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Performance Evaluation of NDOR Mountable Curbs

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ABSTRACT

Three commonly used Nebraska Department of Roads (NDOR) mountable curbs were investigated for relative safety through a combination of full-scale testing and computer simulation using the Highway-Vehicle-Object-Simulation-Model (HVOSM). The curbs that were investigated included one 4-in. and two 6-in. mountable curbs. The applicability of the model was evaluated with 23 full-scale tests, including thirteen tests on a 4-in. wedge shaped curb, two tests on a 6-in. wedge shaped curb and eight tests on a 6-in. Type I Mountable curb. The crash tests were conducted with 1800 and 4500-lb test vehicles at impact speeds of 45, 50, and 55 mph and impact angles of 5, 12.5, and 20 degrees. HVOSM was first validated against all 23 full-scale crash tests and then used to predict vehicle behaviors at alternate impact conditions.

The simulation and crash test program have shown that Nebraska's mountable curbs do not have a potential for causing loss of vehicle control or vehicle destabilization when impacted in a tracking condition. Although the 6-in. mountable curbs were found to cause slightly higher vehicle motions, the differences do not appear significant enough to indicate a reduced safety performance for these curbs. Also, it was determined that the performance of W-beam guardrail can be adversely effected when used in conjunction with roadside curbs. Additionally, through a limited simulation effort of non-tracking impacts, it was determined that these curb types may be traversable over a wide range of vehicle orientations and may not be a significant cause of vehicle rollovers.

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1 INTRODUCTION

1.1 Problem Statement

Curbs have long been recognized as a potential roadside safety hazard on high-speed urban and rural facilities. High speed curb impacts can cause tire blow-out or damage a vehicle's steering mechanism, thereby leading to loss of vehicle control. Curb type and placement have a significant effect on the safety and the utilization of these facilities. Curbing is desirable along highways passing through small towns and suburban areas to facilitate drainage, delineation of pavement edge and pedestrian walkways as well as providing access control. However, state highways passing through these areas often maintain high speed limits with operating speeds near 55 mph. The Nebraska Department of Roads (NDOR) incorporates mountable curbs in these areas to minimize the safety problems associated with curb implementation along high speed roadways. Unfortunately, the safety benefits of this policy have never been adequately evaluated.

1.2 Objective

The goals and objectives of this study were focused on evaluating the relative safety of 4-in. and 6-in. mountable curbs during tracking and non-tracking impacts. This evaluation procedure consisted of a combination of full-scale testing and computer simulation. Such vehicle responses as roll, pitch, and yaw angular displacements as well as overall trajectories, including bumper height trajectories were evaluated and reported. Research findings will contribute to a better understanding of the safety problems posed by mountable curbs installed along high speed roadways.

2 BACKGROUND

While curbs are used extensively on all types of urban and rural highways, caution should be exercised in their use. General guidelines for curb implementation are contained in the American Association of State Highway and Transportation Officials (AASHTO) Policy on the Geometric Design of Highways and Streets (1). This document discusses two general categories of curb, barrier and mountable. Barrier curbs incorporate nearly vertical faces and were originally developed to offer some protection of sidewalk pedestrians and motorists by redirecting vehicles impacting at low angles and low speeds. However, full-scale crash testing and computer simulations of curb impacts indicated that even the tallest barrier curbs do not provide any significant pedestrian or motorist protection(2,3). Even for the low angle impacts in which the taller curbs were found to be capable of redirecting impacting vehicles, both tires on the impact side of the vehicle mounted the curb and redirection was obtained when the offside tires contacted the curb. In this situation, the impacting vehicles penetrated over 5 ft beyond the curb and then were redirected down the middle of a roadside side walk. Thus, these curbs offer no protection to sidewalk pedestrians. As mentioned previously, barrier curbs are believed to be capable of causing tire blowout, steering linkage damage, and tripping of non-tracking vehicles. Thus, the use of these curbs has been discouraged.

Mountable curbs incorporate a low profile and relatively flat slopes in order to reduce the potential for causing tire blowout or suspension damage. Slopes on these curbs are recommended to be 1:1 or less, especially for curb heights above 4 in. to minimize the potential safety problems. Some highway agencies construct a vertical section on the lower face as an allowance for future resurfacing. In this case, the vertical portion of the curb should not exceed 2 in. and the total curb height should be limited to 6 in. These curbs are frequently incorporated along high speed roadsides and medians to provide improved drainage control, pedestrian walkway and roadside delineation, improved pavement durability, and access control. (1)

Curbs should not be incorporated when the same objectives can be attained by other methods. Curbs are almost always incorporated on low speed roadways, such as urban local streets with speed limits in the range of 25-30 mph and curbs are not recommended on freeways and high speed rural highways. However, in the intermediate range where design speeds are between 40 to 50 mph, highway engineers must make a decision regarding curb implementation based on individual roadway conditions. In this case, curbs are generally recommended in predominantly urban areas and discouraged under rural conditions. (1)

2.1 Previous Curb Testing

Very limited research has been performed on the safety effects of mountable curb impacts. Although a few studies have included testing on mountable curbs as part of barrier curb evaluations, none have addressed mountable curb testing specifically. These studies normally report a vehicle's behavior during and after curb impacts in a tracking mode. Vehicle behavior of interest normally includes the overall trajectory, angular displacements, and vaulting potential. Major safety concerns associated with curb impacts include loss of control arising from tire blow-out and suspension damage, tripping of non-tracking vehicles, and secondary impacts with other roadside obstacles.

Most of the research involving curbs has been analytical, involving computer simulations with the Highway Vehicle Object Simulation Model (HVOSM) computer program (4). The program has been successfully validated for moderate and high angle tracking impacts. The program was then used to evaluate vehicle behavior during impacts with various types of curbs and a wide range of impact conditions. The following is a summary of major analytical and full-scale curb testing research studies. Included within this summary are the curb types that were tested and the major findings of the evaluations.

The first published research on curb mounting and redirection was a 1953 study by the California Division of Highways (2). This research consisted of 149 full-scale impact tests on eleven different curb cross-sections. Impact speeds ranged from 5 to 50 mph at angles between 5 and 30 deg. Of the eleven different curbs tested, two of them were 12 in. high, eight were 9 in. high, and one was 6 in. high. All, except for the 6-in. curb, were considered to be barrier curbs. This research focused on identification of the effects of barrier curb face slope and roughness. Prior to testing, researchers hypothesized that a steeper curb face would discourage mounting and enhance redirection. Test results showed this to be correct only for impact angles above 15 and 20 degrees. At the lower angles, the vertical curb face actually enhanced mounting by providing a surface for the wheel rim to catch and bite into. This trade off occurred at a slope of about 2:9 (i.e., 2 in. of slope set back in 9 in. of height). Slopes steeper than 2:9 had a tendency to enhance mounting through rim contact while those with flatter slopes did so by ramping with the tire.

As a direct result of these tests, a second series of barrier curb tests was undertaken in 1955 to provide specific recommendations for the design of more efficient barrier curbs (5). This testing was undertaken to investigate the effects of curb height. As expected, researchers found that increasing curb height did indeed enhance redirection. However, increased curb height also significantly increased vehicle damage and the potential for loss of control for vehicles mounting the curbs. Among the recommendations given as a result of these two series of impact tests are the following:

1. Barrier curbs cannot effectively redirect impacting vehicles at heights less than 10 in. and curb faces should be undercut to prevent tires from mounting due to tire scrubbing forces.
2. Barrier curb texture should not be smooth or rough. A smooth surface was found to redirect an impacting vehicle back into traffic at a relatively high angle, while an overly rough surface increased the probability that an impacting vehicle will mount barrier curbs due to increased scrubbing forces.
3. The upper corner of the curbs should be rounded in order to reduce the tendency of the wheel rim to grab onto the curb top and lift the wheel.

It should be noted that all of this testing involved biased ply tires. Radial tires would be expected to sustain higher scrubbing forces and therefore be even more difficult to redirect.

A study involving an impact evaluation program was performed by Wayne State University and the Highway Safety Research Institute (HSRI) at the University of

Michigan (6). The simulation effort was directed at determination of the redirection capacity of five curb configurations. The effects of curb placement in front of roadside guardrails was also evaluated.

The digital computer simulation program used for the Wayne State evaluation was the Cornell Aeronautical Laboratory Single Vehicle Accident (CALSVA) program (7,8), a precursor to the HVOSM program. In terms of curb impacts, the program was best suited for determining the vehicle dynamic reaction as the vehicle mounted the curb. The program incorporated a thin disk radial spring tire model and reasonably accurate representations of a vehicle's suspension. Although the program could not accurately replicate tire sidewall/curb face friction interactions, these forces were found to be relatively insignificant for impact angles of 10 degrees or more. The researchers obtained good correlation between simulation findings and full-scale crash tests conducted elsewhere. Impact conditions for most of the runs were 40 mph and 25 deg, 60 mph and 10 deg, 60 mph and 25 deg, and 80 mph and 10 deg. The curbs were found to have very limited redirection capacity for these impact conditions. Further, the simulation predicted reasonable guardrail safety performance when the guardrail was at least 27 in. above the ground and the traffic side face of the guardrail and curb were in the same vertical plane or flush with one another.

Full-scale testing and simulation using HVOSM were combined in an extensive curb study conducted at the Texas Transportation Institute (TTI) for the National Cooperative Highway Research Program (NCHRP) in the early 1970's (3). Three then commonly used curbs were tested in this evaluation: one 4-in. curb (AASHTO Type H), two 6-in curbs (AASHTO Types C and E). The geometries of these curb configurations are shown in Figure 1. Also included in the testing was one special configuration 13-in. curb (AASHTO Type X), not shown in Figure 1. These curbs were chosen to be representative of curb designs most widely used around the country at that time.

Eighteen full-scale crash tests were conducted on the two 6-in. curbs with impact speeds of 30, 45, and 60 mph, and approach angles of 5, 12.5, and 20 degrees. Researchers evaluated vehicle trajectory, bumper height trajectory, roll and pitch angular displacements, and vehicle decelerations. These tests were then used to validate the HVOSM program and additional simulations were conducted on each curb to investigate other curb impacts.

The researchers found that curb heights of 6 in. or less with shapes similar to those of AASHTO Types C, E, or H will not redirect vehicles at speeds above 45 mph and encroachment angles greater than approximately 5 deg. Further, even when redirection was obtained, the tires on the impact side of the vehicle were found to mount the curb and the vehicle was only redirected when the offside tires contacted the curbs. Thus, these curbs were found to be ineffective for redirecting impacting vehicles when partial curb mounting may result in impacts with roadside features such as signs or poles. Further, the range of impacts wherein vehicle redirection was obtained was considered to be so limited that the safety benefit of these curbs for rural highways was considered to be negligible. An additional finding was that under certain speed and angle impact conditions, curb impacts produce vaulting or underriding of 27-in. high guardrails located behind the curb. It was found that impacts with curbs 6 in. high can cause a vehicle to

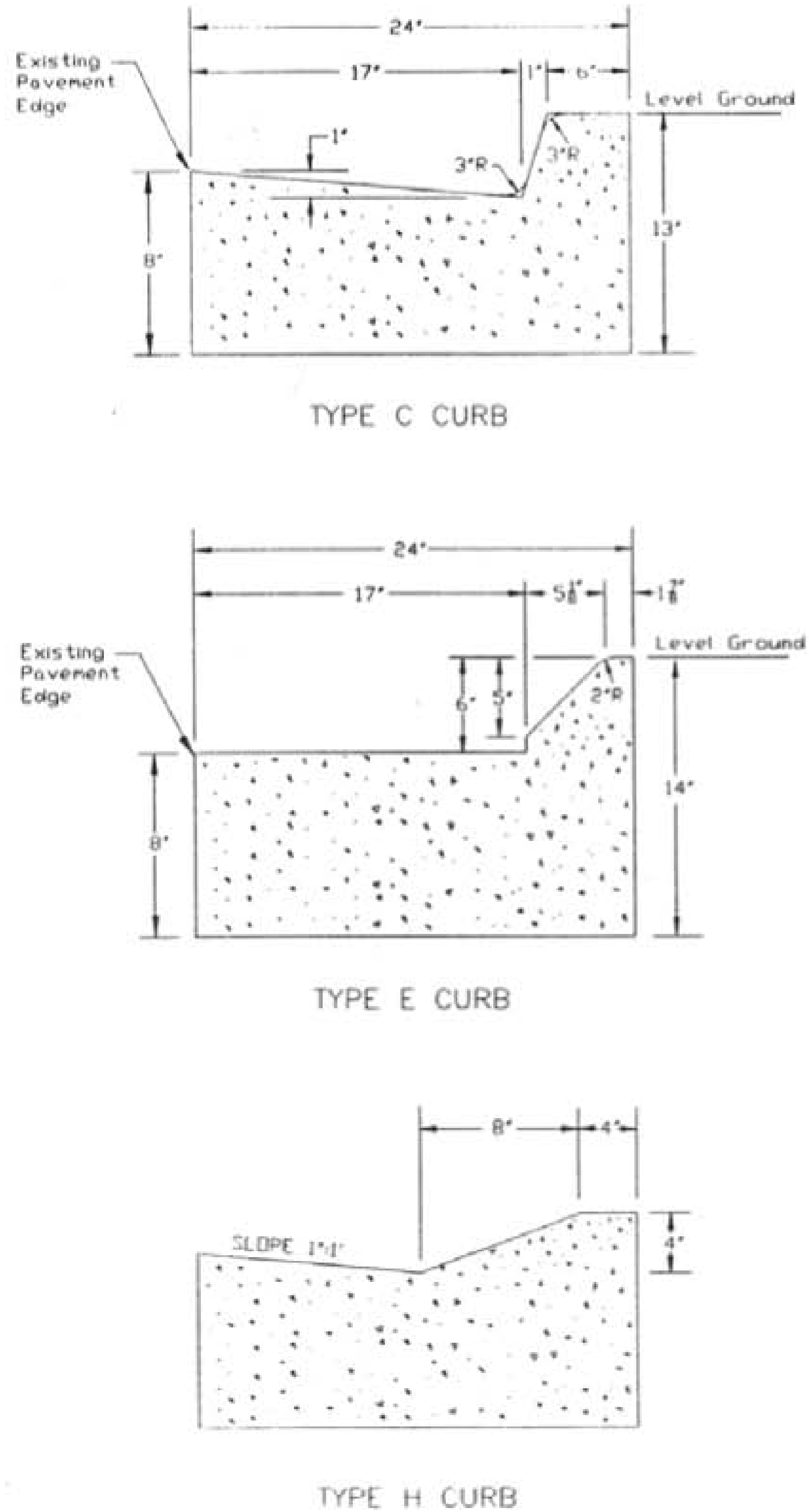


Figure 1. Geometry of AASHTO Types C, E, and H Curbs

impact a 27-in. guardrail with a 2-ft offset, at a point below the lower edge of the rail face, creating the possibility of snagging. This research is still the primary basis for most curb selection and placement guidelines.

A mountable curb (AASHTO Type B) was also analyzed using both full-scale testing and simulation in another National Cooperative Highway Research Program study conducted by TTI (9,10). The geometry of the AASHTO Type B curb is shown in Figure 2. The effects of tracking curb impacts on minicars were studied with tests conducted at several different impact angles and speeds up to 60 mph. While this particular curb type was found to pose no major hazards for the evaluated conditions, some tire and wheel damage was observed during the full-scale crash testing program. This type of damage could lead to loss-of-control and vehicle rollover. Further, the researchers concluded that the Type B curbs could destabilize vehicles, especially minicars, when impacted in a non-tracking mode.

An analytical study conducted at TTI after the publication of NCHRP 150 in 1974, involved the evaluation of automobile behavior traversing selected modified curb configurations and sloped medians (11). The concern was again the potential for vaulting into roadside barriers placed near curbs or sloped medians. Vehicular behavior during and after impacts with the 6-in. and 8-in. curbs, modified curbs, and slopes was investigated using HVOSM. The objective of the study was to compare the effects of standard curb shapes with that of retrofit alternatives. The retrofit designs involved installing wedge-shaped asphalt plugs in front of the curbs and replacement of the curbs with slopes.

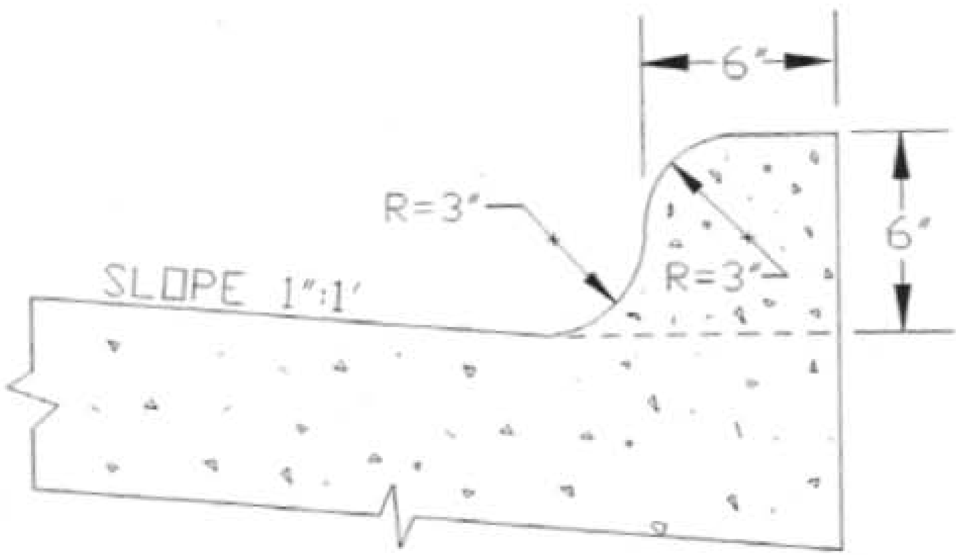


Figure 2. Geometry of AASHTO Type B Curb

The simulation test results led researchers to conclude that the traffic barriers should not be placed near curbs. The presence of curbing may cause the vehicle to vault roadside barriers or to impact them at a lower-than-normal position, causing snagging problems. Creation of a flat approach area in front of the barriers would be most desirable to reduce the probability of either snagging under the bottom face of the rail or vaulting over the top face. Additional findings showed that problems with barriers on raised curb-median or curb-roadside configurations could be reduced in certain areas by sloping the median or the roadside to the roadside barrier-curb combination.

Researchers at the MGA Research Corporation (12) used HVOSM to evaluate three curb types that had been designed for the states of Arizona and New Hampshire. The study was limited to evaluating the effects these curbs would have on the guidelines governing the placement of longitudinal roadside barriers near the curbs. Thirty-six simulations were performed on three different curb types and two different test vehicles. Each curb type was investigated with 3-in. and 6-in. heights and recommended backslope profiles and roadway cross slopes were incorporated into the modeling. While the impact angle remained constant at 15 degrees for all of the tests, the impact velocity was varied between 20, 40, and 60 mph. The results of their tests were compared with the bumper trajectory results from NCHRP Report 150. The results of the simulation study indicated that vehicular response to the curbs was within the same range or less severe than common curb configurations.

3 RESEARCH APPROACH

The effects of mountable curb geometry on vehicle behavior during tracking impacts was the primary focus of this research effort. A combination of full-scale tests and computer simulations using an updated version of the HVOSM (13) were used to investigate vehicle behavior upon impact with three different NDOR mountable curbs types. Full-scale crash testing was used to conduct a limited study of the dynamic response of two automobiles impacting three different curbs and to validate the HVOSM program. A much more comprehensive study of curb impacts, including an investigation of non-tracking curb impacts, was then undertaken through computer simulation.

Curb impact performance was evaluated in terms of vehicular trajectory, roll, pitch and yaw angular displacements, and bumper trajectory. The research was therefore undertaken in order to develop a better understanding of the safety related issues posed by mountable curbs and to address the concerns derived from the reduction in effectiveness of many different roadside appurtenances often located near mountable curbs.

3.1 Mountable Curb Configurations

Three standard NDOR mountable curbs were evaluated in this study, including 4-in. Lip, 6-in. Lip, and 6-in. Type I mountable curbs. Details of the three test curbs are shown in Figures 3, 4, and 5. The 4-in. Lip and 6-in. Type I mountable curbs are currently the most widely used mountable curbs by NDOR. Unfortunately, the 4 in. Lip design does not always provide sufficient depth for drainage control. The 6-in. Lip curb was therefore included in the study as a potential alternative to the 4-in. Lip curb.

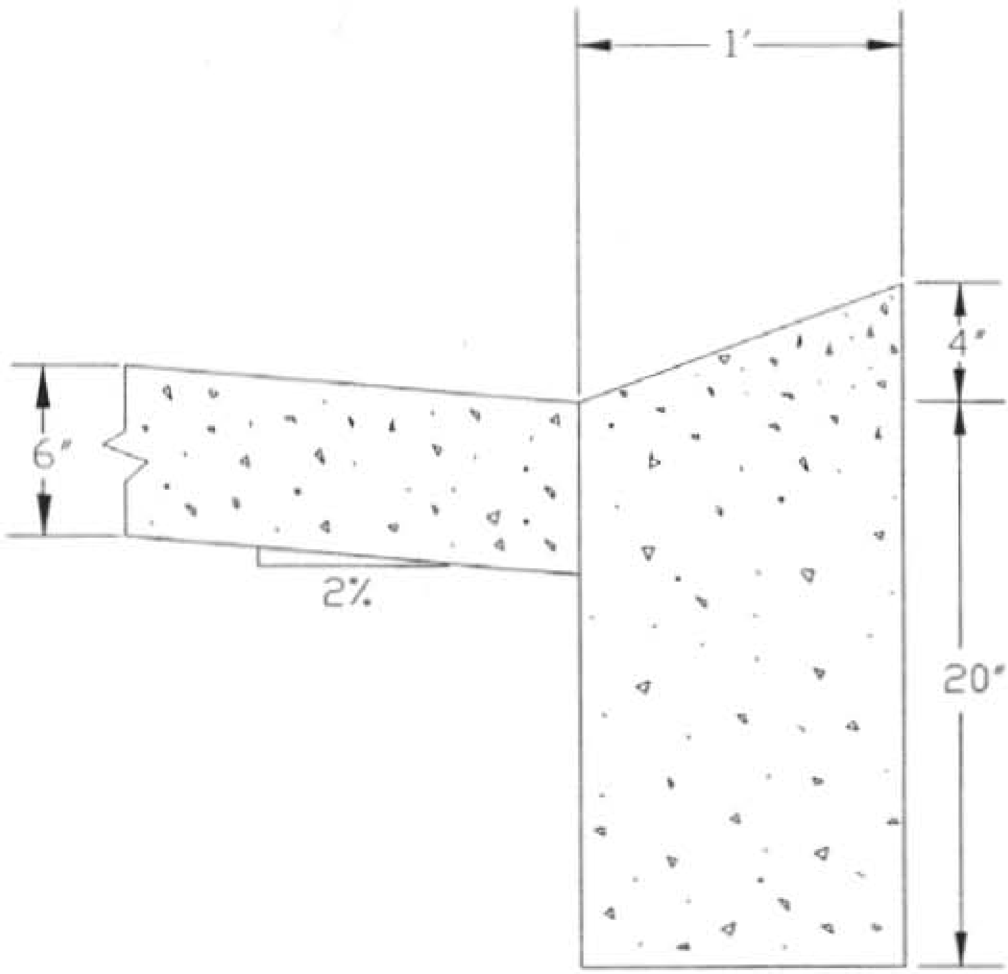


Figure 3. 4-in. Lip Curb Geometry

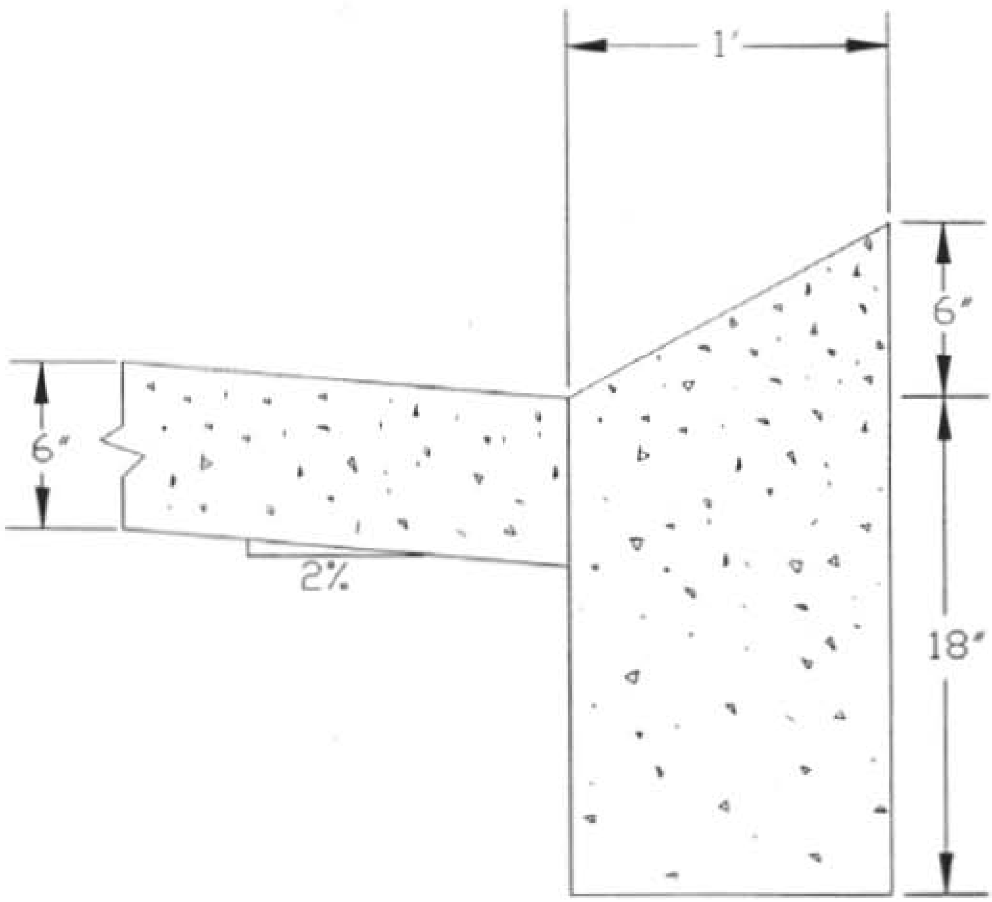


Figure 4. 6-in. Lip Curb Geometry

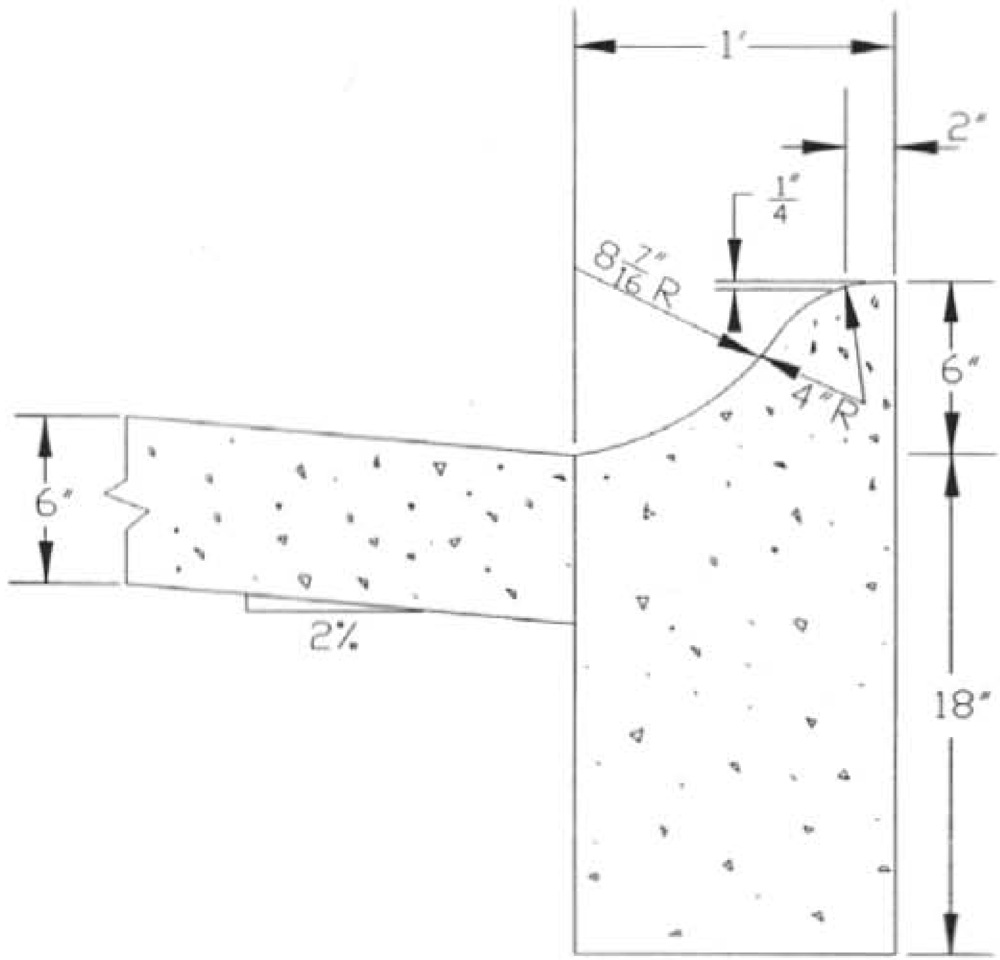


Figure 5. 6-in. Type I Mountable Curb

3.2 Full-Scale Testing Area

Curb installations included in the full-scale crash test program incorporated a paved roadway, a mountable curb, and a rounded dirt backslope to simulate a typical highway cross-section through small towns and rural communities. The roadway consisted of a typical 12-ft wide paved travel lane with a 2 percent cross-slope and an approximate 1 percent downgrade. The travelway downgrade and cross slope were established over the first 10 ft. of the simulated roadway, extending beyond the edge of the flat concrete approach runway. This section provided a smooth transition between the flat approach and the sloping travelway. The rounded backslope incorporated a 4 percent upslope over the first 10 ft immediately behind the curb and a 3 percent downslope over the next 17 ft. Note that the curb installation necessitated that the curb be impacted with the driver's side of test vehicles. This impact orientation is believed to have no effect on vehicle behavior during curb impacts due to test vehicle symmetry. The layout of the curb testing area is shown in Figure 6 and cross-sections for the three test installations are shown in Figures 7, 8, and 9. Photos of the full-scale testing area are shown in Figure 10.

Concrete for the testing area was poured in two different phases, first for the roadway and then for the curb. The curb and the curb footing were poured integrally and then back filled and compacted in order to prevent the curb from shifting during vehicular impacts. Construction photos for the 4-in. Lip curb and the 6-in. Type I Mountable curb are shown in Figures 11 and 12. The 6-in. Lip curb was constructed simply by retrofitting the 4-in. Lip curb. This retrofit process consisted of placing a

