED) 17
CR=VISCOUS DAMPING COEFFICIENT FOR A SINGLE WHEEL, EFFECTIVE AT THE WHEEL,
FOR REAR SUSPENSION 6
CRP=COULOMB DAMPING FOR A SINGLE WHEEL, EFFECTIVE AT THE WHEEL, FOR REAR
SUSPENSION 6
DDEL=INCREMENT FOR DELTA(F) 12
DELB=INITIAL VALUE FOR DELTA(F) 12
DELE=FINAL VALUE FOR DELTA(F) 12
DELTB=INCREMENT OF INTEGRATION DURING BARRIER COLLISION 19
DELTC=INCREMENT OF INTEGRATION DURING CURB IMPACT 15
DELYBP=SIZE OF INCREMENTING STEP IN ESTABLISHING FORCE BALANCE BETWEEN
VEHICLE AND BARRIER 18
DEL10=INITIAL VALUE OF DELTA(1) (SUSPENSION DEFLECTION RELATIVE THE
VEHICLE FROM THE POSITION OF STATIC EQUILIBRIUM AT THE RIG RONT
WHEEL CENTER) 10
DEL10D=INITIAL VALUE OF SUSPENSION VELOCITY (FIRST TIME DERIVATIV DELTA(1))10
DEL20=INITIAL VALUE OF DELTA(2) (SUSPENSION DEFLECTION RELATIVE TO THE
VEHICLE FROM THE POSITION OF STATIC EQUILIBRIUM AT THE LEFT FRONT
WHEEL CENTER) 10
DEL20D=INITIAL VALUE OF SUSPENSION VELOCITY (FIRST TIME DERIVATIVE OF DELTA(2))10
DEL30=INITIAL VALUE OF DELTA(3) (SUSPENSION DEFLECTION RELATIVE TO THE
VEHICLE FROM THE POSITION OF STATIC EQUILIBRIUM AT THE REAR AXLE
ROLL CENTER) 10
DEL30D=INITIAL VALUE OF SUSPENSION VELOCITY (FIRST TIME DERIVATIVE ELTA(3))10
DTCOMP=INCREMENT OF INTEGRATION 1
DTCMP1=0.0,PROGRAM COMPUTES INITIAL POSITION OF VEHICLE TO REST ON AIN 1
=1.0, USER PROVIDES ALL INITIAL POSITION DATA 1
DTPRNT=OUTPUT INTERVAL 1
DRWHJ=INCREMENT VALUE OF R(W)-H'(J) FOR F'(J) TABLE 16

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   EM=APPLICABLE ONLY IF MODE = 0, SEE PINT1 ROUTINE                                 2
  EBAR=APPLICABLE ONLY IF MODE = 0, SEE PINT1 ROUTINE                                2
  EPSB=ACCEPTABLE ERROR IN FORCE BALANCE BETWEEN VEHICLE STRUC          BARRIER19
  EPSF=FRICTION LAG IN FRONT SUSPENSICN TO PREVENT EXTRANEOUS (         ONS
       INDUCED BY ROUND-OFF ERROR IN SUSPENSION VELOCITIES                           5
 EPSPS=FRICTION LAG IN STEERING SYSTEM                                              17
  EPSR=FRICTION LAG IN REAR SUSPENSION TO PREVENT EXTRANECUS OSCILLATIONS
       INDUCED BY ROUND-OFF ERROR IN SUSPENSION VELOCITIES                           6
  EPSV=FRICTION LAG IN VEHICLE-TO-BARRIER FRICTION FORCE
 FRFAC=COEFFICIENT OF FRICTION BETWEEN THE VEHICLE AND TERRAIN                      23
     G=386.4                                                                         3
  HMAX=APPLICABLE ONLY IF MODE = 0, SEE PINT1 ROUTINE                                2
  HMIN=APPLICABLE ONLY IF MODE = 0, SEE PINT1 ROUTINE                                2
  INDB=1.0 RIGID BARRIER FINITE VERTICAL DIM.                                       19
  INDB=2.0 RIGID BARRIER INFINITE VERTICAL DIM.                                     19
  INDB=3.0 DEFORMABLE BARRIER FINITE VERTICAL DIM.                                  19
  INDB=4.0 DEFORMABLE BARRIER INFINITE VERTICAL DIM.                                19
INDCRB=0.0 NO CURB INPUT                                                             1
      =1.0 ACTIVATES STEER DEGREE OF FREEDOM AND RADIAL SPRING TIRE MODEL
       (CURB INPUT)                                                                  1
      =-1.0 ACTIVATES STEER DEGREE ONLY (BARRIER INPUT)                              1
  ITEMP(I)=TEMPLATE NO. (I.E., 1,2,3.....21)                                        14
  MODE=MODE OF INTEGRATION=0.0 VARIABLE ADAMS-MOULTON                                2
                          =1.0 RUNGE-KUTTA                                           2
                          =2.0 FIXED ADAMS-MOULTON                                   2
   NBX=NO. OF TEMPLATES ALONG X'-AXIS                                               14
   NBY=NO. OF POINTS IN Y' DIRECTION ON EACH TEMPLATE                               14
 NMUXY=NO. OF VARIABLE COEFFICIENT FRICTION PATCHES                                 14
 NTBL1= =0.0 MEANS DO NOT READ PSI(F) TABLE                                         13
 NTBL2= =0.0 MEANS DO NOT READ TQ(F) TABLE                                          13
 NTBL3= =0.0 MEANS DO NOT READ TQ(R) TABLE                                          13
   NVP=NUMBER OF POINTS ON THE VEHICLE WHICH ARE TO BE MONITORED FOR CONTACT        23
       WITH THE GROUND
 OMEGF=MAXIMUM SUSPENSION DEFLECTIONS, FROM THE POSITION OF STATIC      LIBRIUM
       RELATIVE TO THE VEHICLE, FOR QUASI-LINEAR LOAD-DEFLECTION
       CHARACTERISTICS OF THE SPRINGS FOR FRONT SUSPENSION                           5
 OMEGR=MAXIMUM SUSPENSION DEFLECTIONS, FROM THE POSITION OF STATIC      LIBRIUM
```

RELATIVE TO THE VEHICLE, FOR QUASI-LINEAR LOAD-DEFLECTIC
CHARACTERISTICS OF THE SPRINGS FOR REAR SUSPENSION 6
OMEGT=DECIMAL PORTION OF A(2)AT WHICH THE ASSUMED PARABOLIC VA OF SIDE
FORCE WITH TIRE LOADING IS ABANDONED TO PRECLUDE REVERSA SIGN
OF THE SIDE LOAD UNDER CONDITIONS OF EXCESSIVE TIRE LOADING 7
OMGPS=ANGULAR DEFLECTION OF THE STEERING SYSTEM AT WHICH ELASTIC STOPS ARE
ENCOUNTERED 17
PHIC=FRONT WHEEL CAMBER 12
PHIC1=FIRST CURB SLOPE ECOUNTERED BY THE VEHICLE 15
PHIC2=SECOND CURB SLOPE ENCOUNTERED BY THE VEHICLE 15
PHILRO=INITIAL VALUE OF PHI(R) (ANGULAR DISPLACEMENT OF THE REAR AXLE
RELATIVE TO THE VEHICLE ABOUT A LINE PARALLEL TO THE X-AXIS THROUGH
THE REAR AXLE ROLL CENTER, POSITIVE WHEN CW VIEWED FROM REAR) 10
PHIO=INITIAL VALUE OF PHI (EULER ANGULAR COORDINATES OF SPRUNG MASS RELATIVE
TO SPACE-FIXED SYSTEM) 8
PHIROD=INITIAL VALUE OF ANGULAR VELOCITY OF REAR AXLE (FIRST TIME DERIVATIVE
OF PHI(R) 10
PO=INITIAL VALUE OF P (SCALAR COMPONENT OF SPRUNG MASS ANGULAR VELOCITY,
TAKEN ALONG X-AXIS 8
PQRMIN=STOPPING TEST=0.0 1
PSIF=STEERING ANGLE OF FRONT WHEELS RELATIVE TO VEHICLE COORDIN. XES 13
SYSTEM, POSITIVE FOR CLOCK-WISE STEER AS VIEWED FROM ABOVE ICLE,
DEGREES
PSIFDO=INITIAL VALUE OF STEERING ANGULAR VELOCITY (FIRST TIME DER IVE OF
PSI(F)) 8
PSIFIO=INITIAL VALUE OF PSI(F) (STEER ANGLE OF FRONT WHEELS RELATIVE TO VEHICLE
COORDINATE AXES SYSTEM, POSITIVE FOR CW STEER AS VIEWED FROM ABOVE
VEHICLE) 8
PSIO=INITIAL VALUE OF PSI (EULER ANGULAR COORDINATES OF SPRUNG MASS RELATIVE
TO SPACE-FIXED SYSTEM) 8
QO=INITIAL VALUE OF Q (SCALAR COMPONENT OF SPRUNG MASS ANGULAR VELOCITY,
TAKEN ALONG Y-AXIS 8
RF=AUXILIARY ROLL STIFFNESS AT THE FRONT SUSPENSION 5
RHO=DISTANCE BETWEEN C.G. OF REAR AXLE AND REAR AXLE ROLL CENTE SITIVE
FOR ROLL CENTER ABOVE C.G. 4
RO=INITIAL VALUE OF R (SCALAR COMPONENT OF SPRUNG MASS ANGULAR CITY,
TAKEN ALONG Z-AXIS 8

RR=AUXILIARY ROLL STIFFNESS AT THE REAR SUSPENSION 5
RW=UNDEFLECTED RADIUS OF WHEELS 4
RWHJB=INITIAL VALUE OF R(W)-H'(J) FOR F'(J) TABLE 16
RWHJE=FINAL VALUE OF R(W)-H'(J) FOR F'(J) TABLE 16
SET=RATIO OF PERMANENT DEFLECTION TO MAXIMUM DEFLECTION OF 19
SIGR=POLYNOMIAL COEFFICIENTS FOR BARRIER FORCE-DEFLECTION CU 20
SIGT=MAXIMUM RADIAL TIRE DEFLECTION FOR QUASI-LINEAR LOAD-DEFLECTION
CHARACTERISTIC 7
SSTIFF=STIFFNESS OF EQUIVALENT GROUND SPRING 23
TB=INITIAL TIME FOR DRIVER CONTROL INPUTS 13
TE=FINAL TIME FOR DRIVER CONTROL INPUTS 13
TF=TREAD AT FRONT SUSPENSION 4
THETAO=INITIAL VALUE OF THETA (EULER ANGULAR COORDINATES OF SPRUNG MASS
RELATIVE TO SPACE-FIXED SYSTEM) 8
THMAX=VALUE OF THETA AT WHICH WE SHIFT PLANES USUALLY=70 DEGREES 1
TINCR=INCREMENT TIME FOR DRIVER CONTROL INPUTS 13
TI=END TIME 1
TO=START TIME 1
TQF=APPLIED TORQUE FOR A SINGLE FRONT WHEEL, EFFECTIVE AT THE WHEEL 13
(POSITIVE FOR TRACTION, NEGATIVE FOR BRAKING), LB.-FT.
