R and D TARADCOM LABORATORY

TECHNICAL REPORT

NO. 12413

INTERACTIVE
VEHICLE DYNAMICS AND RIDE EVALUATION
PACKAGE

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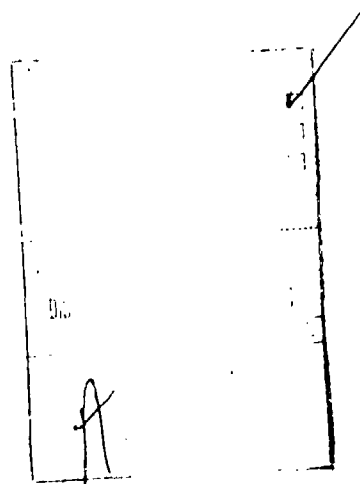# U.S. ARMY TANK-AUTOMOTIVE
RESEARCH AND DEVELOPMENT COMMAND
Warren, Michigan 48090

ABSTRACT

This report describes an integrated package for evaluating the dynamic effects of driving a vehicle across any described section of terrain. The model incorporated includes only the pitch and roll motions of the chasis (or hull). The package is composed of four digital computer programs. Each program is designed to be run interactively and does not require that the user have any programming experience. The programs provide the capability to create vehicle data files, perform simulations, and specify the form and types of the output desired. A general description of the model structure, its capabilities and its limitations is included along with user instructions for running each program in the package.

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INTRODUCTION AND OBJECTIVE

The US Army Tank-Automotive Command has been involved in the simulation of tracked and wheeled vehicles for over twenty years. The objective of one type of simulation often used in the evaluation of vehicle concepts has been to determine the ride performance of a vehicle as it traverses a section of terrain or a discrete obstacle. The model generally used for these simulations represents the vehicle as a sprung mass (the chasis or hull) and a separate mass for each wheel. Springs and dampers were represented by piecewise linear curves. The tires were represented also as a vertical spring and damper between the wheel center and the ground.

This type of model was originally developed and implemented on a set of analog computers with a digital computer providing the forcing function during the simulation. This required specially trained engineers to set up and run the simulations, and required extensive program checkout for each configuration to ensure the validity of model implementation. As a result, vehicle evaluations that were run on this model were very expensive. Due to the extensive checkout required for each implementation, these simulations appeared to be quite reasonable and when field test data were available, they tended to reinforce this judgement.

In recent years, it has often become necessary to obtain results in a matter of a few days. Using the analog computers available, each concept took about two weeks to complete with very little effective overlap between concepts. With the spread of the use of high speed digital computers in the Army community, it became feasible to do large simulations on digital computing machines. With this in mind, a digital counterpart of the analog model was developed under contract by Service Bureau Corporation and was made operational at TARADCOM about 10 years ago. In the ensuring years, countless vehicles and vehicle concepts have been simulated and evaluated using evolutionary forms of this (or very similar) digital models.

Several factors have persistently arisen over the years that have lessened the overall utility of this type of digital model. One of these factors is the converting of vehicle data into a computer use-able format. The person performing such a task must be familiar with both the vehicle data and the computer program requirements. Furthermore, he must not take his task casually, since mistakes may not be readily visible in the results but can cause great repercussions if discovered at a later time.

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Another problem has been that different users may want different types of output from the model. This would necessitate program changes which would slow down the project and increase the possibility of errors in the model, since adequate program checkout time is seldom available.

A third retarding factor is that the engineer responsible for the work has had no opportunity to gain personal confidence in the model being used. If the person making the actual computer runs for him made any data translation or transcription errors, or if any programming errors were made resulting in unreasonable output, the engineer tended to lose confidence in the model. With a couple of bad experiences under his belt, he would soon be very hesitant to use the model.

During the past two years one evolutionary form of this model has been resurrected. A preprocessor and a post-processor program have been developed which when used in conjunction with the digital sim-ulation model, provide a total vehicle ride evaluation package which hopefully will eliminate many of the most severe problems encountered in the past. This package has been implemented on the CDC 6500/6600 computer complex located at Picatinny Arsenal in Dover, New Jersey. The underlying theme used in the development of the package is that the engineer responsible for the results should become personally involved with the model. In order to accomplish this objective, the package was designed to be run interactively from a time-sharing terminal. The vehicle data are entered interactively in engineering-type terms in response to specific requests. Each simulation over a particular ter-rain at a specified velocity is also run interactively, and the standard measures of driver ride comfort are obtained. The post processor portion of the package can be run interactively as well, giving the user the option to obtain various tabular or graphical results from any signal generated during the simulation portion of the package. The full capability of the post processor is available only from a graphics terminal having vector plotting capability. (A Tektronix 4014 is used.)

The remainder of this report is concerned with a user oriented description of this package. Included are a description of the model, some model verification results, and a discussion of how to use each component of the package. Finally, included as Appendix I, is a rather complete example of what can be accomplished with this model. The example begins with the vehicle data in the form an engineer might receive them and proceeds through the sequence of programs to create a vehicle data file, run the simulation, and ultimately obtain additional output via the post processor portion of the package.

MODEL DESCRIPTION AND CAPABILITIES

The model implemented in this package is represented pictorially in Figure 1. It represents a wheeled or tracked vehicle (Note that a tracked vehicle is handled as a wheeled vehicle for the purpose of ride simulation). The pitch and vertical motions of the sprung mass (chassis or hull) are modeled as well as the vertical motion of each wheel. The standard output of the program is the peak and rms vertical accelerations at the driver's station. It also calculates the absorbed power of the driver from the acceleration signal at the driver's station. Absorbed power is a frequency weighted rms acceleration. The weighting is done based on human ride tolerance to the various frequencies, and is explained in reference 1.

The data necessary to run this program are the wheel and CG locations, vehicle sprung and unsprung mass, sprung pitch moment of inertia, suspension spring and damping curves, tire spring and damping characteristics, and a description of the terrain over which the vehicle is to be simulated. The program allows for independently sprung wheels or for a pair of wheels to be joined in a tandem arrangement. The program also allows the input of the vertical clearance and horizontal location of one possible impact point (e.g., a sprocket or bumper), and allows the inclusion of a fifth wheel type trailer hitch with full pitch freedom.

A typical output from this model will contain all the data shown in Figure 2. Additionally a binary output file is created which contains all the relevant displacements, velocities, and accelerations required to reconstruct the entire simulation. The various signals recorded in this file may be further analyzed using a separate post processor program. A detailed description of how to use this capability is contained in the User Instruction Section under the program heading, BANALYZE.

The simulation program contains a set of non-linear differential equations. These equations describe the accelerations of the various bodies being modeled and are as follows:

The vertical acceleration of the sprung center of mass is:

$$\ddot{Y}_o = \sum_{i=1}^{n} \frac{K_i}{M_o}(Y_i - Y_{w_i}) + \sum_{i=1}^{n} \frac{D_i}{M_o}(\dot{Y}_i - \dot{Y}_{w_i}) + g$$

where

K$_i$ = the spring rate at wheel i

M$_0$ = 1/2 the sprung mass of the vehicle

Y$_i$ = the hull reference position of wheel i

Y$_{W_i}$ = vertical position of wheel i

n = number of wheels on one side of vehicle

D$_i$ = the damping rate at wheel i

g = the gravitational constant = 32.16 ft/sec^2

The pitch acceleration of the hull about the sprung center of mass is:

$$\ddot{\theta} = \sum_{i=1}^{n} \frac{L_i K_i}{J_0}(Y_i - Y_{w_i}) + \sum_{i=1}^{n} \frac{L_i D_i}{J_0}(\dot{Y}_i - \dot{Y}_{w_i})$$

where

L$_i$ = the horizontal distance from the CG to wheel i

J$_0$ = 1/2 the sprung pitch moment of inertia of the vehicle

The vertical acceleration of wheel i (for i = 1 to n):

$$\ddot{Y}_{w_i} = \frac{K_i}{M_{w_i}}(Y_i - Y_{w_i}) + \frac{D_i}{M_{w_i}}(\dot{Y}_i - \dot{Y}_{w_i})$$

$$- \frac{K_{w_i}}{M_{w_i}}(Y_{w_i} - A_i) - \frac{D_{w_i}}{M_{w_i}}(\dot{Y}_{w_i} - \dot{A}_i) + g$$

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where

M_{w_i} = the mass of wheel i

A_i = the terrain elevation at wheel i

K_{w_i} = the spring rate of wheel i

D_{w_i} = the damping rate of wheel i

In addition to the above differential equations, a pair of equations for each wheel are used to describe the hull reference point position and velocity associated with each wheel. These give the following equations for wheel i:

$$Y_i = Y_0 + L_i \sin \theta$$
$$\dot{Y}_i = \dot{Y}_0 + \dot{\theta} L_i \cos \theta$$

where
Y_0 = the vertical position of the CG

θ = the pitch angle of the vehicle (front end up is positive)

The simulation is performed by the simultaneous integration of the differential equations concurrently with the solution of the necessary auxiliary equations. This numerical integration is performed using a variable step size numerical integration algorithm. A fourth order Adams-Moulton predictor corrector algorithm is employed whenever sufficient past values are available. A fourth order Runge-Kutta algorithm is used for starting the simulation and is also used for restarting if step size changes have made the appropriate past values unavailable.

Acceleration values are saved at equal intervals of time for subsequent analysis. Upon completion of the simulation portion of the program, the program determines the peak and RMS accelerations for the run, measured at the driver's station (or at some other designated point of interest).

The power spectral density (PSD) of the driver's vertical acceleration is calculated and passed through the absorbed power

weighting function, and integrated. The resulting value is the driver's vertical absorbed power in watts. This value is printed along with the RMS and peak accelerations.

The forcing function for the simulation is the ground profile that would be driven over by one side of the vehicle. This profile may be a surveyed course, a discrete rigid obstacle, or a mathematically generated terrain possessing certain statistical characteristics.

The terrain profile, regardless of its origin, it represented by a series of elevations at known horizonal positions along the course. These known profile points are assumed to be connected by straight line segments. This profile representation is modified by slowly rolling a rigid wheel across it and determining the lowest path that this rigid wheel could follow. This minimum path represents the original path, modified to reflect the effects of tire bridging. When simulating tracked vehicles, the roadwheel radius plus the track thickness is used as the effective radius of the rigid wheel, whereas for wheeled vehicles the rolling radius of the pneumatic tire is used. This terrain modification is performed before the simulation is actually begun. The resulting minimum profile is used as the forcing function input to the bottom of the wheel during the simulation. It should be noted that this terrain modification can be suppressed, if it is so desired, by setting the tire diameter equal to zero in the vehicle data file.