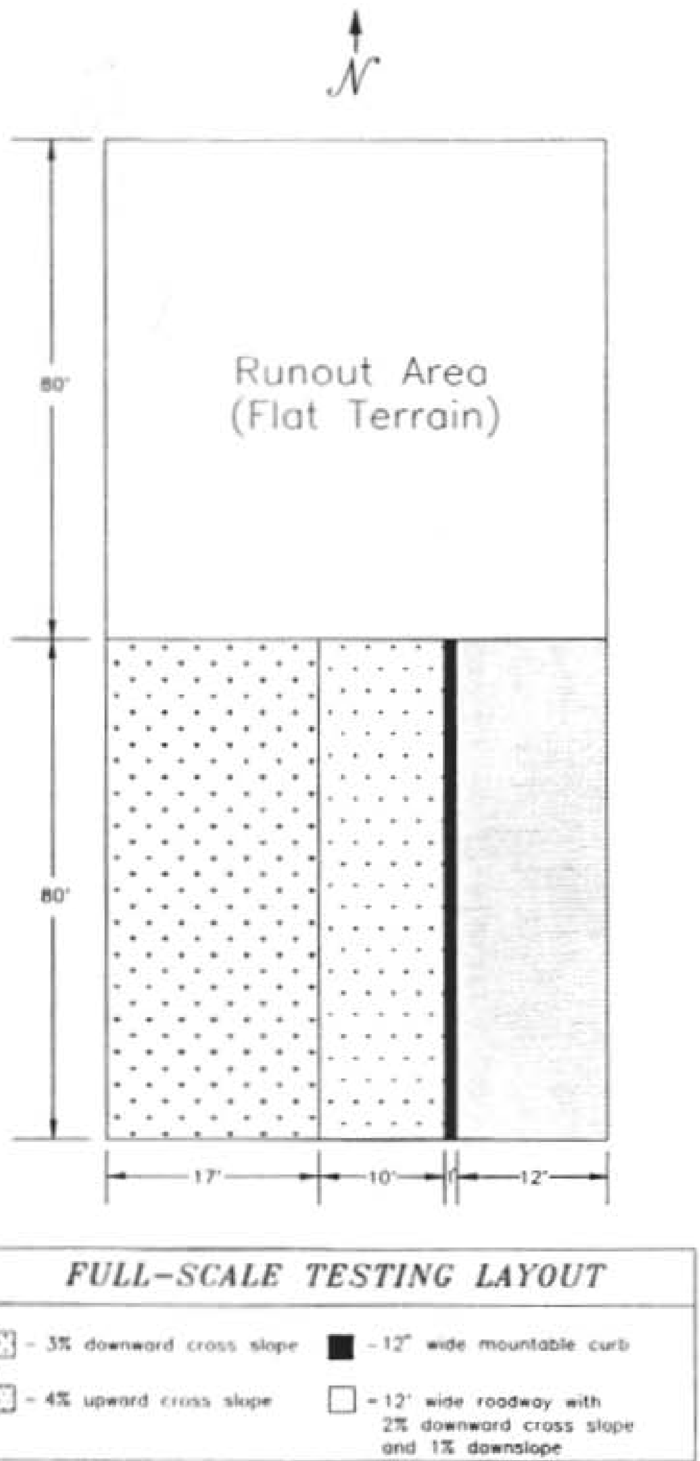


Figure 6. Full-Scale Testing Area Schematic

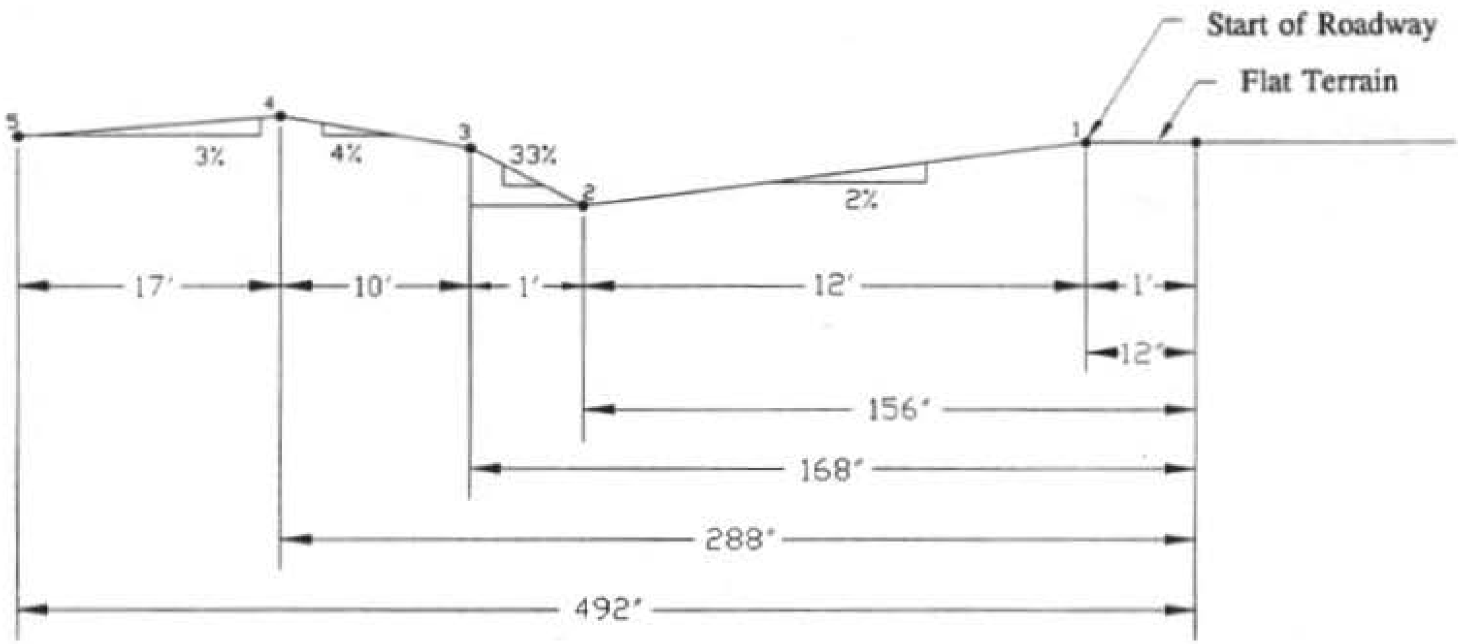


Figure 7. 4-in Lip Curb and Roadway Cross Section

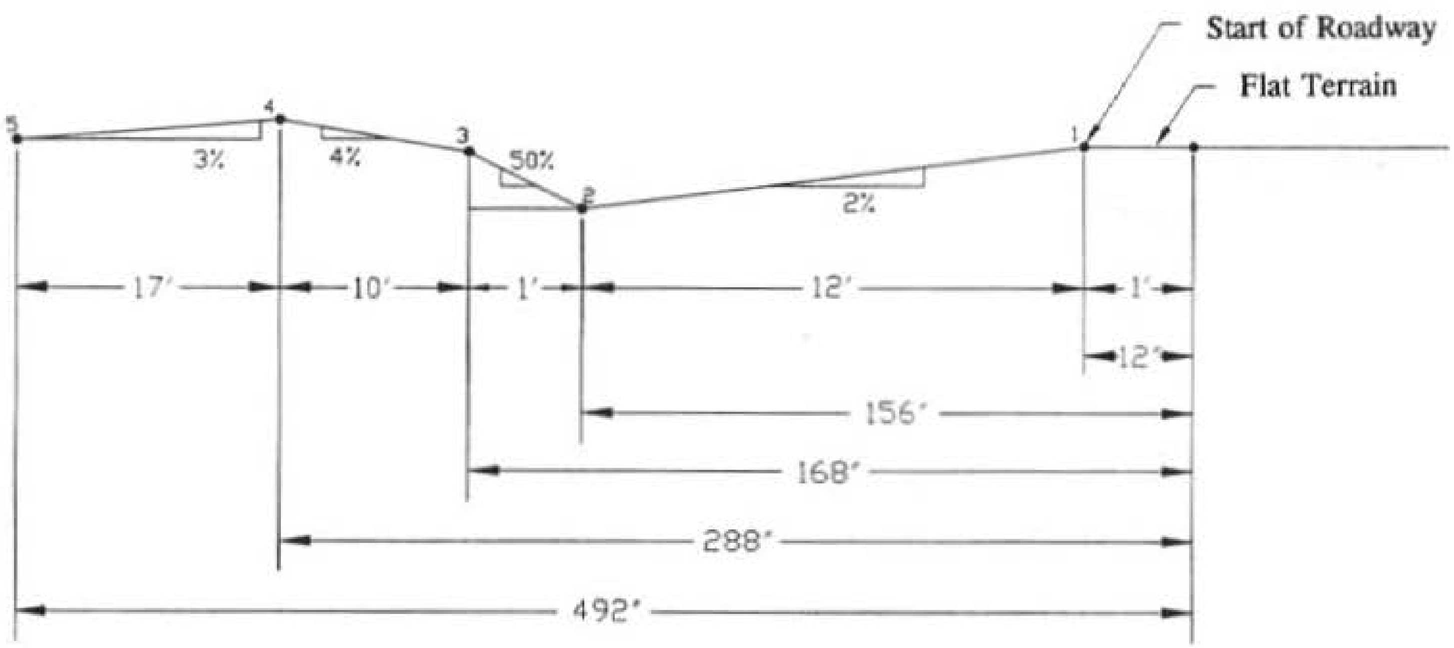


Figure 8. 6-in. Lip Curb and Roadway Cross Section

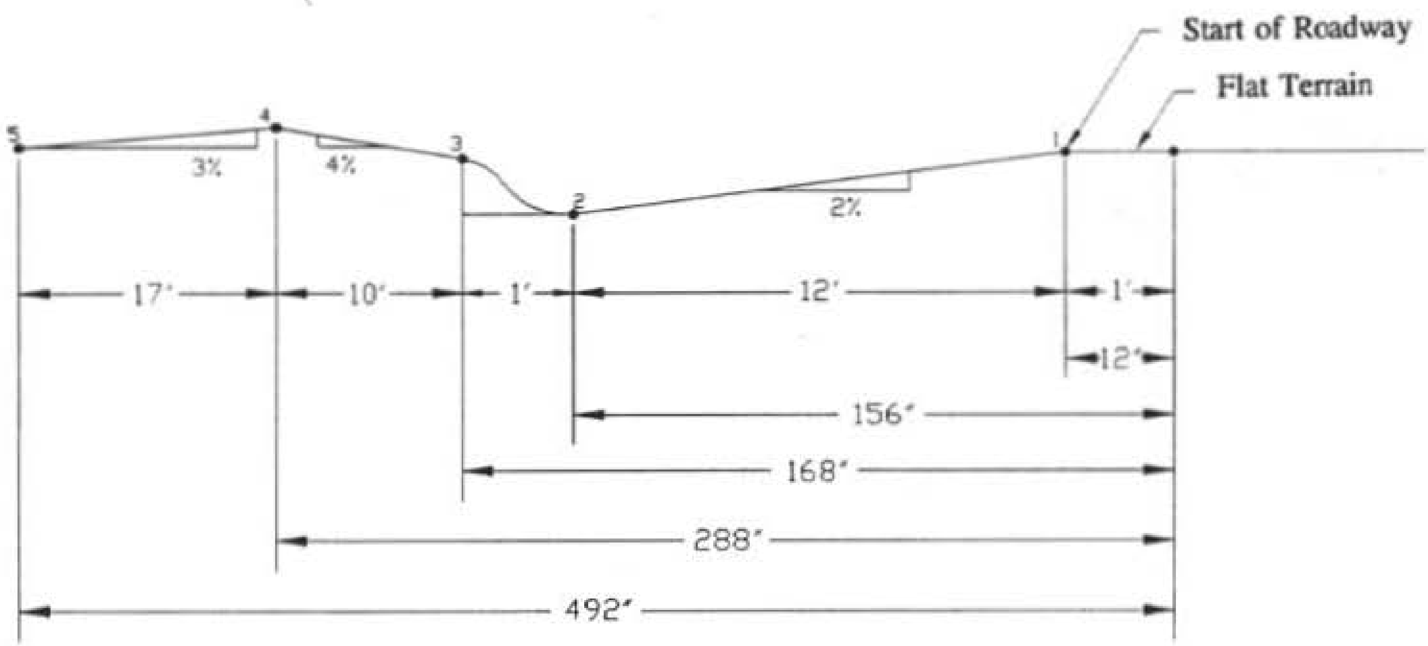


Figure 9. 6-in. Type I Mountable Curb and Roadway Cross Section

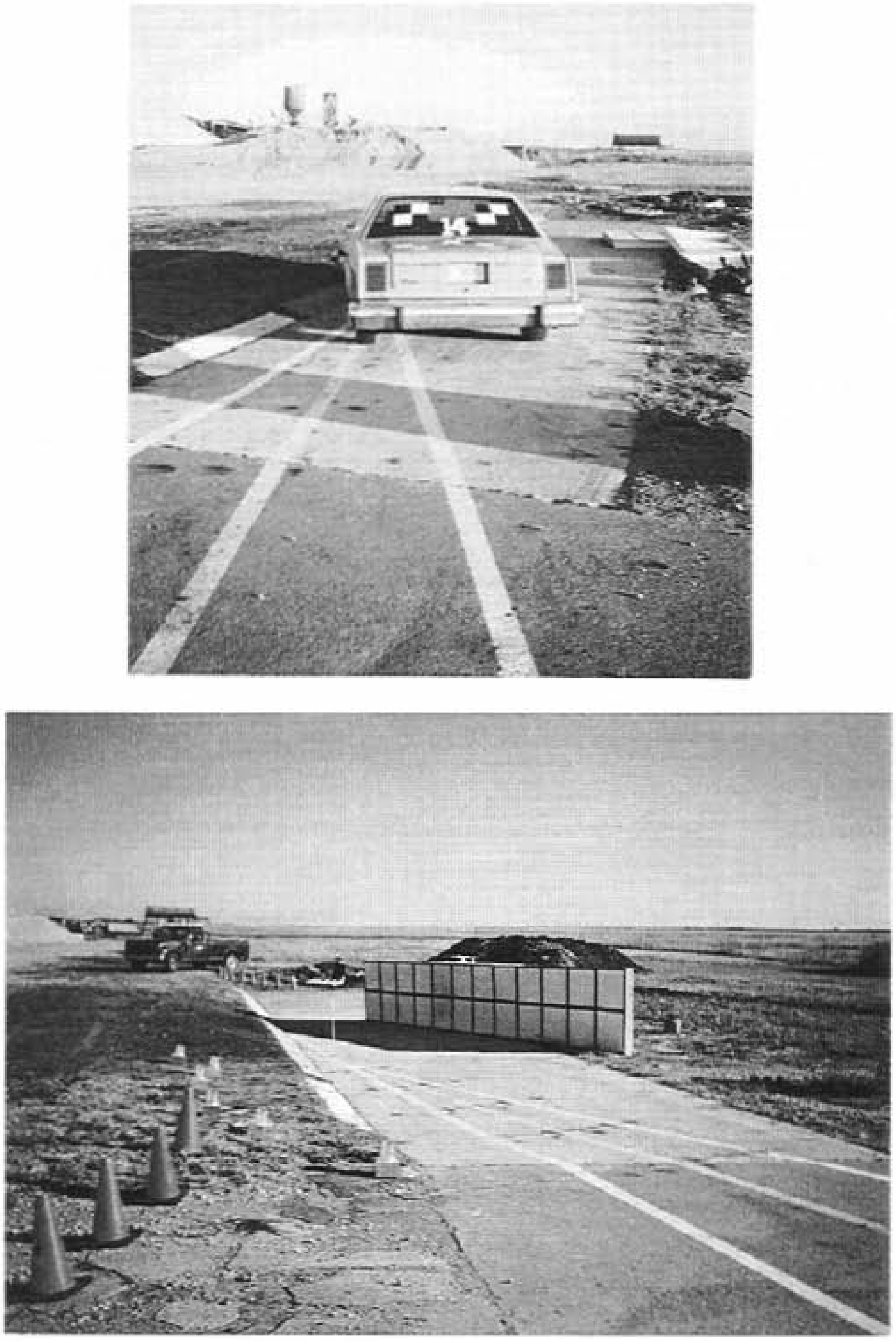


Figure 10. Full-Scale Testing Layout

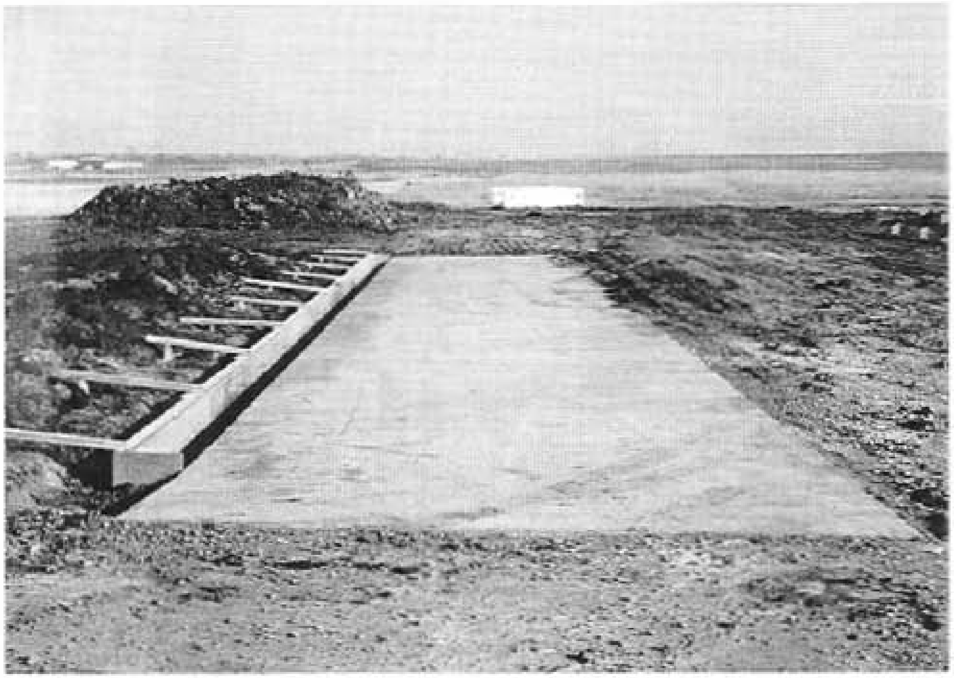


Figure 11. 4-in. Lip Curb Construction

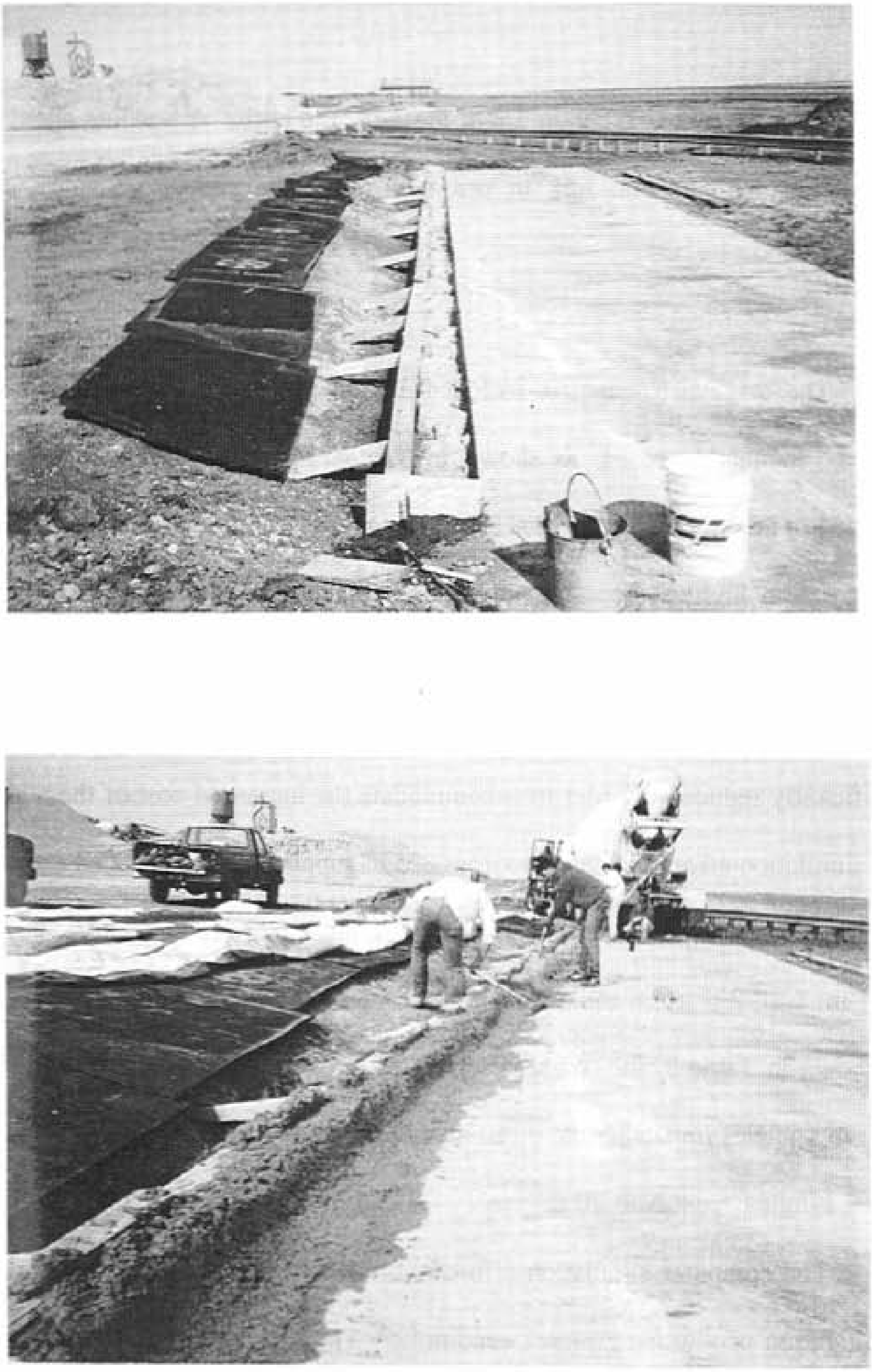


Figure 12. 6-in. Type I Mountable Curb Construction

tapering cement mix overlay on top of the 4-in. Lip curb. A bonding agent was used in conjunction with cement mix in order to retain the proper geometrical shape and structural integrity.

3.3 Testing Matrices

The original test matrix included 36 full-scale tests on the 4-in. Lip and 6-in. Type I mountable curbs, as shown in Tables 1 and 2. Impact speeds and angles included in this test matrix were selected to be representative of impacts expected on low volume rural highways passing through small cities and towns. The test matrix was modified after the first set of full-scale tests (NEMC 1-9) to include the 6-in. Lip curb as a retrofit to the 4-in. Lip configuration. At this point, the crash test matrix was significantly reduced in order to accommodate the increased cost of the additional curb. The simulation effort was then incorporated to supplement the reduced crash test matrix. The modified test matrix, shown in Table 3, included 23 full-scale tests, thirteen tests on the 4-in. Lip, 2 tests on the 6-in. Lip, and 8 tests on the 6-in. Type I mountable curbs. As shown in Table 3, the full-scale crash test program was conducted with 1800 lb and 4500 lb vehicles impacting the curbs at speeds ranging from 45 to 55 mph and approach angles ranging from 5 to 20 degrees.

The computer simulation effort involved two phases, program validation and an investigation of alternate impact conditions. The validation effort involved comparing HVOSM simulations to test results from all 23 full-scale crash tests. Vehicle angular orientations, path, and bumper trajectory were used as the primary measures of simulation accuracy. HVOSM was then used to investigate 31 supplemental curb impact

Table 1. Original Test Matrix (NEMC 1-18)

Test No.	Test Curb[1]	Test Vehicle	Target Angle (deg)	Target Speed (mph)
NEMC-1	4L	1800 LB	5	45
NEMC-2	4L	1800 LB	5	50
NEMC-3	4L	1800 LB	5	55
NEMC-4	4L	1800 LB	12.5	45
NEMC-5	4L	1800 LB	12.5	50
NEMC-6	4L	1800 LB	12.5	55
NEMC-7	4L	1800 LB	20	45
NEMC-8	4L	1800 LB	20	50
NEMC-9	4L	1800 LB	20	55
NEMC-10	4L	4500 LB	5	40
NEMC-11	4L	4500 LB	5	50
NEMC-12	4L	4500 LB	5	40
NEMC-13	4L	4500 LB	12.5	50
NEMC-14	4L	4500 LB	12.5	45
NEMC-15	4L	4500 LB	12.5	55
NEMC-16	4L	4500 LB	20	45
NEMC-17	4L	4500 LB	20	55
NEMC-18	4L	4500 LB	20	45

[1]4L - 4 in. Lip curb

Table 2. Original Test Matrix (NEMC 19-36)

Test No.	Test Curb[1]	Test Vehicle	Target Angle (deg)	Target Speed (mph)
NEMC-19	6S	1800 LB	5	45
NEMC-20	6S	1800 LB	5	50
NEMC-21	6S	1800 LB	5	55
NEMC-22	6S	1800 LB	12.5	45
NEMC-23	6S	1800 LB	12.5	50
NEMC-24	6S	1800 LB	12.5	55
NEMC-25	6S	1800 LB	20	45
NEMC-26	6S	1800 LB	20	50
NEMC-27	6S	1800 LB	20	55
NEMC-28	6S	4500 LB	5	40
NEMC-29	6S	4500 LB	5	50
NEMC-30	6S	4500 LB	5	40
NEMC-31	6S	4500 LB	12.5	50
NEMC-32	6S	4500 LB	12.5	45
NEMC-33	6S	4500 LB	12.5	55
NEMC-34	6S	4500 LB	20	45
NEMC-35	6S	4500 LB	20	55
NEMC-36	6S	4500 LB	20	45

[1]6S - 6 In. Type I curb

Table 3. Modified Full-Scale Testing Matrix (NEMC 1-23)

Test No.	Test Curb[1]	Test Vehicle	Target Angle (deg)	Target Speed (mph)	Actual Angle (deg)	Actual Speed (mph)
NEMC-1	4L	1800 LB	5	45	4.9	34.9
NEMC-2	4L	1800 LB	5	50	5.8	50.6
NEMC-3	4L	1800 LB	5	55	5.1	53.1
NEMC-4	4L	1800 LB	12.5	45	13.0	44.3
NEMC-5	4L	1800 LB	12.5	50	13.1	50.6
NEMC-6	4L	1800 LB	12.5	55	13.1	55.9
NEMC-7	4L	1800 LB	20	45	19.3	44.3
NEMC-8	4L	1800 LB	20	50	19.1	53.1
NEMC-9	4L	1800 LB	20	55	19.2	55.9
NEMC-10	4L	4500 LB	5	40	5.0	39.1
NEMC-11	4L	4500 LB	5	50	5.4	45.3
NEMC-12	4L	4500 LB	20	40	19.7	39.1
NEMC-13	4L	4500 LB	20	50	19.0	51.9
NEMC-14	6L	4500 LB	20	45	19.5	45.2
NEMC-15	6L	4500 LB	20	55	20.0	53.6
NEMC-16	6S	4500 LB	5	45	5.0	41.8
NEMC-17	6S	4500 LB	5	55	4.2	52.4
NEMC-18	6S	4500 LB	20	45	18.3	44.3
NEMC-19	6S	4500 LB	20	55	18.0	52.1
NEMC-20	6S	1800 LB	5	45	5.2	42.7
NEMC-21	6S	1800 LB	5	55	5.9	51.2
NEMC-22	6S	1800 LB	20	45	18.3	43.2
NEMC-23	6S	1800 LB	20	55	20.0	52.9

1 - 4L - 4 in. Lip curb
6L - 6 in. Lip curb
6S - 6 in. Type I curb

situations involving alternate impact speeds and angles for each vehicle size and curb combination. The simulation matrix, including both validation and supplementary runs, is shown in Tables 4 through 6.

3.4 Full-Scale Testing Procedure

Twenty-three full-scale tests were conducted to measure vehicle responses resulting from curb impacts in a tracking mode and also to validate the HVOSM computer simulation model. Vehicle responses such as overall trajectory (longitudinal and lateral displacements with respect to the curb), angular displacements, vertical bumper rise, wheel hop, and vehicle accelerations were measured. These parameters give an indication of the destabilizing effects of a curb impact as well as the vehicle's position immediately before impact with a guardrail, bridge rail, median barrier, or another obstacle located behind a curb. Bumper position is especially important when considering the effects of curbs on the performance of longitudinal barriers. Crash testing and simulation has indicated that the height of the bumper midpoint above ground upon impact with a roadside guardrail is a good indication of the potential for a vehicle to vault over or dive under the barrier (14-16). Therefore, the bumper midpoint was selected as the reference point for tracking the vertical rise with respect to the lateral distance behind each curb.

The test vehicles were driven, instead of towed, into the curb installations in order to expedite testing and provide a driver's appraisal of the severity of impact for the three curb configurations. A series of traffic cones and white painted lines were placed in advance of the curb testing area to aid the driver with establishing target impact angles.

Table 4. Computer Simulation Test Matrix (NEMC 1-18)

Test No.	Test Curb[1]	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)
NEMC-1	4L	1800 LB	4.9	34.9
NEMC-2	4L	1800 LB	5.8	50.6
NEMC-3	4L	1800 LB	5.1	53.1
NEMC-4	4L	1800 LB	13.0	44.3
NEMC-5	4L	1800 LB	13.1	50.6
NEMC-6	4L	1800 LB	13.1	55.9
NEMC-7	4L	1800 LB	19.3	44.3
NEMC-8	4L	1800 LB	19.1	53.1
NEMC-9	4L	1800 LB	19.2	55.9
NEMC-10	4L	4500 LB	5.0	39.1
NEMC-11	4L	4500 LB	5.4	45.3
NEMC-12	4L	4500 LB	19.7	39.1
NEMC-13	4L	4500 LB	19.0	51.9
NEMC-14	6L	4500 LB	19.5	45.2
NEMC-15	6L	4500 LB	20.0	53.6
NEMC-16	6S	4500 LB	5.0	41.8
NEMC-17	6S	4500 LB	4.2	52.4
NEMC-18	6S	4500 LB	18.3	44.3

1 - 4L - 4 in. Lip curb
6L - 6 in. Lip curb
6S - 6 in. Type I curb.

Table 5. Computer Simulation Test Matrix (NEMC 19-23, NE 1-13)

Test No.	Test Curb[1]	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)
NEMC-19	6S	4500 LB	18.0	52.1
NEMC-20	6S	1800 LB	5.2	42.7
NEMC-21	6S	1800 LB	5.9	51.2
NEMC-22	6S	1800 LB	18.3	43.2
NEMC-23	6S	1800 LB	20.0	52.9
NE-1	4L	4500 LB	5	55
NE-2	4L	4500 LB	12.5	45
NE-3	4L	4500 LB	12.5	50
NE-4	4L	4500 LB	12.5	55
NE-5	4L	4500 LB	20	55
NE-6	6L	1800 LB	5	45
NE-7	6L	1800 LB	5	50
NE-8	6L	1800 LB	5	55
NE-9	6L	1800 LB	12.5	45
NE-10	6L	1800 LB	12.5	50
NE-11	6L	1800 LB	12.5	55
NE-12	6L	1800 LB	20	45
NE-13	6L	1800 LB	20	50

1 - 4L - 4 in. Lip curb
6L - 6 in. Lip curb
6S - 6 in. Type I curb.

Table 6. Computer Simulation Test Matrix (NE 14-31)

Test No.	Test Curb[1]	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)
NE-14	6L	1800 LB	20	55
NE-15	6L	4500 LB	5	45
NE-16	6L	4500 LB	5	50
NE-17	6L	4500 LB	5	55
NE-18	6L	4500 LB	12.5	45
NE-19	6L	4500 LB	12.5	50
NE-20	6L	4500 LB	12.5	55
NE-21	6L	4500 LB	20	50
NE-22	6S	1800 LB	5	50
NE-23	6S	1800 LB	12.5	45
NE-24	6S	1800 LB	12.5	50
NE-25	6S	1800 LB	12.5	55
NE-26	6S	1800 LB	20	50
NE-27	6S	4500 LB	5	50
NE-28	6S	4500 LB	12.5	45
NE-29	6S	4500 LB	12.5	50
NE-30	6S	4500 LB	12.5	55
NE-31	6S	4500 LB	20	50

1 - 6L - 6 in. Lip curb
6S - 6 in. Type I curb.

As shown in Table 3, the impact angles measured from high speed film were very near to the target conditions in almost every test.

The test vehicle driver released the steering wheel just prior to impact to establish a free wheeling condition during and after curb impact. The free wheeling condition provided a better estimate of the actual effects of curb impact on vehicle trajectory and potential for loss of control. The driver waited until the vehicle trajectory stabilized after mounting the curb before grasping the steering wheel. In most cases, the driver did not grab the steering wheel until after the test vehicle was completely off the sloped terrain constructed behind the curb. Thus, vehicle behavior was not effected by the driver responses to curb impact. Test vehicle speedometers were calibrated prior to testing in order to minimize impact speed errors. Actual impact speeds, measured with tape pressure switches placed just upstream of curb impact, were generally near target conditions as shown in Table 3.

3.5 Test Vehicles

As mentioned previously, test vehicles weighing 1800 lb and 4500 lb were used in the full-scale crash test program. In order to maintain consistent vehicle conditions throughout the testing program, the test vehicle's front wheels were aligned prior to each series of crash tests. Details of the individual test vehicles are presented below and in the following figures.

1800 lb. Test Vehicle

A 1984 Dodge Colt, shown in Figures 13 and 14, was used as the 1800-lb test vehicle. Vehicle parameters, including basic dimensions, curb, static, and gross weights,

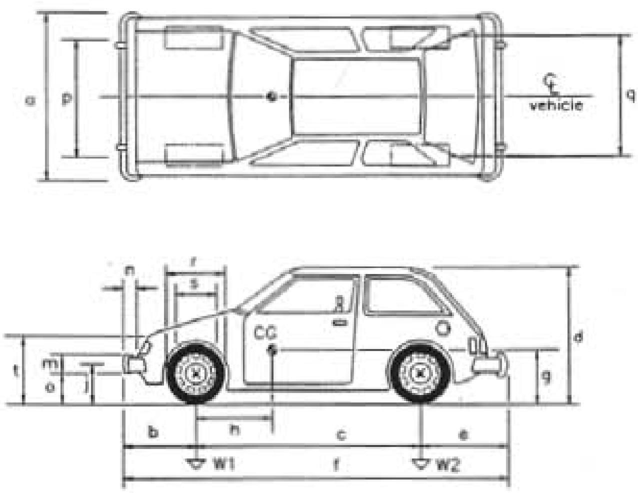
Figure 13. 1800 lb Test Vehicle, NEMC-1

Figure 14. 1800 lb Test Vehicle, NEMC-20

Make: Dodge Test No.: NEMC(1-9),(20-23)

Model: Colt Tire Size: P155/80R13

Year: 1984 VIN: JB3BE24A9EU104612



Vehicle Geometry
Inches

a —	58.0	b —	32.5
c —	90.5	d —	53.0
e —	31.5	f —	154.5
g —	21.0	h —	30.5
j —	17.0	m —	4.5
n —	6.0	o —	15.0
p —	54.0	q —	53.5
r —	22.5	s —	14.25
t —	31.0		

Engine Size: 4 cyl.

Transmission: manual

Weight (lbs)	Curb	Test Inertial	Gross Static
W1	1175	1225	1305
W2	625	625	705
Wtotal	1800	1850	2010

Moment of Inertia (lb-sec^2-in) – Gross Static

Roll (Ix)	1299.0
Pitch (Iy)	5628.0
Yaw (Iz)	9119.0

Damage prior to test: NONE

Figure 15. 1800 lb Test Vehicle Dimensions

and approximate moments of inertia are shown in Figure 15. Targets, used to determine vehicle motions from the high speed films, were placed on the vehicle as shown in in Figure 16. Two 5B flash bulbs, triggered by a pressure switch upon impact with the curb, were mounted on the hood of the vehicle to establish curb impact time on the high-speed film. The vehicle's front wheels were aligned according to factory specifications prior to each set of full-scale tests.

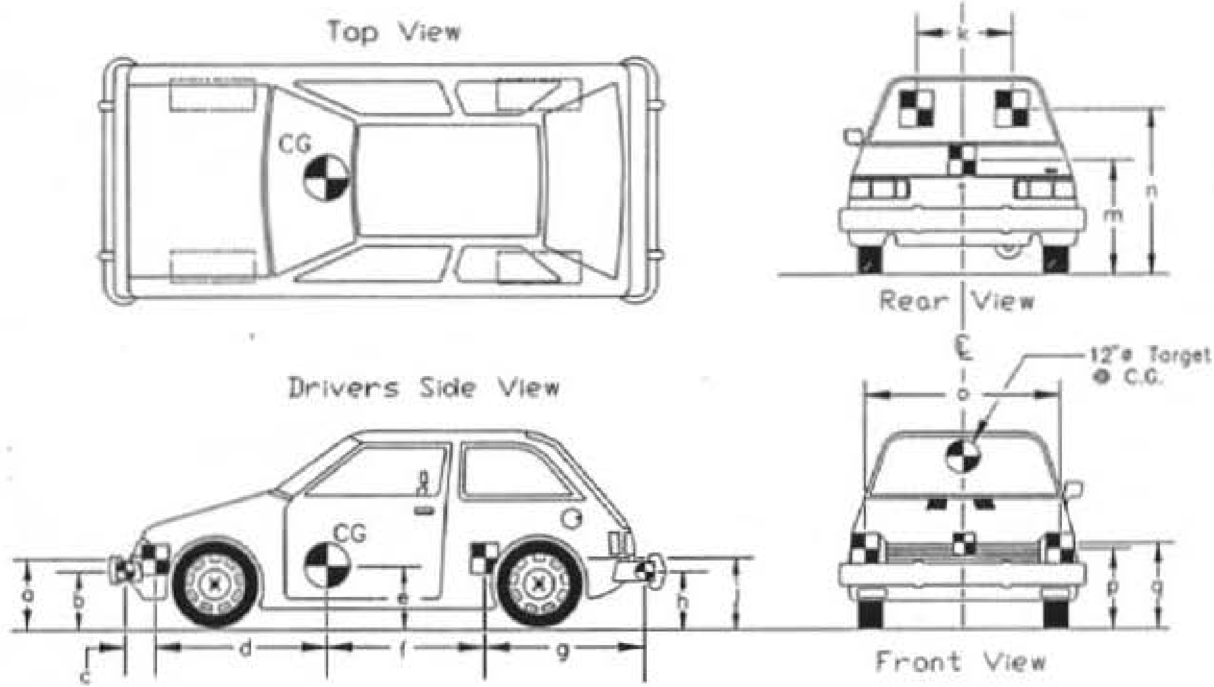
4500 lb. Test Vehicle

A 1986 Ford LTD, shown in Figures 17 and 18, was used as the 4500 lb test vehicle. Vehicle parameters, including basic dimensions, curb, static, and gross weights, and approximate moments of inertia are shown in Figure 19. Targets, used to determine vehicle motions from the high speed films, were placed on the vehicle as shown in Figure 20. Two 5B flash bulbs, triggered by a pressure switch upon impact with the curb, were mounted on the hood of the vehicle to establish curb impact time on the high-speed film. The vehicle's front wheels were aligned according to factory specifications prior to each set of full-scale tests.

3.6 Data Acquisition Systems

Vehicle reactions during the full-scale testing program were monitored through video and high-speed photography, accelerometers, rate gyros, and tape pressure switches. Each of these components of the data acquisition system are described below.