TQR=APPLIED TORQUE FOR A SINGLE REAR WHEEL, EFFECTIVE AT THE WHEEL 13
(POSITIVE FOR TRACTION, NEGATIVE FOR BRAKING), LB.-FT.
TR=TREAD AT REAR SUSPENSION 4
TS=DISTANCE BETWEEN SPRING CONNECTIONS FOR SOLID REAR AXLE 6
UO=INITIAL VALUE OF U (SCALAR COMPONENT OF LINEAR VELOCITY PRING
MASS TAKEN ALONG X-AXIS) 9
UVWMIN=STOPPING TEST=0.0 1
VO=INITIAL VALUE OF V (SCALAR COMPONENT OF LINEAR VELOCITY OF SPRING
MASS TAKEN ALONG Y-AXIS) 9
WO=INITIAL VALUE OF W (SCALAR COMPONENT OF LINEAR VELOCITY OF SPRING
MASS TAKEN ALONG Z-AXIS) 9
XB=INITIAL X' VALUE FOR TERRAIN TABLES 14
XCOP=INITIAL VALUE OF X'(C) (COORDINATE OF THE SPRING MASS C.G. RELATIVE TO
THE SPACE-FIXED COORDINATE AXES SYSTEM) 9
XE=FINAL X' VALUE FOR TERRAIN TABLES 14
XINCR=INCREMENT X' VALUE FOR TERRAIN TABLES 14
XIPS=MOMENT OF INERTIA OF STEERING SYSTEM, EFFECTIVE AT FRONT W ,

(BOTH SIDES INCLUDED) 17

XIR=REAR UNSPRUNG MASS MOMENT OF INERTIA ABOUT A LINE THROUGH TER OF GRAVITY AND PARALLEL TO THE X-AXIS 3

XIX=MOMENT OF INERTIA OF SPRUNG MASS ABOUT X-AXIS 3

XIXZ=PRODUCT OF INERTIA OF SPRUNG MASS 3

XIY=MOMENT OF INERTIA OF SPRUNG MASS ABOUT Y-AXIS 3

XIZ=MOMENT OF INERTIA OF SPRUNG MASS ABOUT Z-AXIS 3

XJ=SOIL DAMPING CONSTANT 23

XLAMF=MULTIPLES OF AKF FOR USE IN SUSPENSION DEFLECTION STOPS 5

XLAMR=MULTIPLES OF AKR FOR USE IN SUSPENSION DEFLECTION STOPS 6

XLAMT=MULTIPLE OF AKT FOR USE IN NONLINEAR RANGE 7

XMUF=FRONT UNSPRUNG MASS (BOTH SIDES) 3

XMUR=REAR UNSPRUNG MASS 3

XMS=SPRUNG MASS 3

XPS=PNEUMATIC TRAIL OF FRONT TIRES 17

XTEMP(I)=X'(G) VALUE OF TEMPLATE ITEMP(I) 14

XVF=DISTANCE FROM C.G. OF VEHICLE TO FRONT OF VEHICLE MEASURED ALONG X-AXIS 18

XVP(I)=X-COORDINATE OF POINT I ON THE VEHICLE, IN VEHICLE FIXED COORDINATES 23

XVR=DISTANCE FROM C.G. OF VEHICLE TO REAR OF VEHICLE MEASURED ALONG X-AXIS 18

X1=COORDINATE OF ACCELEROMETER POSITION ON THE SPRUNG MASS, AT CH ACCELERATION COMPONENTS ARE TO BE CALCULATED AND PRINTED OU ITH REFERENCE TO THE VEHICLE FIXED AXIS) 11

X2=COORDINATE OF ACCELEROMETER POSITION ON THE SPRUNG MASS, AT CH ACCELERATION COMPONENTS ARE TO BE CALCULATED AND PRINTED OU ITH REFERENCE TO THE VEHICLE FIXED AXIS) 11

YB=INITIAL Y' VALUE FOR TERRAIN TABLES 14

YBPO=DISTANCE BETWEEN BARRIER PLANE AND THE X'-Z' PLANE 18

YCIP=INITIAL BOUNDARY OF CURB TO BE ENCOUNTERED BY VEHICLE (FIRST SLOPE CHANGE) 15

YCOP=INITIAL VALUE OF Y'(C) (COORDINATE OF THE SPRING MASS C.G. RELATIVE TO THE SPACE-FIXED COORDINATE AXES SYSTEM) 9

YC2P=BOUNDARY OF SECOND SLOPE OF CURB 15

YE=FINAL Y' VALUE FOR TERRAIN TABLES 14

YINCR=INCREMENT Y' VALUE FOR TERRAIN TABLES 14

YGP(I,J)=Y'(G) VALUE OF POINT J=1 ON TEMPLATE I TEMPLATE ITEMP(I) 14

YGP(I,J+1)=Y'(G) VALUE OF POINT J=2 ON TEMPLATE ITEMP(I) 14

YV=DISTANCE FROM C.G. OF VEHICLE TO EITHER SIDE OF VEHICLE MEASURED ALONG

THE Y-AXIS 18
YVP(I)=Y-COORDINATE OF POINT I ON THE VEHICLE, IN VEHICLE FIXE ATES 23
Y1=COORDINATE OF ACCELEROMETER POSITION ON THE SPRUNG MASS H
ACCELERATION COMPONENTS ARE TO BE CALCULATED AND PRINTE TH
REFERENCE TO THE VEHICLE FIXED AXIS) 11
Y2=COORDINATE OF ACCELEROMETER POSITION ON THE SPRUNG MASS H
ACCELERATION COMPONENTS ARE TO BE CALCULATED AND PRINTED OUT (WITH
REFERENCE TO THE VEHICLE FIXED AXIS) 11
ZBBP=THE ELEVATION OF THE BOTTOM OF THE BARRIER RELATIVE TO THE X'-Y' PLANE 18
ZBTP=THE ELEVATION OF THE TOP OF THE BARRIER RELATIVE TO THE X'-Y' PLANE 18
ZCOP=INITIAL VALUE OF Z'(C) (COORDINATE OF THE SPRING MASS C.G. RELATIVE TO
THE SPACE-FIXED COORDINATE AXES SYSTEM) 9
ZC2P=ELEVATION OF CURB PROFILE AT YC2P 15
ZF=STATIC DISTANCE ALONG THE Z-AXIS BETWEEN THE C.G. OF THE SPRUNG MASS
AND THE C.G.OF THE FRONT UNSPRUNG MASSES 4
ZGP(I,J)=Z'(G) VALUE OF POINT J=1 ON TEMPLATE ITEMP(I) 14
ZGP(I,J+2)=Z'(G) VALUE OF POINT J=2 ON TEMPLATE ITEMP(I) 14
ZR=STATIC DISTANCE ALONG THE Z-AXIS BETWEEN THE C.G. OF THE SPRUNG MASS
AND THE ROLL CENTER OF THE REAR AXLE 4
ZVB=DISTANCE FROM C.G. OF VEHICLE TO BOTTOM OF VEHICLE MEASURED ALONG
Z-AXIS 18
ZVP(I)=Z-COORDINATE OF POINT I ON THE VEHICLE, IN VEHICLE FIXED C INATES 23
ZVT=DISTANCE FROM C.G. OF VEHICLE TO TOP OF VEHICLE MEASURED A Z-AXIS 18
Z1=COORDINATE OF ACCELEROMETER POSITION ON THE SPRUNG MASS, A ICH
ACCELERATION COMPONENTS ARE TO BE CALCULATED AND PRINTED C WITH
REFERENCE TO THE VEHICLE FIXED AXIS) 11
Z2=COORDINATE OF ACCELEROMETER POSITION ON THE SPRUNG MASS, A ICH
ACCELERATION COMPONENTS ARE TO BE CALCULATED AND PRINTED OUT (WITH
REFERENCE TO THE VEHICLE FIXED AXIS) 11

APPENDIX C

APPENDIX C - LIST OF PROGRAM VARIABLES

FORTRAN NAME	PROGRAM VARIABLE		DESCRIPTION
A,B	a, b	=	distances along the vehicle-fixed axis from the sprung mass center of gravity to the center lines of the front and rear wheels, respectively, inches.