The model implementation allows a maximum of ten wheels per side of the vehicle. Each wheel must have a spring associated with it and may also have a shock absorber. In addition, any pair of adjacent wheels may be joined together in a tandem arrangement. The tandem is free to rotate about a point on the sprung mass and is represented by its pitch moment of inertia, its attachment point to the sprung mass, and the span between the two wheels on the tandem.

The spring and damping curves describing the suspension system elements are represented as piecewise linear functions with a maximum of nine linear segments each. The deflection axis for the spring curves is arbitrary, but it must be consistent from wheel to wheel. In other words, the zero deflection point may correspond to zero force, or to the static force, or some other force. The effect of being consistent in the deflection axis definition for all wheels can be described by the following situation. If the chasis were constrained
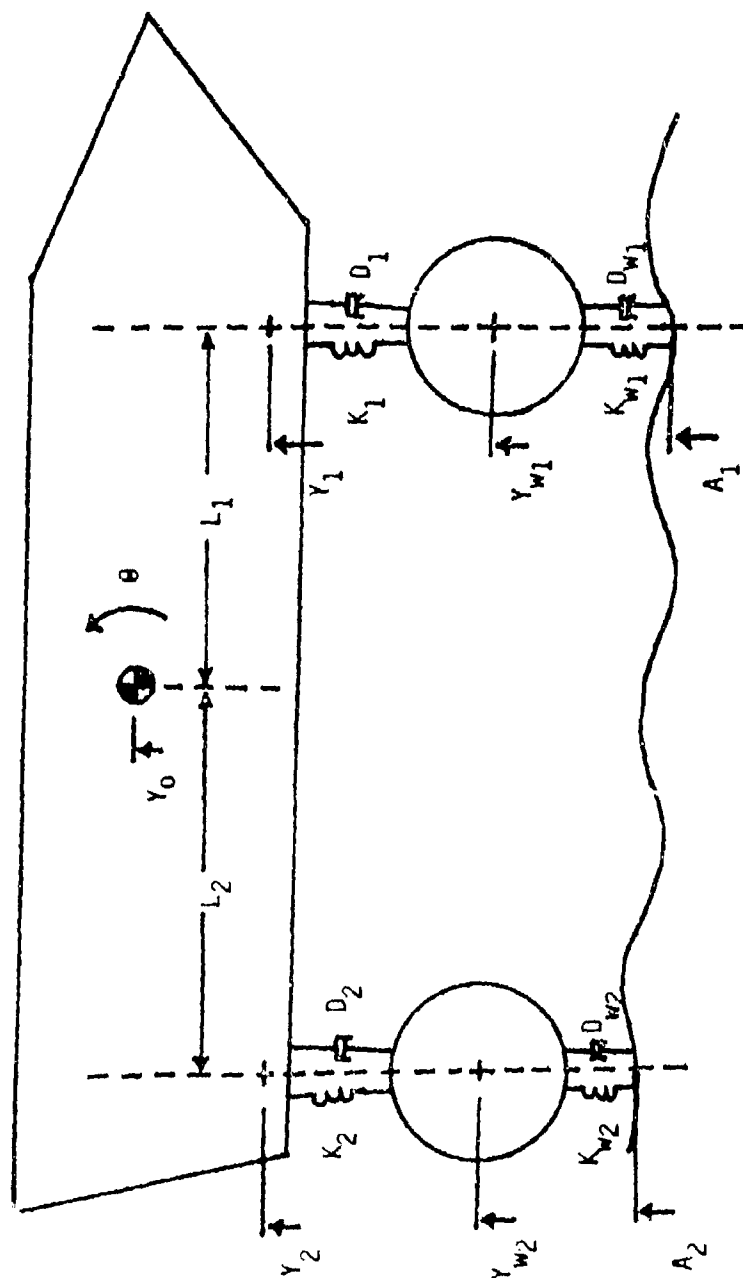
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Figure 1 Vehicle Model with Two Wheels per Side

Direction of Travel

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to remain level, and each wheel were positioned with the same value of deflection (regardless of the value chosen) across its respective spring, then the wheel centerlines would all lie on a single horizonal line. It should then be noted that if all wheels have zero force at zero deflection or if all wheels have static force at zero deflection, then consistency is guaranteed. One of these two definitions is generally used.

An example of an inconsistent definition would be to select the jounce (compression) stop point as the zero deflection point. If this were done for a vehicle that allowed one wheel to travel nearer to the plane formed by the chasis pitch and roll axes than some other wheel, the resulting representation would not be as intended.

The wheels are not assumed to be rigid during the simulation. In fact, the wheel (or tire) vertical spring and damping characteristics along with the unsprung mass of each wheel are required to simulated the interaction between the wheel and the ground.

The vertical spring and damping characteristics of the wheels may differ from wheel to wheel. These characteristics are considered to be piecewise linear functions and may have a maximum of six linear segments to describe each curve. For the wheel spring curves, the point of zero deflection must coincide with the point of zero force. Negative forces cannot be generated by the wheel characteristics within the model. In other words, the wheel cannot be pulled down by the profile, but it can, of course, leave the ground.

```
VEHICLE IDENTIFICATION    M151A1  1/4 TON TRUCK

        GUN                   3120.  LBS
        SPRUNG                2710.  LBS
        UNSPRUNG               410.  LBS
        PITCH MOMENT OF INERTIA 719. SLUG-FT-SQ.

401 POINTS FOR    APG31 16 NOV 76

        VEHICLE VELOCITY= 15.0 MPH
        LENGTH OF RUN=   18.7 SEC.

        PEAK ACCELERATION  =  2.16 G S
        RMS ACCELERATION   =   .38 G S        PSD AREA = .38 G S

        ABSORBED POWER OF  =  5.02 WATTS
             DRIVER
```

Figure 2 Typical Output from BVRIDE

MODEL VALIDATION

The user of any model would like to have some idea of the model's prediction accuracy. In an attempt to provide some degree of confidence in this model, useable field test data were sought.

One such set of results were obtained from the M60A1 STB (Standard Torsion Bar) tests which were run by the Waterways Experiment Station with the assistance of TARADCOM personnel. There were two phases of the test. The first phase was run at Fort Knox in May 1976 when several modifications of the M60 were tested. The second phase included the MICV as well as the M60 and was conducted at Aberdeen Proving Ground in November 1976. The vehicles were run over terrains of varying roughness and the driver's absorbed power was recorded for each vehicle velocity.

Figures 3 and 4 show the velocities at which the driver experienced six watts absorbed power in the tests. The driver comfort limiting velocity is plotted as a function of terrain roughness (quantified by inches rms) for the M60A1 STB and for the MICV. These two vehicles were also simulated over a variety of terrains and the velocity at which the simulated driver experienced six watts of absorbed power was recorded. The results obtained from these simulations for the M60A1 STB and for the MICV are also plotted in Figures 3 and 4 for comparison with the field test results.