Three high-speed 16-mm cameras and a VHS camera were used to film the full-scale tests. A schematic of the camera layout is shown in Figure 21. The first camera was set up to give a perpendicular field of view of the vehicle's path. This camera was



TARGET GEOMETRY
INCHES

a 24.0	d 48.0	g 38.0	k 24.0	o 42.0
b 16.5	e 21.0	h 18.75	m 34.5	p 25.0
c 12.0	f 48.0	j 24.0	n 43.0	q 28.0

Figure 16. 1800 lb Test Vehicle Target Geometry

Figure 17. 4500 lb Test Vehicle, NEMC-10

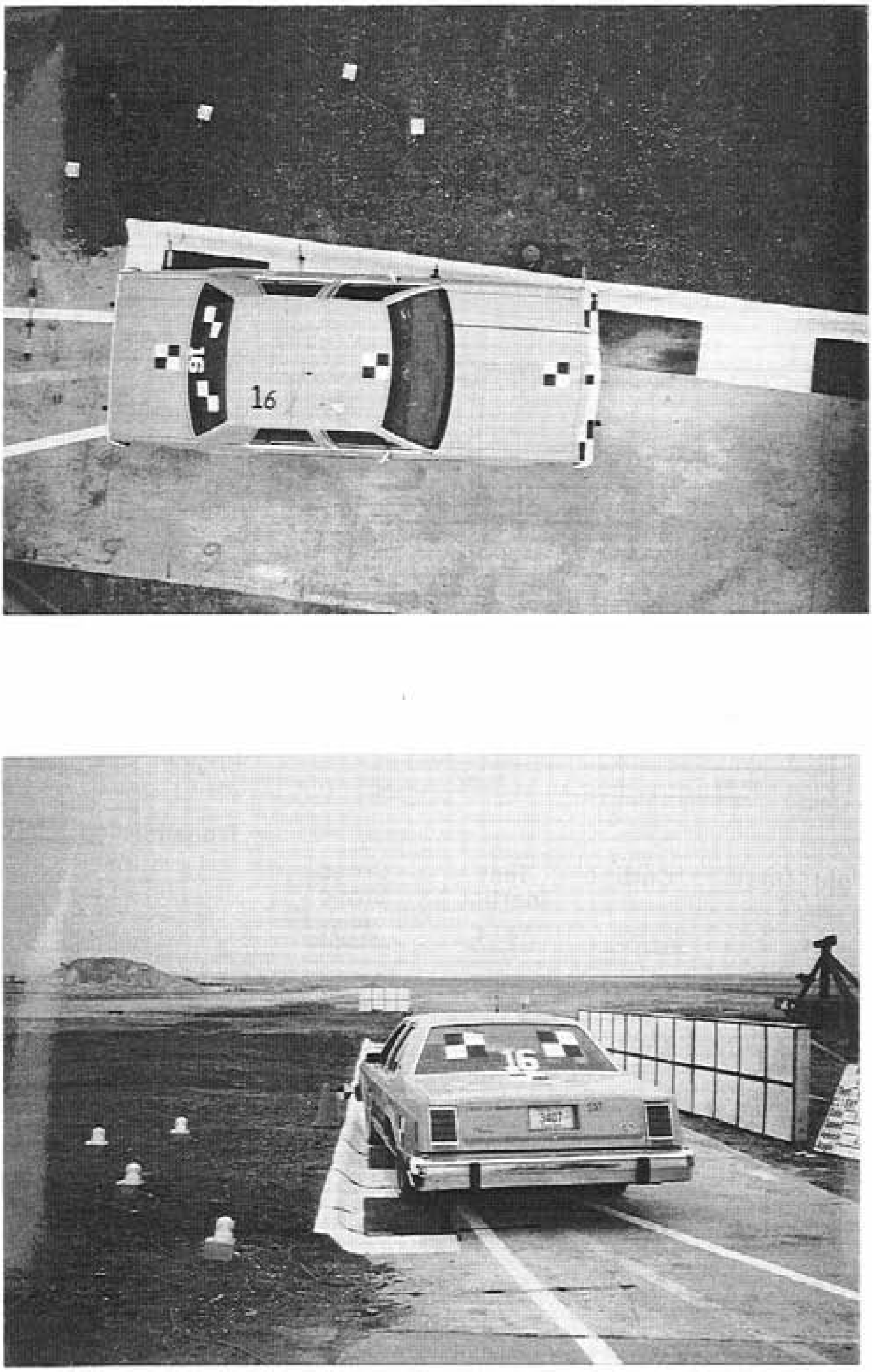


Figure 18. 4500 lb Test Vehicle, NEMC-16

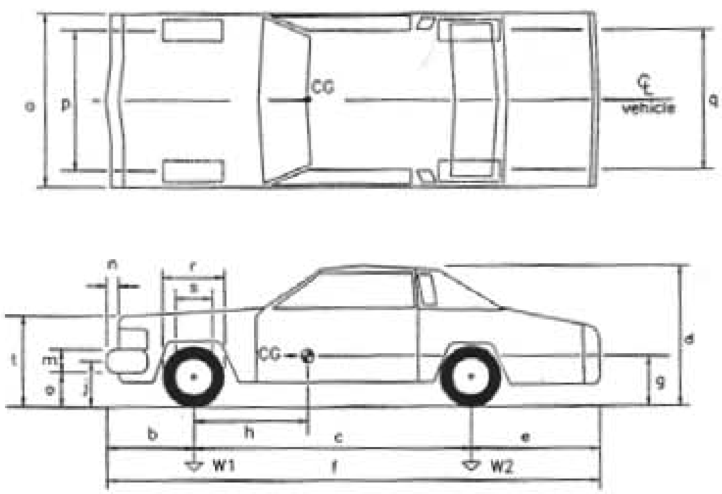
Make: Ford | Test No.: NEMC 10-19

Model: LTD | Tire Size: P205/75R15

Year: 1986 | VIN: 2FABP43F6GX180419

Vehicle Geometry
Inches

a —	76.75	b —	41.5
c —	114.0	d —	36.5
e —	56.5	f —	212.0
g —	22.5	h —	50.0
j —	19.0	m —	7.0
n —	3.5	o —	15.5
p —	62.25	q —	62.0
r —	27.0	s —	16.5
t —	36.5		



Engine Size: V8-5.0L

Transmission: Automatic

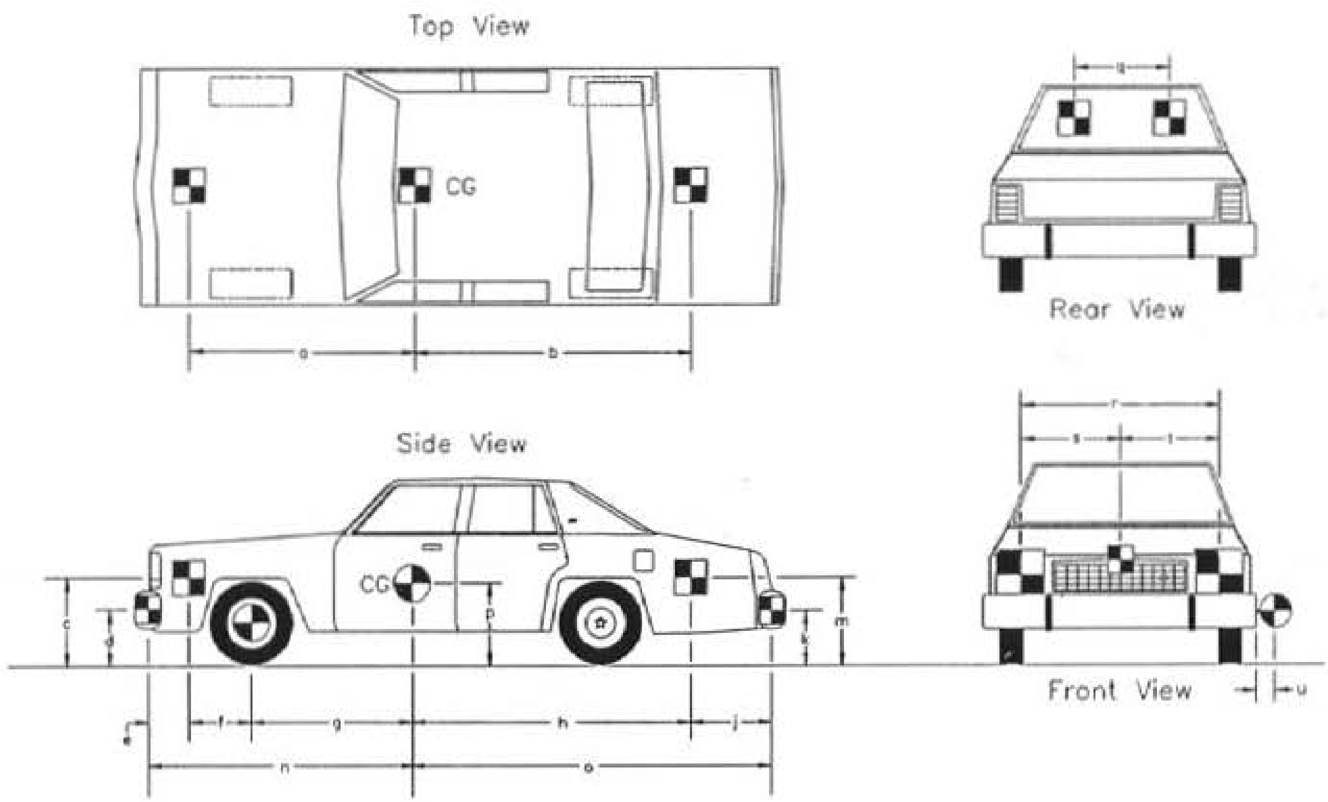
Weight (lbs)	Curb	Test Inertial	Gross Static
W1	2152	2414	2501
W2	1439	1886	1959
Wtotal	3591	4300	4460

Moment of Inertia (lb-sec^2-in) - Gross Static

Roll (Ix)	4,640.0
Pitch (Iy)	24,622.0
Yaw (Iz)	33,387.0

Damage prior to test: None

Figure 19. 4500 lb Test Vehicle Dimensions



TARGET GEOMETRY
INCHES

a 71.0	e 13.0	j 25.5	o 114.0	s 27.0
b 88.5	f 21.0	k 18.0	p 21.0	t 26.5
c 25.0	g 50.0	m 25.0	q 30.0	u 4.0
d 18.0	h 88.5	n 84.0	r 53.5	

Figure 20. 4500 lb Test Vehicle Target Geometry

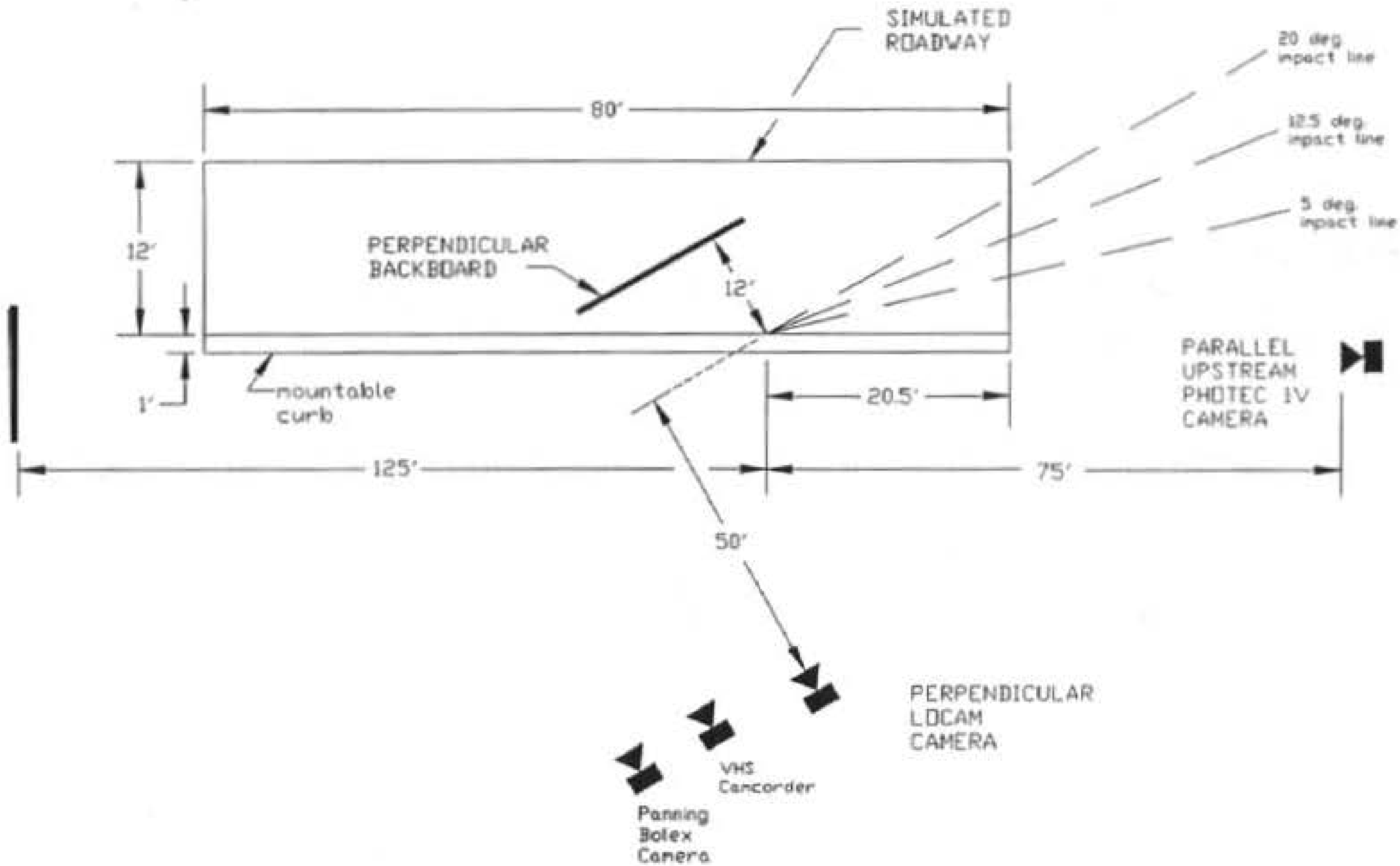


Figure 21. High-Speed Camera Layout

a Redlake Locam with a wide angle 12.5 mm lens and operating at 500 frames/sec. Film analysis from this camera was used to measure angular displacements, bumper trajectory, wheel hop, and to measure the longitudinal displacement of the vehicle along the curb. The second high-speed camera, a Photec IV with an 80 mm lens operating at 500 frames/sec, was used to give an upstream view parallel and on line with the face of the curb. This camera was used to determine impact conditions, lateral offsets, and angular displacements of the vehicle. The third high-speed camera was a 16-mm documentary camera, operating at approximately 64 frames/sec. All high speed film was analyzed on a Van Guard Film Motion Analyzer, and the proper adjustments were made for all camera divergence effects.

Endevco triaxial piezoresistive accelerometers (Model 7264) were used to measure the accelerations in the longitudinal, lateral, and vertical directions of the test vehicle. A Humphrey 3-axis rate transducer with a range of 250 deg/sec in each of the three directions (pitch, roll and yaw) was used to measure the rotational rates of the test vehicle. Both the accelerometers and rate gyro transducers were rigidly attached to the vehicle near the center of gravity of the test vehicle. Signals from the transducers were received and conditioned by an onboard Metraplex unit where the signals were multiplexed and then transmitted by radio telemetry to a Honeywell (101) Analog Tape Recorder in the control van. The data acquisition flowchart is shown in Figure 22. The test vehicle's interior equipment arrangement is shown in Figure 23, and the accelerometer and rate gyro block configuration is shown in Figure 24.

State-of-the-art computer software, "Enhanced Graphics Acquisition and Analysis"

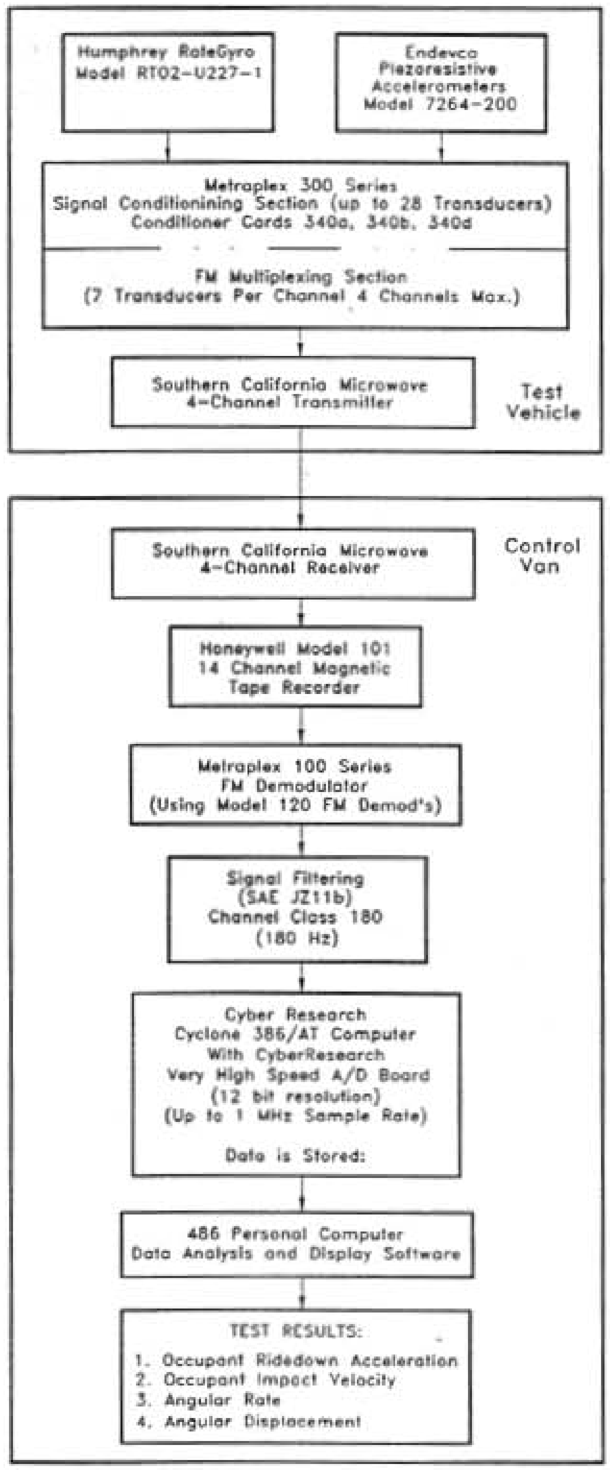


Figure 22. Data Acquisition Flowchart

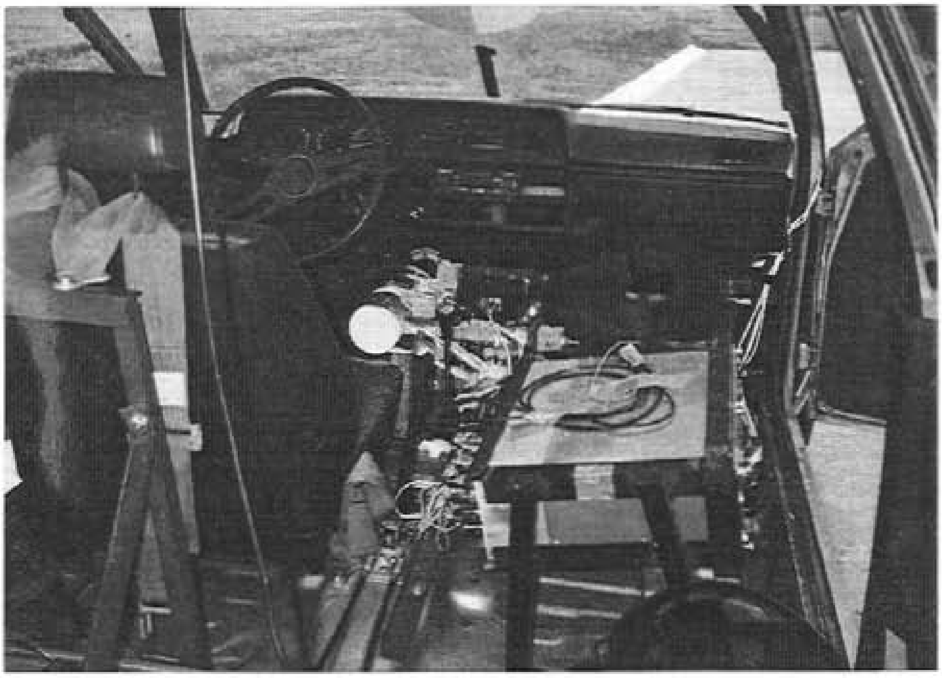


Figure 23. Test Vehicle's Interior Equipment Arrangement

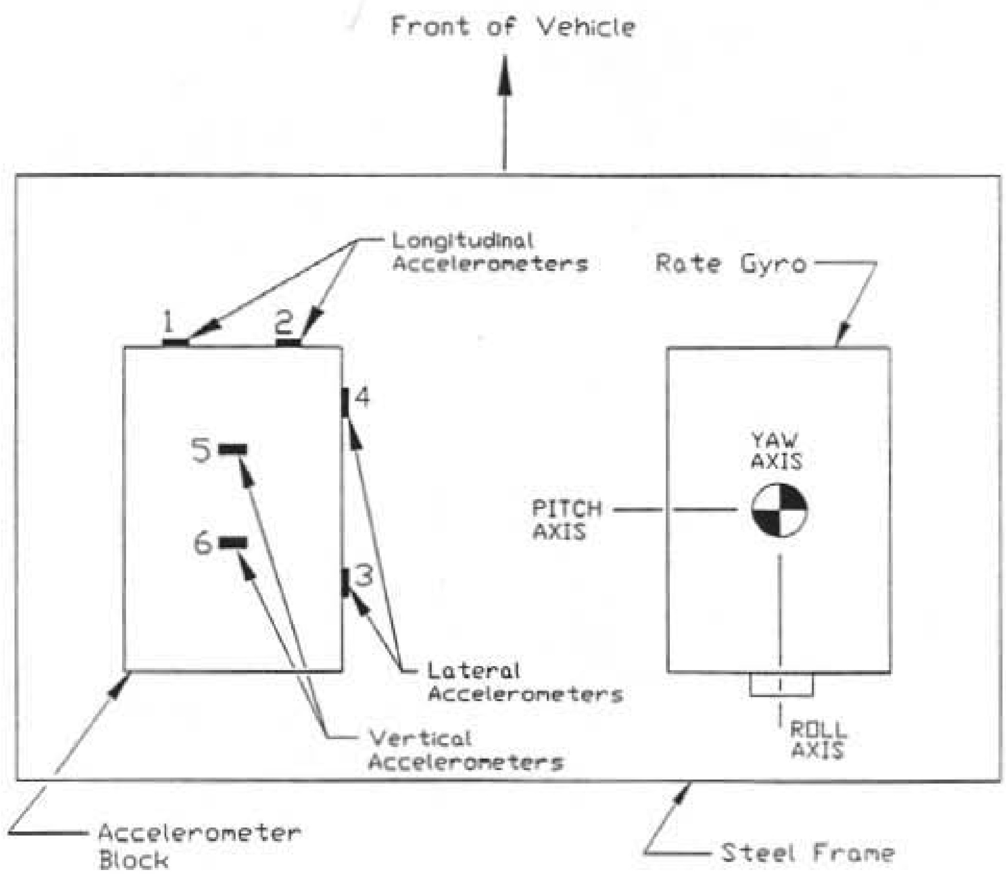


Figure 24. Accelerometer and Rate Gyro Configuration

(EGAA) (17) was used to acquire the rate gyro data and "Data Analysis and Display "Software" (DaDiSP) (18) was used to analyze and plot the data. The software was also used to conduct low pass filtering and smoothing operations to eliminate high frequency noise from the experimental data. Although vehicle rotations become coupled in the presence of high rotation rates, the effort to uncouple the measured angular velocities was abandoned after discovering no significant coupling in the test results from the most severe impact conditions. These findings are not surprising in view of the near zero magnitude of measured yaw velocities and the relatively low magnitudes of measured roll and pitch velocities (19).

Tape pressure switches spaced at 5 ft intervals were used to determine the actual speed of the vehicle before impact. Each tape switch triggered a strobe light located near each switch as the left front tire of the test vehicle passed over it. The average speed of the test vehicle between the tape switches was determined by knowing the distance between the tape switches, the calibrated camera speed, and the number of frames between flashes from the high-speed film. The average speed was also determined from electronic timing mark data which was transmitted through fiber optic cable and recorded on oscilloscope software.

4 FULL-SCALE TESTING RESULTS

As discussed previously, vehicular impacts with roadside curbs can cause tire and suspension damage leading to loss of vehicle control. Further, curbs can cause a vehicle to be out of position when contacting roadside barriers, breakaway structures, and other roadside safety devices. Vehicle angular displacements, bumper height, and overall trajectory are good indicators of the potential safety related problems associated with curb impacts. Other vehicle response parameters were measured, including vehicle accelerations and wheel hop. However, all measured accelerations were extremely low and wheel hop was largely undetectable and therefore these parameters were not reported. The low measured accelerations indicate that there is essentially no risk for occupant injuries arising directly from the curb impact. Similarly, since tires were found to remain in contact with the ground during curb impacts, a driver would retain the ability to steer or brake throughout the event.

Further, all path deviations during the impact testing were found to be very minimal. This finding is another indicator that reasonably prudent drivers would be able to maintain control of a vehicle traversing the mountable curbs included in the test program. The low path deviations were also reflected in the very low magnitude of measured yaw rates. As a result, yaw angular rotations were not reported. Roll and pitch angular displacements were reported in terms the vehicle reference system shown in Figure 25.

Figure 26 shows the design parameters for vehicle impacts on curbs as defined by AASHTO (20). These parameters represent vertical and lateral distances at critical

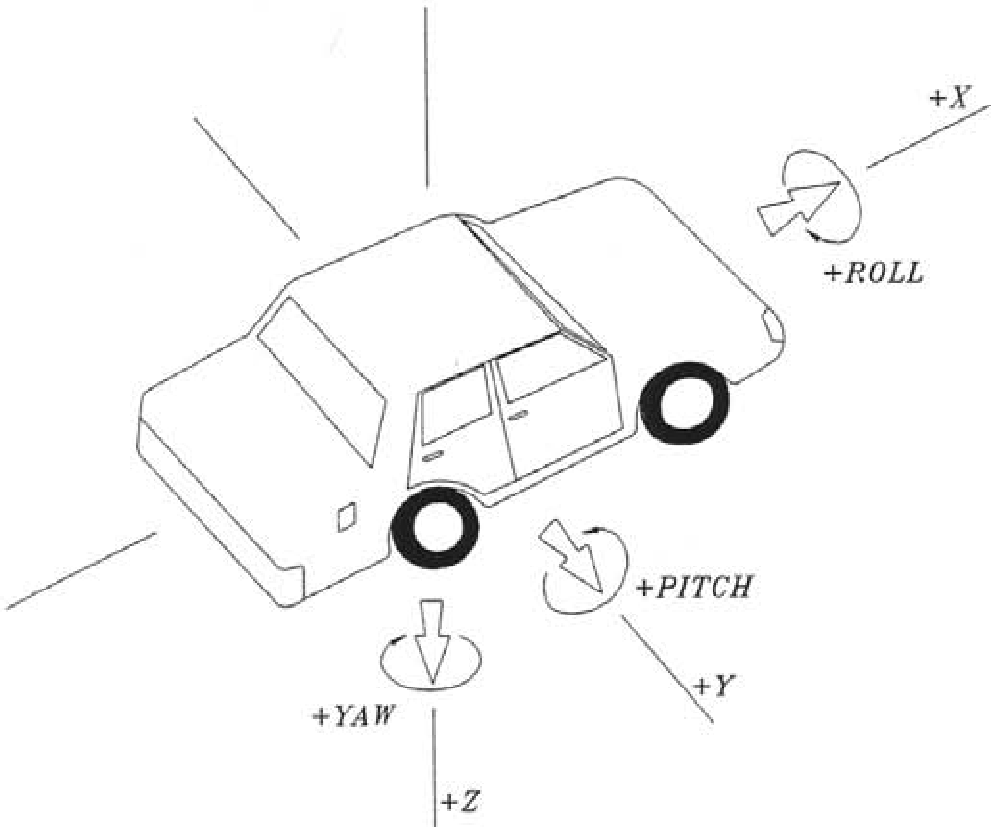
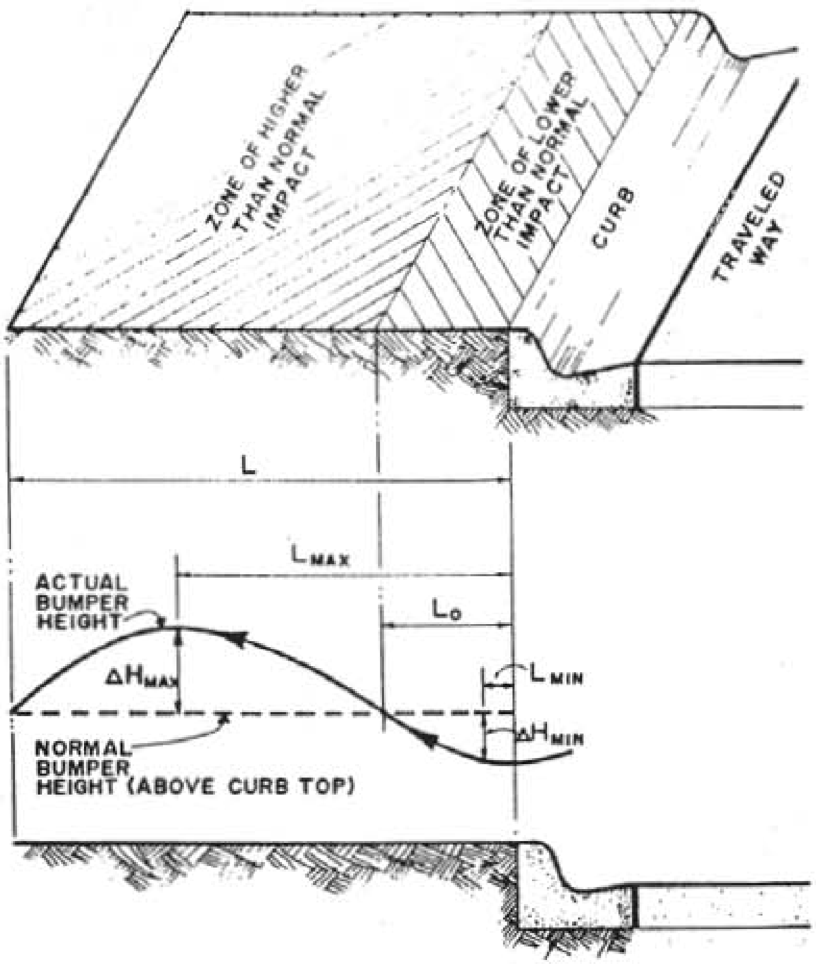


Figure 25. Vehicle Fixed Coordinate Reference System



L = Distance From Top of Curb to the Second Return to Normal Bumper Height

L_{max} = Distance Measured From Top of Curb to Occurrence of Highest Bumper Height Above Normal

L_o = Distance From Top of Curb to the First Return to Normal Bumper Height

L_{min} = Distance From Top of Curb to the Occurrence of Lowest Bumper Height Below Normal

ΔH_{min} = Maximum Bumper Height Below Normal Height

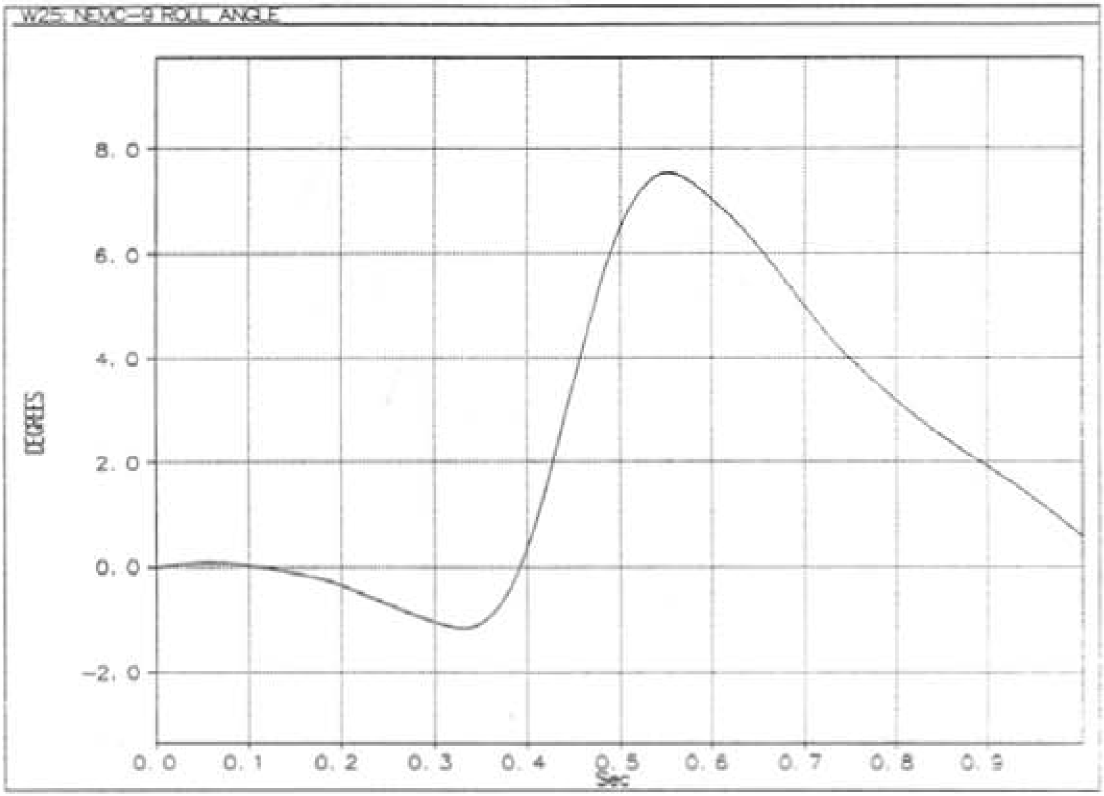
ΔH_{max} = Maximum Bumper Height Above Normal Height

Figure 26. Design Parameters for Curb Impacts as Defined by AASHTO

positions in the overall bumper trajectory. Bumper trajectory results are reported in terms of these design parameters. This procedure provides for a uniform method of presenting the large volumes of bumper trajectory results in a concise manner. Normal bumper height is defined as the distance from the ground to the center of the bumper when the vehicle is in a static position on the given terrain.

Typical roll and pitch angular displacements and bumper trajectories are shown graphically for Tests NEMC-9 (4L, 1800 lb, 19.2 deg, 55.9 mph) and NEMC-13 (4L, 4500 lb, 19.0 deg, 51.9 mph) in Figures 27 through 29. Similar plots are presented in Appendices A and B for all of the full-scale tests conducted. The figures represent the roll and pitch angular displacements versus time and the vertical bumper trajectory versus the lateral offset from initial contact with the curb.