A0,A1,A2,A3,A4	A_0, A_1, A_2, A_3, A_4	=	constant coefficients in parabolas fitted to tire side-force properties.
AMTX	$\|A\|$	=	matrix for transformations from the vehicle-fixed coordinate system to the space-fixed coordinate system.
	$\|A^T\|$	=	transpose of $\|A\|$. Note that the transpose and the inverse of $\|A\|$ are identical, since $\|A\|$ is orthogonal.
	$(A_{INT})_i$	=	intersection area of cutting plane i with the sprung mass, in^2.
	C_{co}	=	small-angle camber stiffness, lbs/radian.
	C_{so}	=	small-angle cornering stiffness, lbs/radian.
CF,CR	C_F, C_R	=	viscous damping coefficient for a single wheel, effective at the wheel for the front and at the spring for the rear suspension, at the front and rear, respectively, lb-sec/in.
CFP,CRP	C_F', C_R'	=	coulomb damping for a single wheel, effective at the wheel for the front and at the spring for the rear suspension, at the front and rear, respectively, lbs.

CPSF	C'_{ψ}	= coulomb resistance in steering sy effective at the wheels (both sid included), lb-in.
	a_i, b_i, c_i	= directional components of a line perpendicular to both the normal to the wheel plane and the radial tire force, F_{R_i} .
	a'_i, b'_i, c'_i	= directional components of lines in the cutting plane i , perpendicular to the line between $(X_1, Y_1, Z_1)_i$ $(X_2, Y_2, Z_2)_i$.
AS,BS,CS	$a_{s_i}, b_{s_i}, c_{s_i}$	= direction components of a line per dicular both to a normal to the ti terrain contact plane and to the w axis, X_{ω_i} , at wheel i .
AX,BX,CX	$a_{x_i}, b_{x_i}, c_{x_i}$	= direction components of a line perpendicular both to a normal to the tire-terrain contact plane and to the vehicle-fixed Y axis, at wheel i .
AY,BY,CY	$a_{y_i}, b_{y_i}, c_{y_i}$	= direction components of a line perpendicular both to a normal to the tire-terrain contact plane and the vehicle-fixed X axis, at wheel i .
CONS	$\overline{CONS}$	= ratio of conserved energy to maximum energy absorbed by barrier.
D1,D2,D3	$D_{1_i}, D_{2_i}, D_{3_i}$	= direction components of a line perpendicular to the normals of both the whee plane and the tire-terrain contact plan at wheel i .
	F_B	= resistance force measured normal to the contact surface of a deformable barrie lbs.
FC	F_{c_i}	= circumferential tire force (i.e., trac or braking force) at wheel i , lbs.

	$(F_N)_t$	=	vehicle force produced by deformation of vehicle structure, measured normal to contacted surface, lbs.
FR	F_{R_i}	=	radial tire force at wheel i, lbs.
FRCP	F'_{R_i}	=	tire force perpendicular to the tire-terrain contact plane at wheel i, lbs.
	$\overline{FRICT}$	=	friction force acting between the vehicle sprung mass and a barrier.
FS	F_{s_i}	=	tire side force in the plane of the tire-terrain contact patch, perpendicular to the line of intersection of the wheel and ground planes at wheel i, lbs.
F1FI,F1RI	F_{1F_i}, F_{1R_i}	=	coulomb damping forces in front and rear suspensions, at an indivudual wheel, effective at wheels in front and at spring locations in rear, lbs.
F2FI,F2RI	F_{2F_i}, F_{2R_i}	=	suspension forces produced by deflection of springs and elastic travel limits, lbs.
FCXU FCYU FCZU	F_{cxu_i} F_{cyu_i} F_{czu_i}	=	components of the circumferential tire force at wheel i along the sprung mass X, Y, Z axes, lbs.
FRXU FRYU FRZU	F_{Rxu_i} F_{Ryu_i} F_{Rzu_i}	=	components of F'_{R_i} at wheel i along the sprung mass X, Y, Z axes, lbs.
FSXU FSYU FSZU	F_{sxu_i} F_{syu_i} F_{szu_i}	=	components of tire side force, F_{s_i}, at wheel i along the sprung mass X, Y, Z axes, lbs.
SFXS SFYS SFZS	ΣF_{xs} ΣF_{ys} ΣF_{zs}	=	components of sprung mass impact force along the sprung mass axes, lbs.

FXU FYU FZU	$F_{xui}, F_{yui}, F_{zui}$	= tire force components along vehicl axes, lbs.
	F'_{ci}	= value of circumferential tire force that is used in approximating the effects of differential gears, at wheel i , lbs.
	F'_{si}	= tire side force for small slip angles and for "equivalent" slip angles t approximate camber effects, at whe i , lbs.
	$(F_{si})_{max}$	= Maximum possible tire side force a wheel i , lbs.
GAIN	(GAIN)	= closed-loop steer control parameter, radians/inch.
G	g	= acceleration of gravity = 386.4 in/sec^2
HI	h_i	= rolling radius of wheel i , inches.
XIR	I_R	= rear unsprung mass moment of inertia about a line through its center of gravi and parallel to the X axis, lb-sec^2-in.
XIX,XIY,XIZ,XIXZ	I_x, I_Y, I_z, I_{xz}	= moments and product of inertia of sprung mass, lb-sec^2-in.
	i	= wheel identification-- 1, 2, 3, 4 = RF, LF, RR, LR, respectively.
XIPS	I_ψ	= moment of inertia of steering system effective at front wheels (both sides included), lb-sec^2-in.
AKF,AKR	K_F, K_R	= suspension load-deflection rate for a single wheel in the quasi-linear range about the design position, effective a the wheel for the front and at the spr for the rear suspension, at the front rear, respectively, lb/in.

AKT	K_T	=	radial tire rate in quasi-linear range for a single tire, lb/in.
AKRS	K_{RS}	=	rear axle roll-steer coefficient (positive for roll understeer)
AKPS	K_ψ	=	load deflection rate of elastic stops in the steering system, effective at the wheels (both sides included), lb-in/rad, reference Fig. C-1.
AKV	K_v	=	load-deflection characteristic of vehicle structure, lb/in^3.
DELPTH	m	=	time increment between sampling times for closed-loop steer control, sec.
XMS	M_s	=	sprung mass, lb-sec^2/in.
XMUF	M_{uF}	=	front unsprung mass (both sides), lb-sec^2/in.
	$M_1 = M_2 = \frac{M_{uF}}{2}$	=	front unsprung mass at a single wheel, lb-sec^2/in.
XMUR	$M_3 = M_{uR}$	=	rear unsprung mass, lb-sec^2/in.
	$\Sigma N_{\phi s}$, $\Sigma N_{\theta s}$, $\Sigma N_{\psi s}$	=	components of moments on sprung mass produced by sprung mass impact forces, lb-in.
	$N_{\phi u}$, $N_{\theta u}$, $N_{\psi u}$	=	moments produced by forces acting on the unsprung masses, lb-in.
	$N_{\phi R}$	=	rolling moment acting on the rear axle, lb-in.
P,Q,R	P, Q, R	=	scalar components of sprung mass angular velocity, taken along X, Y, Z axes, respectively, radians/sec.
XPS	$\overline{PT}$	=	pneumatic trail of front tires, inches.

RF,RR	R_F, R_R	= auxiliary roll stiffness (i.e., roll stiffness in excess of that corresponding to the front wheel rates in ride and to the rear spring rates and spacing), at the front and rear suspensions, respectively, lb-in/radian.
RW	R_W	= undeflected radius of wheels, inches.
	R_{Bi}, R_{BT}, R_{BB}	= constants for barrier face plane, top plane and bottom plane, in.
	$(S_1)_i, (S_2)_i, (S_3)_i$	= the two heights and base, respectively of the triangles used in calculation of the intersection area at cutting plane i, in.
SET	$\overline{SET}$	= ratio of permanent deflection to maximum deflection of barrier.
SI	S_i	= total suspension force produced by the combination of springs, travel stops, viscous damping, friction, and auxiliary roll stiffness, effective at the wheel for the front suspension and at the spring location for the rear suspension, at wheel i, lbs.
	SP_1 through SP_{30}	= polynomial coefficients for curves defining desired vehicle path.
	t	= time, seconds.
DELTC	$(\Delta t)_c$	= time increment size used during curb contact, sec.
TF,TR	T_F, T_R	= tread at front and rear suspensions, respectively, inches.
TI	T_i	= circumferential tire force corresponding to the applied torque at wheel i, which is subjected to force-limiting logic, lbs.