N60A1   STB
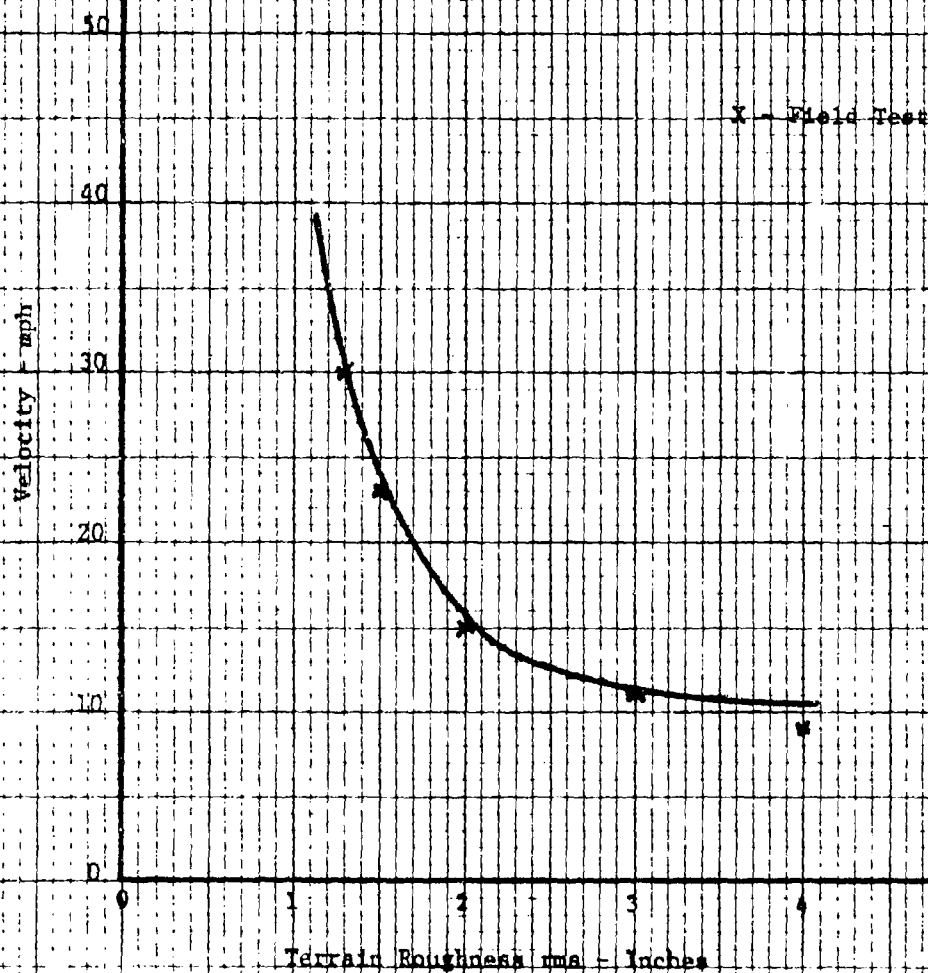
X - Field Test

Velocity - mph

50

40

30

20

10

0

0   1   2   3   4

Terrain Roughness rms - Inches

Comparison of Simulated and Field Tested Driver
Tolerable Maximum Velocity

Figure 3

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MICV
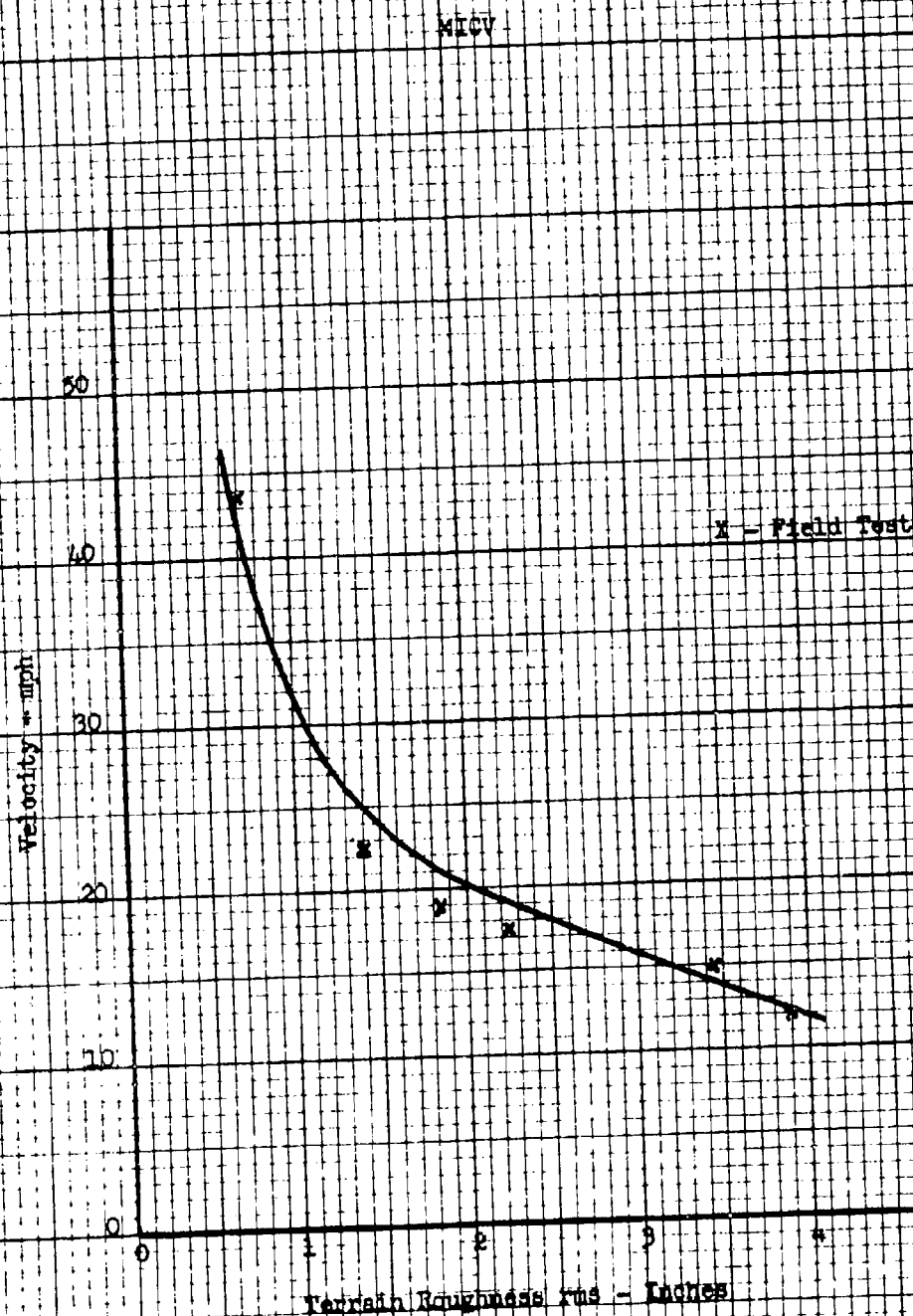
X - Field Test

Comparison of Simulated and Field Tested Driver
Tolerable Maximum Velocity

Figure 4

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USER INSTRUCTIONS

This section contains instructions for accessing and running the various programs that make up this vehicle dynamics package. The various options and limitations associated with each program are discussed.

These programs were designed to be run from a time-sharing terminal and should not require any programming expertise of the user. The user will, of course, have to be able to use a time-sharing terminal. If the user can gain access to the ARRADCOM computer system through a time-sharing terminal, this section will, hopefully, provide him with the instructions necessary to run the various programs in this package.

BCRET

This program was written to allow the user to easily create a
formatted vehicle data file which can then be used as input by the
simulation portion of this package. The program is designed to be
run interactively from a time-sharing terminal. After the user
has initiated the program, various requests are made of the user in
terms he can readily understand.

The first thing the user is asked is what he would like to do.
This question will also be asked each time a phase of the program
has been completed. The user has several options at this point. He
might select to simply stop the program or he could select the data
entry option. If this latter selection is made, the user will be
asked for vehicle data. It has been attempted to make this phase of
the program seem as natural as possible to the engineer. The vehicle
data are requested in the form the engineer would most likely have
received them. The entered data are converted to the form and format
required in the vehicle data file and the file is written on Tape 8.

The user may also select the data check option. This option can
only be employed from a graphics terminal and is selected by typing
an 8 or 9. The number typed corresponds to the tape number from which
vehicle data are to be read. Tape 8 and Tape 9 are used for two
different forms of the vehicle data either of which can be used with
the simulation program. Tape 8 corresponds to the first data file
name in the program run statement. The output of the data entry portion
of the program is written on Tape 8.

If the data check option has been selected by typing an 8, the
vehicle represented by these data is simulated for 3.8 seconds at
5 mph over perfectly flat ground. The pitch and vertical displacement
of the sprung mass (chasis or hull) center of gravity are plotted as a
function of time. These plots should be relatively flat if the data
is reasonable (note the converse is not promised). If the vehicle
stabilizes with an excessive pitch angle, the relative travel in the
various suspension components will be altered. A simple example might
illustrate this problem best. Suppose data for a vehicle were entered
that had 12 inches of wheel travel from the static position to the
jounce stop (jounce represents compression) for each wheel. Suppose
also that the vehicle's sprung center of gravity was behind the
geometric center of the wheels, far enough to cause a static pitch angle
of 0.05 radians (about 2.85 degrees). Assume also that the front wheel

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was 8 feet forward of the vehicle's sprung CG. Then the horizonal distance of 8 feet swung through the pitch angle of 0.05 radians would cause the sprung mass at the front wheel station to rise 0.05 radians times 8 feet, or 0.4 feet. This would mean that the front wheel would have to be driven up, not only 1 foot, but 1.4 feet before the bump stop would be encountered. Note that the other wheels would also be affected but to a lesser extent. In this example the wheels forward of the CG would gain jounce travel and the wheels aft of the CG would have their jounce travel reduced.

A technique for overcoming this difficulty is included in this program. In order to implement this technique the user must select the zero pitch option. The data entry phase must have been completed prior to initiation of the zero pitch phase. In order to level the vehicle a simulation is performed (again for 3.8 seconds at 5 mph), over level ground using the vehicle data obtained from Tape 8. Upon completion of this simulation the vehicle is assumed to have stabilized. The force required by each spring to support the vehicle in this stabilized position is recorded. The user is asked how much static to jounce stop travel should be available at each wheel station. The spring curve associated with each wheel is then translated, first along the deflection axis and then along the force axis. The resulting curve for each wheel will have the appropriate force at the zero deflection point to support the vehicle in a level position on level ground. The vehicle data with these modified spring curves are then written on Tape 9. A flag with a value of 1 is written in column 60 of card 2 to indicate that the vehicle data in this file have been generated by this leveling process. The simulation program tests this flag and uses a simpler initialization procedure when the flag is set to a value of one.

The zero pitch option does not produce any plotted output and therefore need not be run from a graphics terminal. The only immediate indication to the user that the leveling process has been completed is that the option request will be made once again.

After leveling the vehicle the user can (if he is at a graphics terminal) perform a data check on the leveled vehicle data file in Tape 9 by responding to the option request with a 9. This data check is similar to the one described previously to check the data on Tape 8. The only difference is in the method of initializing the vehicle.

Certain points should be emphasized. Tape 8 and Tape 9 correspond to the two file names associated with the program at run time with Tape 8 being the first and Tape 9 the second. If no data file names are given,

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then the local file name for Tape 8 will default to VEHIN and Tape 9 will
default to VEHLEV. If BCRET is run with a leveled vehicle data file
created at some earlier time, and given as the first file name, then a
data check option of 8 would be required to check that file.

A couple of restrictions should be reemphasized. The maximum number
of segments allowed for any spring or damping curve is 9. The curves
are entered as an initial and final slope and breakpoints to define in-
terior linear segments. Also, the number of wheels on one side of the
vehicle cannot exceed 10.

Appendix I contains an interactive example using BCRET to enter
the vehicle data. A description of the contents of the vehicle data
file is given in Appendix II.

To actually run this program, the user must first access the ARRADCOM
computer system from a time-sharing terminal. Once logged into the sys-
tem, the user must type the following two commands to run BCRET:

    ATTACH, BCRET, ID = DRDTAZSA

    BCRET, VEHIN, VEHLEV

In the latter of these commands the two parameters VEHIN and
VEHLEV may be changed or left off altogether. If omitted the default
names are those given in the statement above (i.e. VEHIN and VEHLEV).
In either case the first parameter name will be the local file name
containing the data written on Tape 8 by the data entry option of the
program. The second parameter name will be the local file name
corresponding to Tape 9 (the leveled vehicle data file). If the zero
pitch option (to level the vehicle) is not selected, then nothing will
be written on Tape 9.

BVRIDE

This program will perform a dynamic simulation of a vehicle as it traverses a specified terrain profile. Only the pitch and vertical degrees of freedom are modeled for the sprung mass (hull or chasis) and the vertical response for each wheel. The model as implemented in this program has the full capability described in the section of this report titled Model Description and Capabilities.

This simulation can be run from any time sharing terminal. There is no graphical output generated by BVRIDE and only the vehicle velocity is entered interactively. Before running the simulation the user must extend the time limit allotted for each program run on the time sharing system. He may also desire to inform the system of any increased line width his terminal may have (the defaults for these two items are 7 seconds and 72 characters). These two items can be accomplished when the user first signs on the system and will remain in effect until the terminal is logged out. The following two commands perform these functions:

ETL,500

SCREEN,132

The number 500 in the first command is the maximum run time allotted. It is the number of seconds written in octal (base 8) notation.

The vehicle data must be supplied in a file according to the format specifications spelled out in Appendix II. This file can be created by the user or can more efficiently be generated by the program BCRET which is also described in this report. The only feature not available from BCRET is the allowance for non-linear tire characteristics. If the user's data requires this feature the proper data must be inserted into the vehicle data file according to the format specifications in Appendix II.

The terrain profile data must also be supplied in a separate file. The terrain data in the file will be extended sufficiently in both directions to allow the vehicle to sit on level ground prior to crossing the given profile and to return to level ground upon completion of the profile traverse.