The bumper position relative to a roadside barrier during and after impact is one of the most significant factors when considering the potential for vehicles vaulting over the barrier. Typical plots of vertical bumper trajectory shown in Figure 29 contain four reference lines in addition to the actual plotted trajectories. One of the lines, designated as "NORMAL", is shown at a height of 17 in. above the terrain for the 1800 lb test vehicle and 19 in. above the terrain for the 4500 test vehicle. These lines represent the height of the center of the test vehicle's front bumper with respect to the given terrain in a static position. As previously described in Figure 6, the terrain includes the curb, a modest up slope immediately behind the curb leading to a gentle downslope. The terrain elevation is also shown on the bumper trajectory plots. The final two lines shown on the bumper trajectory plots, designated as "G.R. Top" and "G.R. Bottom", represent



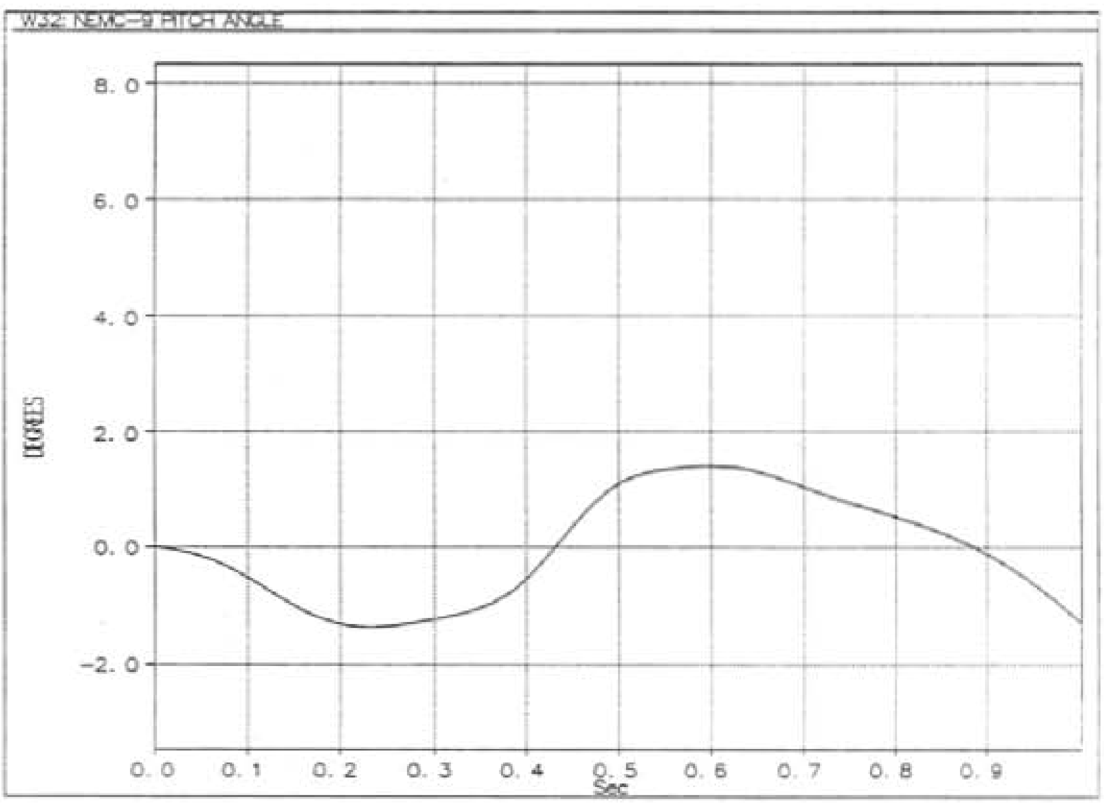
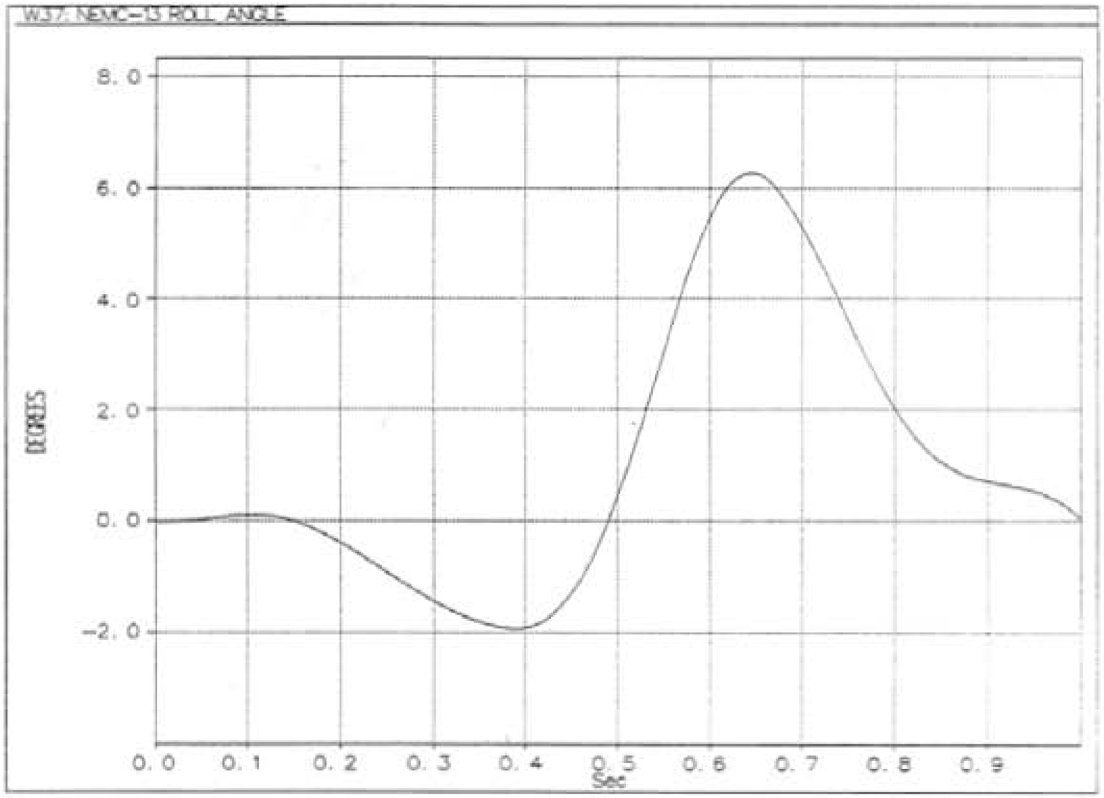


Figure 27. Typical Angular Displacement Plots (NEMC-9)



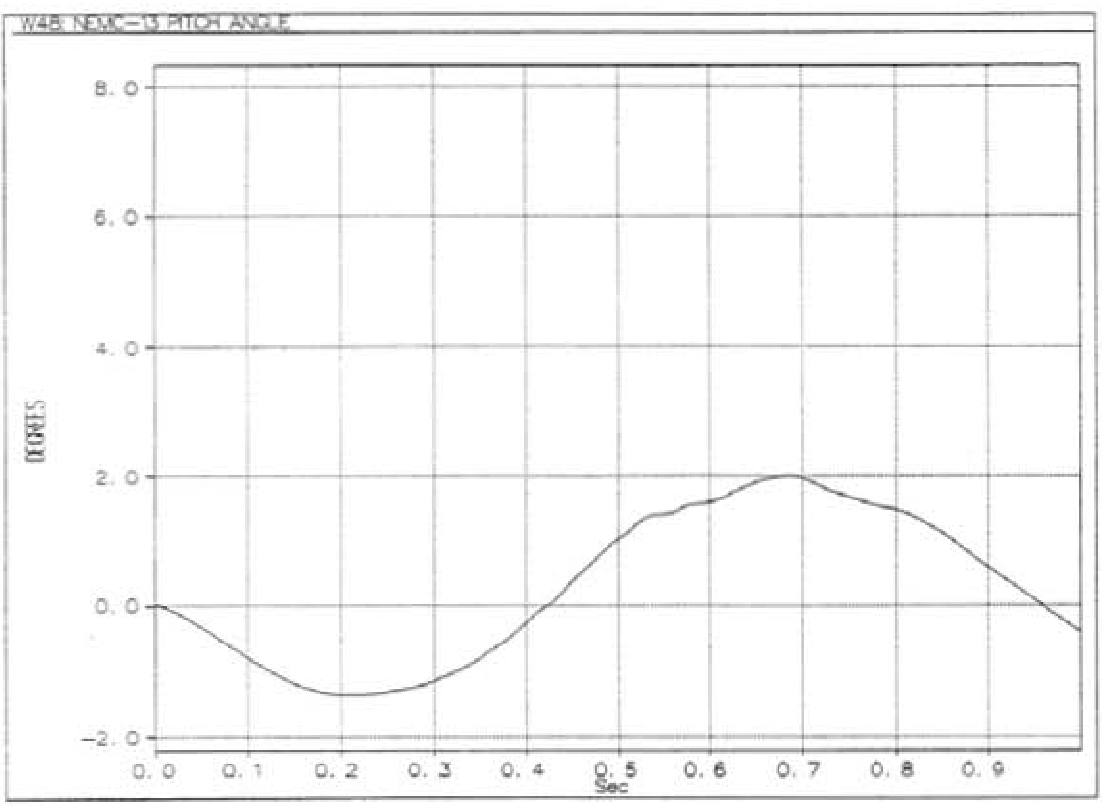
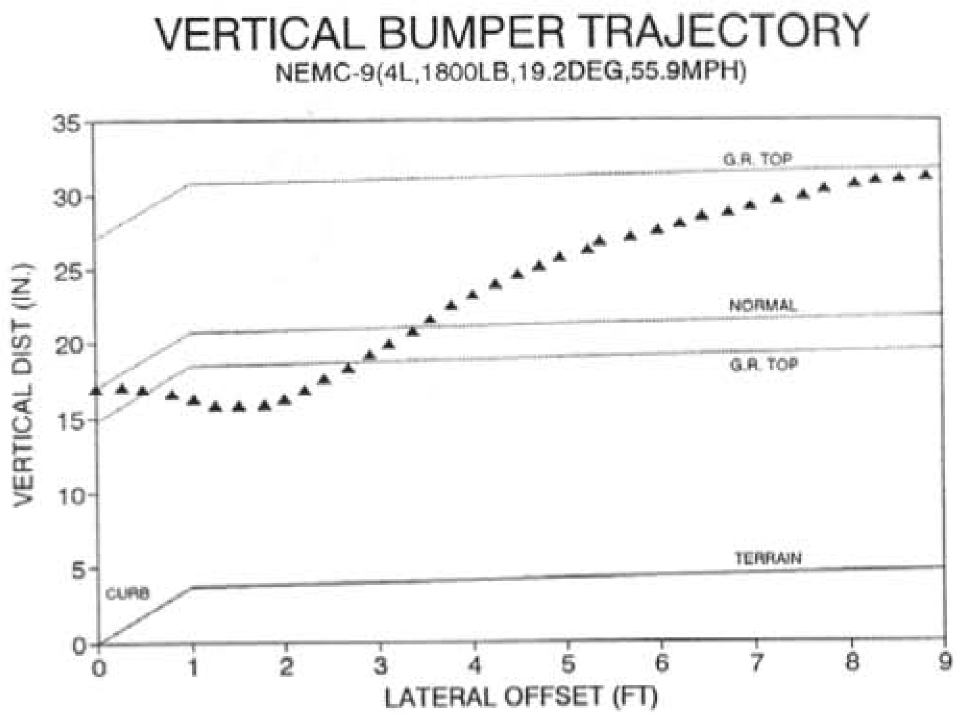


Figure 28. Typical Angular Displacement Plots (NEMC-13)



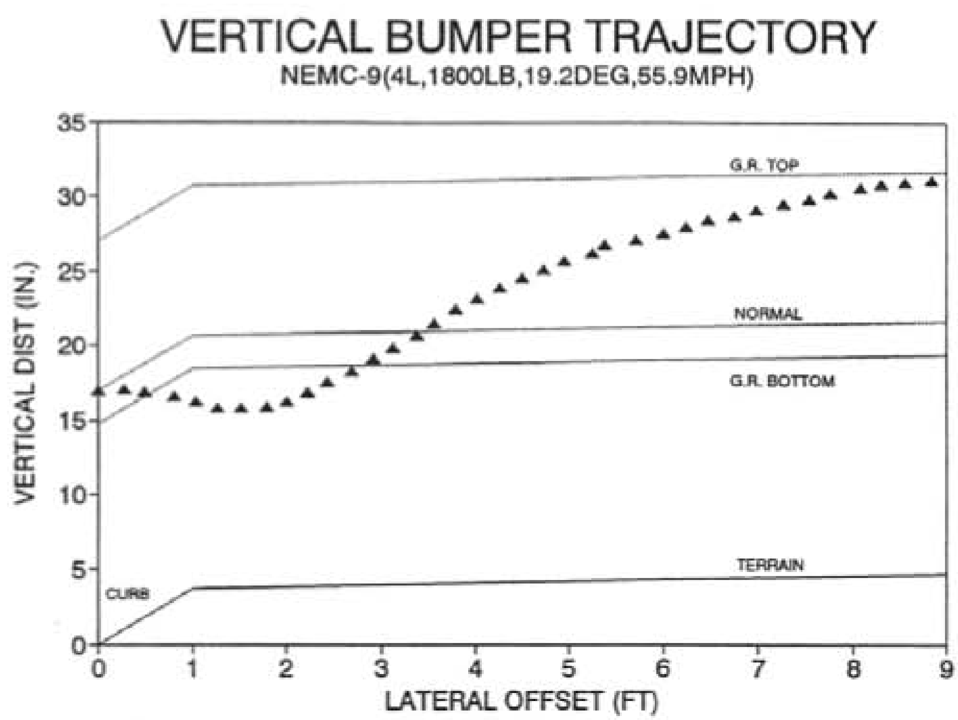


Figure 29. Typical Bumper Trajectory Plots (NEMC-9 and NEMC-13)

the top and bottoms of a standard W-beam rail with a typical post spacing. All of these lines are referenced to the vehicle path and therefore vary with impact angle. Notice that with the lower angle tests the downward slope along the highway is greater than the up-slope behind the curb and thus the terrain is dropping vertically.

The observed bumper trajectory from test NEMC-13, shown in Figure 29, involved a 4500 lb vehicle impacting a 4-in. Lip curb at a speed near 52 mph and at an angle of 19 deg. The approximate 20 degree impact angle causes the test vehicle to travel 2.7 ft down the roadway for every 1 ft of lateral vehicle movement. The 4 percent up-slope behind the curb causes the terrain to rise 0.48 inches for every foot of lateral vehicle movement while the downgrade along the roadway decreases the terrain elevation by 0.32 inches for every foot of lateral motion. Hence the net change in terrain elevation is approximately 0.16 in. upward for every foot of lateral movement. Thus, the reference lines go up slowly as the vehicle encroaches farther onto the roadside.

The initial portion of the travelway over which the down grade and cross slopes were established also affected vehicle behavior during the testing. The test vehicles began to pitch down and roll toward the edge of the roadway upon encountering down grade and cross sloped portions of the simulated roadway. Unfortunately, the vehicles did not reach a steady state condition prior to impacting the curb installations at a point approximately 20 ft downstream from the beginning of the simulated travelway. Thus, test vehicle angular orientations were neither zero nor at a steady state position with respect to the travelway. In an effort to produce a consistent frame of reference with which to compare all crash tests, angular displacement plots were begun at the point the test vehicle encountered the simulated roadway. At this point vehicle orientation angles and angular rotation rates were essentially zero. As a result, curb impact time on these plots ranges from 0.25 sec to 0.32 sec after simulated roadway impact (time = 0.0 sec), depending on the specific testing impact conditions. The low end of this range resulted from low angle, high speed tests, ie.. 5 deg and 55 mph, and the high end of this range results from high angle, low speed tests, ie.. 20 deg and 45 mph.

Implementation of this zone into the analysis proved to be very important in the simulation validation. It was necessary to represent this as part of the curb in order to properly match the vehicle responses. The effects of the transition zone on the vehicle also explains the initial dip in the bumper trajectory results as well as the non-zero angular displacements at curb impact. The effects of the transition zone and longitudinal downslope were examined with a series of simulations that are presented in Chapter 5.

The results for the full-scale tests (NEMC 1-23) are presented in both graphical and tabular form. The graphical form is given in Appendices A, B, D, and E, and the tabular data is given in Tables 7 through 10. Only the positive values of the maximum angular displacements were reported in tabular form since these were the critical values which exemplified the adverse effects from vehicular curb impacts. As shown in Figure 25, a positive pitch angle involves the front of the vehicle pitching upward while a positive roll angle involves a vehicle rolling away from the curb. These orientations increase the likelihood of a vehicle vaulting over a roadside barrier or increasing the height of impact with breakaway structures and are therefore considered to be more critical than the negative rotations.

4.1 4 and 6-in. Lip Curb Results (NEMC 1-15)

Thirteen full-scale crash tests were conducted on a 4-in. Lip curb, designated NEMC(1-13), and two tests were conducted on a 6-in. Lip curb, designated as tests NEMC-14 and NEMC-15. Results of these tests are summarized in Tables 7 and 8. Table 7 contains the maximum angular displacements and Table 8 contains bumper trajectory results. Also presented in the tables are the actual impact conditions and the vehicle corresponding to the test. Graphical representations of the angular displacements and the bumper trajectories are shown in Appendices A and B respectively.

For the low angle tests with the small vehicle (NEMC 1-3) the maximum roll angles ranged from 5.6 to 9.0 degrees and the maximum pitch angles ranged from 0.7 to 1.4 degrees. Maximum roll and pitch angles for these tests were observed to increase with increasing impact velocity. Maximum roll and pitch angles increased only slightly for the moderate impact angle tests with the small vehicle (NEMC 4-6). As shown in Table 7, the maximum roll angles for these tests ranged from 6.0 to 9.3 degrees and the maximum pitch angles ranged from 1.5 to 1.8 degrees. Maximum observed roll angles still increased as impact speed increased, while maximum pitch angles decreased with higher impact velocity. High angle impacts with this vehicle (NEMC 7-9) produced maximum roll angles ranging from 6.2 to 7.5 degrees and maximum pitch angles ranging from 1.4 to 2.6 degrees. Roll angles were again observed to increase with increasing impact speed while maximum pitch angles decreased with higher impact velocity. The maximum observed roll angles for all small car tests with the 4-in. curb were less than 9.5 degrees. This is the roll angle of a vehicle when stopped or parked on a 6:1 roadside

Table 7. Full-Scale Testing Angular Displacements (4&6-in. Lip Curbs)

Test No.	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)	Max Pos. Roll Angle (deg)	Max Pos. Pitch Angle (deg)
NEMC-1	1800 LB	4.9	34.9	5.6	0.7
NEMC-2	1800 LB	5.8	50.6	6.3	1.4
NEMC-3	1800 LB	5.1	53.1	9.0	1.3
NEMC-4	1800 LB	13.0	44.3	6.0	1.8
NEMC-5	1800 LB	13.1	50.6	6.2	1.7
NEMC-6	1800 LB	13.1	55.9	9.3	1.5
NEMC-7	1800 LB	19.3	44.3	6.2	2.6
NEMC-8	1800 LB	19.1	53.1	6.7	1.6
NEMC-9	1800 LB	19.2	55.9	7.5	1.4
NEMC-10	4500 LB	5.0	39.1	6.0	1.1
NEMC-11	4500 LB	5.4	45.3	7.2	0.7
NEMC-12	4500 LB	19.7	39.1	6.4	1.8
NEMC-13	4500 LB	19.0	51.9	6.3	2.0
NEMC-14[1]	4500 LB	19.5	45.2	7.8	2.2
NEMC-15[1]	4500 LB	20.0	53.6	7.2	2.6

[1] 6-in. Lip Curb

Table 8. Full-Scale Testing Bumper Trajectory Results (4&6-in. Lip Curbs)

Test No.	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)	ΔH_{min} (in.)	L_{min} (ft)	L_o (ft)	ΔH_{max} (in.)	L_{max} (ft)
NEMC-1	1800 LB	4.9	34.9	NA	NA	NA	3.9	0.4
NEMC-2	1800 LB	5.8	50.6	2.7	0.0	0.7	5.4	1.8
NEMC-3	1800 LB	5.1	53.1	0.0	0.0	0.0	6.1	1.9
NEMC-4	1800 LB	13.0	44.3	3.6	0.0	1.7	8.6	3.4
NEMC-5	1800 LB	13.1	50.6	4.4	0.0	1.1	7.4	3.9
NEMC-6	1800 LB	13.1	55.9	5.3	0.2	1.7	6.8	5.0
NEMC-7	1800 LB	19.3	44.3	4.7	0.0	2.0	10.4	6.7
NEMC-8	1800 LB	19.1	53.1	4.3	0.0	2.2	8.2	7.5
NEMC-9	1800 LB	19.2	55.9	5.2	0.5	2.5	9.5	8.2
NEMC-10	4500 LB	5.0	39.1	5.9	0.0	0.8	0.0	0.8
NEMC-11	4500 LB	5.4	45.3	6.4	0.0	1.2	0.0	1.2
NEMC-12	4500 LB	19.7	39.1	4.7	0.0	2.7	7.6	4.8
NEMC-13	4500 LB	19.0	51.9	5.5	1.5	5.2	4.4	7.5
NEMC-14[1]	4500 LB	19.5	45.2	7.7	0.0	4.7	2.7	7.5
NEMC-15[2]	4500 LB	20.0	53.6	NA	NA	NA	NA	NA

[1] 6-in. Lip curb
[2] Test Not Filmed; 6-in. Lip curb
NA - Not Available

slope. In view of the fact that drivers are routinely observed to drive along slopes of this magnitude at relatively high rates of speed, the effects of this curb can only be considered to be very minor. The maximum observed pitch angle of 2.6 degrees would correspond to a vehicle traveling up a 4.5 percent grade. Thus, maximum roll and pitch angles produced by the 4-in. Lip curb must be considered relatively insignificant in terms of producing loss of vehicle control.

Further, as shown in Table 8, these tests indicated that the 4-in. curb would have only a slight potential for producing a guardrail underriding problem. The midpoint of the small car bumper was observed to go below the bottom of a standard W-beam rail, i.e. $\Delta H_{min} > 2.25$ in., only in the first region within 2.5 ft of the curb. The testing also indicated a potential for the small vehicle's bumper to go above the center of the top corrugation on a W-beam rail, i.e. $\Delta H_{max} > 7.0$ in., and thus it can be concluded that vaulting of the barrier would be likely in a region of 2.5 to 9.0 ft behind the curb.

For the low impact angle tests with the large vehicle (NEMC-10 and 11) the maximum roll angles ranged from 6.0 to 7.2 degrees and the maximum pitch angles ranged from 0.7 to 1.1 degrees. High impact angle tests (NEMC-12 and 13) exhibited only slightly higher maximum roll angles, ranging from 6.3 to 7.8 degrees. Maximum pitch angles were also observed to increase and ranged between 1.8 to 2.6 degrees. Note that there was no dramatic increase in roll and pitch angles even though tests (NEMC-14 and 15 involved a 6-in. Lip curb. At low impact angles maximum roll angles seemed to increase with higher speeds while the opposite trend was observed for high impact angles. Maximum pitch angles appeared to decrease with increasing impact speed while pitch angles seemed to diminish with increasing speed at high impact angles. For the large automobile, barrier underride would become possible when $\Delta H_{min} > 4.25$ in. and vaulting would be expected when $\Delta H_{max} > 5.0$ in. As shown in Table 8, the testing indicated a very slight potential for underriding a W-beam guardrail was observed for barriers placed within 4 ft. of the curb and there appeared to be no real potential for a large automobile to vault over the barrier.

Time based sequential photographs of tests NEMC-3 and NEMC-7 are shown in Figure 30. Sequential photographs of tests NEMC-11 and NEMC-12 are shown in Figure 31. These figures contain both low angle and a high angle impact tests, with each test vehicle, conducted on the 4-in. Lip curb. These figures contain four photographs each with the first photo representing the time that vehicle's left front tire impacted the curb. The second photo indicates the time and position of the vehicle when the left front tire is offset laterally 1 ft. from the point of impact. The third photo shows the time and position of the vehicle when the left rear tire is 1 ft beyond the curb. The fourth photo indicates the time and position of the vehicle when the right rear tire is 1 ft beyond the curb face. These vehicle positions were selected to establish a consistent comparison between the tests.

4.2 6-in Type I Mountable Curb Results (NEMC 16-23)

Eight full-scale tests were conducted on a 6-in. Type I mountable curb, designated as NEMC(16-23). Results of these tests are shown in Tables 9 and 10. Table 9 contains maximum angular displacements and Table 10 summarizes vehicle bumper trajectories. Graphical representations of the angular displacements and bumper trajectories are shown

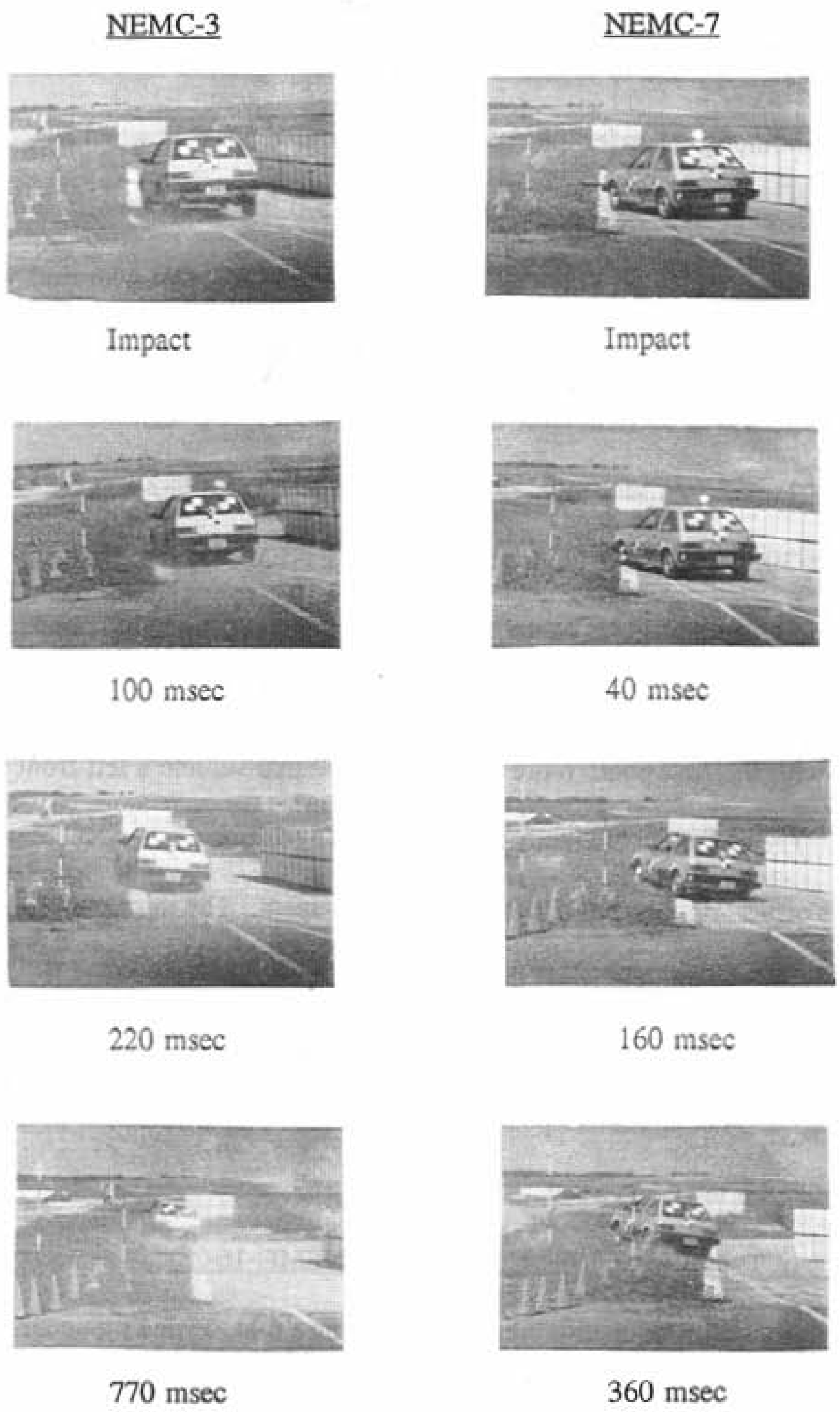


Figure 30. Sequentials of 1800 lb Vehicle Impacts (NEMC-3 and NEMC-7)

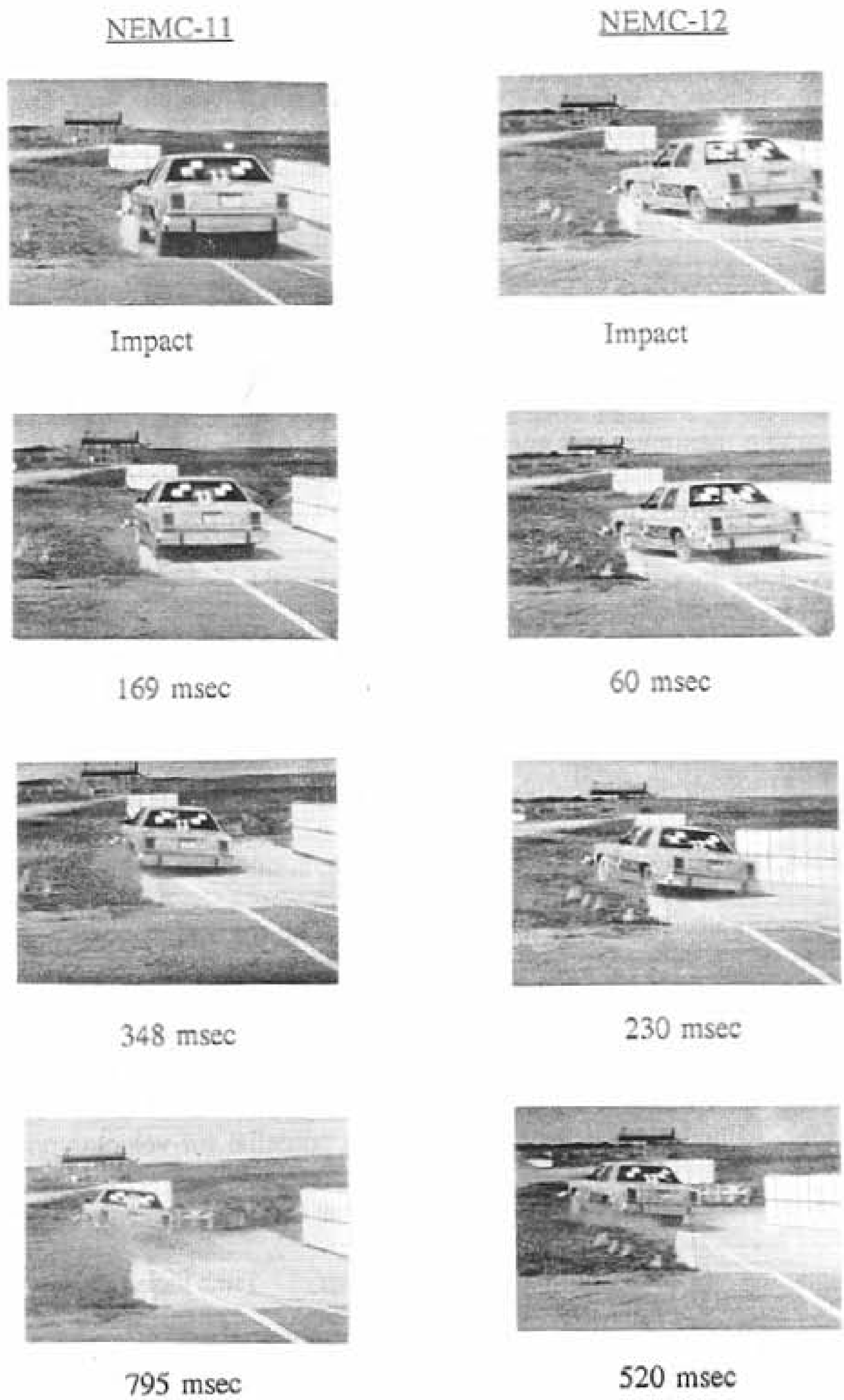


Figure 31. Sequentials of 4500 lb Vehicle Impacts (NEMC-11 and NEMC-12)

in Appendices A and B respectively. The small vehicle, low angle tests exhibited maximum roll angles in the range from 7.5 to 9.7 degrees and maximum pitch angles ranging from 1.5 to 1.9 degrees. Low angle tests with the large automobile exhibited somewhat lower maximum roll angles, ranging from 5.8 to 7.4 degrees, and maximum pitch angles in the range from 1.0 to 1.3 degrees. High impact angle tests exhibited comparable maximum roll angles ranging from 6.8 to 9.5 degrees for the small car and 6.4 to 7.8 degrees for the large automobile. However, maximum pitch angles were observed to increase significantly during these tests, especially for the large car. Maximum pitch angles for the high impact angle tests ranged from 1.8 to 2.1 degrees for the small automobile and 1.6 degrees to 3.1 degrees for the large car.

Although maximum observed roll and pitch angles were somewhat higher during the 6-in. Type I mountable curb tests, vehicle motions were again considered to indicate little opportunity for driver loss of control. The maximum observed roll angle would correspond to the vehicle roll associated with a car parked on a 5.8:1 slope and the maximum observed pitch angle would correspond to a vehicle driving up a 5.5% upgrade. Although these tests did indicate a potential for vehicle underride of W-beam guardrails placed within 4 ft of the curb, there did not appear to be any significant risk of impacting vehicles vaulting over the barrier. Time based sequential photographs of tests NEMC-19 are shown in Figure 32. Sequential photographs of tests NEMC-21, 22, and 23 are shown in Figure 33. The figures contain both low and high impact angles with both test vehicles conducted on the 6-in. Type I mountable curb. Photographs were selected at the same vehicle positions as for the Lip curb testing described previously in an effort to provide a consistent comparison with prior testing.

Table 9. Full-Scale Testing Angular Displacements (6-in. Type I Curb)

Test No.	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)	Max Pos. Roll Angle (deg)	Max Pos. Pitch Angle (deg)
NEMC-16	4500 LB	5.0	41.8	5.8	1.3
NEMC-17	4500 LB	4.2	52.4	7.4	1.0
NEMC-18	4500 LB	18.3	44.3	7.8	1.6
NEMC-19	4500 LB	18.0	52.1	6.4	3.1
NEMC-20	1800 LB	5.2	42.7	7.5	1.9
NEMC-21	1800 LB	5.9	51.2	9.7	1.5
NEMC-22	1800 LB	18.3	43.2	9.5	2.1
NEMC-23	1800 LB	20.0	52.9	6.8	1.8

Table 10. Full-Scale Testing Bumper Trajectory Results (6-in. Type I Curb)

Test No.	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)	ΔH_{min} (in.)	L_{min} (ft)	L_o (ft)	ΔH_{max} (in.)	L_{max} (ft)
NEMC-16	4500 LB	5.0	41.8	NA	NA	NA	6.8	0.4
NEMC-17	4500 LB	4.2	52.4	NA	NA	NA	6.4	0.0
NEMC-18	4500 LB	18.3	44.3	7.3	1.0	5.0	1.4	5.9
NEMC-19	4500 LB	18.0	52.1	6.8	1.0	5.5	3.2	6.8
NEMC-20	1800 LB	5.2	42.7	NA	NA	NA	11.6	1.0
NEMC-21	1800 LB	5.9	51.2	NA	NA	NA	12.1	2.2
NEMC-22	1800 LB	18.3	43.2	6.3	0.0	1.7	6.8	6.5
NEMC-23	1800 LB	20.0	52.9	6.8	0.5	3.9	4.5	8.5

NA - Not Applicable

The only vehicle damage that occurred during the full-scale testing was associated with high angle tests of the 6-in Type I mountable curbs. Damage sustained for these tests included tire bulging to the left front (impacting tire) for tests NEMC-18 and 19. The left front was replaced after NEMC-18 and then again after NEMC-19. The small car, high impact angle tests of this curb, tests NEMC-22 and 23, caused some bending of the left front wheel rim, but there was no tire blowout or loss of control as a result of the bent rim. Wheel damage for both of the test vehicles is shown in Figure 34.

The driver reported only modest jostling and minor vehicle path deviations associated with any of the testing. The most severe effects on the driver were associated with tests involving high angle impacts with the 6-in. curbs. Both vehicle suspensions became fully compressed during these tests and a small jolt was sent into the driver's seat when the left front suspension bottomed out against the suspension bumper stops. The driver reported that there appeared to be no potential for injury of a belted occupant during these impacts.