TQF,TQR	$\overline{TQ}_F$, $\overline{TQ}_R$	=	tabular inputs of applied torque for a single wheel, effective at the wheel, for front and rear wheels, respectively (positive for traction, negative for braking), lb-ft.
TS	T_S	=	distance between spring connections for solid rear axle, inches.
	$T_{1\psi}$	=	coulomb friction torque in steering system, effective at wheel i , lb-in.
	$T_{2\psi}$	=	resistance torque produced by front wheel steer angle stops, effective at wheel i, lb-in.
U,V,W	u, v, w	=	scalar components of linear velocity of the sprung mass, taken along the X , Y , Z axes, respectively, inches/sec.
	u', v', w'	=	scalar components of linear velocity of sprung mass, taken along space-fixed X', Y' , Z' axes, respectively, inches/sec.
UG	u_{G_i}	=	forward velocity of wheel center in the direction parallel to the tire-terrain contact plane, inches/sec.
	$\lvert u_{G_i} \rvert$	=	absolute value of u_{G_i}.
	$1 \text{ sgn } u_{G_i}$	=	algebraic sign of u_{G_i} .
	u'_n, v'_n, w'_n	=	scalar components of the velocity of the three or four points that define the intersection area of the barrier and the vehicle along the space-fixed axes, in/sec.

	u'_R, v'_R, w'_R	= scalar components of the velocity of the point of application of the spru mass contact force along the space-fixed axes, in/sec.
VG	v_{G_i}	= lateral velocity of the contact point of wheel i in the direction parallel to the tire-terrain contact plane, inches/sec.
	$\overline{VTAN}$	= velocity of the point of application of the sprung mass impact force tangential to the barrier, in/sec.
	X_{VP}	= vehicle reference dimension for closed-loop steer control, inches.
	X, Y, Z	= coordinates of a point relative to the vehicle-fixed coordinate axes system, inches.
	X', Y', Z'	= coordinates of a point relative to the space-fixed coordinate axes system, inches.
X1,Y1,Z1 X2,Y2,Z2	X_1, Y_1, Z_1 X_2, Y_2, Z_2	= coordinates of accelerometer positions on the sprung mass, at which acceleration components are to be calculated and printed out, inches.
	$X_{B_i}, Y_{B_i}, Z_{B_i}$	= coordinates of the intersection of the Y' axis with barrier cutting plane i, in the vehicle-fixed axes, inches.
X	X_{BT}, Y_{BT}, Z_{BT}	= coordinates of the intersection of the Z' axis with the barrier top plane in the vehicle-fixed axes, inches.
	X_{BB}, Y_{BB}, Z_{BB}	= coordinates of the intersection of the Z' axis with the barrier bottom plane in the vehicle-fixed axes, inches.

	$X'_{CPn}, Y'_{CP}, Z'_{CPn}$	=	coordinates of vehicle corner point n in the space-fixed axes, inches.
XCP,YCP,ZCP	X'_c, Y'_c, Z'_c	=	coordinates of the sprung mass center of gravity relative to the space-fixed coordinate axes system, inches.
	$(X_R)_i, (Y_R)_i, (Z_R)_i$	=	coordinates of the centroid of the intersection area on barrier cutting plane i, projected onto the actual vehicle-barrier interface of the previous time increment, inches.
	$(\Sigma X_R)_t, (\Sigma Y_R)_t, (\Sigma Z_R)_t$	=	the coordinates of the point of application of the sprung mass impact forces, inches.
	Y'_B	=	Y' coordinate of barrier face plane, inches.
YCIP	Y'_{C1}	=	initial boundary of curb to be encountered by vehicle, inches.
XC2P	Y'_{C2}	=	boundary of second slope change of curb, inches.
	$Y'_{P1}, Y'_{P2}, Y'_{P3}, Y'_{P4}$	=	transition boundaries for polynomial curves defining desired vehicle path, inches.
ZC2P	Z'_{C2}	=	elevation of curb profile at Y'_{C2}.
XGPP,YGPP,ZGPP	$X'_{GPi}, Y'_{GPi}, Z'_{GPi}$	=	coordinates of the "ground contact point" of wheel i relative to the space-fixed coordinate axes system, inches.
ZF	Z_F	=	static distance along the Z axis between the center of gravity (c.g.) of the sprung mass and the c.g. of the front unsprung masses (c.g. of the individual front masses assumed to coincide with the wheel centers), inches.

ZR	Z_R	=	static distance along the Z axis between the c.g. of the sprung mass and the roll center of the rear axle, inches.
ZPGI	Z'_{Gi}	=	ground elevation with respect to space-fixed Z' axis, under the center of wheel i, inches.
	$\bar{Z}'_{Gi}$	=	a vector through the ground contact point, normal to the actual or "equivalent" tire-terrain contact plane, at wheel i (Fig. 4.4, Ref. 3
XVF,XVR,YV,ZVT,ZVB	$X_{VF}, X_{VR}, Y_V, Z_{VT}, Z_{VB}$	=	vehicle dimensions for sprung mass impact, inches.
ZBTP,ZBBP	Z'_{BT}, Z'_{BB}	=	elevations of barrier top and bottom planes for sprung mass impact, inches.
CAB CBB CGB	$\cos\alpha_B$ $\cos\beta_B$ $\cos\gamma_B$	=	directional cosines of a normal to the barrier face plane relative to the vehicle-fixed axes.
	$\cos\alpha_B$ $\cos\beta_B$ $\cos\gamma_B$	=	directional cosines of a normal to the barrier top and bottom planes relative to the vehicle-fixed axes.
CAC CBC CGC	$\cos\alpha_{ci}$ $\cos\beta_{ci}$ $\cos\gamma_{ci}$	=	direction cosines of a line perpendicu[illegible] to the normals both of the wheel plane and the tire-terrain contact plane at wheel i.
CAGZ CBGZ CGGZ	$\cos\alpha_{GZ'i}$ $\cos\beta_{GZ'i}$ $\cos\gamma_{GZi}$	=	direction cosines of a normal to the tire-terrain contact plane at wheel i.
CAH CBH CGH	$\cos\alpha_{hi}$ $\cos\beta_{hi}$ $\cos\gamma_{hi}$	=	directional cosines of the resultant radial force on wheel i, with respect to the vehicle-fixed axes.

	$\cos\alpha_j$, $\cos\beta_j$, $\cos\gamma_j$	=	directional cosines of a line to wheel center i, from the point of contact with the ground (or curb) of radial spring j, relative to the space-fixed axes.
CAR, CBR, CGR	$\cos\alpha_{Ri}$, $\cos\beta_{Ri}$, $\cos\gamma_{Ri}$	=	direction cosines of the resultant radial force on wheel i, with respect to the space-fixed axes.
CAS, CBS, CGS	$\cos\alpha_{si}$, $\cos\beta_{si}$, $\cos\gamma_{si}$	=	direction cosines of a line perpendicular both to a normal to the tire-terrain contact plane and to the wheel axis, $X_{\omega i}$, at wheel i.
CAX, CBX, CGX	$\cos\alpha_x$, $\cos\beta_x$, $\cos\gamma_x$	=	direction cosines of X axis.
CAY, CBY, CGY	$\cos\alpha_y$, $\cos\beta_y$, $\cos\gamma_y$	=	direction cosines of Y axis.
CAYW, CBYW, CGYW	$\cos\alpha_{Y\omega i}$, $\cos\beta_{Y\omega i}$, $\cos\gamma_{Y\omega i}$	=	direction cosines of a normal to the plane of wheel i.
CAZW, CBZW, CGZW	$\cos\alpha_{z\omega i}$, $\cos\beta_{z\omega i}$, $\cos\gamma_{z\omega i}$	=	directional cosines of the kingpin axis of wheel i (kingpin axis assumed to lie in wheel plane)
BET	β_i	=	slip angle at wheel i, radians.
BETBR	$\bar{\beta}_i$	=	non-dimensional slip angle variable for wheel i.
BETP	β'_i	=	"equivalent slip angle" produced by camber effects at wheel i, radians.
	$f(\bar{\beta}_i)$	=	non-dimensional side force at wheel i.

	δ_B	= barrier deflection, inches.
	$\Delta y'_B$	= size of increment between barrier cutting planes, i, inches.
DELTA	Δi	= distance from the center of wheel i to the "ground contact point", inches.
DEL1,DEL2,DEL3	$\delta_1, \delta_2, \delta_3$	= suspension deflections relative to the vehicle from the positions of static equilibrium, at the right front whee center, left front wheel center, anc rear axle roll center, respectively, inches.
	ϵ_n	= permanent set of barrier, inches.
EPSB	ϵ_B	= acceptable error in force balance between vehicle structure and barrier, lbs.
EPSF,EPSR	ϵ_F, ϵ_R	= friction lag in front and rear suspensions respectively, to prevent extraneous oscillations induced by round-off error in suspension velocities, in/sec.
EPSV	ϵ_V	= friction lag in vehicle-to-barrier friction force, in/sec.
EPSPS	ϵ_ψ	= friction lag in steering system, rad/se
	$(\zeta_0)_n, (\zeta_1)_n, (\zeta_2)_n$	= coefficients for parabolic form of barr load-deflection characteristics for barrier unloading.
ZETA3,ZETA4	ζ_3, ζ_4	= suspension deflections relative to the vehicle, from the positions of static equilibrium, measured at the right rear and left rear spring positions, respectively, inches.