The user can create his own terrain data files according to the required format shown in Appendix III. The other alternative is to use one of the standard terrains already on the system. A catalog of these

standard terrains is incorporated as Appendix IV. Any of these terrains may be accessed by selecting the appropriate file name and typing the following command:

        ATTACH, filename, ID=DRDTAZSA

Once the user has a vehicle data file and a terrain data file residing as local files, he is ready to run the simulation. The two commands necessary to run this program are:

        ATTACH,BVRIDE,ID=DRDTAZSA

        BVRIDE,VEH,TER,BINARY

The parameters in the second statement represent the local file names corresponding to the vehicle data file, the terrain data file, and the binary output file respectively. These names should be replaced with the local file names the user has employed.

The program requests only the vehicle velocity (in MPH) and then proceeds with the simulation and the output. The printed output includes a short description of the vehicle and terrain used for the run. The vehicle velocity and length of run are also printed out followed by the simulation results. The only results printed are the RMS (root means square) and peak vertical acceleration at the driver's station followed by the driver's vertical absorbed power.

When the simulation is complete, the user may run the post processor program BANALYZE (also described within this report) with the binary output file generated by BVRIDE. With this technique it is possible to obtain a wide variety of types of output from this simulation package. If one chooses to run the post processor at some later time, the user may wish to make use of the system CATALOG command to save the binary output file. If this is not done, and another simulation is run using the same local file name for the binary output file, the original contents are over written and only the output of the most recent simulation will remain.

BANALYZE

In the past it has often occured that different users of the vehicle dynamics models would have varying objectives. One user might be quite satisfied with simply the ride comfort level as a function of vehicle velocity and terrain profile. The next might be more concerned with the force levels encountered in a spring or shock absorber during a particular run. Changing the output specifications would necessitate changes to the programs being used. This required a person knowledgeable of that program to get involved and greatly increased both the risk and the cost associated with the simulation results. Since the thrust of this total effort was to provide an unchanging vehicle dynamics package that the engineer could use and grow confortable with, it was determined that the addition of a post processor program to the package was required.

This program is that post processor. A survey was made of the types of output that users have requested in the past. This program attempts to provide access to the output forms desired for a wide variety of signals from the simulation. Since it was specifically developed to accept the simulation model output included in this package, it was also possible to write a user oriented interface. This interface portion of the program allows the user to specify the signal he desires in terms he can understand. The signal is then constructed as a linear combination of the required, stored signals and automatically generated. This reduces the chance of the user inadvertantly plotting the wrong signal and perhaps never knowing that he did. As long as the automatic signal generation capability is used, the signal will be correctly labeled on all output forms generated.

The automatically generated signals that can be selected include vertical motion of any point on the sprung mass (i.e. chasis or hull), pitch motion of sprung mass about its CG, the vertical motion of any wheel or the forcing function (terrain profile) at any wheel, or the relative motion across any suspension system component. This last item corresponds to the spring deflection or shock absorber velocity. When the signal values for this relative motion are greater than zero, the travel is in the jounce direction (i.e. the direction that tends to compress the suspension system springs).

The user also has the opportunity to create his own signal by specifying the option OTHER when the signal position is requested. If this is specified the user is asked for the label he would like to have associated with that signal and the proper units for the signal. He is then permitted to construct a signal as any linear combination of up to (and including) three items that are written in the simulation output file. This file contains the time histories of the accelerations, velocities and displacements of the sprung CG pitch and vertical motions as well as for the vertical motion of each wheel center. Also included is the forcing function or profile height at each wheel. Certain vehicle and terrain characteristics are also contained in the file and are used to label the various forms of output from this program.

In order to create his own signals the user must give the item number of the desired signal and the scale factor by which he desires that signal to be multiplied. The item numbers correspond to the signal's position within each record. The arrangement of a record is shown in Table 1. The user is responsible for making the signal units agree with the units label he types in. To accomplish this it should suffice to remember that the primary units of the data in the simulation output file are feet and radians. Therefore, if a velocity signal were desired in inches per second, a scale factor of 12 would have to be supplied with the appropriate signal element to convert from ft/sec which is the standard units for linear velocity.

It is easy to see (and easier to learn by experience) that using this option to construct one's own signals requires a great deal of care by the user if the integrity of the output is to be maintained. It is felt (and strongly hoped) that in most studies the automatic signal generation capability will provide the desired output signals.

Once a signal has been constructed, either automatically or as specified by the user, several options are available for processing that signal. Each time an option has been completed, the user is allowed to reselect from the list of options. At this point the program may be stopped or a new signal selected. The available processing options include listing certain signal statistics, computing the Power Spectral Density (PSD) of the signal, plotting the signal as a function of time, and generating a histogram from the signal. Samples of several of the processing option outputs are included in Appendix I.

Item No.	Signal Description	Units
1	CG Vertical Acceleration	ft/sec^2
2	CG Vertical Velocity	ft/sec
3	CG Vertical Displacement	ft
4	CG Pitch Acceleration	rad/sec^2
5	CG Pitch Velocity	rad/sec
6	CG Pitch Displacement	rad
7	Wheel 1 Vertical Acceleration	ft/sec^2
8	Wheel 1 Vertical Velocity	ft/sec
9	Wheel 1 Vertical Position	ft
10	Profile Height Beneath Wheel 1	ft
.		
.		
.		
$4N+3$	Wheel N Vertical Acceleration	ft/sec^2
$4N+4$	Wheel N Vertical Velocity	ft/sec
$4N+5$	Wheel N Vertical Position	ft
$4N+6$	Profile Height Beneath Wheel N	ft

Table 1   Signal Position Within The Record For The Binary Data File

The full power of this package can only be realized by using a graphics terminal. Most of the options, however, are available in some form even if a graphics terminal is not used. Following computation of either the PSD or the histogram for a signal the user has the opportunity to ask for either a tabular listing or a plot of the respective output. The statistics (this includes the number of samples, minimum, maximum, mean and rms levels of the signal) and the vertical absorbed power do not make use of the graphics. It should be noted that the results of the absorbed power option will have their normal significance only if the signal specified represents a vertical acceleration in ft/sec^2. The signal plotting option of course cannot be employed unless the program is being run from a graphics terminal.

A local file name PRINT will be generated whenever this program is run. This file will contain at least limited results for each option that is run. This will always include certain simulation and signal identification followed by a limited set of signals statistics (the rms will not be included unless the statistics, PSD, or absorbed power options are run). If the PSD option is run and tabular output is specified, a listing of signal power and signal amplitude as a function of frequency will be written in this PRINT file. In this case no similar listing will be presented at the user's terminal. This is the only situation in running this program where this is done. The rationale for this is that these listings may be as long as 200 lines and the time sharing terminals are very slow. The contents of the PRINT file may be obtained in either of two ways. Once the user has stopped this program he may still list the PRINT file at his terminal with the following two statements:

REWIND, PRINT

COPY, PRINT, OUTPUT

If instead it is desired to print the file on a remote batch terminal the following two statements will suffice:

REWIND, PRINT

BATCH, PRINT, PRINT,B5, NAME

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In the BATCH command, the first occurence of PRINT refers to the file name. The parameter B5 is the terminal ID at which the output is to be printed (B5 is currently the ID for the batch terminal at TARADCOM). The final parameter NAME is some arbitrary name that will be associated with the printout.

The running of this post processor program (i.e. BANALYZE) can be initiated with the following two statements:

    ATTACH, BAN, BANALYZE, ID=DRDTAZSA

    BAN, BINARY

The parameter BINARY in the second statement above, should be replaced with the local file name corresponding to the binary data file which is to be analyzed. This file should have been created by the simulation package described within this report.

It is necessary, of course, to run this program from a graphics terminal (a Tektronix 4014) if any plotting is to be done. If the plotting options are not used, any interactive terminal will be adequate.

BWHEELS

One type of vehicle dynamic analysis often requested is to find
the driver's ride limiting velocity across various cross country
terrains. This analysis can be performed using the program BVRIDE.
The problem also arises to determine the driver's ride limiting speed
over discrete semicircular obstacles of various heights. The ride
limiting criteria for the driver over discrete obstacles is usually
considered to be 2.5g peak vertical acceleration, whereas for cross
country driving an average vertical absorbed power limit of six watts
is used. The BVRIDE program prints the peak acceleration and average
absorbed power for each simulation and could be used for the ride
performance evaluations over discrete obstacles.

However, since several simulations are run for each obstacle height
and each one is quite short, a modified version of BVRIDE is offered
for simulating the vehicle over semicircular obstacles. The advantage
offered by this modified program is that up to ten vehicle velocities
can be run over a particular user specified obstacle with a single
run command.

The output is a table of vehicle velocity versus the simulated
driver's peak vertical acceleration at each velocity. Rather than
requiring a single velocity the user must supply an initial velocity,
a delta velocity, and a final velocity. Runs will be made at increasing
velocities until one of three things occur. The three possible con-
ditions that will cause the run to terminate are: the maximum velocity
requested has been exceeded; ten different velocities have been simulated;
or a run has been made in which the driver experienced at least 2.5g
vertical acceleration.

This program acepts the same vehicle data file as does the program
BVRIDE and the time limit may have to be extended for this program,
as shown in the BVRIDE description. No terrain data file is require,
however, since the appropriate obstacle is generated within this program.
A binary file can be generated by this program which can be analyzed
with the post processor program BANALYZE. This binary file will not
normally be created but when it is it will contain the results from
a single simulation (i.e. at only one vehicle velocity). If a binary
file is desired, the user can cause its generation by entering a zero
for the maximum vehicle velocity. If this is done a single simulation
will be performed at the minimum velocity entered, the results will be
printed and the binary output file will be written.