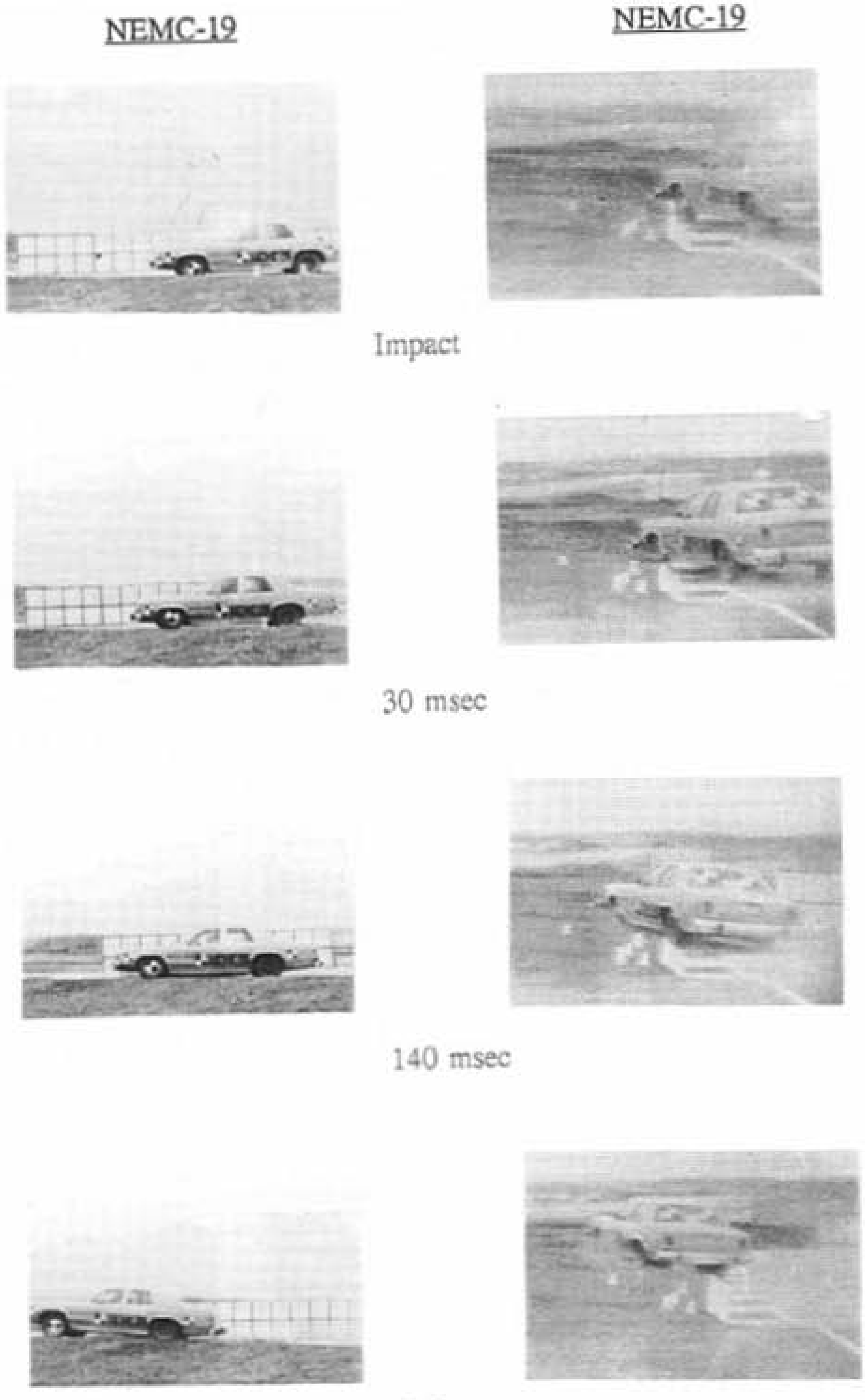


Figure 32. Sequentials of a 4500 lb Vehicle Impact (NEMC-19)

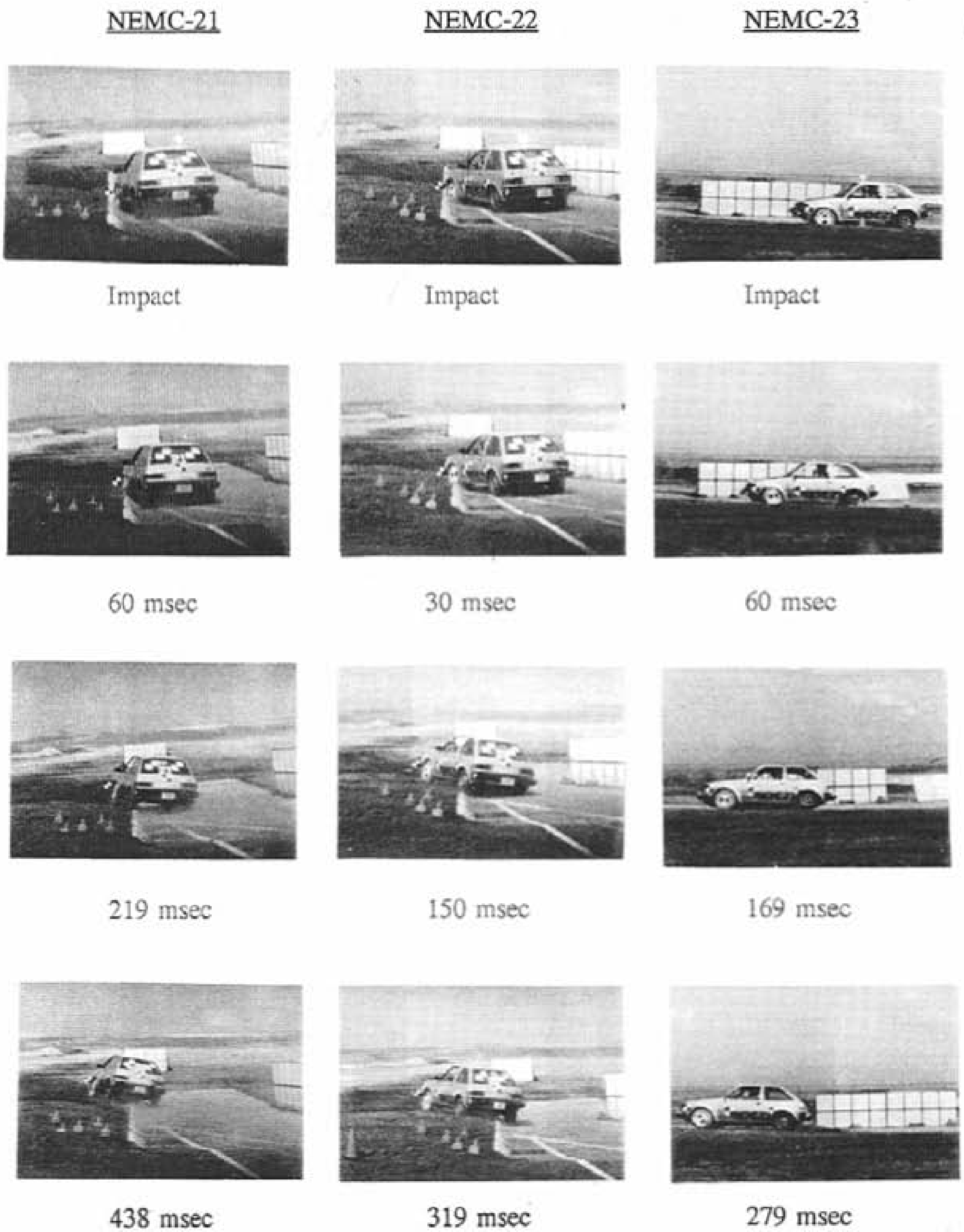


Figure 33. Sequentials of 1800 lb Vehicle Impacts (NEMC-21, 21, and 23)

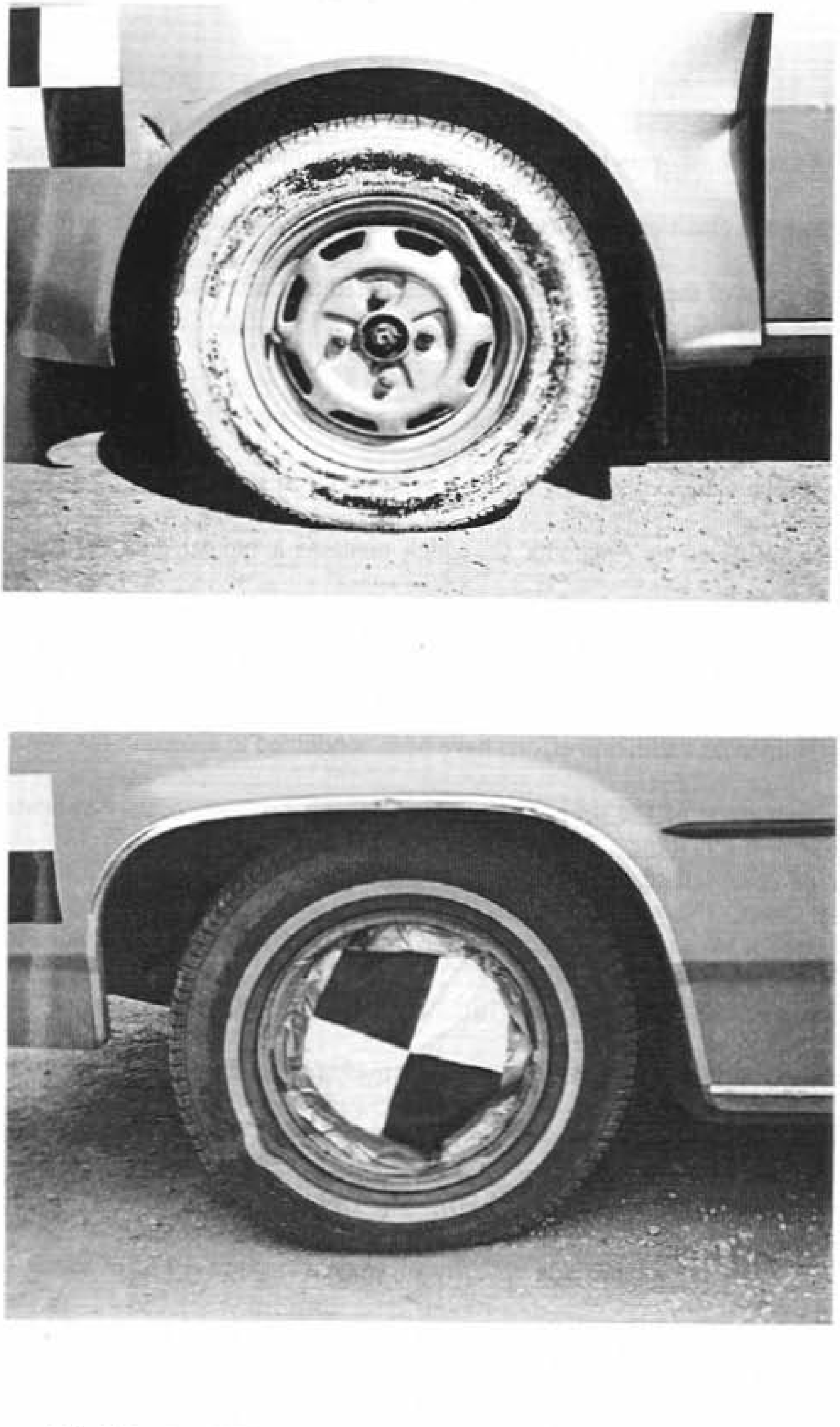


Figure 34. Wheel and Tire Damage

5 HVOSM SIMULATION

As outlined previously, a computer simulation effort was undertaken to extrapolate the crash test results to alternate impact conditions. The complex approach terrain in front of the curb installation necessitated that a revised version of the HVOSM computer program be incorporated for this effort (13).

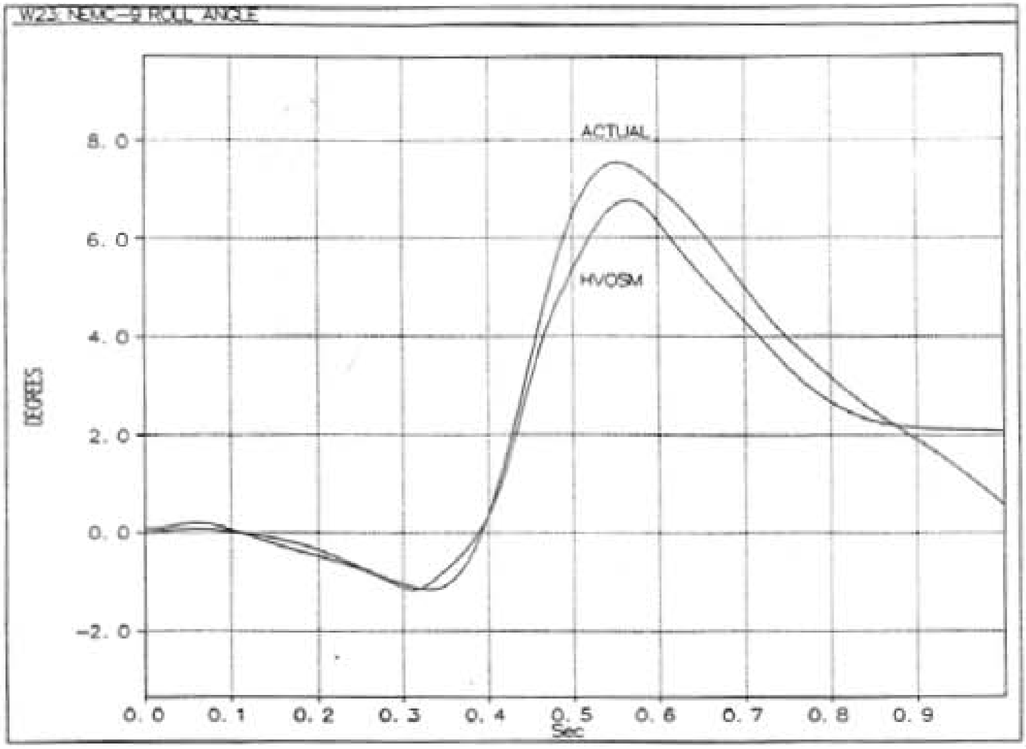
Vehicle inputs were made up of a combination of calculated values (4) and representative values of similar vehicles from previous studies (3,9,10,21). The vehicle data sets are given in Appendix C, which contains a typical data set for each of the simulated vehicles and each of the curb types that were modeled.

5.1 Simulation Validation

Numerous validation efforts have been conducted to ascertain the accuracy as well as the limitations of the program. The model has been previously validated with the results of curb full-scale testing (3,9,10,22). There has been many other significant studies which have used and validated the model for simulation of vehicles impacts with roadside geometrics, curbs, and drainage structures (23). Four of these studies conducted at TTI used HVOSM to evaluate the safety of culvert treatments and roadside geometrics (24-27). Another TTI study used HVOSM to quantify severity of side slopes and various ditch cross sections (28-30). The University of Nebraska conducted a study using HVOSM for quantifying severity of vehicle impacts with driveway slopes (31). A study conducted at Calspan, used HVOSM to determine the effects of roadside terrain geometrics on the dynamic behavior of an automobile and to quantify the severity of encroachments (32). The Highway Safety Research Institute (HSRI) conducted a study using HVOSM to evaluate the effects of dike geometry on vehicle behavior (33).

The simulation approach for this study involved first performing a series of simulation validation tests in order to verify that the results were comparing favorably with those from the actual full-scale testing. This was accomplished by simulating the 23 full-scale tests (NEMC 1-23) and comparing angular displacements, bumper trajectories, and overall trajectories. As shown in Figures 35 through 37 and Appendices A and B, the program was capable of accurately replicating vehicle angular rotations and bumper trajectories. Comparisons between simulated and measured maximum angular rotations for all 23 full-scale crash tests are summarized in Table 11. The maximum simulated roll angles were within 0 to 5 deg of the measured roll angle and the maximum simulated pitch angle was within 0.1 to 2.5 deg of the measured pitch angle. The bumper trajectory comparisons were very favorable, and in most cases the simulated trajectories were within 1-5 inches of the full-scale test bumper trajectories. As shown in Table 11 and in Appendices A and B, the model was considered sufficiently validated and therefore was used as a tool to quantify additional curb impacts.

The HVOSM program version used for this study (13), utilizes a set of planar curb surfaces with arbitrary orientations in three-dimensional space to model the curb and the terrain. The intersections of these curb faces are straight lines, but are not restricted to being parallel to one another. This curb is represented by a series of planar elements with polygonal shapes. The representation of this curb modeling is similar to a finite element mesh where a set of nodes is required along with a set of elements. The user is required to specify coordinates of each node with respect to a space fixed coordinate



NEMC-9(4L,1800LB,19.2DEG,55.9MPH)

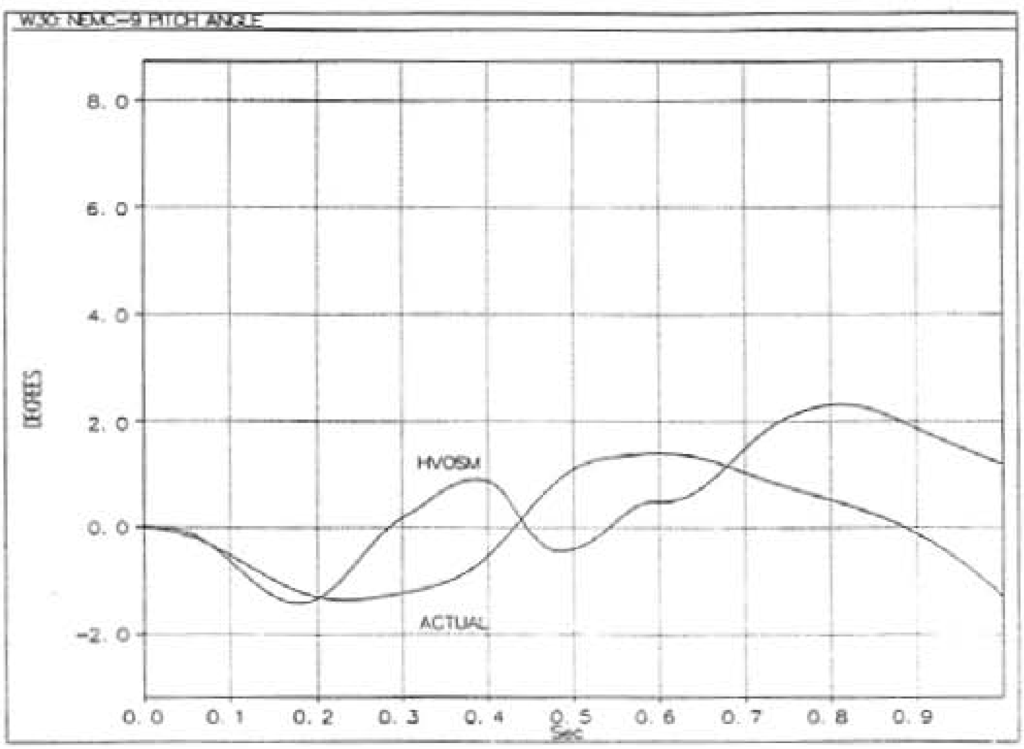
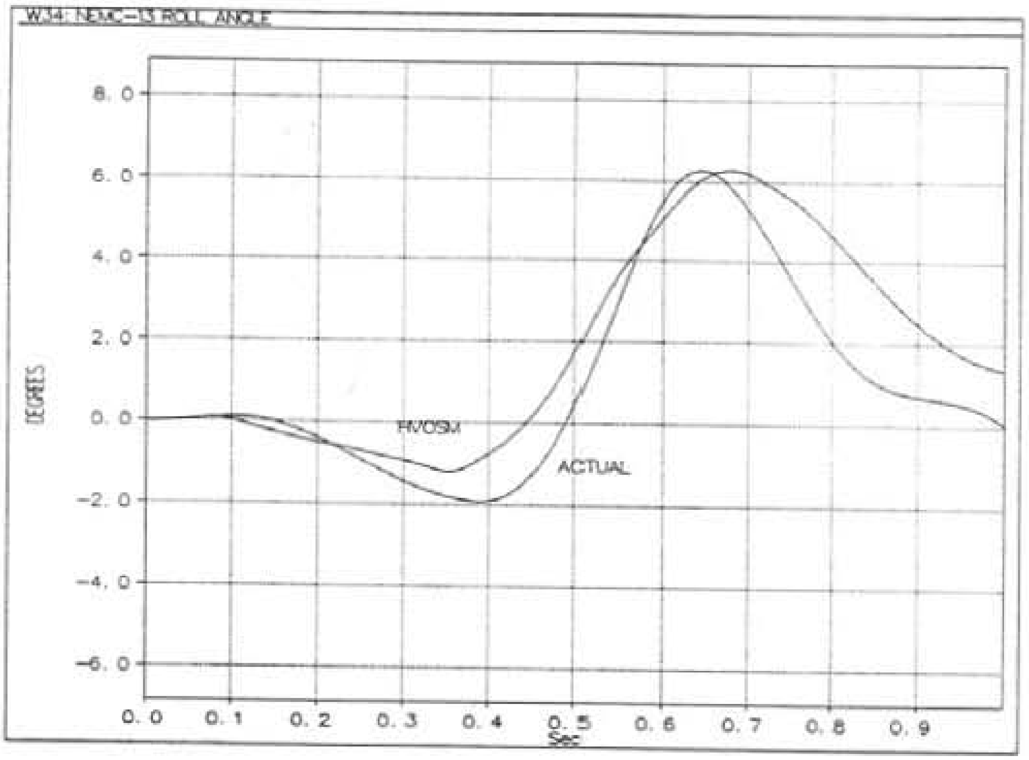


Figure 35. Typical Angular Displacement Validation Plots (NEMC-9)



NEMC-13(4L,4500LB,19.0DEG,51.9MPH)

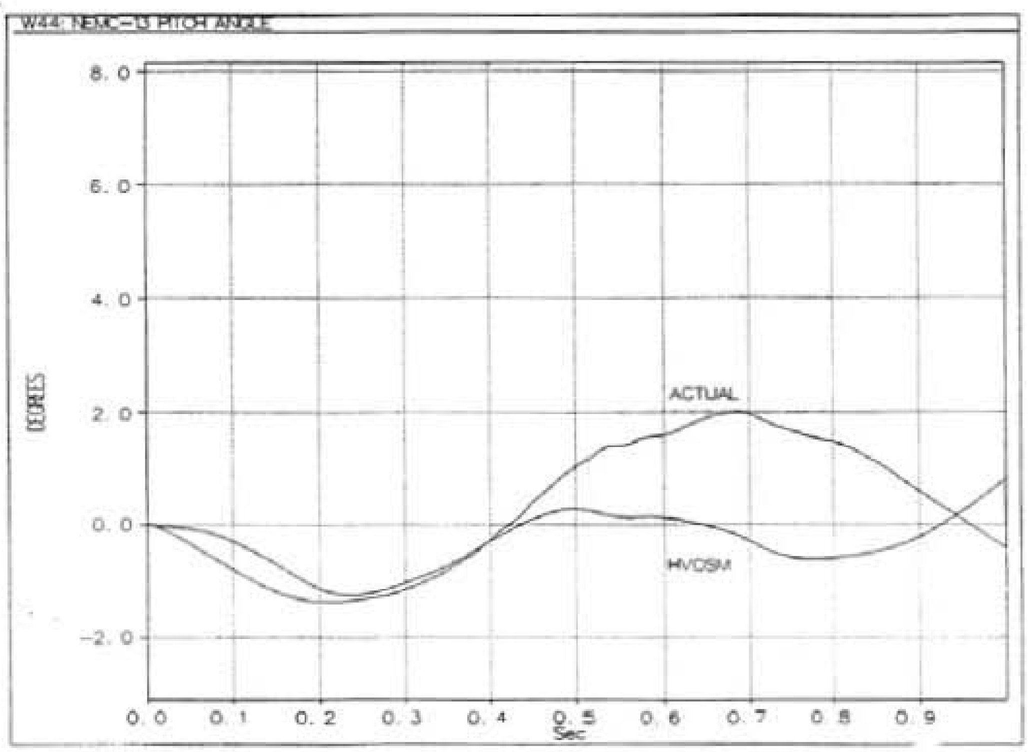
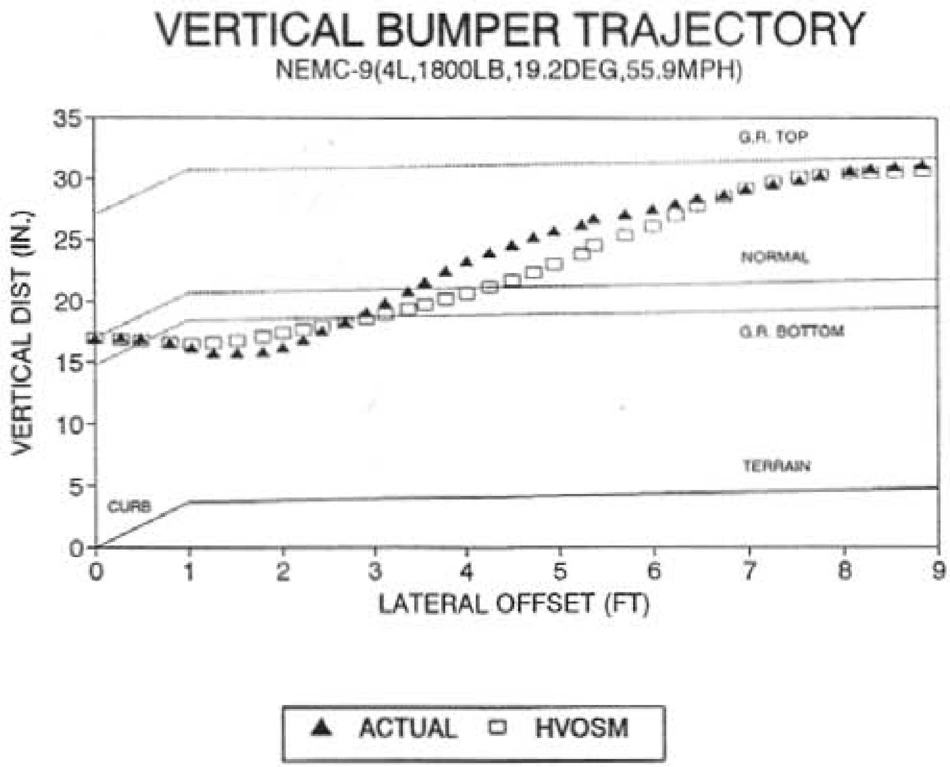


Figure 36. Typical Angular Displacement Validation Plots (NEMC-13)



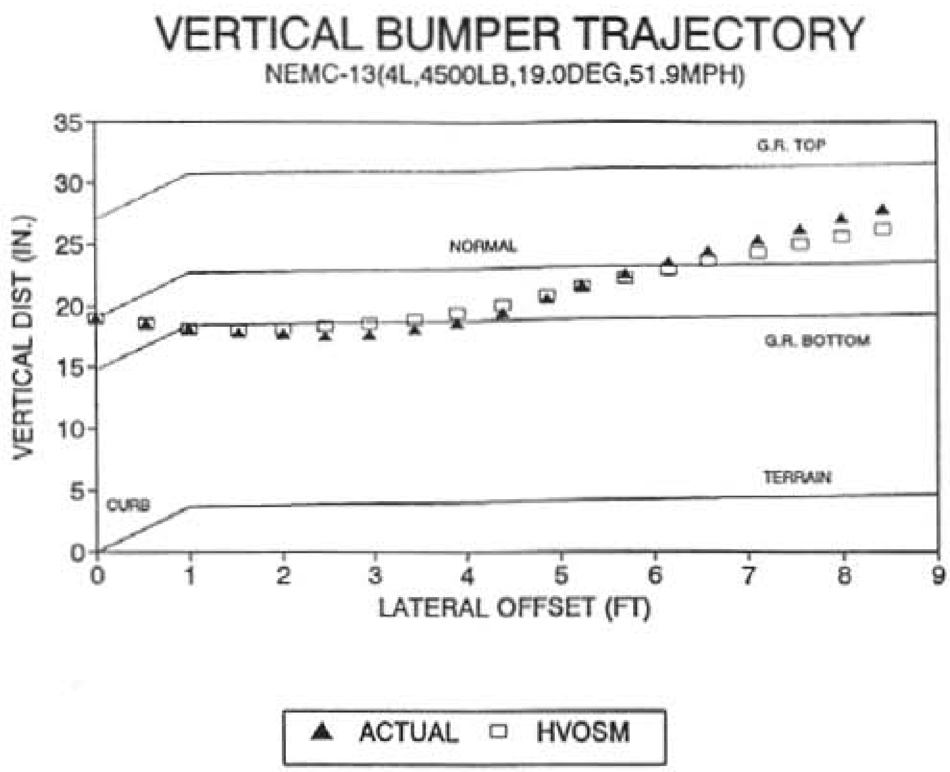


Figure 37. Typical Bumper Trajectory Validation Plots (NEMC-9 and NEMC-13)

Table 11. Simulation Validation Angular Displacements (NEMC 1-23)

Test No.	Test[1] Curb	Test Vehicle	Impact Angle (Deg)	Impact Speed (Mph)	Max Pos. Roll Angle *Test* (Deg)	Max Pos. Roll Angle *HVOSM* (Deg)	Max Pos. Pitch Angle *Test* (Deg)	Max Pos. Pitch Angle *HVOSM* (Deg)
NEMC-1	4L	1800 LB	4.9	34.9	5.6	6.2	0.7	0.8
NEMC-2	4L	1800 LB	5.8	50.6	6.3	8.6	1.4	1.0
NEMC-3	4L	1800 LB	5.1	53.1	9.0	8.9	1.3	0.8
NEMC-4	4L	1800 LB	13.0	44.3	6.0	9.0	1.8	2.0
NEMC-5	4L	1800 LB	13.1	50.6	6.2	8.9	1.7	1.8
NEMC-6	4L	1800 LB	13.1	55.9	9.3	8.3	1.5	1.8
NEMC-7	4L	1800 LB	19.3	44.3	6.2	7.7	2.6	1.8
NEMC-8	4L	1800 LB	19.1	53.1	6.7	7.1	1.6	2.1
NEMC-9	4L	1800 LB	19.2	55.9	7.5	6.8	1.4	2.3
NEMC-10	4L	4500 LB	5.0	39.1	6.0	7.1	1.1	0.5
NEMC-11	4L	4500 LB	5.4	45.3	7.2	7.4	0.7	0.5
NEMC-12	4L	4500 LB	19.7	39.1	6.4	6.4	1.8	0.3
NEMC-13	4L	4500 LB	19.0	51.9	6.3	6.3	2.0	0.8
NEMC-14	6L	4500 LB	19.5	45.2	7.8	7.6	2.2	0.6
NEMC-15	6L	4500 LB	20.0	53.6	7.2	7.0	2.6	0.5
NEMC-16	6S	4500 LB	5.0	41.8	5.8	10.8	1.3	0.6
NEMC-17	6S	4500 LB	4.2	52.4	7.4	11.1	1.0	0.8
NEMC-18	6S	4500 LB	18.3	44.3	7.8	7.7	1.6	1.1
NEMC-19	6S	4500 LB	18.0	52.1	6.4	6.5	3.1	1.6
NEMC-20	6S	1800 LB	5.2	42.7	7.5	9.8	1.9	0.6
NEMC-21	6S	1800 LB	5.9	51.2	9.7	13.2	1.5	0.6
NEMC-22	6S	1800 LB	18.3	43.2	9.5	10.6	2.1	2.0
NEMC-23	6S	1800 LB	20.0	52.9	6.8	9.5	1.8	3.0

[1] - 4L - 4 in. Lip curb; 6L - 6 in. Lip curb; 6S - 6 in. Type I curb

system and the number of nodes for each element. The node numbers of each element and an element connectivity array giving the element numbers connected to each element was also needed. Finally, the outside node numbers and the numbers of the outer elements are required. With the given node and element information the program determines the orientation of the curb and a nodal connectivity array. Details on the development and the modifications of this modeling technique are documented in Appendix C of Reference 13.

This modeling technique allowed the researchers to model the actual terrain and curb that was used for the full-scale testing as a single curb element. This included the approach runway, the simulated roadway (including the transition area), the actual curb, and the terrain behind the curb, which consisted of two different cross slopes and a longitudinal downslope. The input used for this model is given in Appendix C. Schematics of the finite element meshes produced to represent the total curb layout are shown in Figures 38 and 39. The curbs were represented with a series of straight lines, these representations of each curb are shown in Figures 40, 41, and 42. As shown in the full-scale testing section of this report, the layout of the HVOSM testing area is shown in Figure 43. Note that it is a mirror image of the full-scale testing area shown in Figure 6. The HVOSM documentation is all referenced for passenger side impacts, therefore this method was used and some sign conventions needed to be adjusted for the comparisons with full-scale test results. HVOSM output is shown in Figure 44.

5.2 Simulation Results

The simulation effort consisted of a total of 78 computer simulations. Included

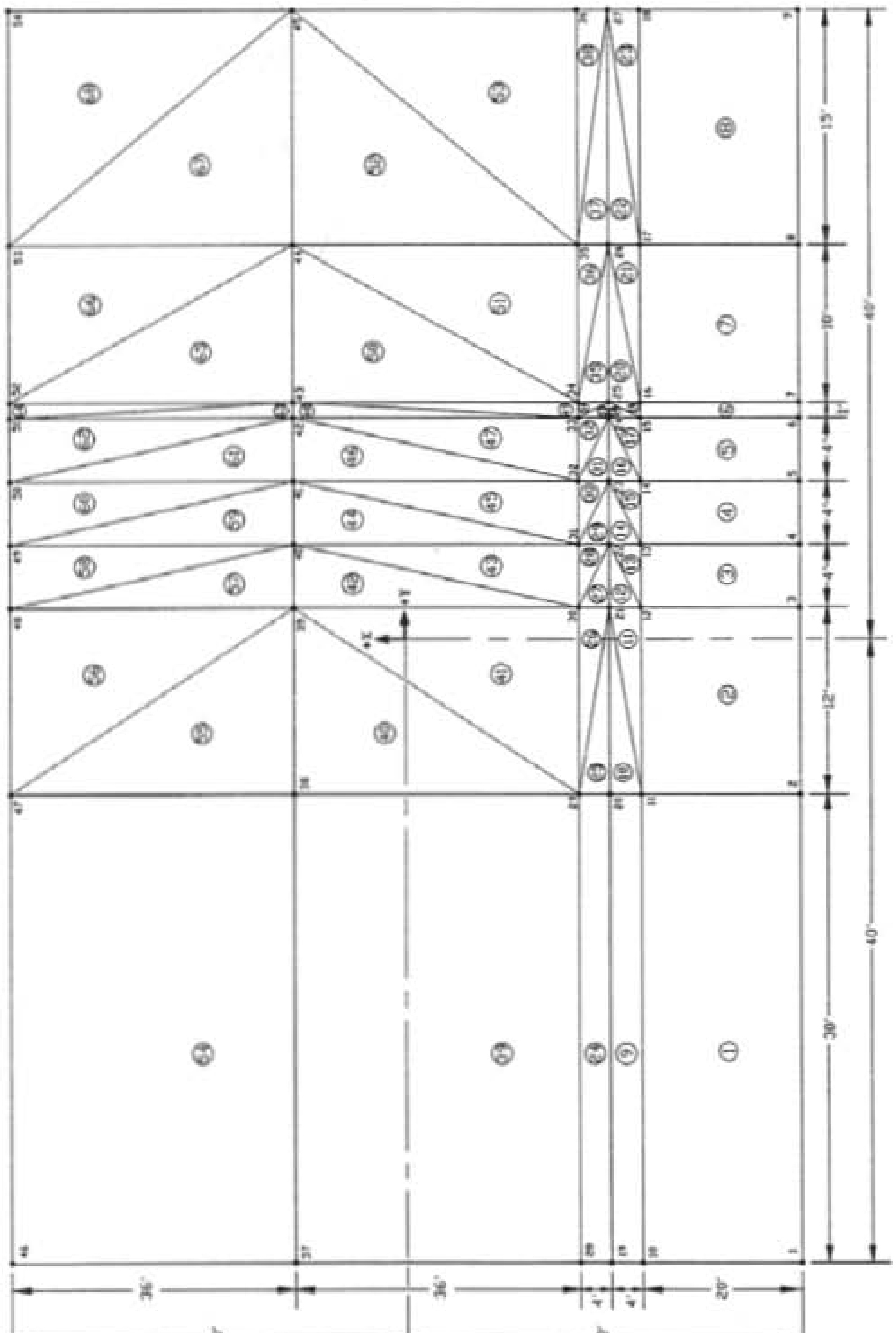


Figure 38. 4 and 6-in. Lip Curb and Terrain Model

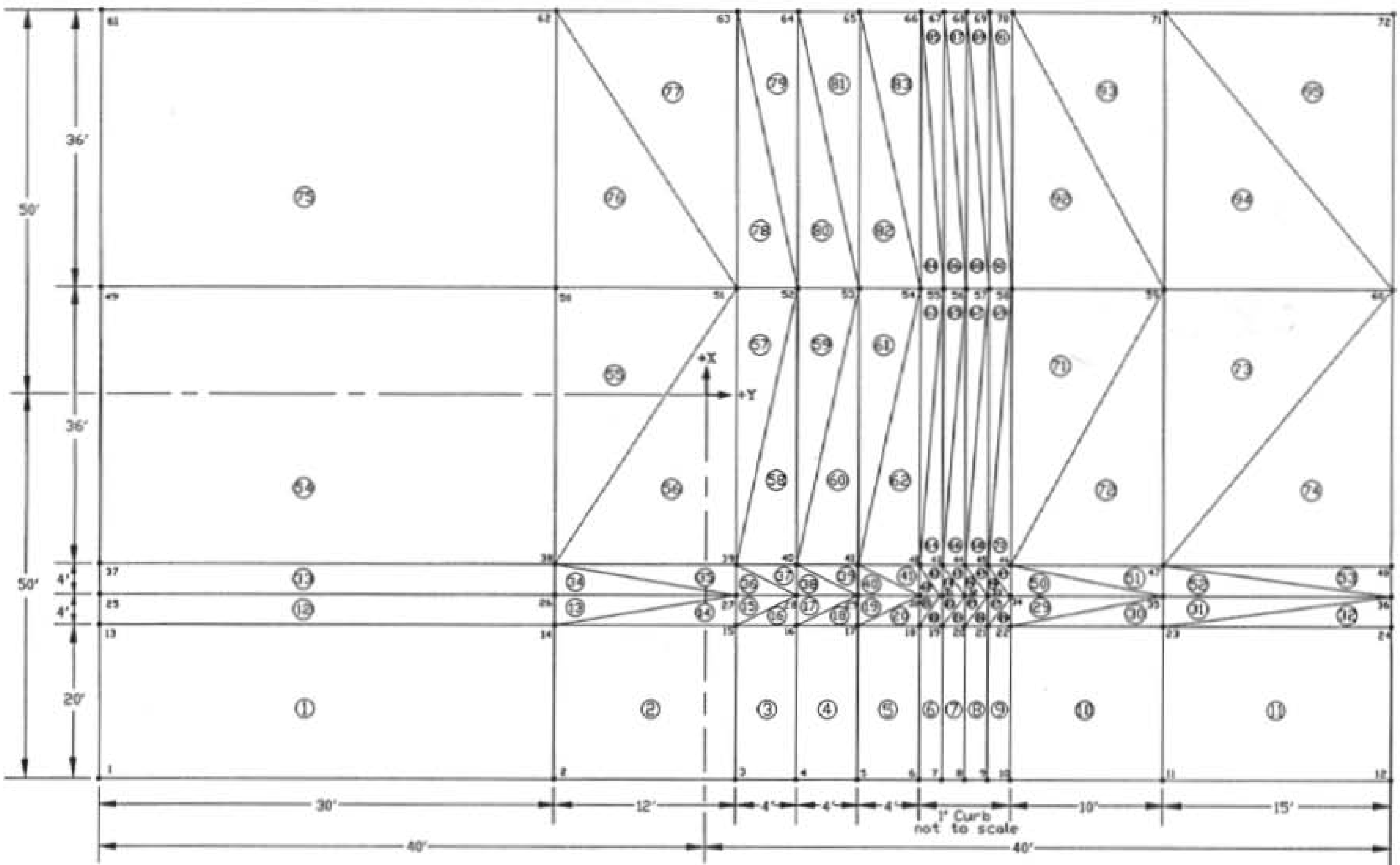


Figure 39. 6-in. Type I Mountable Curb and Terrain Model

Point	Y'	Z'	Ø'
1	12	0	1.1458
2	156	2.88	-18.4349
3	168	-1.12	-2.2906

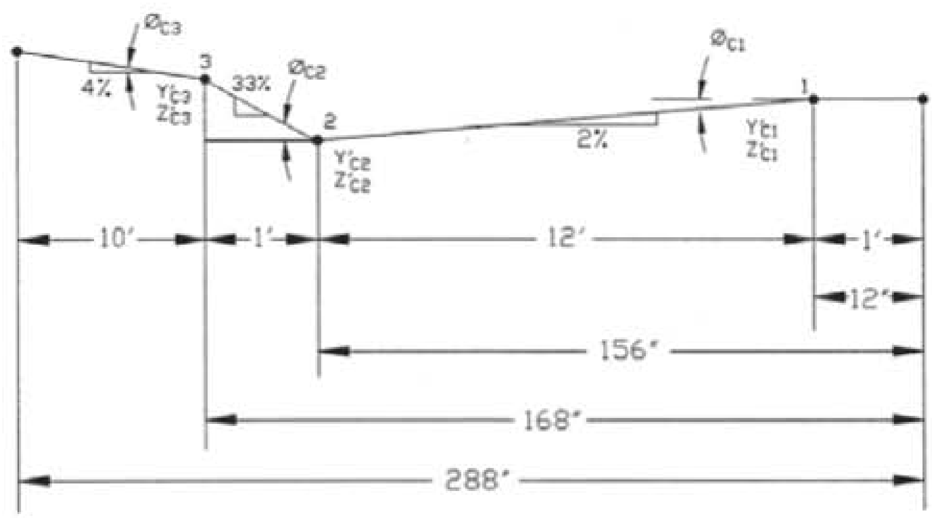


Figure 40. 4-in. Lip Curb Straight Line Representation

Point	Y'	Z'	Ø'
1	12	0	1.1458
2	156	2.88	-26.5631
3	168	-1.12	-2.2906

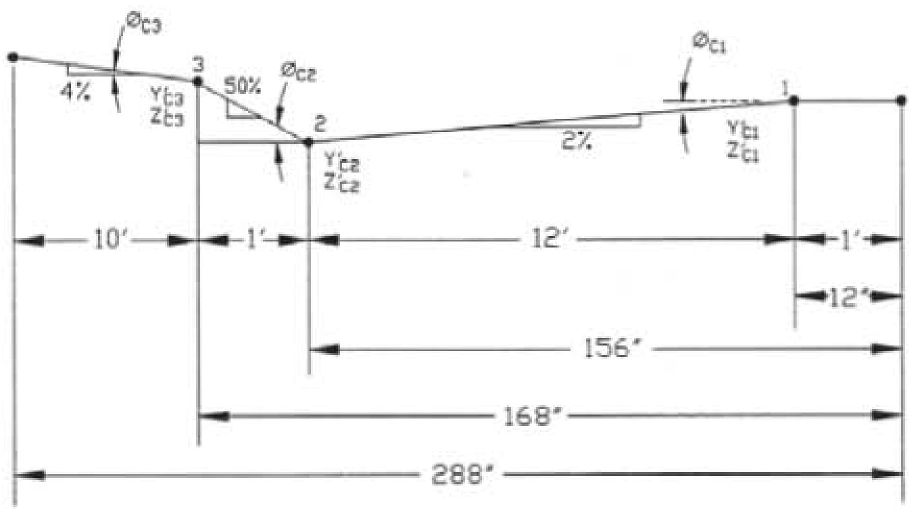


Figure 41. 6-in. Lip Curb Straight Line Representation

Point	Y'	Z'	Ø'
1	12	0	1.1458
2	156	2.88	-11.211
3	159.34	2.218	-46.546
4	162.71	-1.339	-27.057
5	165.31	-2.667	-9.559
6	168	-3.12	-2.2906