	ϕ, θ, ψ	= Euler angular coordinates of sprung mass relative to the space-fixed axis system, radians.
	ϕ', θ', ψ'	= Euler angular coordinates of sprung mass relative to indexed intermediate reference axes systems (i.e., to permit unrestricted ranges of angular travel), radians.
	θ_{XG_i}	= angle between X-axis and tire-terrain contact plane at wheel i, radians.
PHGI,THGI	ϕ_{Gi}, θ_{Gi}	= Euler angular coordinates of terrain profile relative to the space-fixed axis system, under the center of wheel i, radians.
XLAMF,XLAMR	λ_F, λ_R	= multiples of K_F, K_R, respectively, for use in suspension deflection stops (Fig. 4.15, Ref. 3).
XLAMT	λ_T	= multiple of K_T for use in nonlinear range of tire deflection (i.e., travel limit).
AMU	μ	= tire-to-ground friction coefficient.
AMUC	μ_c	= tire-to-curb friction coefficient.
AMUB	μ_B	= sprung mass-to-barrier friction coefficient.
AMUI	μ_i	= tire-to-ground friction coefficient (dependent on tire location on terrain surface).
AMUXY	μ_{XY}	= tire-to-ground friction coefficient (variable over terrain surface).

RHO	ρ	= distance between center of gravity o rear axle and rear axle roll center, positive for roll center above c.g., inches.
SIGT	σ_T	= maximum radial tire deflection for quasi-linear load-deflection characteristic, inches.
SIGR	σ_R	= coefficients for polynomial form of barrier load-deflection characteristi (for increasing loading).
PHIC1,PHIC2	ϕ_{C1}, ϕ_{C2}	= first and second curb slopes encounte by the vehicle, radians.
PHIR	ϕ_R	= angular displacement of the rear axle relative to the vehicle about a line parallel to the X-axis through the rear axle roll center (positive when clockwise as viewed from the rear), radians.
PHI1, PHI2	ϕ_1, ϕ_2	= right front and left front wheel camber angles, respectively, relative to the vehicle-fixed coordinate axes (positive when clockwise as viewed from the rear), radians.

$$\left[\begin{array}{l} \phi_1 = \phi_c \text{ , evaluated for } \delta_f = \delta_1 \text{ (RF wheel).} \\ \phi_2 = -\phi_c \text{ , evaluated for } \delta_f = \delta_2 \text{ (LF wheel).} \\ \text{where } \phi_c \text{ vs } \delta_f = \text{Tabular Input.} \end{array}\right]$$

	ϕ_{YGi}	= angle between Y-axis and tire-terrain contact plane at wheel i , radians.
	ϕ_{CGi}	= camber angle of wheel i relative to its tire-terrain contact plane, radians.

PSIF,PSIF1,PSIF2 $\psi_f = \psi_1 = \psi_2$ = steer angle of front wheels relative to vehicle coordinate axes system, positive for clockwise steer as viewed from above vehicle (assumed equal at the two wheels), radians.

$\psi_3 = \psi_4$ $(= K_{RS}\phi_R)$ = steer angle of rear wheels relative to vehicle coordinate axes system, positive for CW steer as viewed from above vehicle, radians.

PSIIP ψ_i' = steer angle of wheel i in its tire-terrain contact plane, radians.

OMEGAF,OMEGAR Ω_F , Ω_R = maximum suspension deflections, from the positions of static equilibrium relative to the vehicle, for quasi-linear load-deflection characteristics of the springs (Fig. 4.15, Ref.3), inches.

OMGPS Ω_ψ = angular deflection of the steering system at which elastic stops are encountered, radians, reference Fig. C-1.

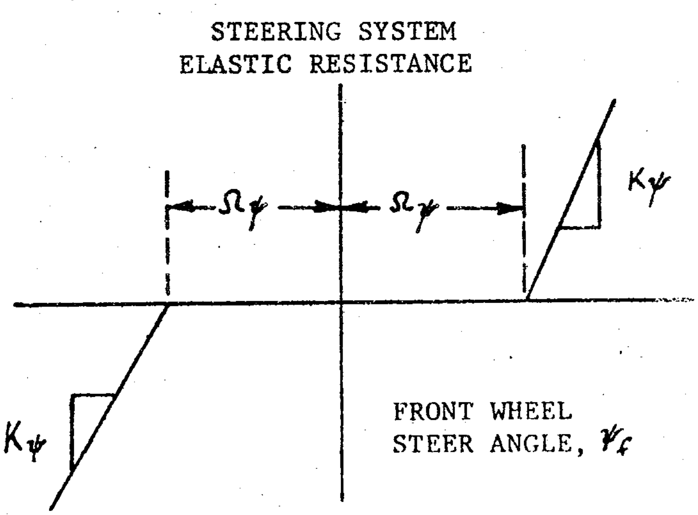

Figure C-1 STEERING SYSTEM ELASTIC RESISTANCE VS STEER ANGLE

OMEGT Ω_T = multiple of A_2 at which the assumed parabolic variations of small-angle cornering and camber stiffnesses with tire loading are abandoned to preclude reversal in the sign of the side force under conditions of excessive tire loading.

APPENDIX D

Appendix D - Derivation of Vehicle-Ground Interaction

Inevitably, for certain combinations of vehicle-maneuvers and terrain configurations, the vehicle body must come in contact with the terrain. To incorporate the effect of this occurrence in the vehicle's response, subroutine "VGCP" has been added to the original CALSVA program.

This subroutine essentially monitors certain points on the vehicle, selected and input by the user as explained in Part 2.1. Whenever any of the chosen vehicle-points engage the terrain, contact forces are computed and transferred to the center of gravity of the vehicle. The magnitudes of these forces depend on soil stiffness, soil damping characteristics, depth of penetration and velocity of the vehicle-point in question.

It was decided, after trying other ideas, that the soil should impart only two forces to the vehicle at the point in contact, namely a force normal to the terrain surface and a frictional force tangent to the terrain surface. To compute the magnitudes and directions of these two forces, the following parameters are needed:

(1) The amount of soil penetration, in a direction normal to the terrain surface, at the point of contact,

(2) The velocity vector of the point on the vehicle, in a direction normal to the terrain surface,

(3) The velocity vector of the point on the vehicle, in a direction tangent to the terrain surface.

The derivation of each of these parameters follows, and in each case, the actual Fortran names of the variables are used.

Amount of Soil Penetration Normal to Terrain

Consider a point "I" on the vehicle body defined by coordinates XVP(I), YVP(I), and ZVP(I) in vehicle-fixed coordinates,

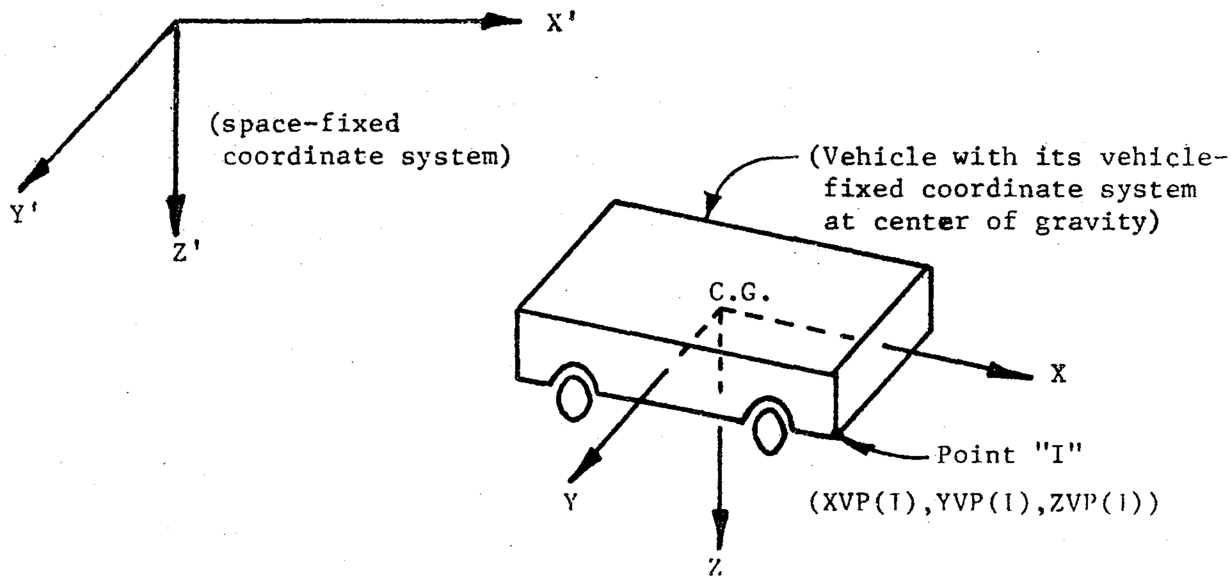

Figure D-1. Coordinate Systems

The coordinates of the vehicle point "I" in space-fixed coordinates (XVPP(I), YVPP(I), ZVPP(I)) are obtained by:

$$\begin{Bmatrix} XVPP(I) \\ YVPP(I) \\ ZVPP(I) \end{Bmatrix} = \begin{bmatrix} & & \\ & AMTX & \\ & & \end{bmatrix} \begin{Bmatrix} XVP(I) \\ YVP(I) \\ ZVP(I) \end{Bmatrix} + \begin{Bmatrix} X_c' \\ Y_c' \\ Z_c' \end{Bmatrix}$$

AMTX is a transformation matrix used to transform from vehicle-fixed to space-fixed coordinates (see page 185, Ref. 3). X_c', Y_c', and Z_c' are the coordinates of the vehicle center of gravity in the space-fixed system.