This program can be run from any time sharing terminal with the following two statements:

    ATTACH,BWHEELS,ID=DRDTAZSA

    BWHEELS,VEH,BINARY

The parameters VEH and BINARY have the same interpretation here as they do in the running of BVRIDE.

subroutine	function
TRAJ	calculate wheel path
SEG	
UPA	initialize integration routines
LINEAR	initialize vehicle
YCALC	get wheel position
INNEG	integrate wheel equations
TANDOM	tandom equations (if present)
INNEG	integrate c.g. equations
PPCALC	driver's acceleration
UPD	update integration package
UPC	
UPB	
ZOOM	driver's absorbed power
PSD	
CONVRT	
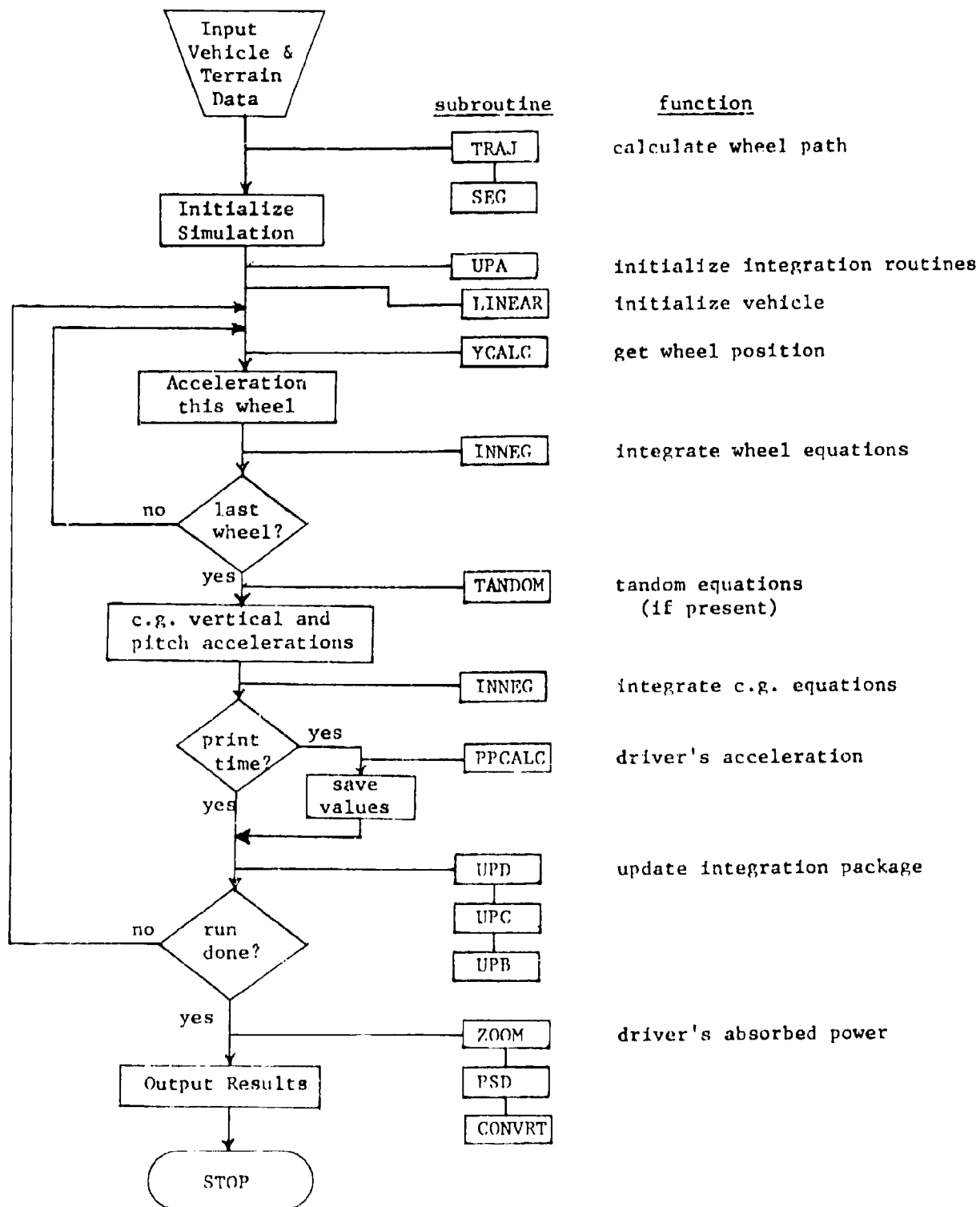
VRIDE Flow Diagram by Subroutine

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1. Lins, William F., "Human Vibration Response Measurement",
TACOM Technical Report No. 11551, June 1972.

2. Hoogterp, Francis B., "Simulated Vehicle Suspension and
Stability", TACOM Technical Report No. 11432, October 1971.

3. Hoogterp, Francis B., "Digital/Analog Vehicle Ride Simulation",
TACOM Technical Report No. 11705, November 1972.

APPENDIX I

Sample Vehicle Analysis

Engineering Data Required for Test Jeep

Sprung Weight . . . . 2710 lbs

Unsprung Weight . . . . 410 lbs

Sprung Pitch Moment of Inertia about
the CG . . . . 719 slug-ft^2

Wheel No. 1 Forward of CG . . . . 44 in

Wheel No. 2 Aft of CG . . . . 40 in

Driver's Position Forward of CG . . . . 1 in

Spring Rate of Tires . . . . 675 lbs/in

Damping Rate of Tires . . . . 0.75 lbs-sec/in

The spring and damping curves representing the vehicles suspension
system are shown in the following two pages.

This test vehicle is similar to the data for the M151A1 1/4 ton truck.
Certain minor changes were made, however, in the interest of simplifying
the data input example. If precise data on the M151A1 is desired, it
should be obtained from another source.
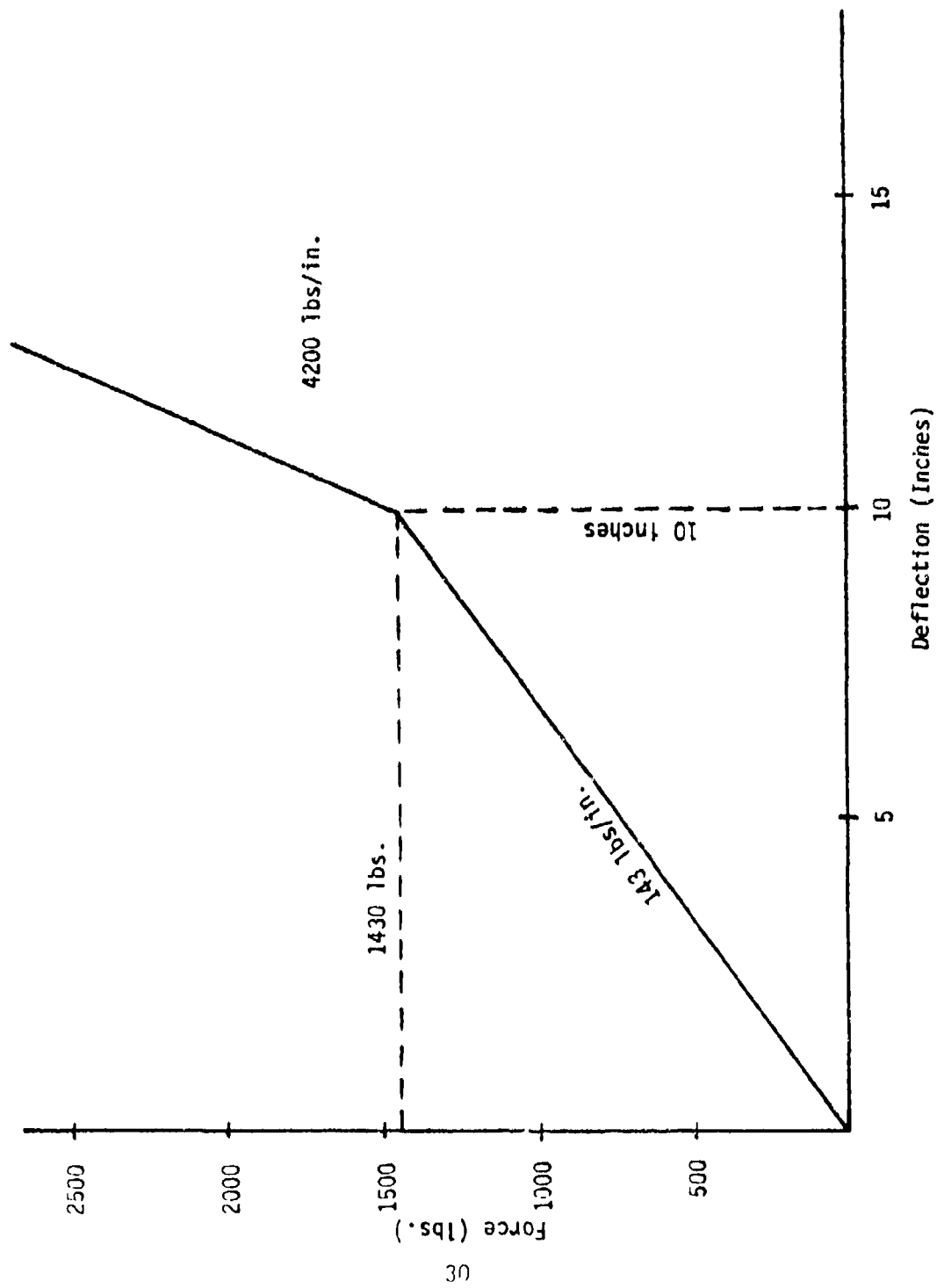
CURVE FOR THE WHEEL SPRINGS
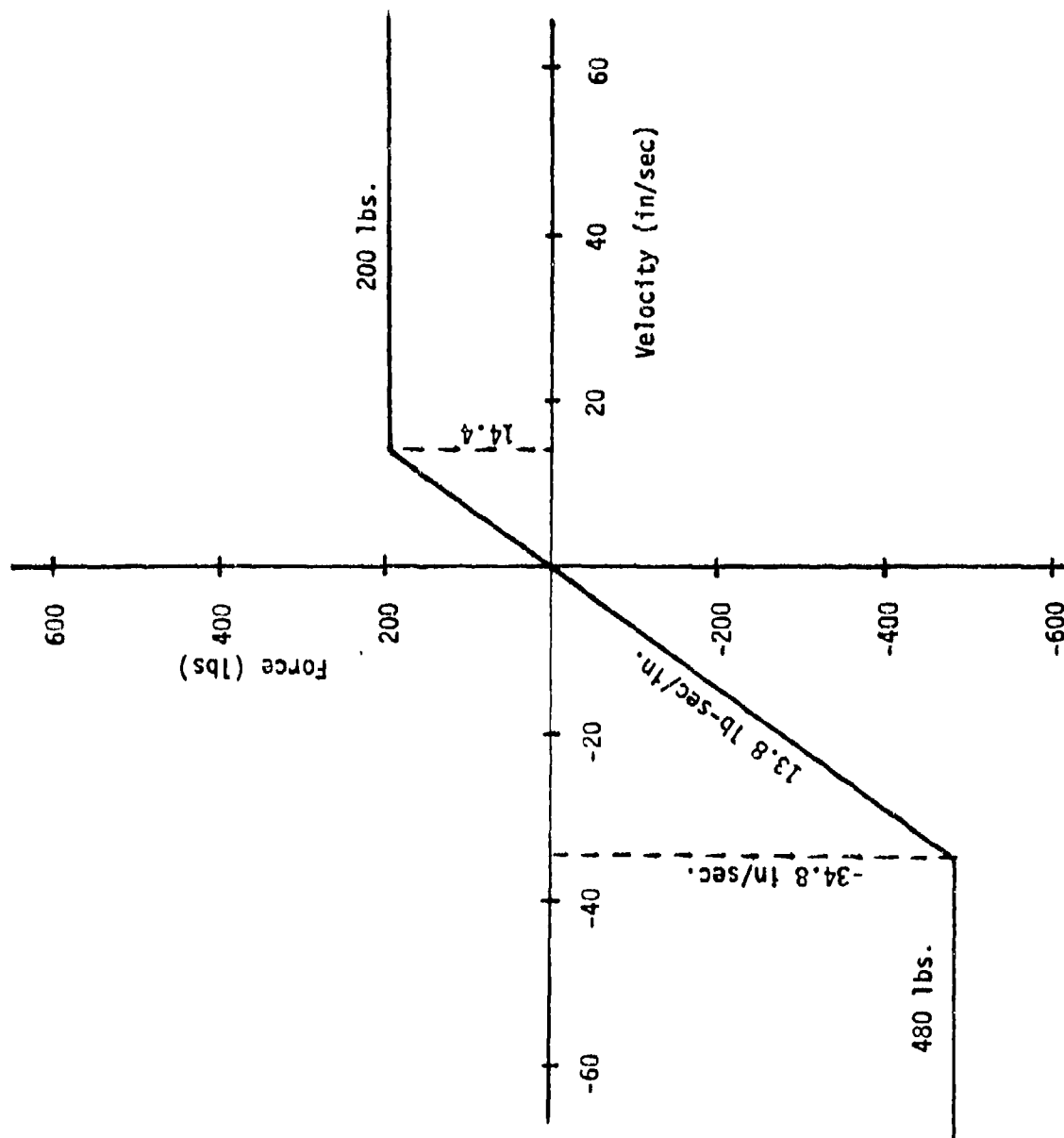
DAMPING CURVE FOR THE SHOCK ABSORBERS