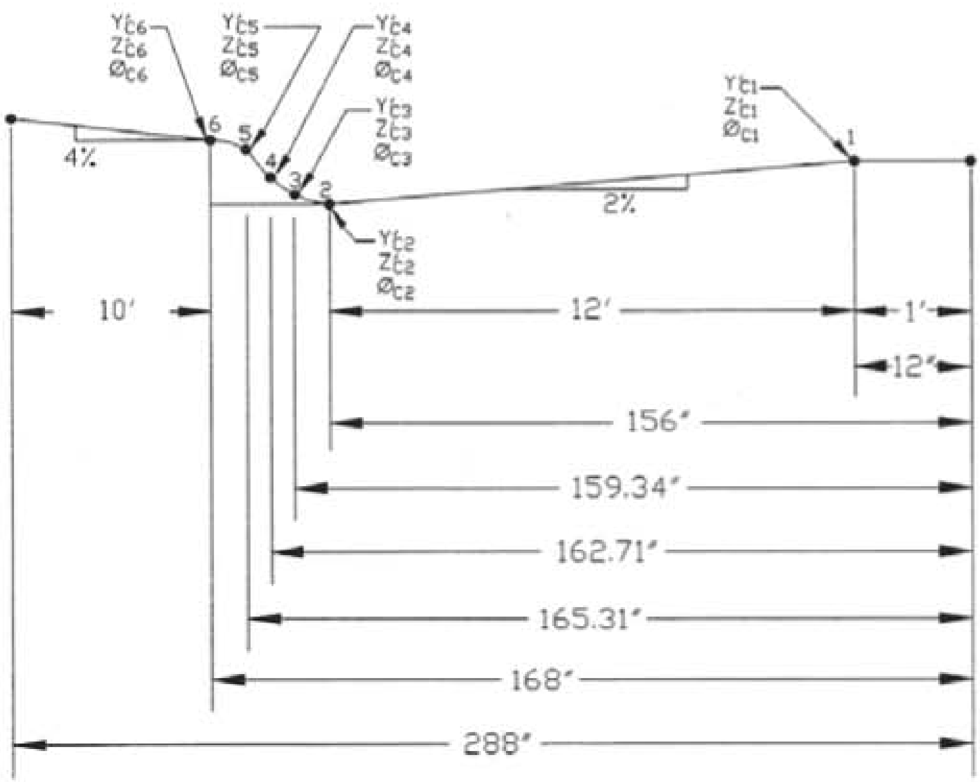


Figure 42. 6-in. Type I Mountable Curb Straight Line Representation

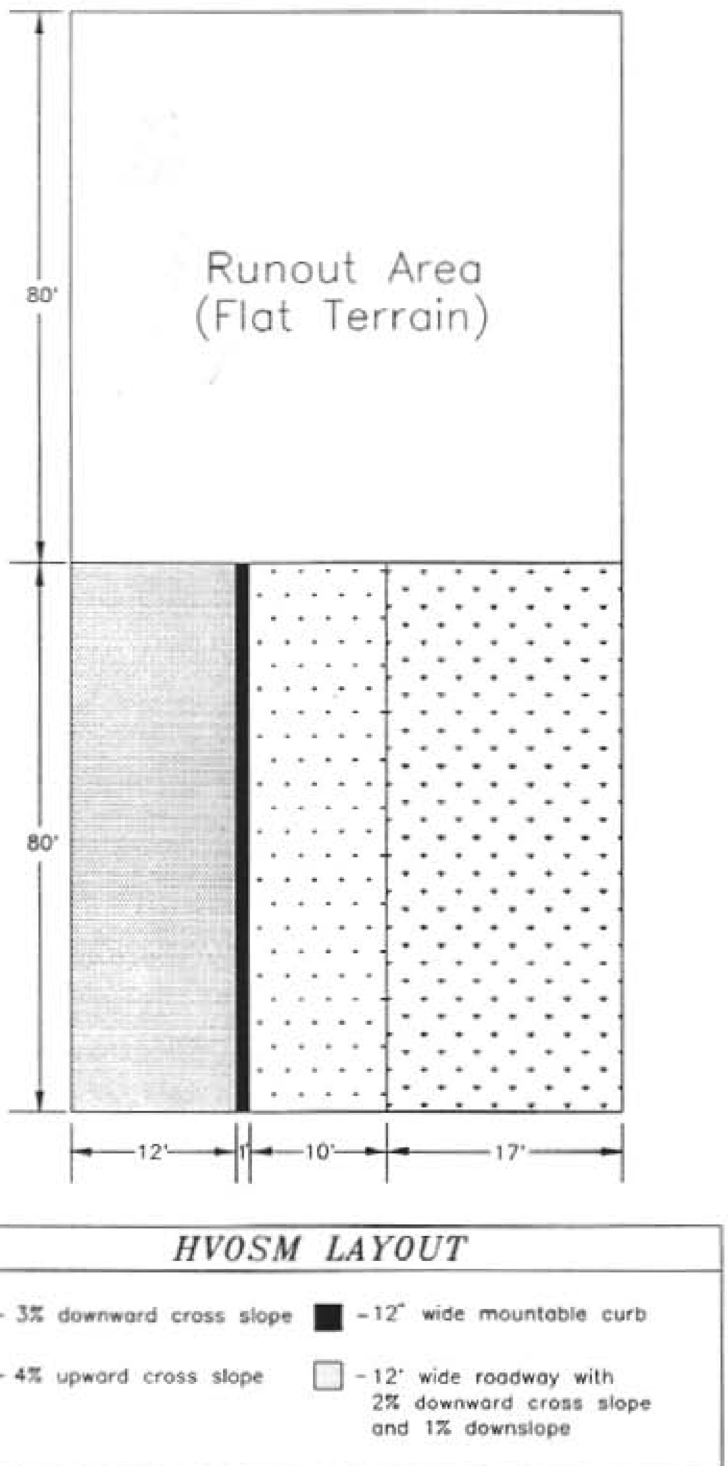


Figure 43. HVOSM Simulation Area Layout

File Name	Description
FILE2	Input Deck
FILE11	Position (ft) Sprung Mass Velocity (ft/sec) Forward:Lateral:Vertical Acceleration (g's) Long:Lat:Vertical:Result
FILE12	Angular Velocities(deg/sec) RR:PR:YR Orientation(deg) R:P:Y Sideslip angle(deg), Course angle(deg) Front steer angle(deg), Rear steer angle(deg)
FILE13	Wheel Ride Displacement (in) RF:LF:RR:LR Wheel Ride Velocities (in/sec) RF:LF:RR:LR
FILE14	Sprung Mass Angular Accl.(deg/sec^2) DP/DT:DQ/DT:DR/DT Wheel Ride Accl. (in/sec^2) RF:LF Rear Roll Center Ride Deflection (in) :Vel.(in/sec):Accl.(in/sec^2) Rear Axle Angular Deflection (deg) :Vel.(deg/sec):Accl.(deg/sec^2)
FILE15	Steer Friction (Torque(lb-in)) Steer Stop (Torque(lb-in) Steer Velocity (deg/sec) Steer Acceleration. (deg/sec^2)
FILE16	Steer Angle in Ground Plane (deg) RF:LF:RR:LR Camber Angle Relative to Ground Plane (deg) RF:LF:RR:LR Camber Angle (deg) RF:LF
FILE17	Long. Wheel Center Velocity Parallel to Ground Plane (ft/sec) RF:LF:RR:LR Lateral Contact Point Velocity Parallel to Ground Plane (ft/sec) RF:LF:RR:LR
FILE18	Tire Contact Point Elevation (in) RF:LF:RR:LR Wheel Pos.(in) RF(x',y'):LF(x',y'):RR(x',y'):LR(x',y')
FILE19	Total Suspension Force (lbs) RF:LF:RR:LR Suspension Anti-Pitch Force (lbs) RF:LF:RR:LR
FILE20	Suspension Damping Force (lbs) RF:LF:RR:LR Suspension Spring Force (lbs) RF:LF:RR:LR
FILE21	Radial Tire Force (lbs) RF:LF:RR:LR Rolling Radius (in) RF:LF:RR:LR Slip Angle (deg) RF:LF:RR:LR
FILE22	Tire Normal Force (lbs) RF:LF:RR:LR Tire Side Force (lbs) RF:LF:RR:LR Tire Rim Force (lbs) RF:LF:RR:LR
FILE23	Z-Direction Tire Force (lbs) RF:LF:RR:LR X-Direction Tire Force (lbs) RF:LF:RR:LR Y-Direction Tire Force (lbs) RF:LF:RR:LR
FILE24	Sprung Mass Acceleration Locational 1 (g's) Longitudinal:Lateral:Vertical:Result Sprung Mass Acceleration Locational 2 (g's) Longitudinal:Lateral:Vertical:Result

Figure 44. HVOSM Output Files

in this effort were 23 validation simulations (NEMC 1-23), 31 supplemental simulations (NE 1-31), and 24 additional simulations (NE 32-55). Only the positive values of the maximum angular displacements were reported since these were the critical values which exemplified the adverse effects from vehicular curb impacts. As shown in Figure 25, a positive pitch angle involves the front of the vehicle pitching upward while a positive roll angle involves a vehicle rolling away from the curb.

5.3 4 and 6-in. Lip Curb Results (NE 1-21)

The results of the 4 and 6-in. Lip curb supplemental simulations (NE 1-21) are given in Tables 12 and 13, and are shown graphically in Appendices D and E. As shown in Table 12, the 4-in. Lip curb simulations with the large vehicle (NE1-5) produced maximum roll angles ranging from 5.4 to 7.8 degrees and the maximum pitch angles ranging from 0.4 to 0.7 degrees. The angular displacements were observed to decrease with an increasing impact velocity. As shown in Table 13 and in Appendices D and E, the bumper trajectories showed no potential for either underriding or vaulting a W-beam guardrail installation located behind the curb.

For the low angle simulations with the small vehicle (NE 6-8) the maximum roll angles ranged from 9.4 to 12.4 degrees and the maximum pitch angles ranged from 0.6 to 0.9 degrees. The roll angle increased while the pitch angle decreased with an increased velocity. Maximum angular displacements increased slightly for the moderate angle simulations with the small vehicle (NE 9-11). The maximum roll angles ranged from 11.4 to 12.0 degrees and the maximum pitch angles ranged from 0.9 to 1.3 degrees. The roll angle decreased and the pitch angle increased with an increased impact

Table 12. Simulated Angular Displacements (4&6-in. Lip Curbs)

Simulation No.	Curb[1]	Vehicle	Impact Angle (deg)	Impact Speed (mph)	Max Pos. Roll Angle (deg)	Max Pos. Pitch Angle (deg)
NE1	4L	4500 LB	5.0	55	7.7	0.7
NE2	4L	4500 LB	12.5	45	7.8	0.6
NE3	4L	4500 LB	12.5	50	7.5	0.6
NE4	4L	4500 LB	12.5	55	7.3	0.5
NE5	4L	4500 LB	20.0	55	5.4	0.4
NE6	6L	1800 LB	5.0	45	9.4	0.9
NE7	6L	1800 LB	5.0	50	10.6	0.6
NE8	6L	1800 LB	5.0	55	12.4	0.6
NE9	6L	1800 LB	12.5	45	12.0	0.9
NE10	6L	1800 LB	12.5	50	11.9	1.2
NE11	6L	1800 LB	12.5	55	11.4	1.3
NE12	6L	1800 LB	20.0	45	9.9	0.8
NE13	6L	1800 LB	20.0	50	9.5	1.0
NE14	6L	1800 LB	20.0	55	9.2	1.2
NE15	6L	4500 LB	5.0	45	10.6	0.8
NE16	6L	4500 LB	5.0	50	10.7	0.9
NE17	6L	4500 LB	5.0	55	11.0	0.9
NE18	6L	4500 LB	12.5	45	10.5	1.0
NE19	6L	4500 LB	12.5	50	10.0	1.0
NE20	6L	4500 LB	12.5	55	9.4	0.9
NE21	6L	4500 LB	20.0	50	6.3	1.4

[1] - 4L - 4 in. Lip
6L - 6 in. Lip

Table 13. Simulated Bumper Trajectory Results (4&6-in. Lip Curbs)

Simulation No.	Curb[1]	Vehicle	Impact Angle (deg)	Impact Speed (mph)	ΔH_{min} (in.)	L_{min} (ft)	L_o (ft)	ΔH_{max} (in.)	L_{max} (ft)
NE1	4L	4500 LB	5.0	55	NA	NA	1.2	7.2	3.4
NE2	4L	4500 LB	12.5	45	4.4	0.2	2.7	5.5	6.8
NE3	4L	4500 LB	12.5	50	4.4	0.3	3.1	4.5	6.8
NE4	4L	4500 LB	12.5	55	4.9	0.4	3.9	3.7	7.0
NE5	4L	4500 LB	20.0	55	4.3	0.7	7.7	4.0	15.9
NE6	6L	1800 LB	5.0	45	NA	NA	NA	14.7	1.2
NE7	6L	1800 LB	5.0	50	NA	NA	0.2	15.3	1.6
NE8	6L	1800 LB	5.0	55	NA	NA	0.2	16.2	2.0
NE9	6L	1800 LB	12.5	45	NA	NA	1.3	14.8	5.5
NE10	6L	1800 LB	12.5	50	NA	NA	1.2	16.2	5.7
NE11	6L	1800 LB	12.5	55	NA	NA	1.4	15.3	6.1
NE12	6L	1800 LB	20.0	45	NA	NA	2.6	13.1	6.9
NE13	6L	1800 LB	20.0	50	6.6	0.5	3.5	10.7	7.4
NE14	6L	1800 LB	20.0	55	5.2	0.1	2.9	10.5	7.2
NE15	6L	4500 LB	5.0	45	NA	NA	0.4	11.9	2.0
NE16	6L	4500 LB	5.0	50	NA	NA	0.6	11.4	2.3
NE17	6L	4500 LB	5.0	55	NA	NA	0.7	10.7	2.9
NE18	6L	4500 LB	12.5	45	NA	NA	2.1	8.1	6.3
NE19	6L	4500 LB	12.5	50	NA	NA	2.4	7.5	6.0
NE20	6L	4500 LB	12.5	55	6.7	0.1	3.1	6.7	6.8
NE21	6L	4500 LB	20.0	50	7.1	0.5	5.0	4.4	9.3

[1] - 4L - 4 in. Lip
6L - 6 in. Lip
[2] - NA - Not Applicable

velocity. High impact angle simulations with the small vehicle (NE 12-14) produced maximum roll angles ranging from 9.2 to 9.9 degrees and maximum pitch angles ranging from 0.8 to 1.2 degrees. The roll angle decreased and the pitch angle increased with increasing impact velocity. The maximum observed roll and pitch angles for the small car simulations with the 6-in. Lip curb were 12.4 and 1.3 degrees respectively. These maximum angular displacements occurred with a 55 mph impact velocity, but these angular motions are minor in terms of potential loss of vehicle control.

Further, as shown in Table 13 and in Appendices D and E, these simulations indicated that the 6-in. curb would have only a potential for producing a guardrail underriding problem. The midpoint of the small car bumper was observed to go below the bottom of a standard W-beam rail, i.e. $\Delta H_{min} > 2.25$ in., only in the first region within 3.5 ft of the curb. The simulations also indicated a potential for the small vehicle's bumper to go above the center of the top corrugation on a W-beam rail, i.e. $\Delta H_{max} > 7.0$ in., and thus it can be concluded that vaulting of the barrier would be likely in a region of 1.5 to 12.0 ft behind the front face of the curb.

For the low angle simulations with the large vehicle (NE 15-17) the maximum roll angles ranged from 10.6 to 11.0 degrees and the maximum pitch angles ranged from 0.8 to 0.9 degrees. For the moderate and high angle simulations (NE 18-21) the maximum roll angles ranged from 6.3 to 10.5 degrees and the maximum pitch angles ranged from 0.9 to 1.4 degrees. The roll angle and pitch angles increased for the low angle simulations and decreased for the moderate and high angle simulations with an increasing impact velocity. The simulation results indicated a slight potential for underriding a W-beam guardrail placed within 3 ft. of the curb and the results also indicated a potential for the small vehicle's bumper to go above the center of the top corrugation on a W-beam rail, i.e. ΔH_{max} > 5.0 in., and thus it can be concluded that vaulting of the barrier would be likely in a region of 2 to 10 ft behind the front face of the curb.

5.4 6-in. Type I Mountable Curb Results (NE 22-31)

The results of the 6-in. Type I curb supplemental simulations (NE 22-32) are given in Tables 14 and 15, and are shown graphically in Appendices D and E. As shown in Table 14, the small vehicle simulations (NE 22-26) produced maximum roll angles ranging from 9.7 to 12.7 degrees and the maximum pitch angles ranging from 0.5 to 1.2 degrees. The roll angle decreased and pitch angle increased with an increasing impact velocity. As shown in Table 15 and in Appendices D and E, there was a potential for underriding a W-beam guardrail placed within 2 ft. of the curb for the low and moderate impact angles and 4 ft for the high impact angle. Simulation results also indicated a potential for the small vehicle's bumper to go above the center of the top corrugation on a W-beam rail in a region of 1.5 to 10 ft behind the curb.

The large vehicle simulations (NE 27-31) produced maximum roll angles ranging from 6.5 to 11.1 degrees and the maximum pitch angles ranging from 0.9 to 1.5 degrees. The roll and pitch angles decreased with an increasing impact velocity. As shown in Table 15 and in Appendices D and E, there was a potential for underriding a W-beam guardrail placed within 2 ft. of the curb for the low and moderate impact angles and 4 ft for the high impact angle. Also indicated from the simulation results was a potential for the large vehicle's bumper to go above the center of the top corrugation on a W-beam rail in a region of 2 to 12 ft behind the curb.

Table 14. Simulated Angular Displacements (6-in. Type I Curb)

Simulation No.	Vehicle	Impact Angle (deg)	Impact Speed (mph)	Maximum Roll Angle (deg)	Maximum Pitch Angle (deg)
NE22	1800 LB	5.0	50	11.9	0.5
NE23	1800 LB	12.5	45	12.7	0.6
NE24	1800 LB	12.5	50	12.1	1.0
NE25	1800 LB	12.5	55	11.8	1.2
NE26	1800 LB	20.0	50	9.7	0.9
NE27	4500 LB	5.0	50	11.1	1.0
NE28	4500 LB	12.5	45	10.1	1.0
NE29	4500 LB	12.5	50	9.6	1.0
NE30	4500 LB	12.5	55	9.0	0.9
NE31	4500 LB	20.0	50	6.5	1.5

Table 15. Simulated Bumper Trajectory Results (6-in. Type I Curb)

Simulation No.	Test Vehicle	Impact Angle (deg)	Impact Speed (mph)	ΔH_{min} (in.)	L_{min} (ft)	L_o (ft)	ΔH_{max} (in.)	L_{max} (ft)
NE22	1800 LB	5.0	50	NA	NA	0.2	16.2	1.7
NE23	1800 LB	12.5	45	NA	NA	NA	15.0	1.9
NE24	1800 LB	12.5	50	NA	NA	1.5	14.9	5.6
NE25	1800 LB	12.5	55	5.8	0.1	1.8	14.8	6.0
NE26	1800 LB	20.0	50	6.7	0.5	4.0	10.1	7.4
NE27	4500 LB	5.0	50	NA	NA	0.7	11.7	2.6
NE28	4500 LB	12.5	45	NA	NA	2.1	8.1	5.0
NE29	4500 LB	12.5	50	NA	NA	2.4	6.7	6.2
NE30	4500 LB	12.5	55	7.0	0.1	3.1	6.7	6.2
NE31	4500 LB	20.0	50	7.0	0.5	4.4	4.9	8.6

NA - Not Applicable

5.5 Additional Simulations (NE 32-55)

The results of the 24 additional simulations are given in Table 16. This set of simulations (NE 32-55) was conducted to evaluate the effects of modeling the curb element without the transition zone and longitudinal downslope associated with the full-scale testing area. The impact conditions chosen for these simulations were the extreme angles (5 and 20 deg) and the extreme impact speeds (45 and 55 mph). All three curb types and both vehicles were incorporated into the simulation matrix. The simulation matrix is shown in Table 16, along with the maximum angular displacements resulting from the simulations.

For the simulations on the 4-in. Lip curb (NE 32-39) the maximum roll angle ranged from 6.0 to 8.1 degrees and the maximum pitch angles ranged from 0.4 to 1.6 degrees. The simulations on the 6-in. Lip curb (NE 40-47) yielded maximum roll angles ranging from 5.9 to 11.3 degrees and the maximum pitch angles ranging from 0.7 to 1.8 degrees. The simulations on the 6-in. Type I mountable curb (NE 48-55) produced maximum roll angles ranging from 6.1 to 11.5 degrees and the maximum pitch angles ranging from 0.9 to 2.0 degrees.

Based on the comparisons of maximum angular displacements from these simulations (NE 32-55) with the actual curb/terrain tests and simulations (NEMC 1-23, NE 1-31) it was determined that the maximum angular displacements differed by no more than 1.0 degree for the lip curbs and by no more than 2.0 degrees for the Type I curb. Due to the minor differences in angular displacement magnitudes, the full-scale tested terrain with the inclusion of the transition area and the longitudinal downslope did not

Table 16. Simulated Angular Displacements (4&6-in. Lip, 6-in. Type I Curbs)

Simulation No.	Curb[1]	Vehicle	Impact Angle (deg)	Impact Speed (mph)	Maximum Roll Angle (deg)	Maximum Pitch Angle (deg)
NE32	4L	1800 LB	5.0	45	7.3	1.2
NE33	4L	1800 LB	5.0	55	8.1	1.3
NE34	4L	1800 LB	20.0	45	6.5	1.6
NE35	4L	1800 LB	20.0	55	6.2	1.6
NE36	4L	4500 LB	5.0	45	7.3	0.7
NE37	4L	4500 LB	5.0	55	7.9	0.6
NE38	4L	4500 LB	20.0	45	6.0	0.4
NE39	4L	4500 LB	20.0	55	6.0	0.4
NE40	6L	1800 LB	5.0	45	9.9	1.0
NE41	6L	1800 LB	5.0	55	11.2	0.8
NE42	6L	1800 LB	20.0	45	8.9	1.8
NE43	6L	1800 LB	20.0	55	8.5	1.5
NE44	6L	4500 LB	5.0	45	10.7	0.9
NE45	6L	4500 LB	5.0	55	11.3	0.7
NE46	6L	4500 LB	20.0	45	6.5	1.2
NE47	6L	4500 LB	20.0	55	5.9	1.6
NE48	6S	1800 LB	5.0	45	9.9	1.3
NE49	6S	1800 LB	5.0	55	11.2	0.9
NE50	6S	1800 LB	20.0	45	9.2	1.4
NE51	6S	1800 LB	20.0	55	8.5	1.1
NE52	6S	4500 LB	5.0	45	11.1	0.9
NE53	6S	4500 LB	5.0	55	11.5	0.9
NE54	6S	4500 LB	20.0	45	6.6	1.7
NE55	6S	4500 LB	20.0	55	6.1	2.0

[1] - 4L - 4 in. Lip curb; 6L - 6 in. Lip curb
6S - 6 - in. Type I curb

have any significant adverse effects on the peak angular displacements. It was essential to model the exact terrain during the validation phase of the simulation study, and therefore it was incorporated into the modeling procedure.

5.6 Non-Tracking Impact Simulations

Since the majority of roadside accidents involve a vehicle that is moving in a non-tracking condition, ie.. side slipping mode, a limited simulation effort was conducted to evaluate the safety performance of the same three mountable curb types previously evaluated in the tracking impact portion of this study. Results of previous simulation and full-scale testing, including this study have shown that curbs 6-in. high or less do not pose a significant hazard when impacted by vehicles in a tracking mode. However, many research documents, including AASHTO (1), have discouraged the use of mountable and barrier curbs on high speed roadways due to the increased potential for tripping vehicles during non-tracking impacts. Thus, the continued use of mountable curbs on high speed roadways creates potential tort liability risks.

The same computer modeling techniques that were used on the tracking impact portion of this study, and validated with the full-scale testing program results, was used for the non-tracking simulation evaluation. Due to lack of full-scale testing results for non-tracking impacts, the validation of the model for non-tracking impacts was not possible. A total of 18 simulations (NT10-27) were performed, consisting of three impact conditions, three curb types and two vehicles. A slightly different representation of the 6-in. Type I mountable curb and terrain is shown in Figure 45 and in the input deck shown in Appendix F. This modification was necessary due to the program's

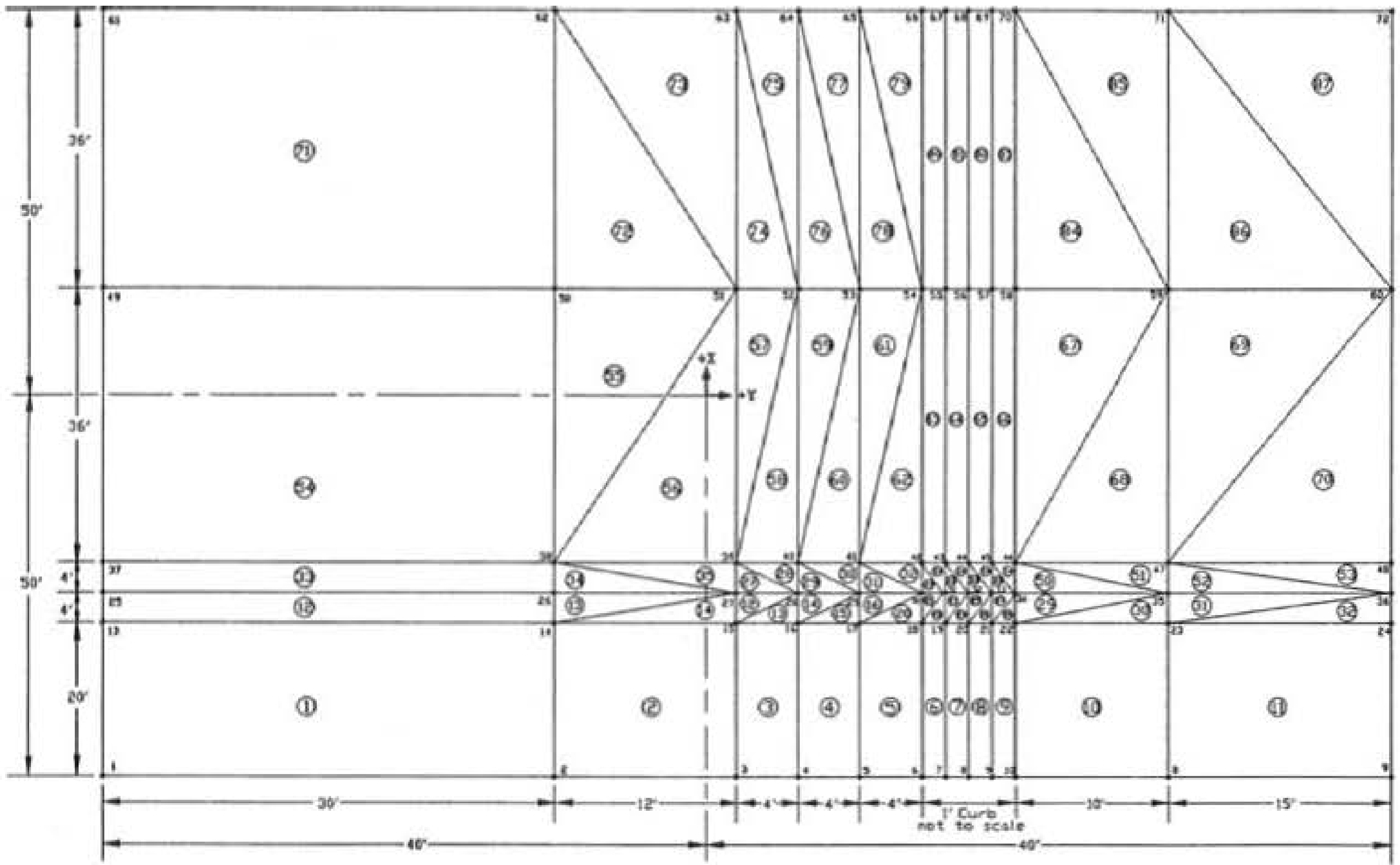


Figure 45. 6-in. Type I Mountable Curb and Terrain Model (Non-Tracking Impacts)

restriction on the number of elements that a tire can contact simultaneously. Another difference between the tracking and non-tracking simulations was that the non-tracking simulations were conducted and reported with passenger side impacts, which are more representative of actual roadway conditions. The simulations modeled the curb element without the transition zone and longitudinal downslope associated with the full-scale testing area, similar to the additional simulations performed and reported in Section 5.5 of this report.

Impact conditions used in this study included those contained in Appendix G of NCHRP Report 350 (34) as well as findings from accident data analysis studies. Three different target impact conditions were used for the simulation evaluation. The actual impact conditions are shown in Table 17. As shown in Table 17, the non-tracking simulation evaluation was conducted on the 4 and 6-in. Lip curbs as well as the 6-in. Type I mountable curb. The simulation vehicles used were the same 1800 and 4500 lb vehicles used in the tracking impact evaluation. The target translational velocity for all three impact conditions was 50 mph, with a c.g. impact angle of 20 degrees. Each of these impact conditions represent realistic and common ran-off-road accidents.

The first impact condition consisted of a 150 deg yaw angle and a 50 deg/sec yaw rate, as shown in Figures 46 and 47, which resulted in the left front (LF) tire of the vehicle impacting the mountable curb first followed by the left rear (LR) tire impacting.

The second impact condition consisted of a -30 deg yaw angle and a -25 deg/sec yaw rate, as shown in Figures 48 and 49, which resulted in the right rear (RR) tire impacting the mountable curb first followed by the right front (RF) tire impacting.