Now consider a top view (X'-Y' plane) of the terrain (Fig. D-2) assuming that the vehicle point "I" lies somewhere between terrain template (J) and terrain template (J+1), and points (K) and (K+1) on these two templates. Let the point "PT" represent the point on the terrain directly above or below (depending on whether contact occurs) the point "I" on the vehicle. The coordinates of point "PT", in the space-fixed coordinate system, are defined as XXX, YYY, and ZVPPGI; therefore it necessarily follows that:

XXX = XVPP(I)

YYY = YVPP(I)

ZVPPGI = terrain elevation corresponding to XXX and YYY (computed)

Points P1 and P2 with coordinates as shown in Fig. D-2 are also computed based on input terrain information. With these three points (PT, P1, P2), two vectors which lie on the terrain surface and extend from point PT may be defined as follows:

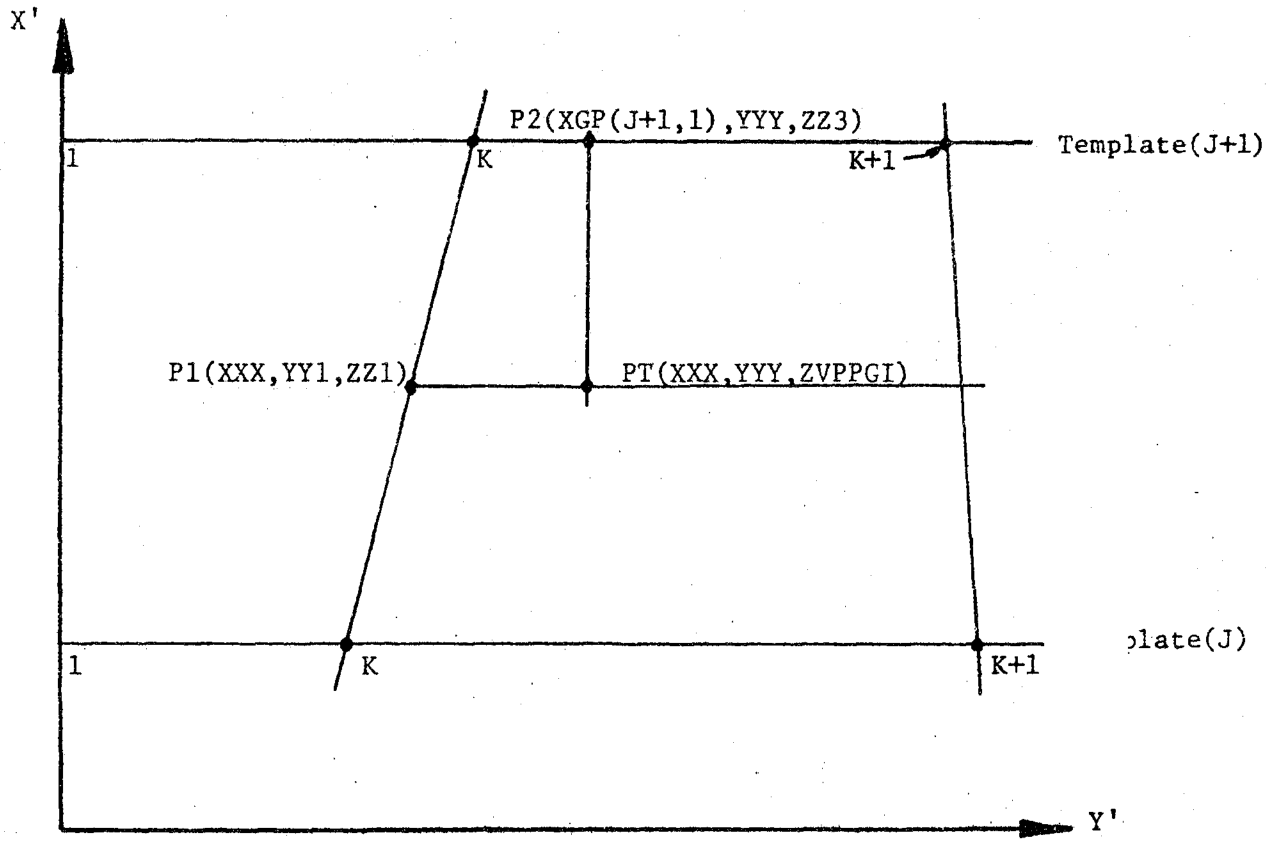

Figure D-2. TOP VIEW OF TERRAIN

$$\overline{PT\ P1} = (XXX\text{-}XXX)\bar{I} + (YY1\text{-}YYY)\bar{J} + (ZZ1\text{-}ZVPPGI)\bar{K}$$

or,

$$\overline{PT\ P1} = (YY1\text{-}YYY)\bar{J} + (ZZ1\text{-}ZVPPGI)\bar{K}$$

$$\overline{PT\ P2} = (XGP(J+1,1)\text{-}XXX)\bar{I} + (YYY\text{-}YYY)\bar{J} + (ZZ3\text{-}ZVPPGI)\bar{K}$$

or,

$$\overline{PT\ P2} = (XGP(J+1,1)\text{-}XXX)\bar{I} + (ZZ3\text{-}ZVPPGI)\bar{K}$$

NOTE: $\bar{I}$, $\bar{J}$, and $\bar{K}$ represent unit vectors parallel to X', Y', and Z', respectively.

Let $\bar{N} = \overline{PT\ P1} \times \overline{PT\ P2}$, the inward normal vector to the terrain surface at point PT.

Thus

$$\bar{N} = \begin{vmatrix} \bar{I} & \bar{J} & \bar{K} \\ 0 & (YY1\text{-}YYY) & (ZZ1\text{-}ZVPPGI) \\ (XGP(J+1,1)\text{-}XXX) & 0 & (ZZ3\text{-}ZVPPGI) \end{vmatrix}$$

or

$$\bar{N} = (YY1\text{-}YYY)(ZZ3\text{-}ZVPPGI)\bar{I} + (XGP(J+1,1)\text{-}XXX)(ZZ1\text{-}ZVPPGI)\bar{J} - (XGP(J+1,1)\text{-}XXX)(YY1\text{-}YYY)\bar{K}$$

Since XVPP(I) = XXX and YVPP(I) = YYY,

$$\bar{N} = (YY1\text{-}YVPP(I))(ZZ3\text{-}ZVPPGI)\bar{I} + (XGP(J+1,1)\text{-}XVPP(I))(ZZ1\text{-}ZVPPGI)\bar{J} - (XGP(J+1,1)\text{-}XVPP(I))(YY1\text{-}YVPP(I))\bar{K}$$

For convenience define:

$$\left.\begin{aligned} AA &= (YY1-YVPP(I))(ZZ3-ZVPPGI) \\ BB &= (XGP(J+1,1)-XVPP(I))(ZZ1-ZVPPGI) \\ CC &= (XGP(J+1,1)-XVPP(I))(YY1-YVPP(I)) \end{aligned}\right\} \quad (D-1)$$

and $\bar{N} = (AA)\bar{I} + (BB)\bar{J} + (CC)\bar{K}$

From Equations D-1, it is now possible to define the equation of a plane which is tangent to the terrain surface at point PT, and the equation of a line which is normal to the terrain surface, passing through point "I" on the vehicle (Fig. D-3).