DORET,VEH

OPTIONS: STOP=-1; DATA ENTRY=0; ZERO PITCH=4; DATA CHECK=2 OR 9
0

ENTER VEHICLE IDENTIFICATION:
M151A1 1/4 TON TRUCK

SPRUNG & UNSPRUNG WEIGHT ? 2730,414

UNSPRUNG WEIGHT EVENLY DISTRIBUTED (YES=1) ? 1

PITCH MOMENT (SLUG-FT2) AND DRIVER (X,Y) (INCHES) ? 719,1,0

NO. OF WHEELS, NO. OF WHEELS FORE OF CG, & NC. OF TANDEMS ? 2,1,0

HORIZONAL WHEEL POSITION FROM CG (IN INCHES) ?
WHEEL NO.
   1   44
   2   48

NO. OF SEGMENTS IN SPRING CURVE :   (OR 0 FOR PREVIOUS CURVE) = 3
INITIAL SLOPE (LBS/IN) ? 143
BREAKPOINT 1 (INCHES,LBS) = 0,0
BREAKPOINT 2 (INCHES,LBS) = 10,1430

SOURCE STOP SLOPE (LBS/IN) =6200

NO. OF SEGMENTS IN DAMPING CURVE 1 (OR 0=PREVIOUS CURVE; -1=NO DAMPING) 4
INITIAL SLOPE (LBS/IN/SEC) =0
BREAKPOINT 1   (IN/SEC,LBS) = -34.8,-420
BREAKPOINT 2   (IN/SEC,LBS) = 0,0
BREAKPOINT 3   (IN/SEC,LBS) = 14.4,200
FINAL SLOPE (LBS/IN/SEC) = 0

SAME CHARACTERISTICS FOR EACH WHEEL (YES=1) ? 1

TIRE 1 SPRING & DAMPING RATES (LBS/IN & LBS/IN/SEC) ? 675,0.75

NO. OF SEGMENTS IN SPRING CURVE 2 (OR 0 FOR PREVIOUS CURVE) = 0

NO. OF SEGMENTS IN DAMPING CURVE 2 (OR 0=PREVIOUS CURVE; -1=NO DAMPING) 0

ROLLING RADIUS (INCHES) = 16

IS A BUMPER OR SPROCKET TO BE INCLUDED (YES=1) ?0

OPTIONS: STOP=-1; DATA ENTRY=0; ZERO PITCH=4; DATA CHECK=8 OR 9
-1

STOP
COMMAND-.186 CP SECONDS EXECUTION TIME

M151A1 1/4 TON TRUCK

```
                                    .883    719.    0.000  2  1  0  0  0
                                           09/07/78

M151A1 1/4 TON TRUCK
2710.       410.
3.667       3.333
0030441221010
0       0       1       2       1       1       0
1716.   1716.          1716.
0.              0.              50400.
0.000   .833            -40570.
0.0     165.5   166.7   100.000   0.0
-400.0  0.0     0.0             200.0
-2.000  0.000   1.200           100.000
8100.
0.
100.    165.5   166.7           0.0
0.0     0.0     0.0             200.0
100.    0.000   1.200           100.000
0.      -400.0
-2.000
32.0
```

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VEHICLE IDENTIFICATION   M151A: 1/4 TON TRUCK

GVW   3189.   LBS

SPRUNG   2718.   LBS

UNSPRUNG   418.   LBS

PITCH MOMENT OF INERTIA 718.   SLUG-FT-SQ.

198 POINTS FOR   THREE INCH SPACED BUMP COURSE

VEHICLE VELOCITY= 10.0 MPH

LENGTH OF RUN= 12.6 SEC.

PEAK ACCELERATION   :   .47 G S

RMS ACCELERATION   :   .15 G S   PSD AREA =   .15 G S

ABSORBED POWER OF   :   1.90 WATTS
DRIVER

STOP
16.646 OF SECONDS EXECUTION TIME
COMMAND—

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M151A1 1/4 TON TRUCK
10.0 MPH   THREE INCH SPACED BUMP COURSE

CG VERTICAL DISPLACEMENT

TIME--SEC

INCHES
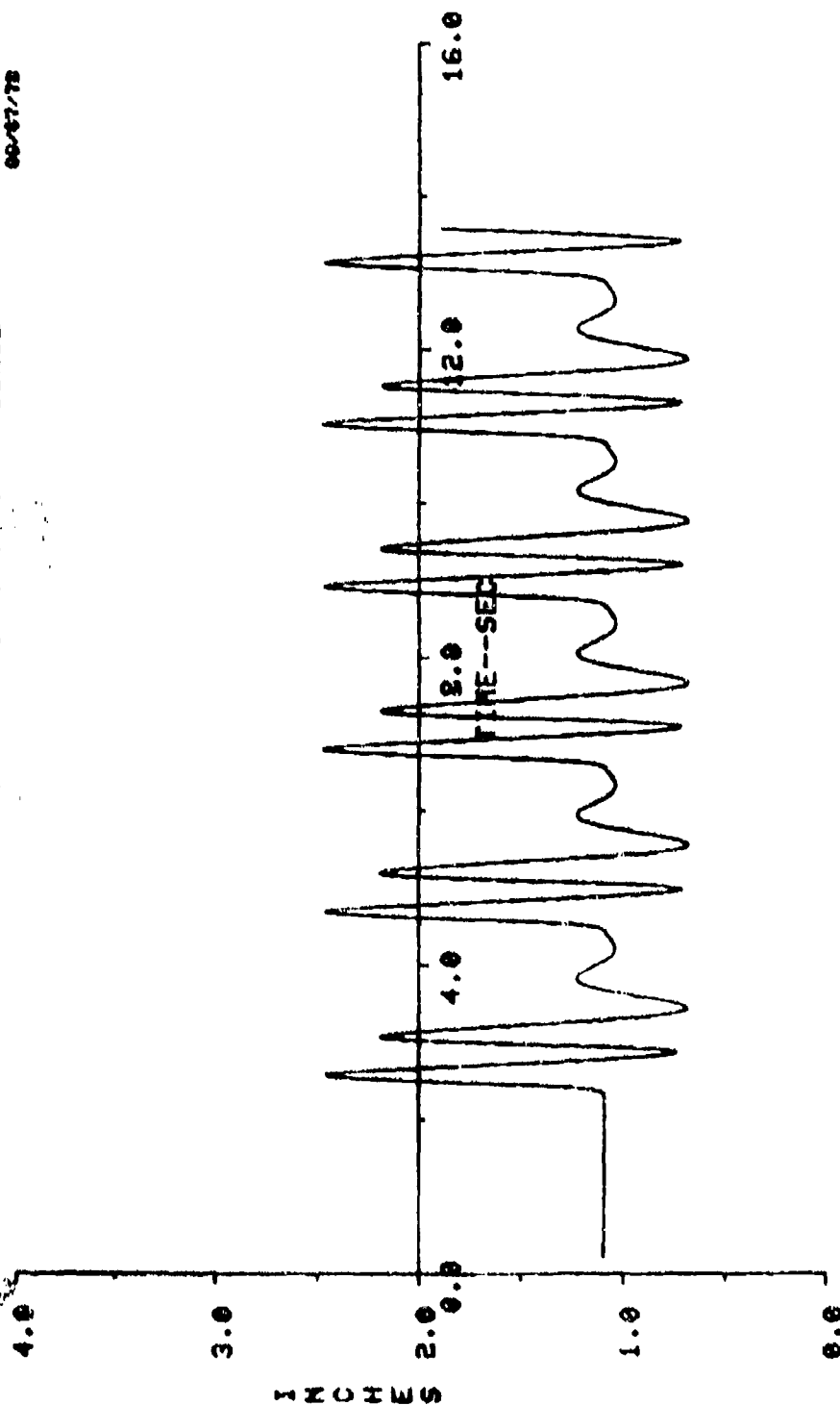
M151A1 1/4 TON TRUCK
10.0 MPH   THREE INCH SPACED BUMP COURSE

WHEEL 1 TO CHASIS DISPLACEMENT

09/07/78

M151A1 1/4 TON TRUCK
10.0 MPH   THREE INCH SPACED BUMP COURSE
VERTICAL ACCELERATION OF CG

09/07/75

FREQUENCY--HZ

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APPENDIX II

Vehicle Data File Contents

CARD 1   FORMAT (6A10)

The first 60 columns of this card are used for the vehicle name and description. This information will serve not only to identify the file but will also appear on all outputs from this package.