Table 17. Non-Tracking Simulation Actual Impact Conditions

Simulation No.	Curb[1]	Vehicle	YawAngle (deg)	Translational Velocity (mph)	C.G. Impact Angle (deg)	Yaw Angular Velocity (deg/sec)
NT10	6L	4500 LB	150.3	51.2	20.4	47.8
NT11	6L	4500 LB	-29.8	48.9	22.4	-27.5
NT12	4L	4500 LB	150.3	51.2	20.4	47.8
NT13	4L	4500 LB	-29.8	48.9	22.4	-27.5
NT14	6S	4500 LB	150.3	51.2	20.4	47.8
NT15	6S	4500 LB	-29.8	48.9	22.4	-27.5
NT16	6L	1800 LB	149.9	49.2	23.0	49.4
NT17	6L	1800 LB	-30.1	52.6	19.4	-23.7
NT18	4L	1800 LB	149.9	49.2	23.0	49.4
NT19	4L	1800 LB	-30.1	52.6	19.4	-23.7
NT20	6S	1800 LB	149.9	49.2	23.0	49.4
NT21	6S	1800 LB	-30.1	52.6	19.4	-23.7
NT22	6L	4500 LB	179.9	52.1	22.6	50.9
NT23	4L	4500 LB	179.9	52.1	22.6	50.9
NT24	6S	4500 LB	179.9	52.1	22.6	50.9
NT25	6L	1800 LB	180.3	49.5	23.8	49.3
NT26	4L	1800 LB	180.3	49.5	23.8	49.3
NT27	6S	1800 LB	180.3	49.5	23.8	49.3

[1] - 4L - 4 in. Lip curb; 6L - 6 in. Lip curb
6S - 6 - in. Type I curb

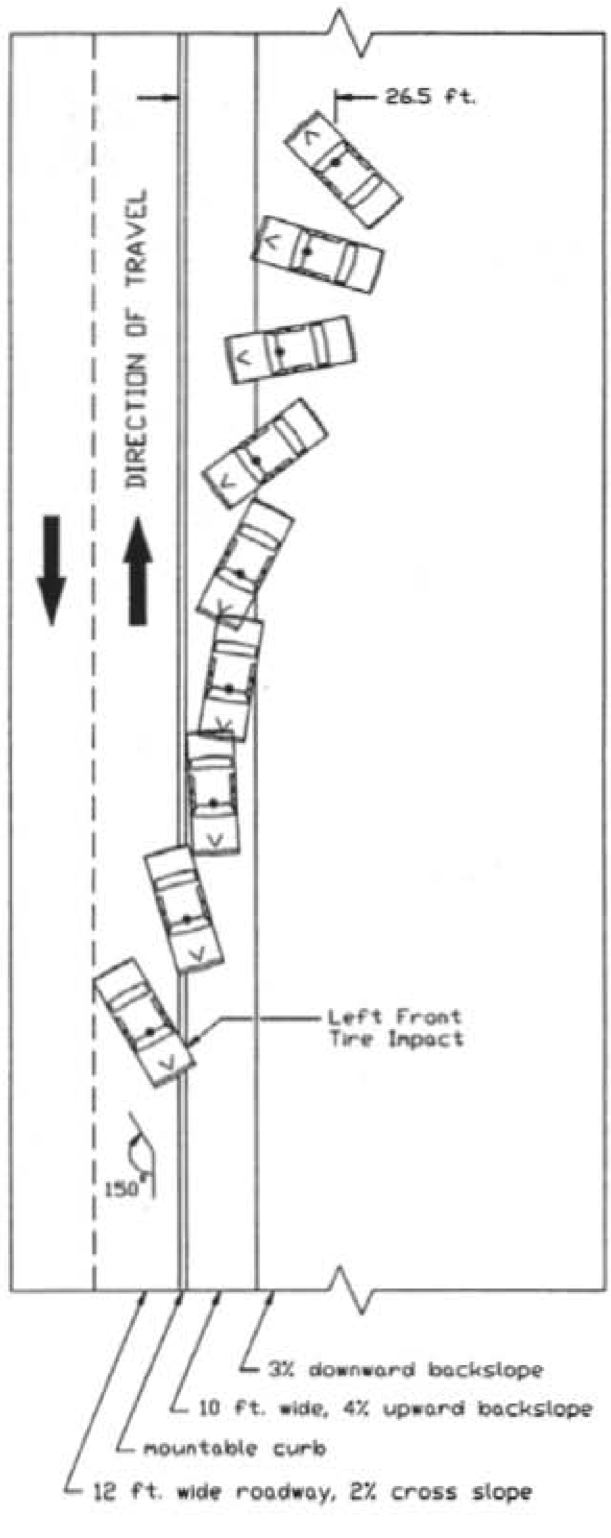


Figure 46. NT14 (6S, 150 deg yaw, 4500 lb) Trajectory Plot

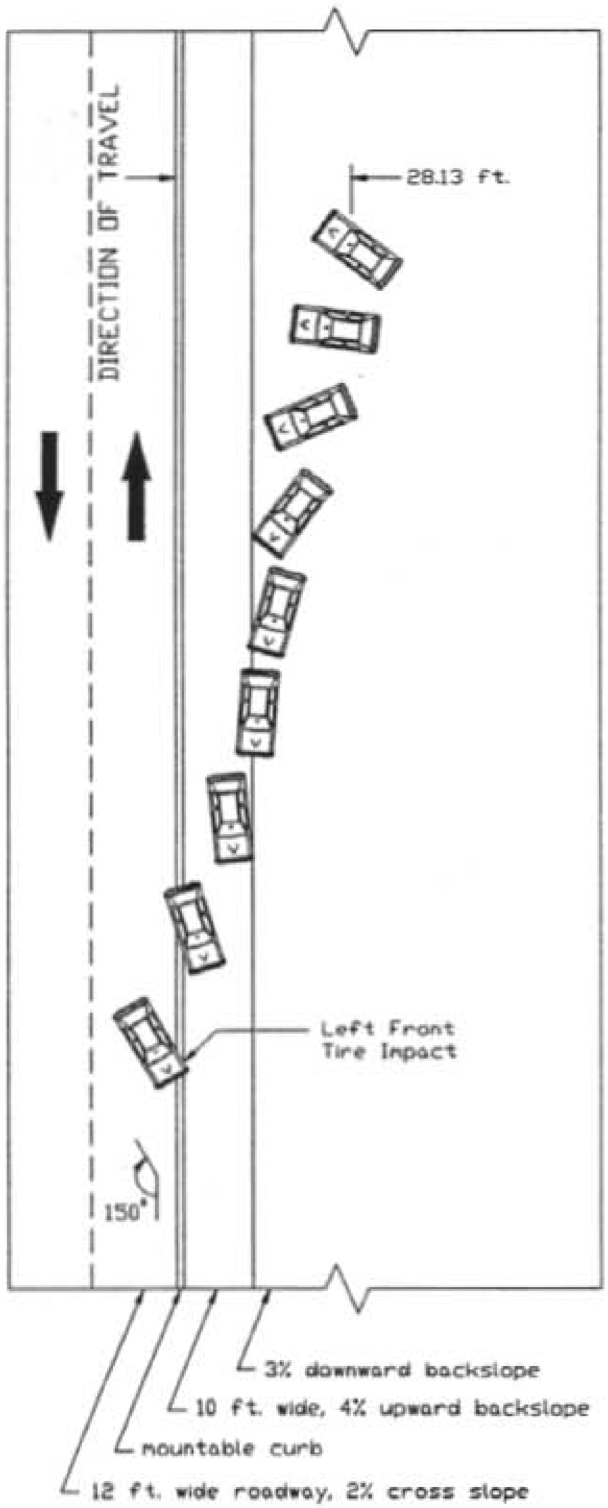


Figure 47. NT20 (6S, 150 deg yaw, 1800 lb) Trajectory Plot

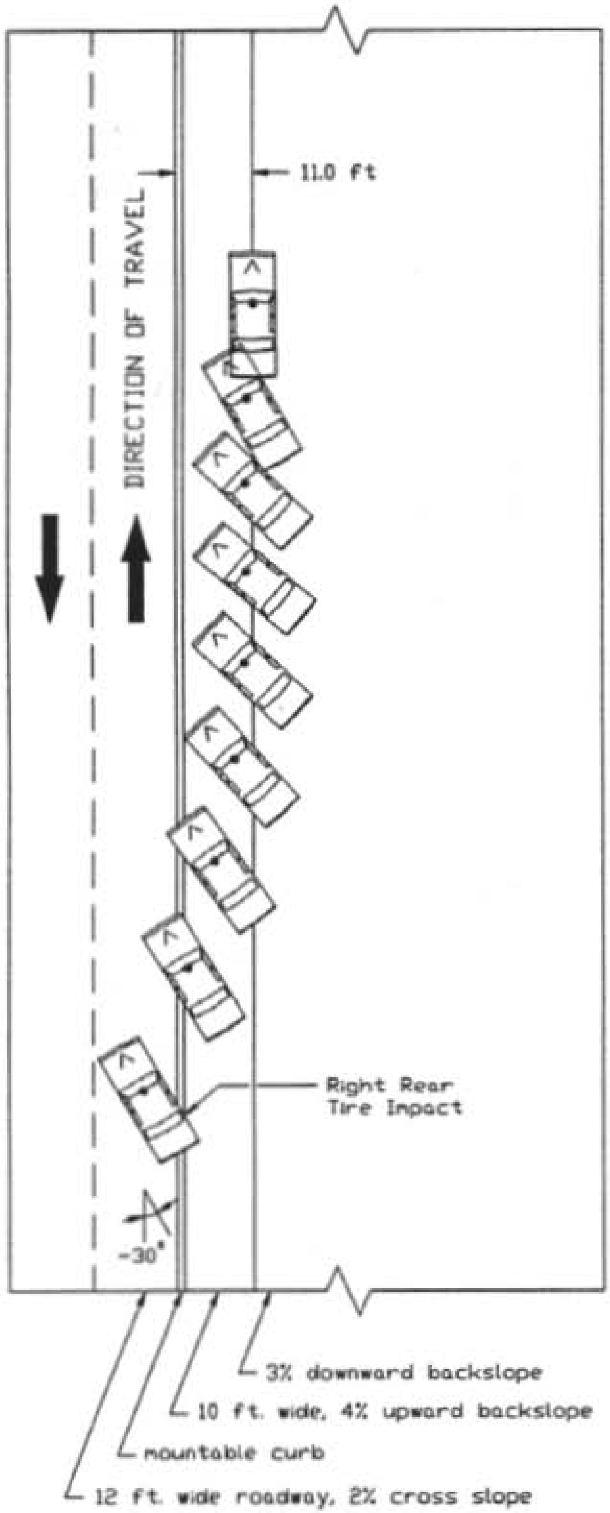


Figure 48. NT15 (6S, -30 deg yaw, 4500 lb) Trajectory Plot

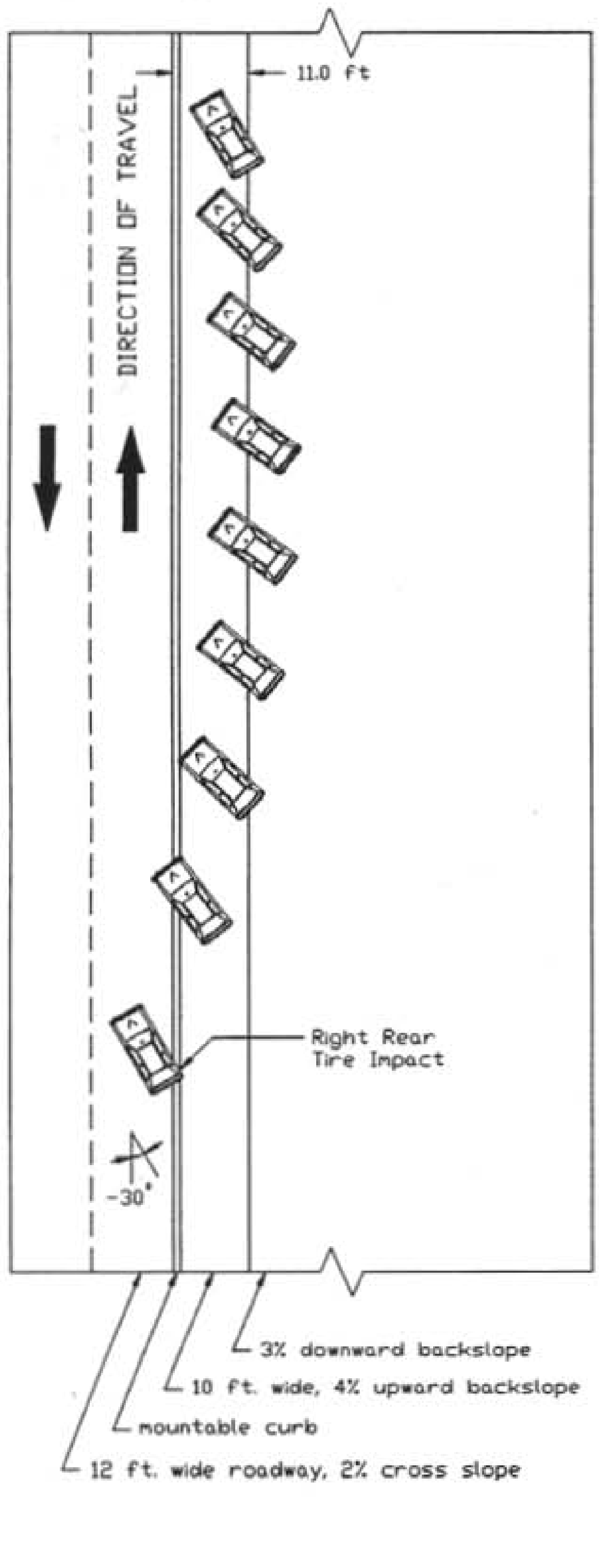


Figure 49. NT21 (6S, -30 deg yaw, 1800 lb) Trajectory Plot

The third and final impact condition, as shown in Figures 50 and 51, consisted of a 180 deg yaw angle impact and a 50 deg/sec yaw rate, which resulted in the left front (LF) and rear (LR) tires impacting the mountable curb simultaneously.

5.7 Non-Tracking Simulation Results

This simulation effort consisted of 18 computer simulations (NT10-27). The maximum angular displacement results are tabulated in Table 18, and are shown graphically in Appendix G. As shown previously in Figure 25, a positive pitch angle involves the front of the vehicle pitching upward while a positive roll angle involves a vehicle rolling towards the curb for the -30 deg yaw angle impact condition and away from the curb for the other two impact conditions (150 and 180 deg yaw).

Examples of angular displacement graphical representations for NT10,12 and 14 are shown in Figures 52 through 54. These plots consist of the roll and pitch angular displacements throughout an impacting event. The simulations chosen as examples for these plots represent a typical group of simulations. This particular group consisted of the 150 deg yaw impact condition with the 4500 lb vehicle for all three curb types. Similar plots for all groups are given in Appendix G.

The simulations were run for approximately 2.0 seconds which allowed for the vehicles to at least reach the top of the 10 ft. upslope located directly behind the curb. This was considered the "area of interest" for both the tracking and non-tracking portions of this study. As shown on the plots, impact with the curb was designated with time equal to zero seconds. The non-zero angular displacements at this time were due to the behavior of the vehicle prior to impact.

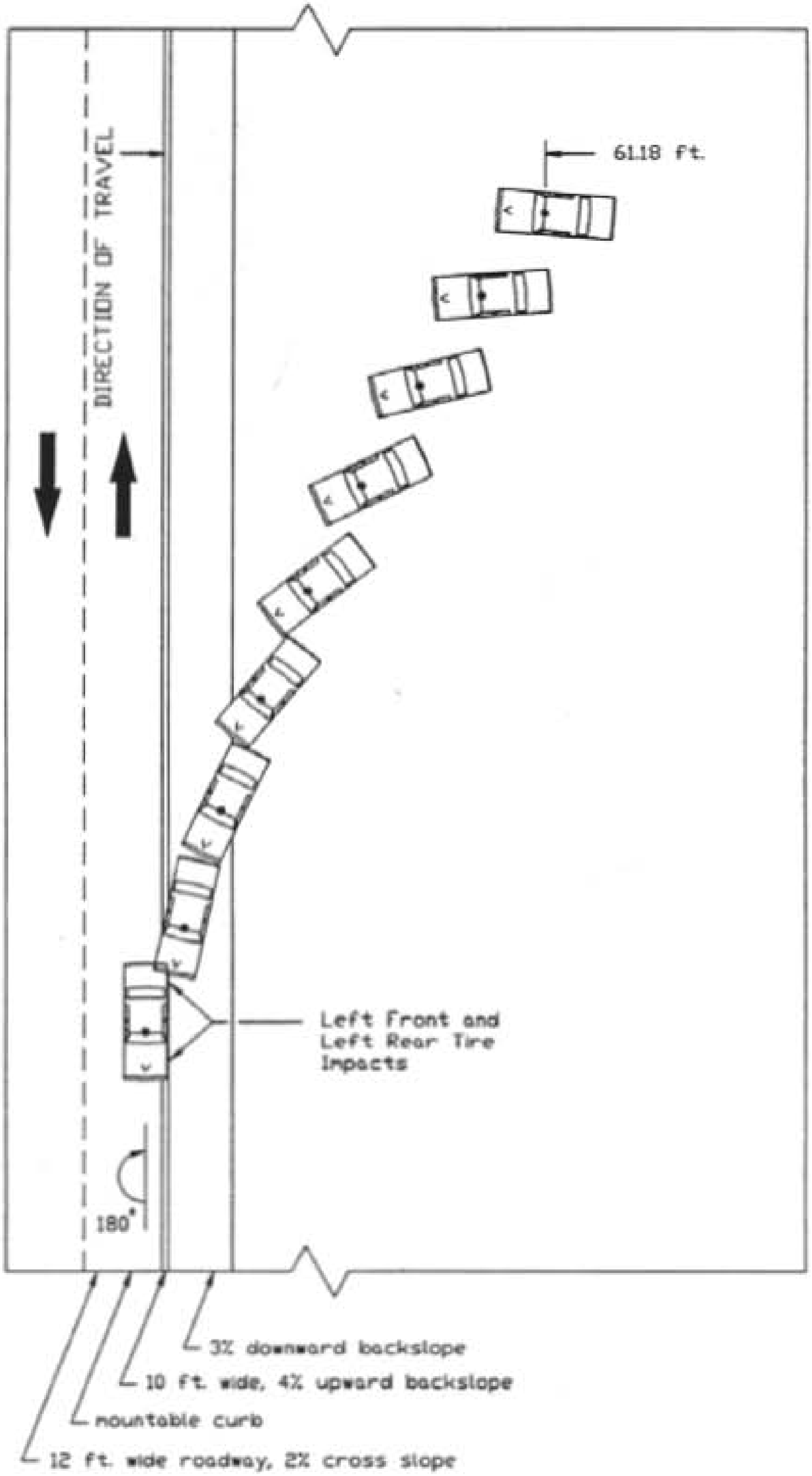


Figure 50. NT24 (6S, 180 deg yaw, 4500 lb) Trajectory Plot

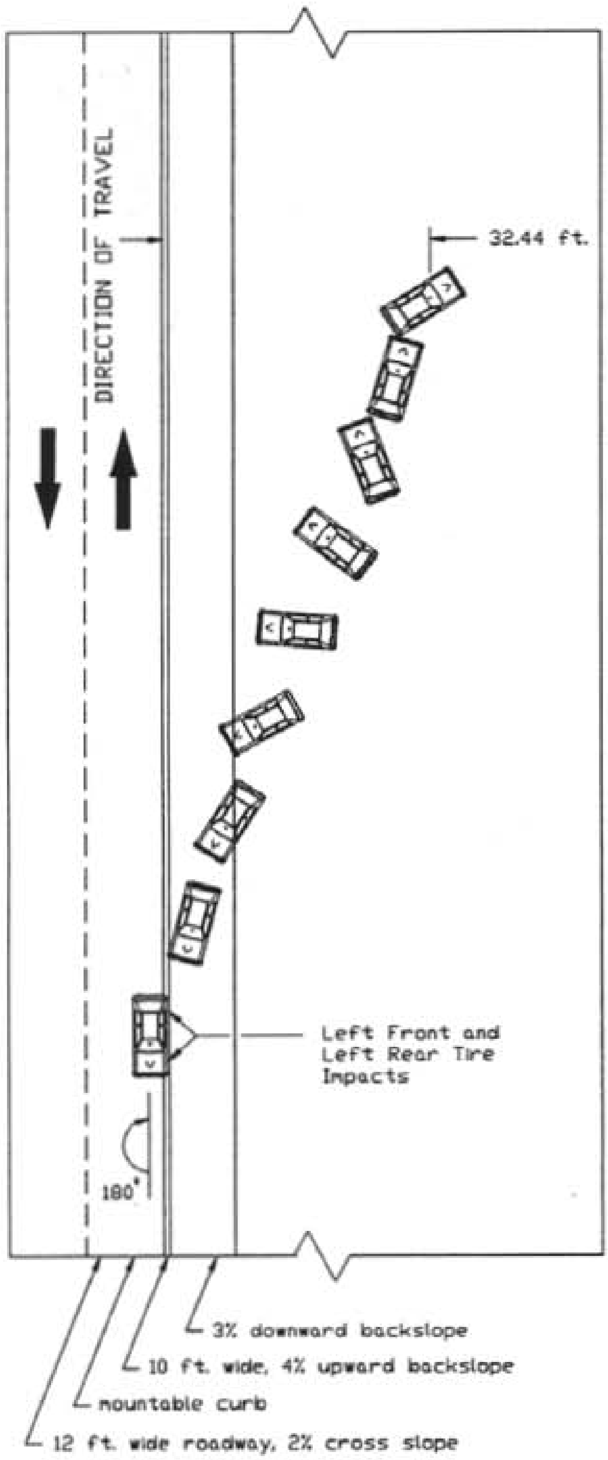


Figure 51. NT27 (6S, 180 deg yaw, 1800 lb) Trajectory Plot

Table 18. Non-Tracking Simulated Angular Displacements

Simulation No.	Curb[1]	Vehicle	Impact Yaw Angle (deg)	Max Pos. Roll Angle (deg)	Max Neg. Roll Angle (deg)	Max Pos. Pitch Angle (deg)	Max Neg. Pitch Angle (deg)
NT10	6L	4500 LB	150	8.5	-8.0	2.4	-0.8
NT11	6L	4500 LB	-30	10.6	-5.1	0.9	-3.3
NT12	4L	4500 LB	150	6.8	-9.1	1.6	-1.3
NT13	4L	4500 LB	-30	8.1	-4.5	0.9	-3.6
NT14	6S	4500 LB	150	9.1	-7.5	2.3	-0.7
NT15	6S	4500 LB	-30	9.9	-4.9	0.9	-3.3
NT16	6L	1800 LB	150	8.6	-6.2	2.4	-2.7
NT17	6L	1800 LB	-30	6.8	-3.2	0.6	-5.7
NT18	4L	1800 LB	150	8.2	-6.8	2.1	-2.6
NT19	4L	1800 LB	-30	6.9	-2.6	0.5	-4.7
NT20	6S	1800 LB	150	8.6	-6.2	2.3	-2.7
NT21	6S	1800 LB	-30	6.8	-3.8	0.5	-5.5
NT22	6L	4500 LB	180	4.9	-8.9	2.9	-0.1
NT23	4L	4500 LB	180	6.7	-8.8	1.0	-1.2
NT24	6S	4500 LB	180	5.0	-8.7	3.2	-0.1
NT25	6L	1800 LB	180	7.3	-8.7	3.0	-2.8
NT26	4L	1800 LB	180	7.5	-8.1	0.9	-3.1
NT27	6S	1800 LB	180	7.4	-8.1	3.1	-3.0

[1] - 4L - 4 in. Lip curb; 6L - 6 in. Lip curb
6S - 6 - in. Type I curb

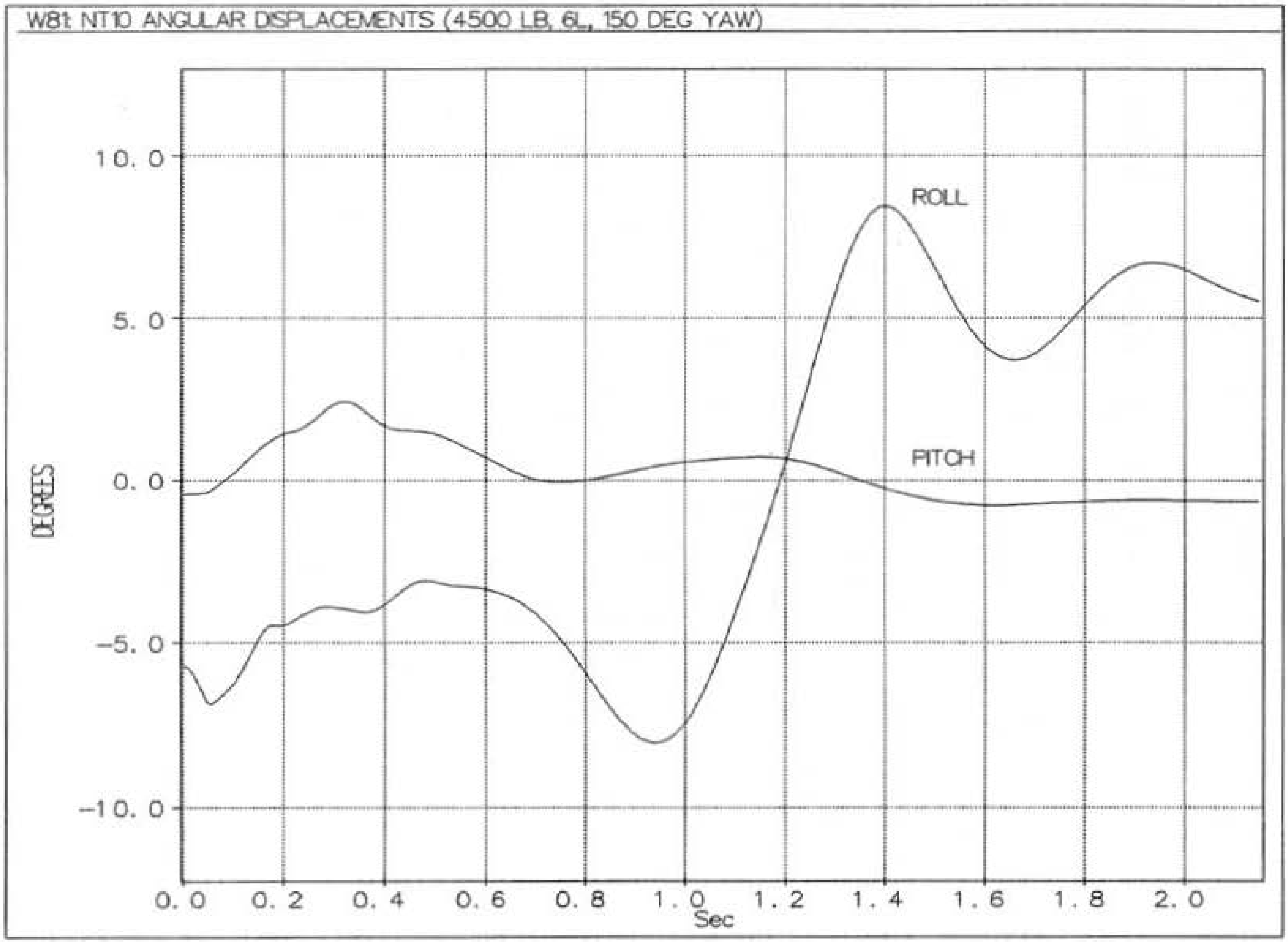


Figure 52. NT10 Angular Displacements (4500 lb, 6L, 150 deg yaw)

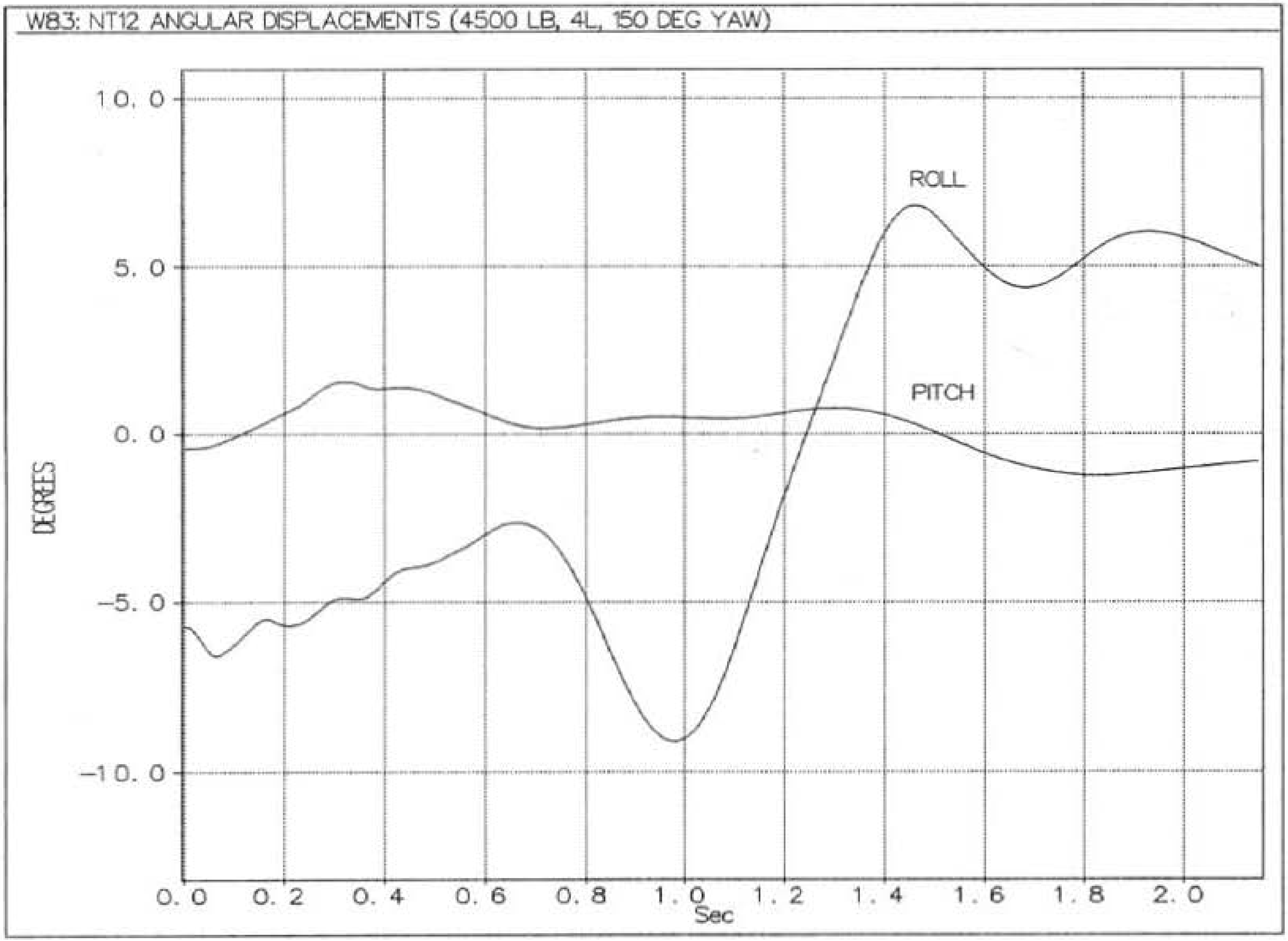


Figure 53. NT12 Angular Displacements (4500 lb, 4L, 150 deg yaw)

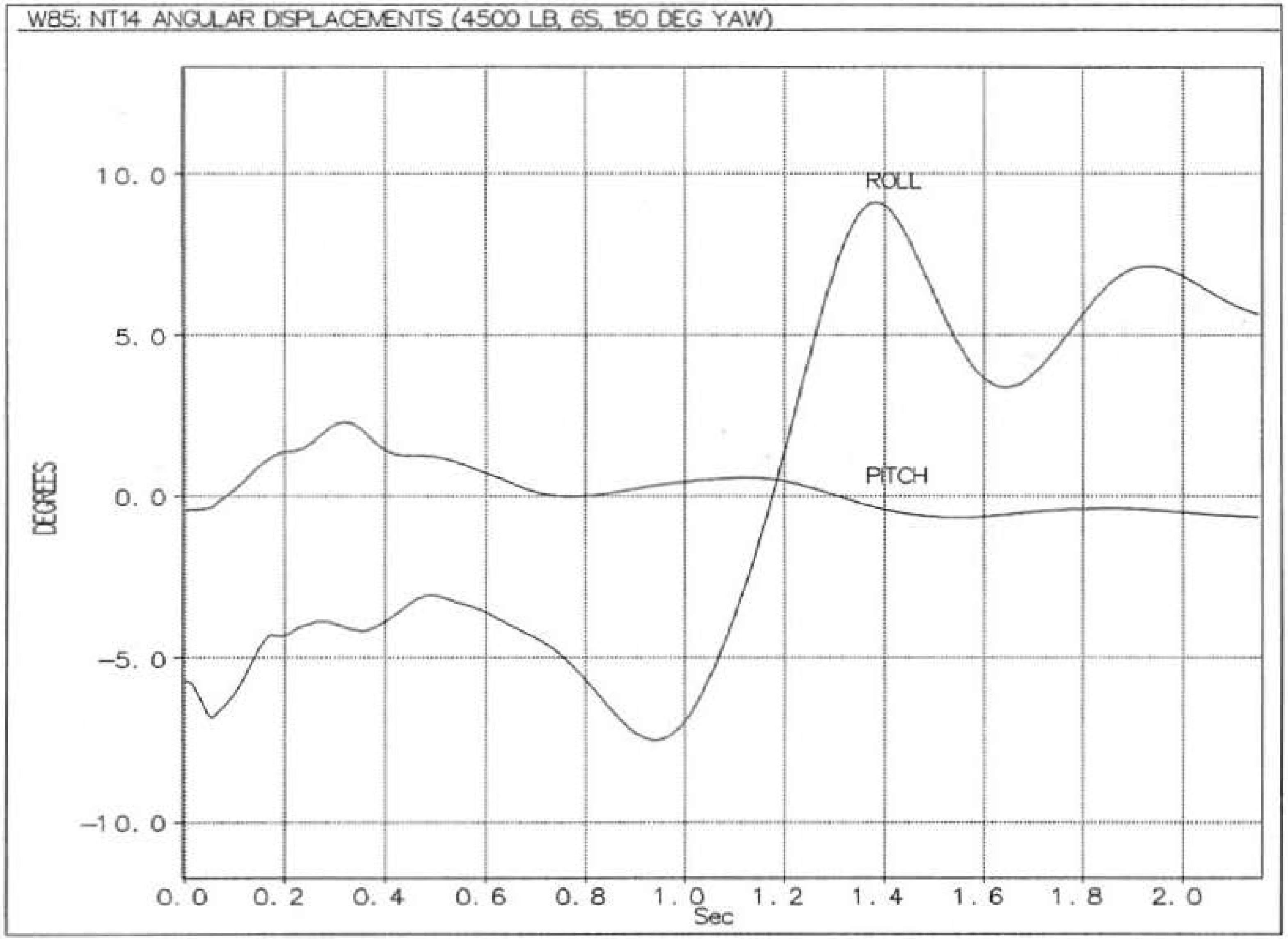


Figure 54. NT14 Angular Displacements (4500 lb, 6S, 150 deg yaw)

As shown in Table 18, the 150 deg yaw angle simulations produced maximum positive roll angles ranging from 6.8 to 9.1 degrees and maximum negative roll angles ranging from -6.2 to -9.1 degrees; the maximum positive pitch angles ranged from 1.6 to 2.4 degrees and from -0.7 to -2.7 degrees for the maximum negative pitch angles.

Figures 46 and 47 are representative trajectory plots for the 150 deg impact condition. These plots consist of impacts on the 6-in Type I mountable curb (6S). As shown in the figures, the maximum lateral offset relative to curb impact was 26.5 ft with the 4500 lb vehicle and approximately 28 ft. with the 1800 lb vehicle. The model did not predict any tire blowout conditions for the six 150 deg impact simulations (NT 10,12,14,16,18 and 20).

Also shown in Table 18, the -30 deg yaw angle simulations produced maximum positive roll angles ranging from 6.8 to 10.6 degrees and maximum negative roll angles ranging from -2.6 to -5.1 degrees; the maximum positive pitch angles ranged from 0.5 to 0.9 degrees and from -3.3 to -5.7 degrees for the maximum negative pitch angles.

Figures 48 and 49 are representative trajectory plots for the -30 deg impact condition. These plots consist of impacts on the 6-in Type I mountable curb (6S). As shown in the figures, the maximum lateral offset with respect to curb impact was approximately 11.0 ft with both the 4500 lb and 1800 lb vehicle. The model did not predict any tire blowout conditions for the six -30 deg impact simulations (NT 11,13,15,17,19 and 21).

The 180 deg yaw angle simulations produced maximum positive roll angles ranging from 4.9 to 7.5 degrees and maximum negative roll angles ranging from -8.1 to

-8.9 degrees; the maximum positive pitch angles ranged from 0.9 to 3.3 degrees and from -0.1 to -3.1 degrees for the maximum negative pitch angles.

Figures 50 and 51 are representative trajectory plots for the 180 deg impact condition. These plots consist of impacts on the 6-in Type I mountable curb (6S). As shown in the figures, the maximum lateral offset with respect to curb impact was approximately 61 ft with the 4500 lb vehicle and approximately 44 ft with the 1800 lb vehicle. The model did predict left rear (LR) tire blowouts for all four simulations involving the 6-in. mountable curbs (NT22,24,25 and 27), but did not predict tire blowout for the 4-in. curb tests (NT23 and 26).

The maximum positive and negative roll angles obtained from the 18 simulations were 10.6 deg (NT11) and -9.1 deg (NT12), respectively. The maximum positive and negative pitch angles obtained from the simulations were 3.3 deg (NT24) and -5.7 deg (NT17), respectively. These maximum angular displacements were relatively small and were not any higher than the angular displacements obtained from the tracking impact study, refer to Tables 11, 12, 14 and 16.

6 CONCLUSIONS AND RECOMMENDATIONS

The research study described herein clearly indicates that the three NDOR mountable curbs investigated would not pose a significant hazard for vehicles impacting in a tracking mode. Measured and simulated maximum roll and pitch angles were found to be relatively small for both large and small vehicles impacting over a wide range of speeds and angles of approach. Vehicle accelerations were also very small and vehicle damage was not found to be a problem.

There appeared to be no significant difference in impact performance for the two 6-in. curbs studied. Further, although tests on the 4-in. curbs exibited lower vehicle motions, the differences were not considered to be sufficient enough to significantly improve the safety of these systems for tracking impacts.

Even though NDOR's mountable curb designs were found to have little potential for producing loss of vehicle control during tracking impacts, the curbs still represent a roadside discontinuity which may cause problems under some circumstances. Therefore, wherever possible, alternate methods should be used to provide normal curb functions, such as roadway delineation and drainage control. The performance of W-beam guardrails can also be adversely effected by roadside curbs. In those situations where curbs must be used in conjunction with W-beam guardrail, the face of the barrier should be mounted flush with the face of the curb. This configuration will minimize the potential for vehicle ramping initiated by tire/curb contact.

Computer simulations of non-tracking impacts with mountable curbs indicate that these curbs may be traversable over a wide range of vehicle orientations. This research indicates that mountable curbs may not be a significant cause of vehicle rollovers, even on high speed roadways. Thus, although further research is needed, the NDOR's mountable curbs may provide adequate safety performance for all impact conditions and all highways.