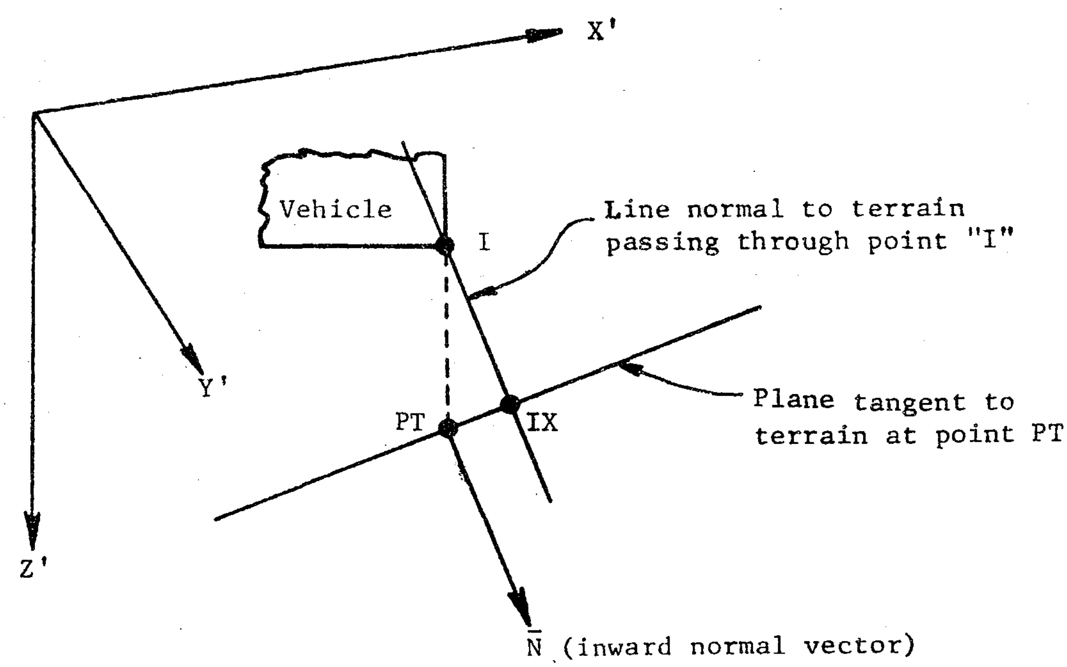

Figure D-3. Tangent Plane, Normal Line

The equation of the plane, passing through point PT, having $\bar{N}$ for a normal is

$$(AA)X' + (BB)Y' + (CC)Z' = G \qquad (D\text{-}2)$$

where $G = AA(XVPP(I)) + BB(YVPP(I)) + CC(ZVPPGI).$

The equation of the line passing through vehicle point "I" and parallel to $\bar{N}$ is

$$\frac{X' - XVPP(I)}{AA} = \frac{Y'-YVPP(I)}{BB} = \frac{Z' - ZVPP(I)}{CC} \qquad (D\text{-}3)$$

Solving equations D-2 and D-3 simultaneously yields the coordinates of point "IX" shown in Fig. D-3, i.e., the point of intersection of the line and plane in question. These coordinates are

$$\left.\begin{aligned} X'_{IX} &= XVPP(I) + \frac{(AA)(XL)}{H} \\ Y'_{IX} &= YVPP(I) + \frac{(BB)(XL)}{H} \\ Z'_{IX} &= ZVPP(I) + \frac{(CC)(XL)}{H} \end{aligned}\right\} \qquad (D\text{-}4)$$

where, $XL = CC(ZVPPGI-ZVPP(I))$

and $H = (AA)^2 + (BB)^2 + (CC)^2$

To find the distance, DLTVG, between points "I" and "IX" (Fig. D-3), define

$$\overline{IIX} = (X'_{IX} - XVPP(I))\bar{I} + (Y'_{IX} - YVPP(I))\bar{J} + (Z'_{IX} - ZVPP(I))\bar{K}$$

or

$$\overline{IIX} = \frac{XL}{H}((AA)\bar{I} + (BB)\bar{J} + (CC)\bar{K})$$

DLTVG is determined by $|\overline{IIX}|$. Hence,

$$DLTVG = \frac{XL}{H} \cdot \sqrt{(AA)^2 + (BB)^2 + (CC)^2}$$

or

$$DLTVG = \frac{(XL)(\sqrt{H})}{H} \qquad \text{(D-5)}$$

It is noted that "DLTVG" is computed only when the quantity (ZVPP(I)-ZVPPGI) is a positive number, i.e., when point "I" is in contact with the terrain. As such, "DLTVG" is the amount which point "I" penetrates the terrain in a direction normal to the terrain plane.

Velocity Vector of Vehicle-Point "I", Components Normal and Tangent to Terrain

Since the solution of equations for the model is performed in vehicle-fixed coordinates, the forces applied to the vehicle by the soil are computed in vehicle-fixed coordinates rather than space-fixed. Therefore $\bar{N}$ (vector normal to the terrain) must be converted accordingly.

$$\bar{N} = (AA)\bar{I} + (BB)\bar{J} + (CC)\bar{K} \qquad \text{(space-fixed)}$$

or

$$\bar{N} = (AV)\bar{i} + (BV)\bar{j} + (CV)\bar{k} \qquad \text{(vehicle-fixed)}$$

where $\bar{i}$, $\bar{j}$, and $\bar{k}$ are unit vectors parallel to X, Y, and Z, respectively (vehicle-fixed coordinate system).

By definition of AMTX (page 185 of Ref. 3),

$$\begin{Bmatrix} (AA) \\ (BB) \\ (CC) \end{Bmatrix} = \begin{bmatrix} & & \\ & AMTX & \\ & & \end{bmatrix} \begin{Bmatrix} (AV) \\ (BV) \\ (CV) \end{Bmatrix}$$

and by the property that $[AMTX]^{-1} = [AMTX]^{T}$,

$$\begin{Bmatrix} (AV) \\ (BV) \\ (CV) \end{Bmatrix} = \begin{bmatrix} & & \\ & AMTX & \\ & & \end{bmatrix}^{T} \begin{Bmatrix} (AA) \\ (BB) \\ (CC) \end{Bmatrix}$$

thus completely defining $\bar{N}$ in the vehicle-fixed coordinate system.

To define the velocity vector of point "I" on the vehicle the following known parameters are needed: U, V, and W which are the scalar components of linear velocity of the center of gravity of the vehicle taken along X, Y, and Z axes, respectively; and P, Q, and R which are scalar components of vehicle angular velocity taken about X, Y, and Z axes, respectively.

Let $(\overline{VCG} = U\bar{i} + V\bar{j} + W\bar{k})$ represent the linear velocity of the vehicle center of gravity, and $(\bar{\omega} = P\bar{i} + Q\bar{j} + R\bar{k})$ represent the angular velocity vector of the vehicle center of gravity and $(\bar{r} = XVP(I)\bar{i} + YVP(I)\bar{j} + ZVP(I)\bar{k})$ represent the radius vector from the vehicle center of gravity to the vehicle point "I".

Using the vectors $\overline{VCG}$, $\bar{\omega}$, and $\bar{r}$, the velocity vector of point "I" $(\overline{VI})$ is

$$\overline{VI} = \overline{VCG} + \bar{\omega} \times \bar{r} \quad .$$

and

$$\bar{\omega} \times \bar{r} = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ P & Q & R \\ XVP(I) & YVP(I) & ZVP(I) \end{vmatrix}$$

or

$$\bar{\omega} \times \bar{r} = (Q(ZVP(I)) - R(YVP(I))\ \bar{i}$$

$$- (P(ZVP(I)) - R(XVP(I))\ \bar{j}$$

$$+ (P(YVP(I)) - Q(XVP(I))\bar{k}$$

If $\overline{VI}$ is further defined as,

$$\overline{VI} = VUP\bar{i} + VVP\bar{j} + VWP\bar{k}$$

then

$$VUP = U + Q(ZVP(I)) - R(YVP(I))$$

$$VVP = V + R(XVP(I)) - P(ZVP(I))$$

$$VWP = W + P(YVP(I)) - Q(XVP(I))$$

At this point, with $\bar{N}$ and $\overline{VI}$ defined in the same coordinate system, $\overline{VI}$ can be resolved into two components one normal to the terrain plane and the other tangential to the terrain plane. Both of these components lie in a plane defined by and containing both $\bar{N}$ and $\overline{VI}$, as shown in Figure D-4. The vector normal to this plane is defined by

$$\overline{VI} \times \bar{N} = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ VUP & VVP & VWP \\ AV & BV & CV \end{vmatrix}$$

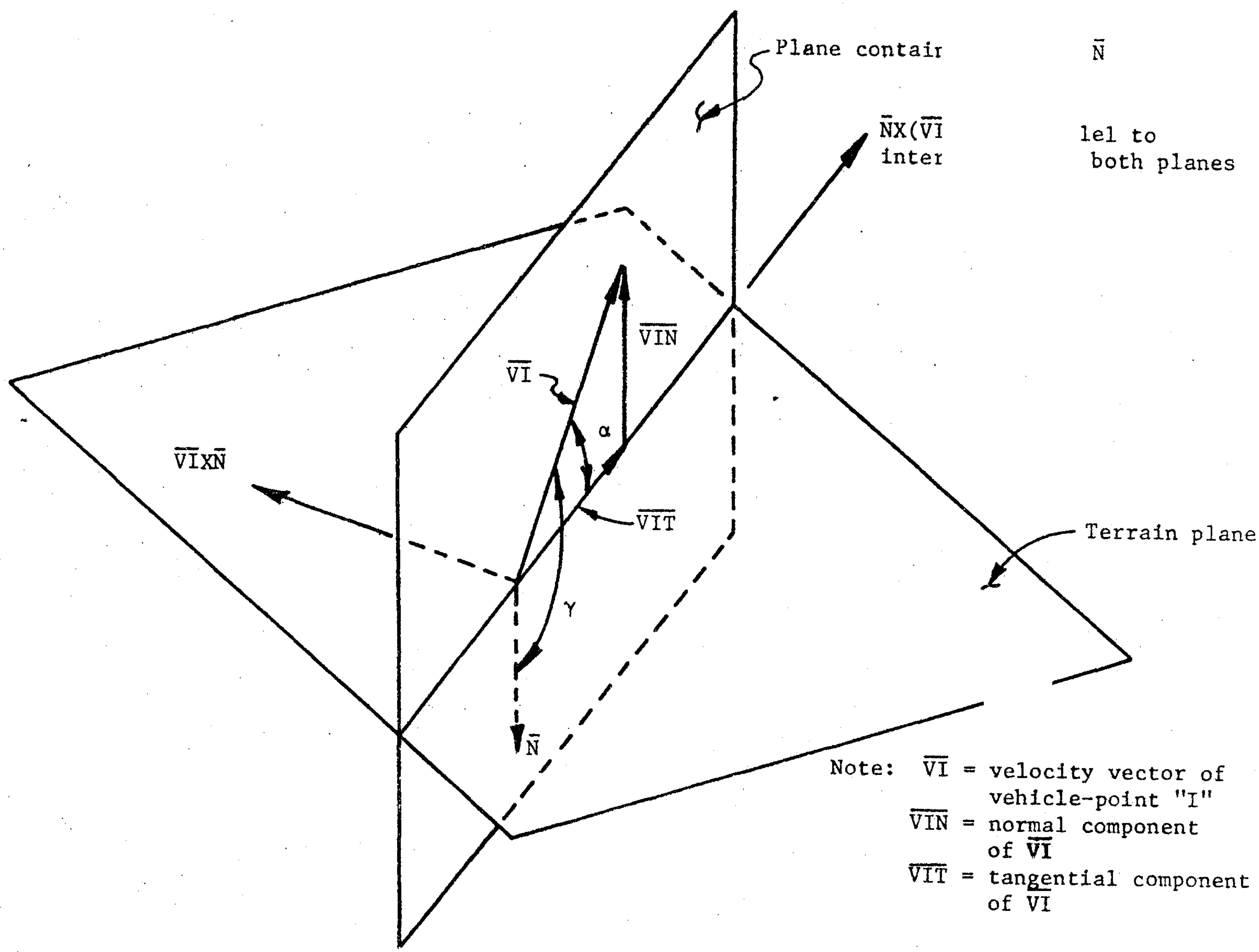

Figure D-4. SCHEMATIC OF COMPONENTS NORMAL AND TANGENT TO TER
OF VELOCITY VECTOR OF VEHICLE-POINT "I"

or

$$\overline{VI} \times \bar{N} = (AVT)\bar{i} + (BVT)\bar{j} + (CVT)\bar{k}$$

where

$$AVT = (VVP)(CV) - (BV)(VWP)$$

$$BVT = (AV)(VWP) - (VUP)(CV)$$

$$CVT = (VUP)(BV) - (AV)(VVP) \quad .$$