CARD 2   FORMAT (5F10.0, 4I2)

WS   Sprung weight of vehicle (lbs)

WU   Unsprung weight of vehicle (lbs)

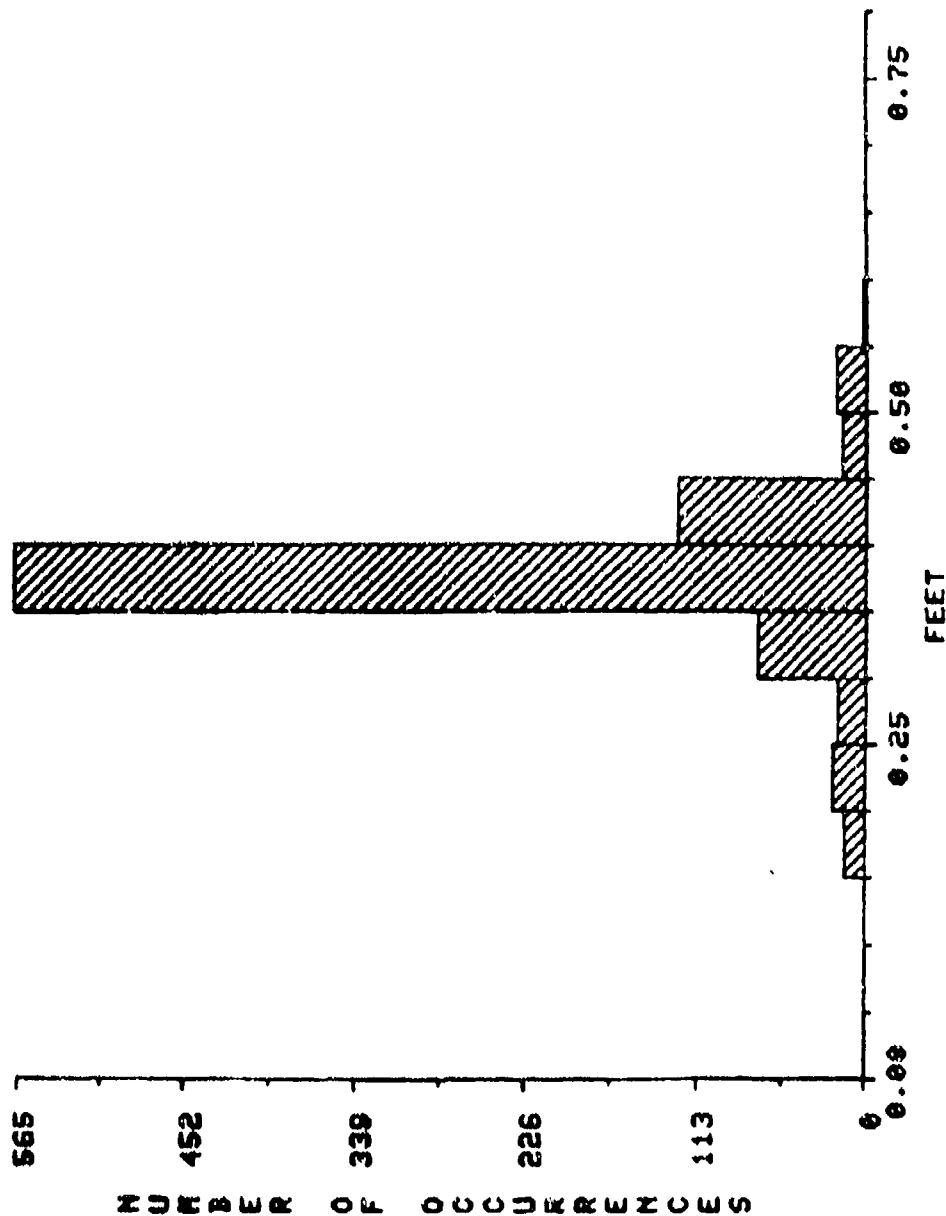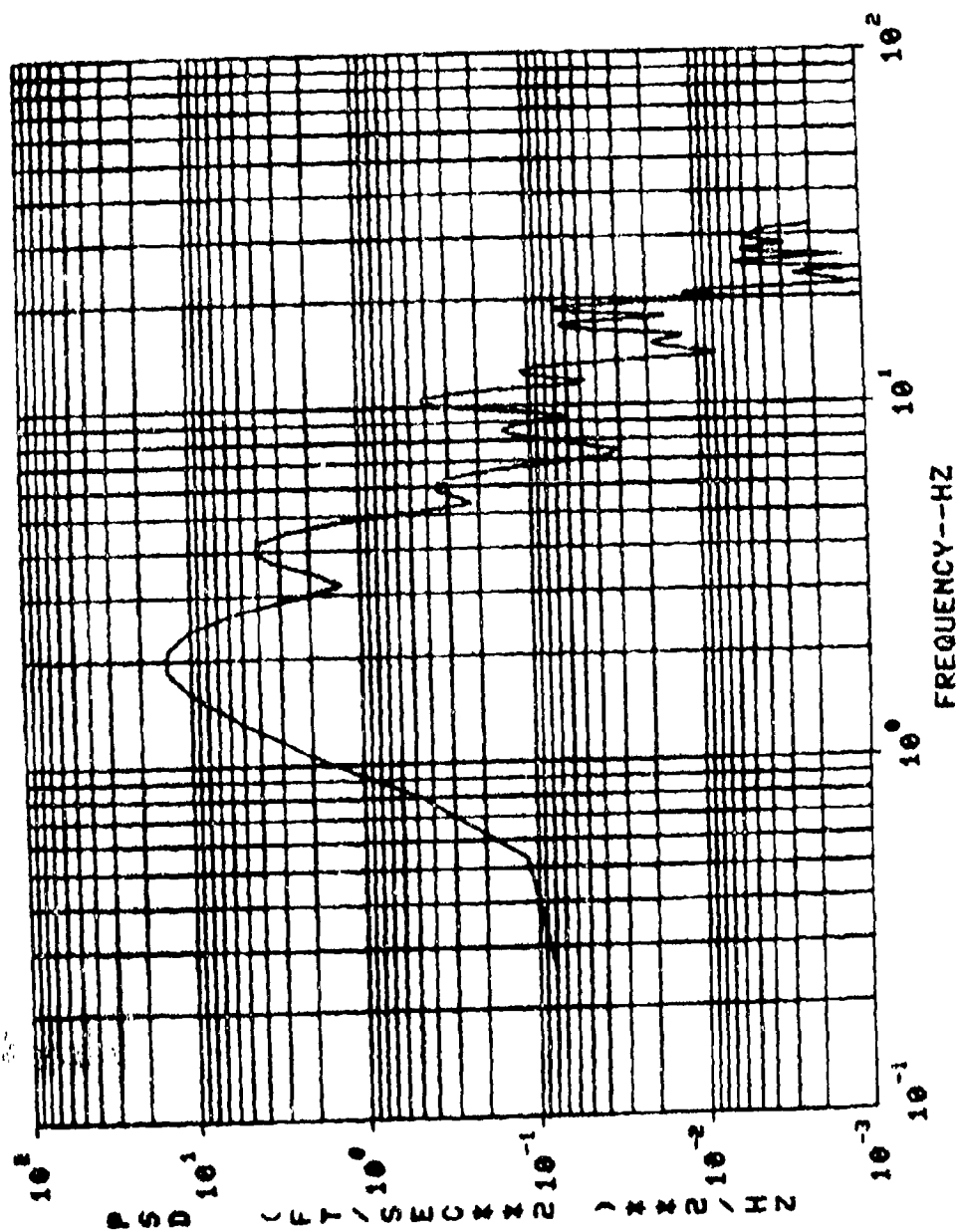J   Sprung pitch moment of inertia of vehicle (slug-ft^2)

XC(1)   Horizontal distance of selected location from CG (ft). This must be negative if location is behind the CG.

YC(1)   Vertical distance of selected location from CG (ft). This must be negative if location is CG. Note: this location is referred to as the driver's position on output.

N   Number of wheels on one side of vehicle.

NCG   Number of wheels in front of CG on one side of vehicle.

NT   Number of tandems on one side of vehicle.

NTCG   Number of tandems in front of CG on one side of vehicle. The tandem is considered to be in front of the CG, if, and only if, the pivot point of the tandem is in front of the CG.

CARD 3   FORMAT (7F10.0)

L(I)   For I = 1 to N, the number of wheels per side. Horizontal distance from CG to Ith wheel. Enter absolute value of number (ft). If there are more than seven wheels, on a side, two cards will be needed.

CARD 4   FORMAT (60I1)

TNDARY (I) Enter a 0 if the wheel is not in tandem, a 1 if it is the front wheel in a tandem, and a 2 if it is the second wheel in a tandem.

NOSSEG (I) Number of segments in vehicle's spring curves, (maximum is 6).

NODSEG (I) Number of segments in vehicle's damping curves, (maximum is 6).

DMPTYP (I)   Enter a 0 to indicate no damper; a 1 for a one-way damper
                (i.e., damping on the compression stroke only); and a 2
                for a two-way damper.

NORSEG (I)   Number of segments in tire's spring curve, (maximum is 6).

NORDEG (I)   Number of segments in tire's damping curve, (maximum is
                6).

NOTE: I goes from 1 up through N, the number of wheels on one side. The
        N values of one variable are entered before any of the next variable.

CARD 5   FORMAT (7I4)

VELOPT   Enter a 1 if a sprocket is to be included in the simulation,
                otherwise a 0. If a one is entered, CARD 12 must be included.

POOPT   Enter a 0 if the unsprung weight is to be divided evenly
                among the wheels or a 1 if the weight of each wheel is to
                be entered. If a 1 is entered, then CARD 7 must be
                present.

SPOPT   A 1 signifies all vehicle's spring curves are the same (thus
                only the first need be in the data deck providing NOSSEG
                (I) = 0 on CARD 5 for I1). A value greater than 1 indicates
                the number of cures to be read in. The Cards 8 thru 10
                are needed for each wheel that has NOSSEG (I)   0. The
                spring curve for any wheel that is not read in will be set
                the same as the curve of the previous wheel.

DAMOPT   A 1 signifies all vehicle damping curves are the same.
                A 2 indicates that all the wheels do not have the same
                damping. If only certain wheels have damping, a 2 must
                be entered.

SRUBOP   A 1 indicates all tires have the same spring curve; a 2
                means they don't all have the same spring curve.

DRUBOP   A 1 indicates that all tires have the same damping curve;
                a 2 means they don't all have the same damping curve.

KTYPE   Enter a 1 if this vehicle has a fifth wheel hitch, otherwise
                enter a 0. If a 1 isentered, CARD 13 is required.

NOTE: At present, at least one segment must be used for the tire, spring,
        and damping curves.

CARD 6   FORMAT (7 F10.0)

This card is optional. It is needed only when the value of POOPT on
CARD 5 is greater than zero. The sum of the wheel weights should be the
unsprung weight for one side of the vehicle.