The vector parallel to the intersection of the terrain plane with the plane containing $\overline{VI}$ and $\bar{N}$ (Figure D-4) is defined by

$$\bar{N} \times (\overline{VI} \times \bar{N}) = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ AV & BV & CV \\ AVT & BVT & CVT \end{vmatrix} \quad .$$

or

$$\overline{XIV} = \bar{N} \times (\overline{VI} \times \bar{N}) = (AVNT)\bar{i} + (BVNT)\bar{j} + (CVNT)\bar{k}$$

where

$$AVNT = (BV)CVT) - (BVT)(CV)$$

$$BVNT = (AVT)(CV) - (AV)(CVT)$$

$$CVNT = (AV)(CVT) - (AVT)(CV) \quad .$$

The magnitude of the tangential component of $\overline{VI}$ is expressed by

$$VMPT = \left|\overline{VI}\right| \cdot \cos\alpha = VMP \cdot \cos\alpha$$

where

$$VMP = \left|\overline{VI}\right| = \sqrt{(VUP)^2 + (VVP)^2 + (VWP)^2} \tag{D-6}$$

and

$$\cos \alpha = \frac{\overline{VI} \cdot \overline{XIV}}{\left|\overline{VI}\right| \, \left|\overline{XIV}\right|} \quad .$$

Also,

$$VNTIM = \left|\overline{XIV}\right| = \sqrt{(AVNT)^2 + (BVNT)^2 + (CVNT)^2}$$

and

$$\overline{VI} \cdot \overline{XIV} = (VUP)(AVNT) + (VVP)(BVNT) + (VWP)(CVNT) \quad .$$

Then

$$VMPT = \frac{(VUP)(AVNT) + (VVP)(BVNT) + (VWP)(CVNT)}{VNTIM} \tag{D-7}$$

The direction of the tangential component of $\overline{VI}$ is the same as that of the unit vector $\overline{UXIV}$, defined as

$$\overline{UXIV} = \frac{\overline{XIV}}{VNTIM} = \frac{\overline{XIV}}{\left|\overline{XIV}\right|} \quad . \tag{D-8}$$

Hence,

$$\overline{VIT} = \frac{VMPT(\overline{XIV})}{VNTIM} \quad . \tag{D-9}$$

The magnitude of the normal component of $\overline{VI}$ is expressed by

$$VELPN = (VMP) \cos \gamma$$

where,

$$VMP = \left|\overline{VI}\right| \text{ , (Equation (D-6)}$$

and

$$\cos \gamma = \frac{\overline{VI} \cdot \bar{N}}{\left|\overline{VI}\right| \; \left|\bar{N}\right|}$$

Also,

$$VNTM = \left|\bar{N}\right| = \sqrt{(AV)^2 + (BV)^2 \; (CV)^2}$$

and

$$\overline{VI} \cdot \bar{N} = (VUP)(AV) + (VVP)(BV) + (VWP)(CV) \; .$$

Then,

$$VELPN = \frac{(VUP)(AV) + (VVP)(BV) + (VWP)(CV)}{VNTM} \qquad \text{(D-10)}$$

The direction of the normal component of $\overline{VI}$ is the same as that of the unit vector $\overline{UN}$, defined as

$$\overline{UN} = \frac{\bar{N}}{\left|\bar{N}\right|} = \frac{\bar{N}}{VNTM} \quad . \qquad \text{(D-11)}$$

Hence,

$$\overline{VIN} = \frac{VELPN(\bar{N})}{VNTM} \quad . \qquad \text{(D-12)}$$

Using equations D-7 through D-12, the forces afforded by the soil to the vehicle are computed. The soil is modeled as a spring having a stiffness "SSTIFF" (lbs./in.) and a damper having a damping coefficient "XJ" (sec./in.), at the point of contact.

The force vector normal to the terrain is

$$\overline{FN} = -K(\overline{UN})$$

where $\overline{UN}$ is defined by Equation (D-11) and K = (SSTIFF)(DLTVG)(1.0 + (XJ)(VELPN)). (Note DLTVG is defined in equation (D-5). For convenience, re-define $\overline{FN}$ as,

$$\overline{FN} = FNTX\bar{i} + FNTY\bar{j} + FNTZ\bar{k}$$

where

$$\left.\begin{aligned} FNTX &= \frac{-K(AV)}{VNTM} \\ FNTY &= \frac{-K(BV)}{VNTM} \\ FNTZ &= \frac{-K(CV)}{VNTM} \end{aligned}\right\} . \qquad \text{(D-13)}$$

The force vector tangential to the terrain (friction force) is

$$\overline{FT} = -(KK)(\overline{UXIV})$$

where $\overline{UXIV}$ is defined by equation (D-8) and,

$$KK = (SSTIFF)(DLTVG)(FRFAC)$$

Note: FRFAC = Friction factor between vehicle and terrain

For convenience, re-define $\overline{FT}$ as,

$$\overline{FT} = FRFCX\bar{i} + FRFCY\bar{j} + FRFCZ\bar{k}$$

where

$$\left.\begin{aligned} FRFCX &= \frac{-(KK)(AVNT)}{VNTIM} \\ FRFCY &= \frac{-(KK)(BVNT)}{VNTIM} \\ FRFCZ &= \frac{-(KK)(CVNT)}{VNTIM} \end{aligned}\right\} \quad . \qquad \text{(D-14)}$$

The resulting force vector on vehicle-point "I" when terrain contact occurs can be expressed as

$$\overline{FRES} = \overline{FN} + \overline{FT} = (FXVG)\bar{i} + (FYVG)\bar{j} + (FZVG)\bar{k}$$

where

$$\left.\begin{aligned} FXVG &= FNTX + FRFCX \\ FYVG &= FNTY + FRFCY \\ FZVG &= FNTZ + FRFCZ \end{aligned}\right\} \qquad \text{(D-15)}$$

Since the mass of the vehicle-structure is concentrated at a point (the center of gravity), it is necessary that any force applied to the vehicle-structure be transferred to that point. This transfer is accomplished by applying the forces defined in equations (D-15) plus an additional moment vector defined as

$$\overline{XMV} = \bar{r} \times \overline{FRES}$$

where

$$\bar{r} = (XVP(I))\bar{i} + (YVP(I))\bar{j} + (ZVP(I))\bar{k} \quad .$$

$$\overline{XMV} = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ XVP(I) & YVP(I) & ZVP(I) \\ FXVG & FYVG & FZVG \end{vmatrix}$$

If $\overline{XMV}$ is re-defined as

$$\overline{XMV} = (XMVGX)\bar{i} + (XMVGY)\bar{j} + (XMVGZ)\bar{k}$$

then,

$$\left.\begin{aligned} XMVGX &= (YVP(I)(FZVG) - (FYVG)(ZVP(I)) \\ XMVGY &= (FXVG)(ZVP(I)) - (XVP(I))(FZVG) \\ XMVGZ &= (XVP(I))(FYVG) - (FXVG)(YVP(I)) \end{aligned}\right\} \qquad (D-16)$$

Therefore, in summary, the forces and moments defined by equations (D-15) and (D-16) are applied to the center of gravity of the vehicle when contact occurs between some point on the vehicle-structure and the terrain.