MW (I)   For I=1 to N. The weight of the Ith wheel (lbs).

CARD 7   FORMAT (3 F10.0)

One of these cards must be supplied for each tandem I for I=1, NT.

TNDJ (I)   The pitch moment of inertia of the tandem (slug-ft^2)
                about its pivot point.

LWB (I)   Distance from wheel center to tandem pivot (feet).

LK (I)   Horizontal distance from vehicle's sprung CG to tandem
                pivot (feet).

CARDS 8 - 10   FORMAT (6 F10.0)

This set of data cards will come in groups of three. These cards will be
used to describe the curves for the various spring and damper elements
of the vehicle model.

The values of NOSSEG (I), NODSEG (I), NORSEG (I), AND NORDEG (I) were
obtained from CARD 4 for each wheel I. These values will then be checked
in that order for each wheel. Each time a positive value is found, call
that value N1, three cards will be read in. The first card will contain
the N1 slopes of the linear segments of the curve. The second card will
contain the Y-intercepts of each of these N1 segments of the curve. The
third card will then contain the N1 horizontal values at which the corres-
ponding segments end. The values on these three cards should be in LBS/FT,
respectively (or LBS-SEC/FT, LBS, and FT/SEC for damping curves).

Whenever a 0 is found for the number of segments of a curve, no data
cards are read in. This process is continued for I=1 up to and including
I=N where N is the number of wheels on one side of the vehicle.

It should be noted that if the vehicle spring curves, vehicle damping
curves, tire spring curves, or tire damping curves are identical for
all wheels, then only the curve for the first wheel needs to be read in.
In order to do this, however, the number of segments for that curve must

be equal to zero for all other wheels on CARD 5. Also, the appropriate option must be set equal to one on CARD 5 (SPOPT, DAMOPT, SRUBOP or DRUBOP).

It should be noted also that all curves needed for one wheel must be supplied before any curves for the next wheel.

This program determines the average static load required at each wheel to support the vehicle. The actual static position is then assumed to be on the same linear segment as the average static load is. In other words, once the proper segment is determined, this segment is assumed to be extended over the necessary range of deflection in order to carry out the initialization of the vehicle. Once the initial conditions are determined the actual spring curve representations are used in the simulation.

CARD 11   FORMAT (F10.0)

DIAM   The effective wheel diameter (i.e., twice the rolling
           radius) in inches.

CARD 12   FORMAT (3F10.0)

This card is needed only if the value of VELOPT on CARD 5 is equal to 1. This card provides the necessary data on the sprocket if one is to be included in the simulation.

SPRCL   The vertical sprocket clearance at static (ft).

SPROC   The horizontal distance of the sprocket from the
           CG (ft).

SPRK   The spring rate of the sprocket (lbs/ft).

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<u>CARD 13</u>   FORMAT (3 F10.0)

This card is needed if the value of KTYPE on CARD 5 is equal to 1.
This card provides the necessary data for the hitch on a truck tractor
when modeling tractor-trailer combinations.

CGHT   Horizontal distance from vehicle CG to fifth wheel
            hitch (ft).

SRHT   Spring rate of fifth wheel hitch (lbs/ft).

DRHT   Damping rate of fifth wheel hitch (lbs/ft/sec).

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APPENDIX III

Terrain Data File Format

CARD 1   FORMAT (I5,F10.0,5A10)

NTER   The number of terrain data points that are to be read
              in.

D2SINC   The horizonal spacing of the terrain data points (in feet).

TERIDT   A terrain label of up to 50 characters in length may be
              entered here. This label will appear on all printouts
              using this terrain.

CARD 2 thru LAST CARD   FORMAT (6F10.0)

ATAB   The terrain elevations in feet at the
                             specified horizonal spacing.

APPENDIX IV

Standard Terrain Files

FILE NAME	RMS (IN.)	LENGTH (PTS.)	DESCRIPTION (DATE)
APG9	1.04 RMS	301 FT. (301)	APG COURSE NINE
APG11	1.32 RMS	401 FT. (401)	APG COURSE ELEVEN
APG12	1.70 RMS	301 FT. (301)	APG COURSE TWELVE
APG14	3.40 RMS	301 FT. (301)	APG COURSE TWELVE DOUBLED
APG29	2.17 RMS	301 FT. (301)	APG COURSE TWENTY-NINE (11 NOV 76)
APG30	1.15 RMS	251 FT. (251)	APG COURSE THIRTY (10 NOV 76)
APG31	3.88 RMS	401 FT. (401)	APG COURSE THIRTY-ONE (16 NOV 76)
APG37	0.68 RMS	401 FT. (401)	APG COURSE THIRTY-SEVEN (13 NOV 76)
APGIV	3.43 RMS	469 FT. (469)	APG COURSE PROFILE FOUR
FTHDT1	2.00 RMS	100 FT. (200)	FT. HOOD TRAIL T1
FTHDT3	0.60 RMS	401 FT. (401)	FT. HOOD TRAIL T3
FTHDCC1A	0.50 RMS	400 FT. (400)	FT. HOOD TRAIL CC1A
FTHDSR1	0.40 RMS	401 FT. (401)	FT. HOOD SECONDARY ROAD
TERR4	1.94 RMS	372 FT. (372)	FT. KNOX MEDIUM TERRAIN
PERRY	4.12 RMS	442 FT. (442)	PERRYMAN TERRAIN SIX
LEVELRD	0.00 RMS	132 FT. (132)	FLAT LEVEL ROAD (30 AUG 78)
BUMP6	X.XX RMS	95 FT. (190)	ONE 6 INCH TRAPEZOIDAL BUMP
BUMPS3	X.XX RMS	190 FT. (190)	THREE INCH TRAPEZOIDAL BUMPS SPACED 31 FT. APART.
ROUND3	X.XX RMS	18.3 FT. (220)	ONE 3 INCH SEMICIRCULAR BUMP
ROUND6	X.XX RMS	11 FT. (132)	ONE 6 INCH SEMICIRCULAR BUMP
ROUND8	X.XX RMS	84 FT. (370)	ONE 8 INCH SEMICIRCULAR BUMP
ROUND12	X.XX RMS	70.5 FT. (370)	ONE 12 INCH SEMICIRCULAR BUMP
FTNX01	.75 RMS	501 FT. (501)	FT. KNOX COURSE #1 RT. TRACK (27 MAR 78)
FTNX02	.84 RMS	501 FT. (501)	FT. KNOX COURSE #1 LEFT TRACK (28 MAR 78)
FTNX03	1.10 RMS	501 FT. (501)	FT. KNOX COURSE #2 RT. TRACK (24 MAR 78)
FTNX04	1.24 RMS	501 FT. (501)	FT. KNOX COURSE #2 LEFT TRACK (18 MAR 78)
FTNX05	1.80 RMS	501 FT. (501)	FT. KNOX COURSE #3 LEFT TRACK (23 MAR 78)
FTNX06	1.95 RMS	501 FT. (501)	FT. KNOX COURSE #3 RT. TRACK (23 MAR 78)
FTNX07	2.84 RMS	401 FT. (401)	FT. KNOX COURSE #4 LEFT TRACK (18 MAR 78)

FILE NAME	RMS(IN.)	LENGTH (PTS.)	DESCRIPTION (DATE)
FTNX08	3.61 RMS	401 FT. (401)	FT. KNOX COURSE #4 RT. TRACK (18 MAR 78)
FTNX09	5.22 RMS	401 FT. (401)	FT. KNOX COURSE #5 RT. TRACK (18 MAR 78)
FTNX10	5.27 RMS	401 FT. (401)	FT. KNOX COURSE #5 LEFT TRACK (18 MAR 78)
FTKN1	.82 RMS	501 FT. (501)	FT. KNOX COURSE #1 RT. TRACK (5 MAY 78)
FTKN2	.83 RMS	501 FT. (501)	FT. KNOX COURSE #1 LEFT TRACK (27 MAY 78)
FTKN3	1.03 RMS	501 FT. (501)	FT. KNOX COURSE #2 RT. TRACK (5 MAY 78)
FTKN4	1.04 RMS	501 FT. (501)	FT. KNOX COURSE #2 LEFT TRACK (26 MAY 78)
FTKN5	2.07 RMS	501 FT. (501)	FT. KNOX COURSE #3 RT. TRACK (1 MAY 78)
FTKN6	1.85 RMS	501 FT. (501)	FT. KNOX COURSE #3 LEFT TRACK (2 MAY 78)
FTKN7	3.91 RMS	401 FT. (401)	FT. KNOX COURSE #4 RT. TRACK (3 MAY 78)
FTKN8	3.57 RMS	401 FT. (401)	FT. KNOX COURSE #4 LEFT TRACK (5 MAY 78)
FTKN9	2.31 RMS	401 FT. (401)	FT. KNOX COURSE #5 RT. TRACK (3 MAY 78)
FTKN10	2.40 RMS	401 FT. (401)	FT. KNOX COURSE #5 LEFT TRACK (1 MAY 78)
FORT2	.87 RMS	501 FT. (501)	FT. KNOX COURSE #1 LEFT TRACK (14 JUL 78)
FORT3	.99 RMS	501 FT. (501)	FT. KNOX COURSE #2 RT. TRACK (14 JUL 78)
FORT4	1.05 RMS	501 FT. (501)	FT. KNOX COURSE #2 LEFT TRACK (14 JUL 78)
FORT5	1.69 RMS	501 FT. (501)	FT. KNOX COURSE #3 RT. TRACK (14 JUL 78)
FORT6	1.88 RMS	501 FT. (501)	FT. KNOX COURSE #3 LEFT TRACK (14 JUL 78)
FORT7	3.73 RMS	401 FT. (401)	FT. KNOX COURSE #4 RT. TRACK (14 JUL 78)
FORT8	3.74 RMS	401 FT. (401)	FT. KNOX COURSE #4 LEFT TRACK (14 JUL. 78)
FORT9	2.28 RMS	401 FT. (401)	FT. KNOX COURSE #5 RT. TRACK (14 JUL 78)
FORT10	2.41 RMS	401 FT. (401)	FT. KNOX COURSE #5 LEFT TRACK (14 JUL 78)

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Ride Evaluation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes an integrated package for evaluating the dynamic effects of driving a vehicle across any described section of terrain. The model incorporated includes only the pitch and roll motions of the chasis (or hull). The package is composed of a four digital computer programs. Each program is designed to be run interactively and does not require that the user have any programming experience. The programs provide the capability to create vehicle data files, perform simulations, and specify the form and types of the output desired. A general description of the model structure, its capabilities and its (cont

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20. Abstract

limitations is included along with user instructions for running each program
in the package.