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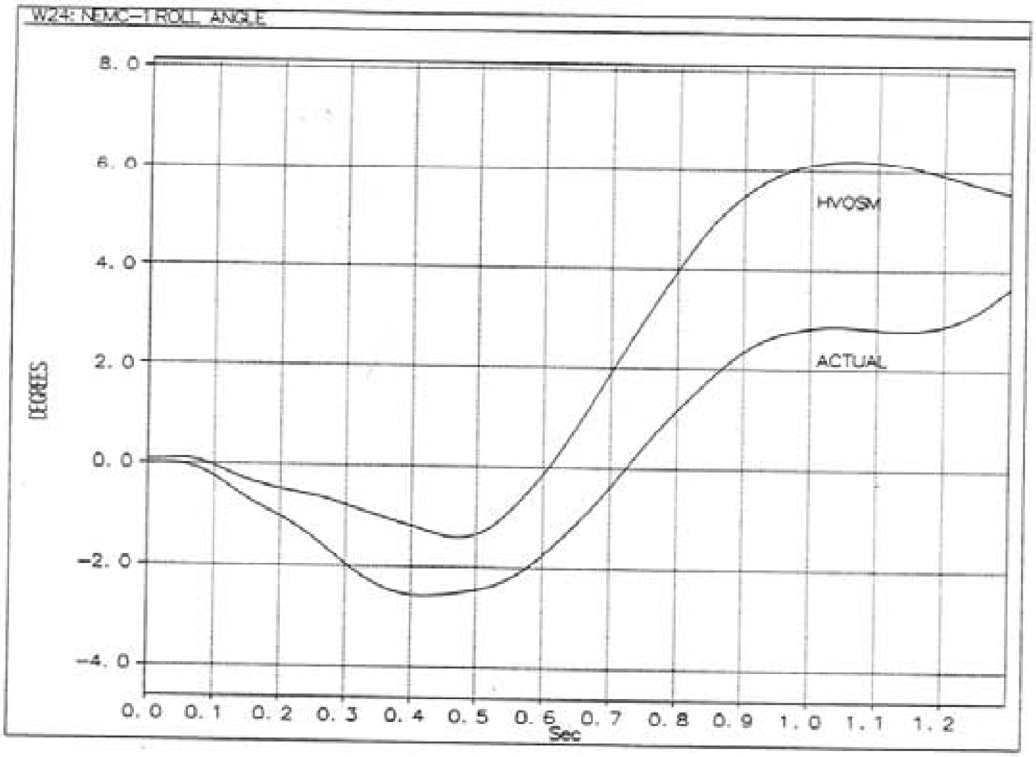
8 APPENDICES

APPENDIX A:

Actual and Simulated Angular Displacements (NEMC 1-23)



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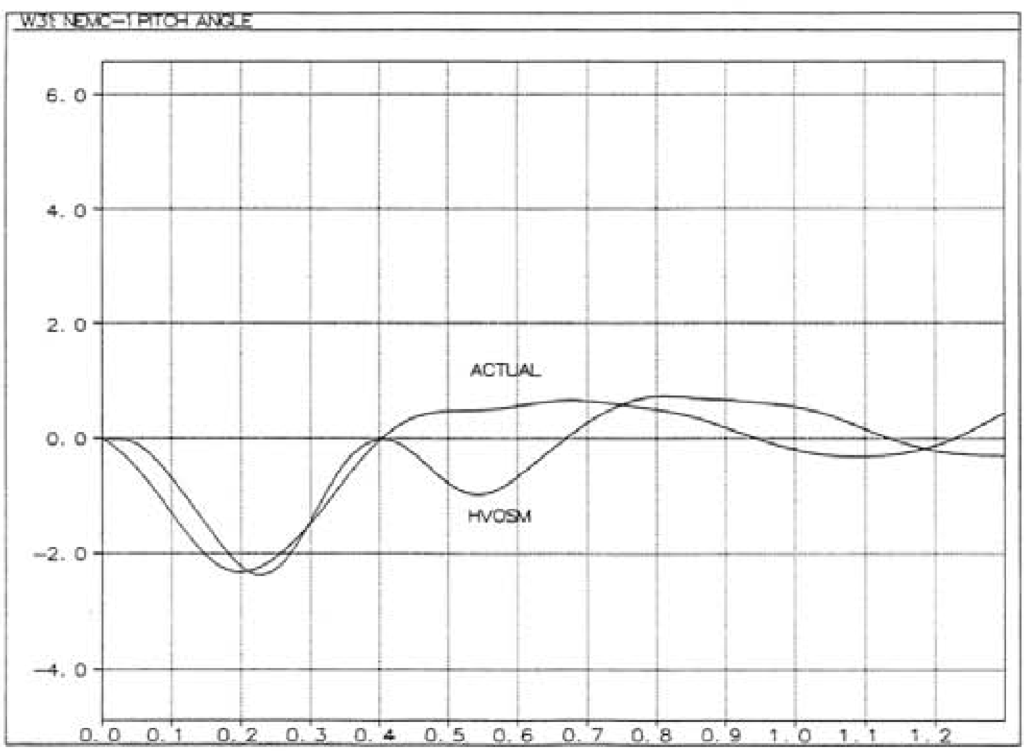

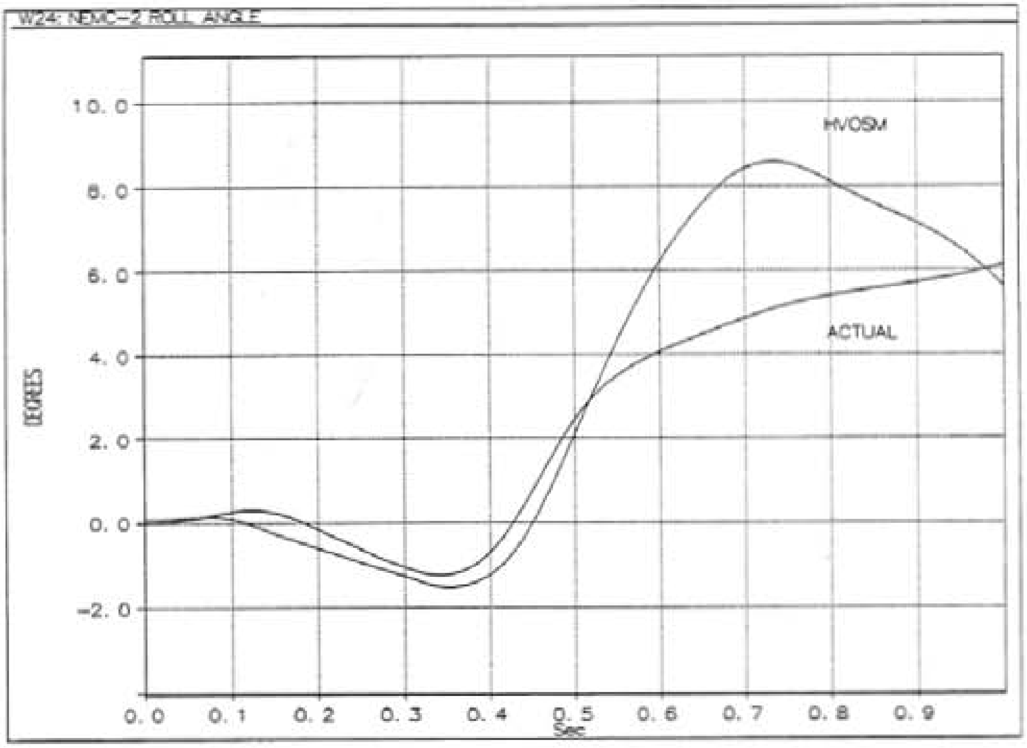

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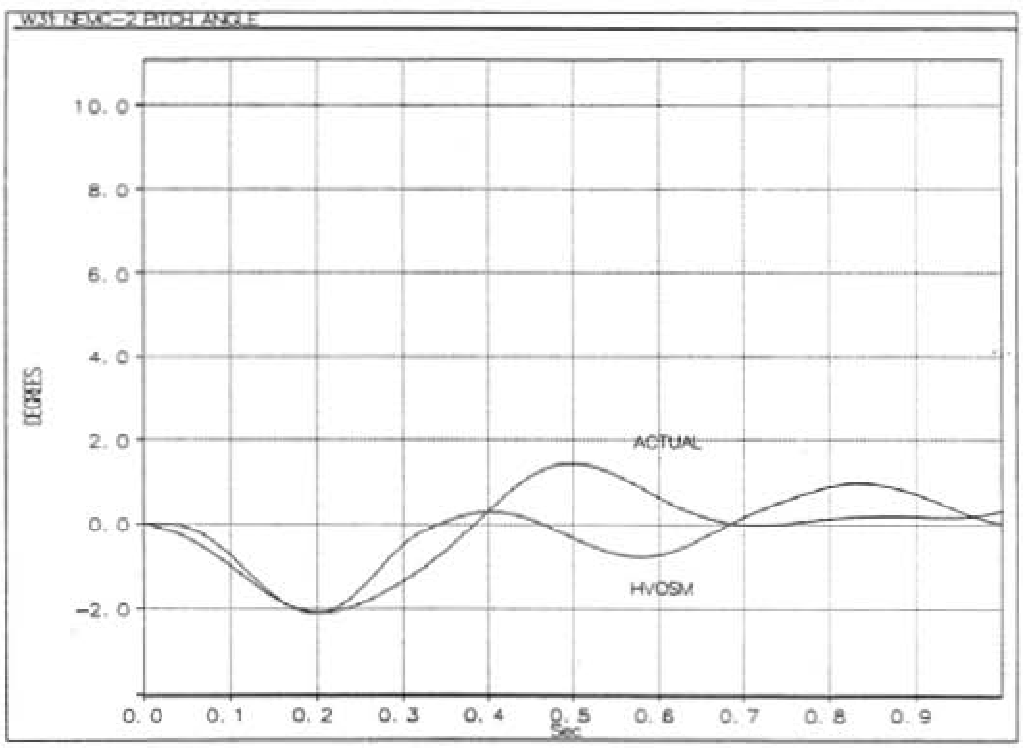

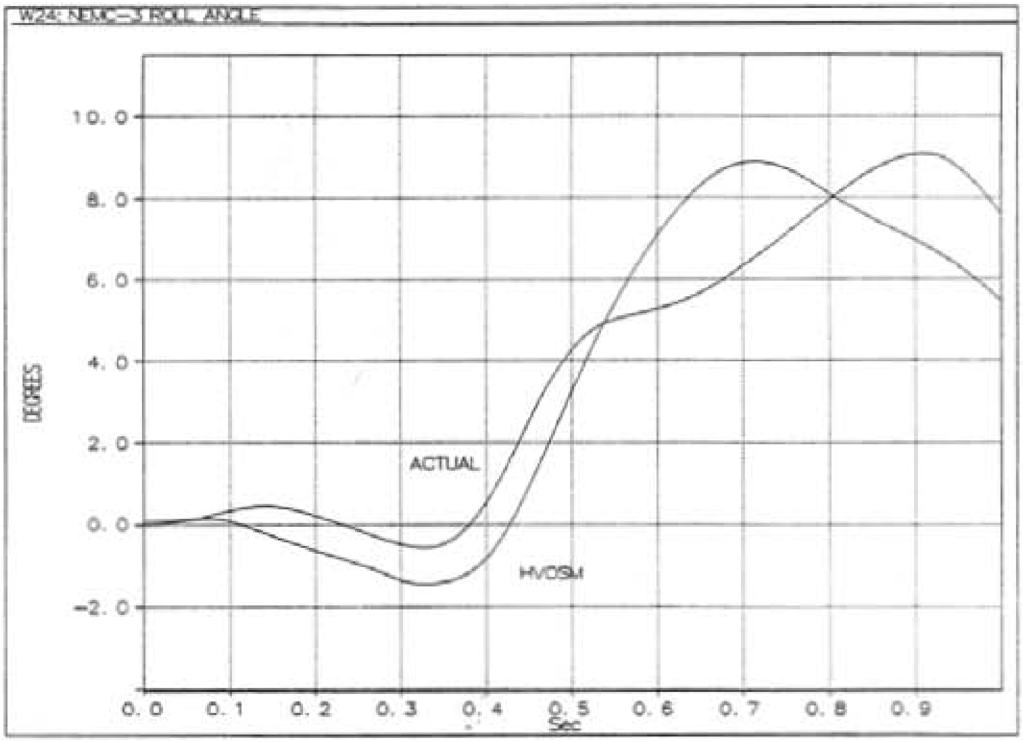

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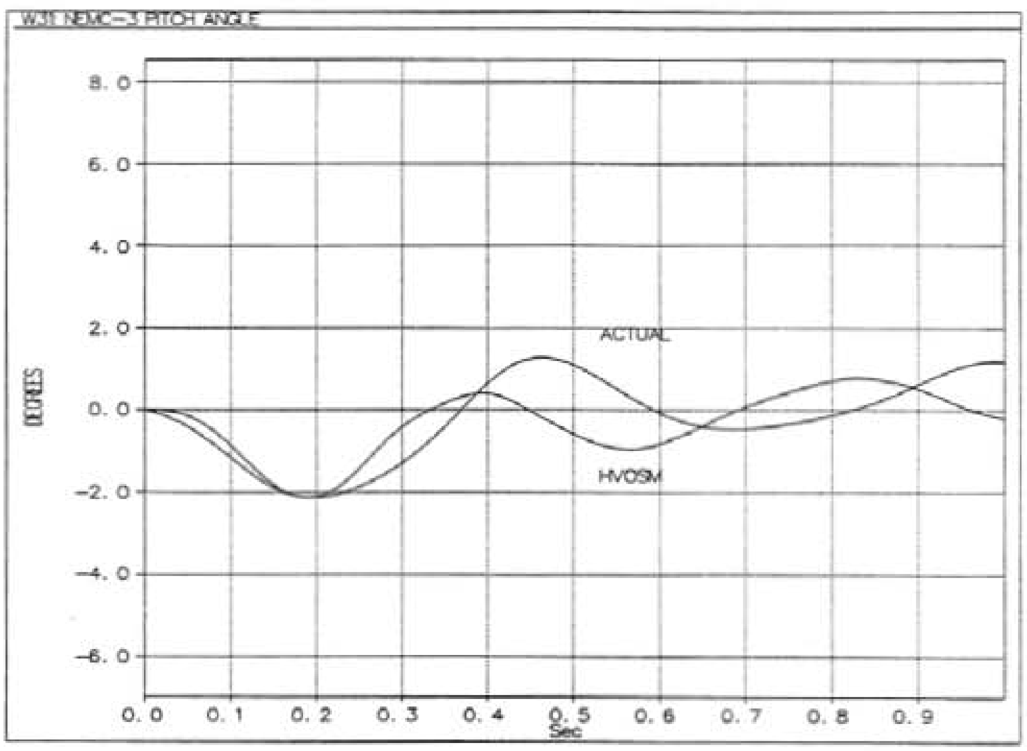

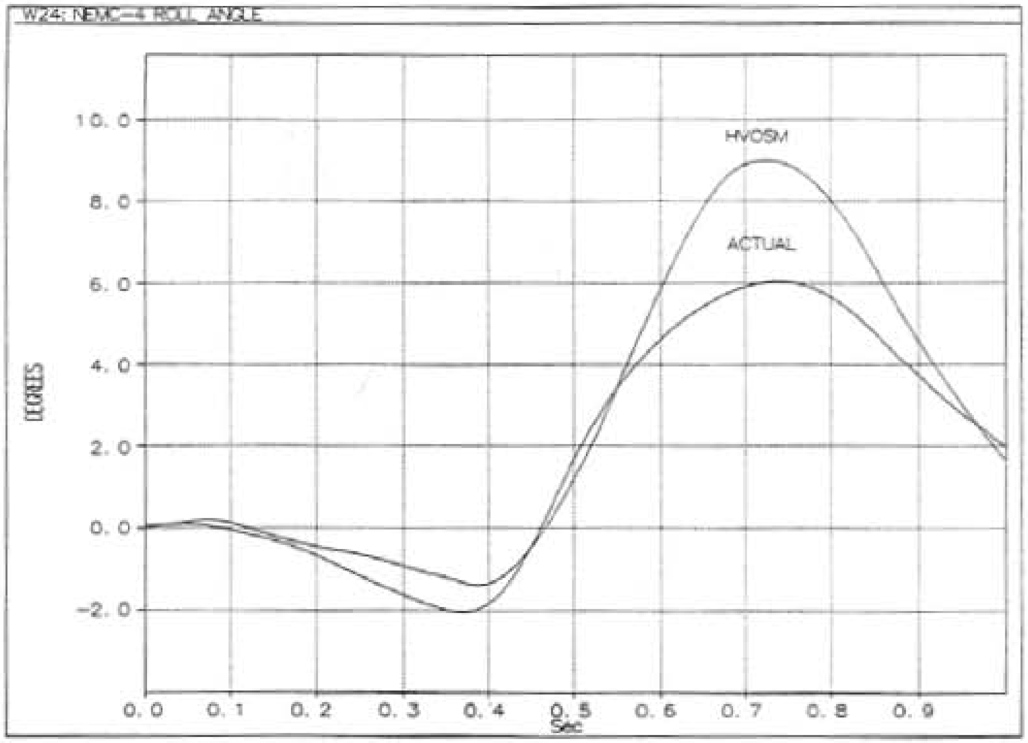

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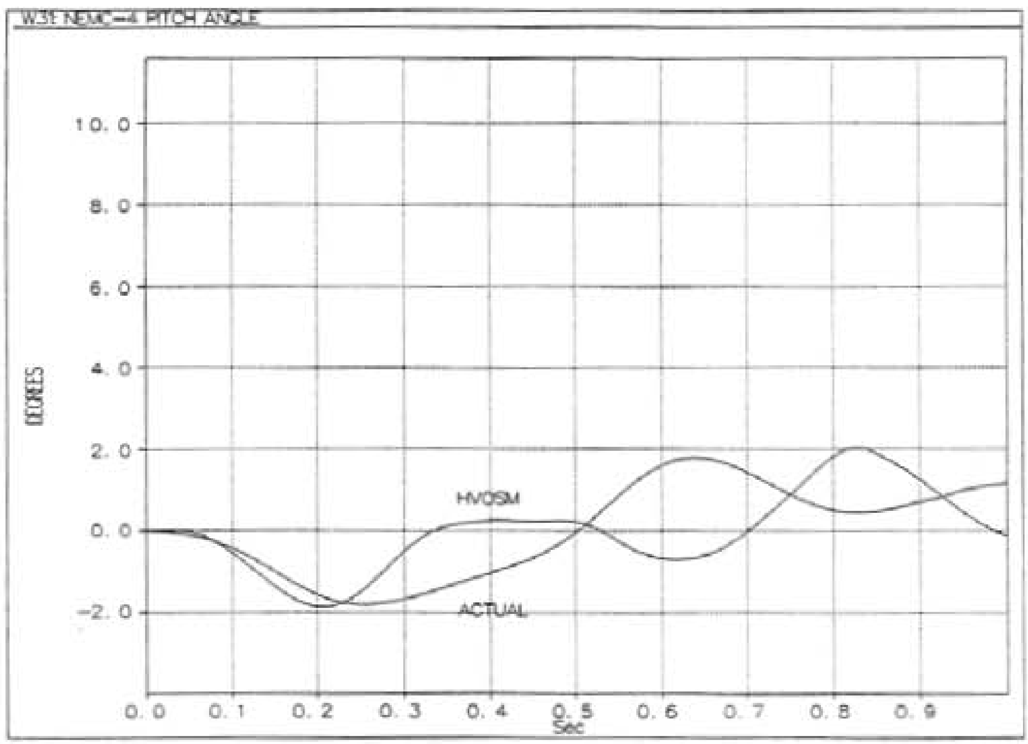

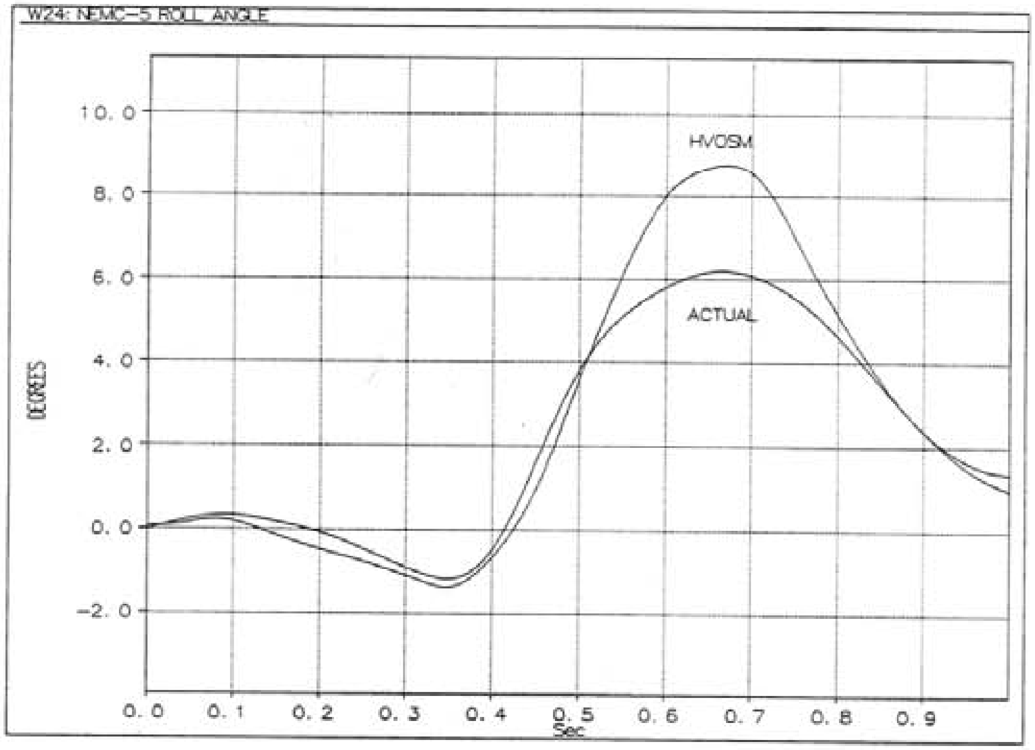

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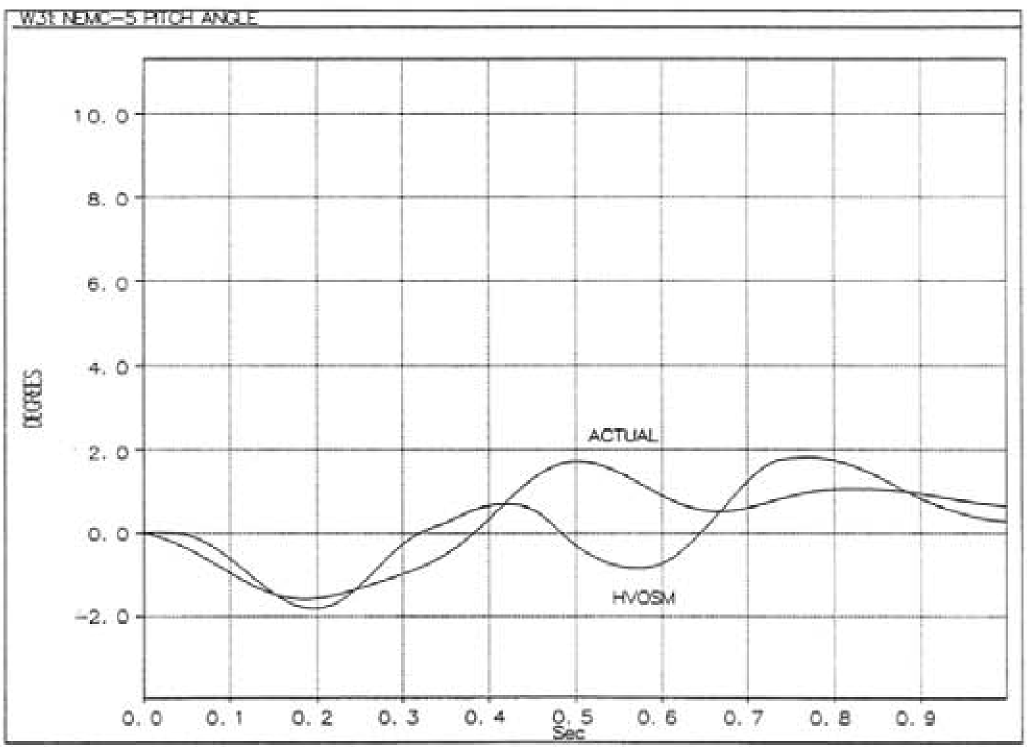

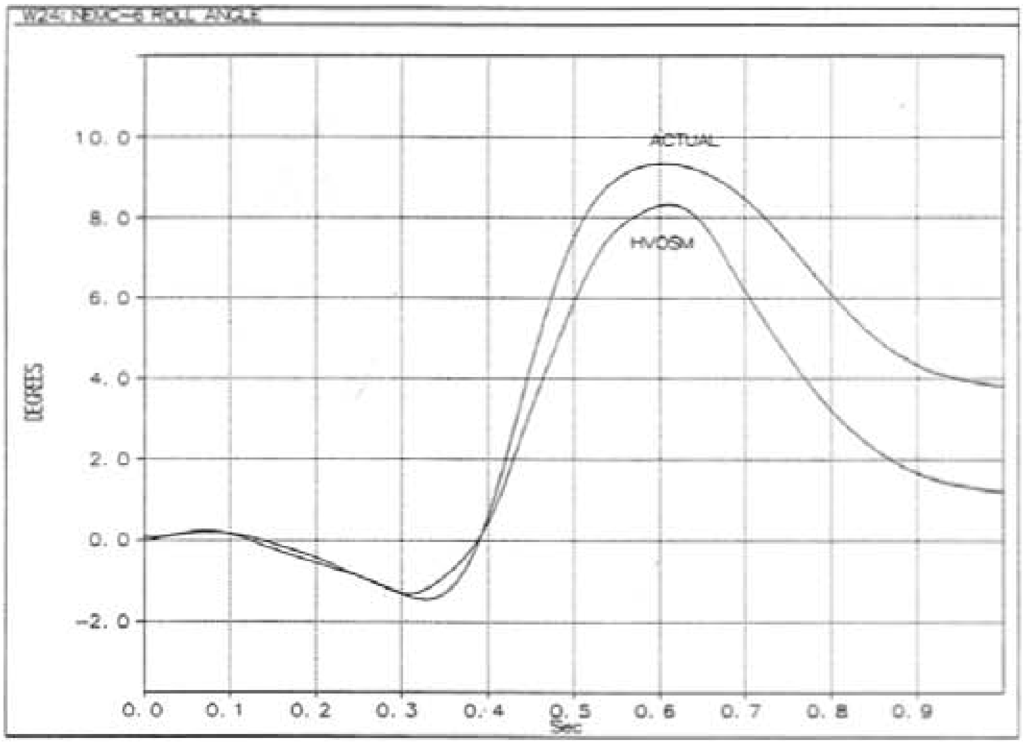

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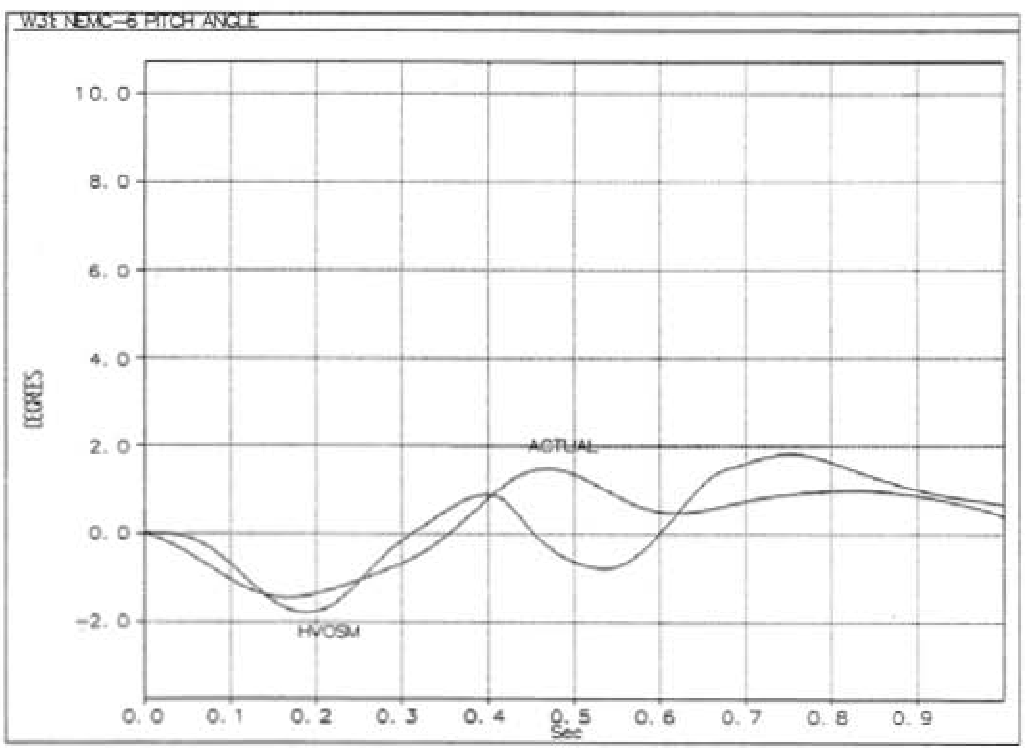

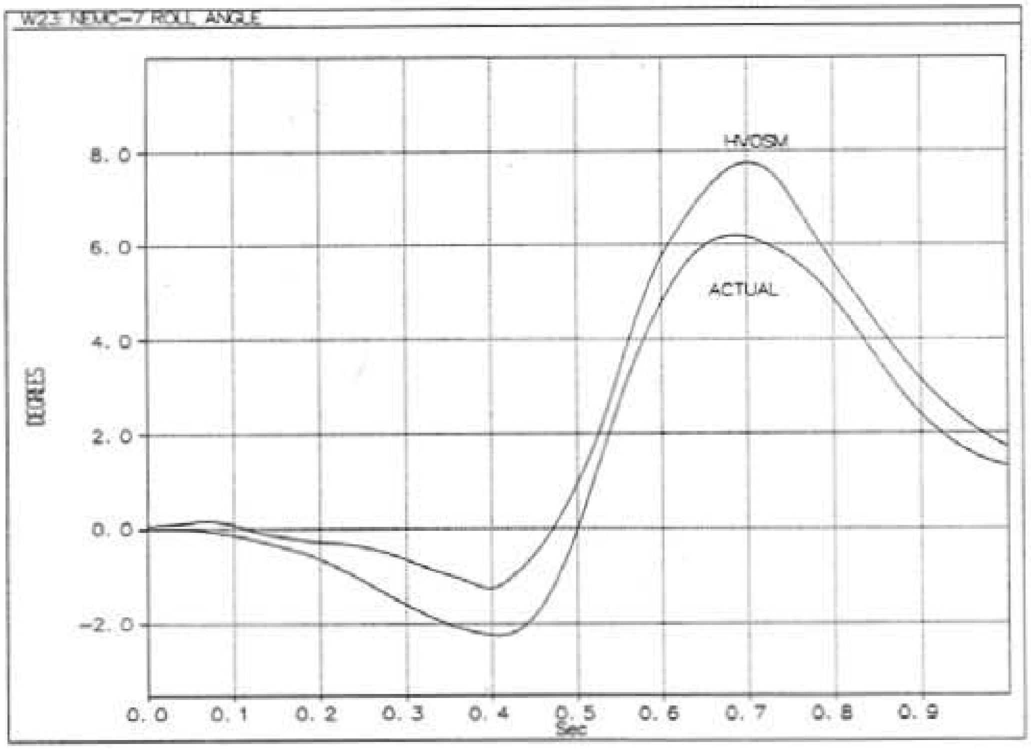

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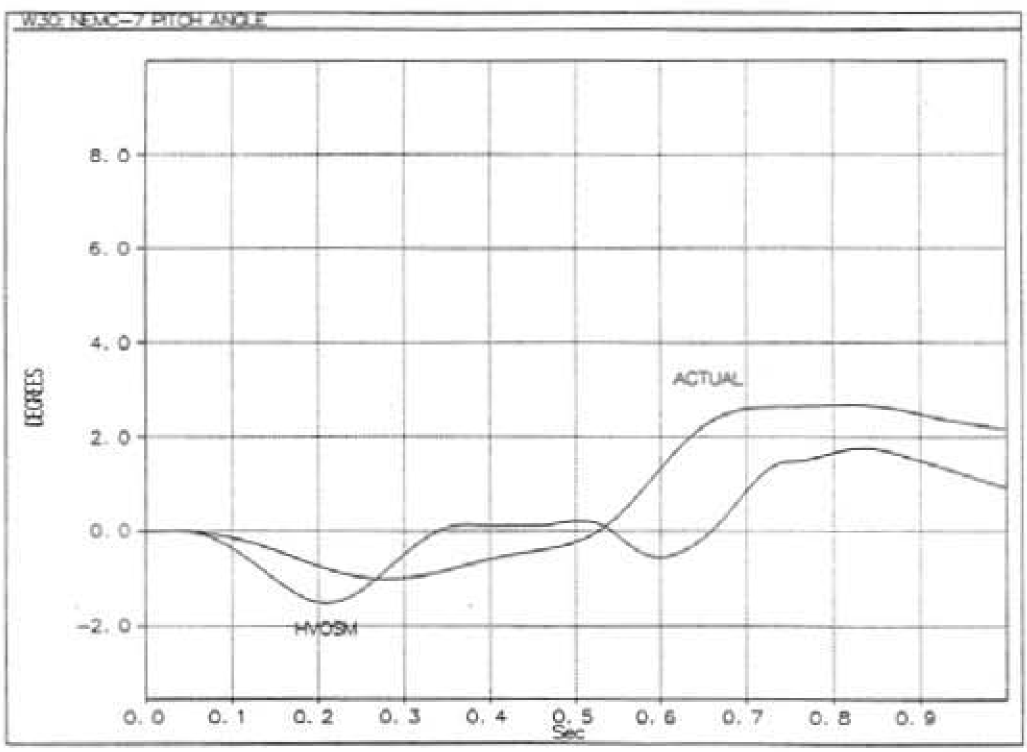

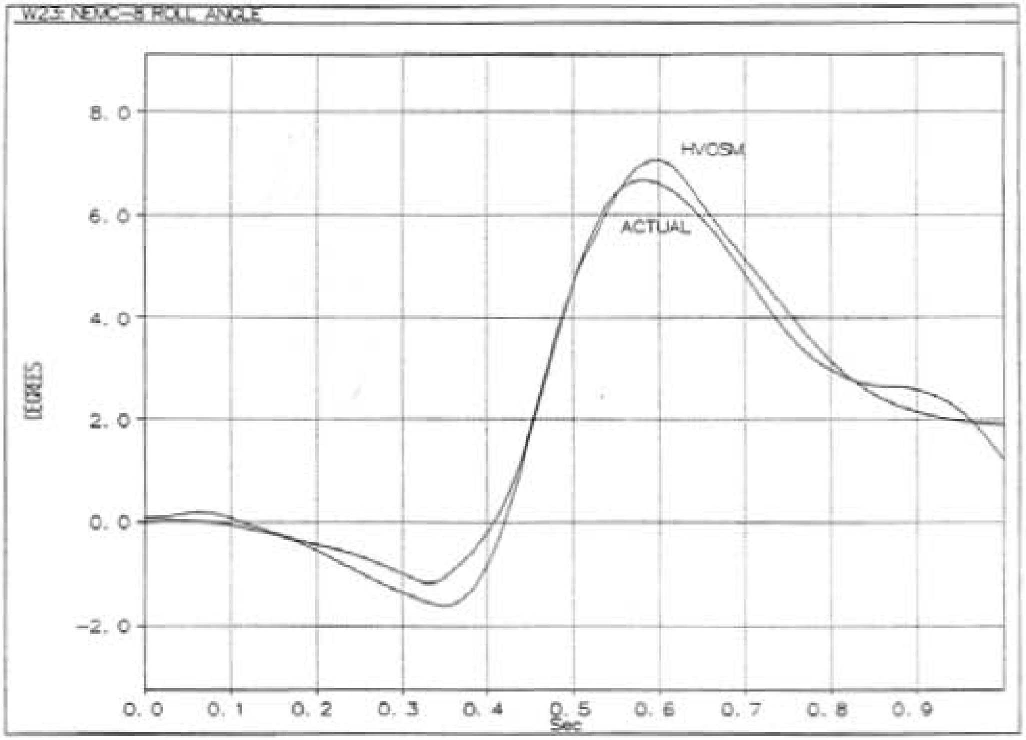

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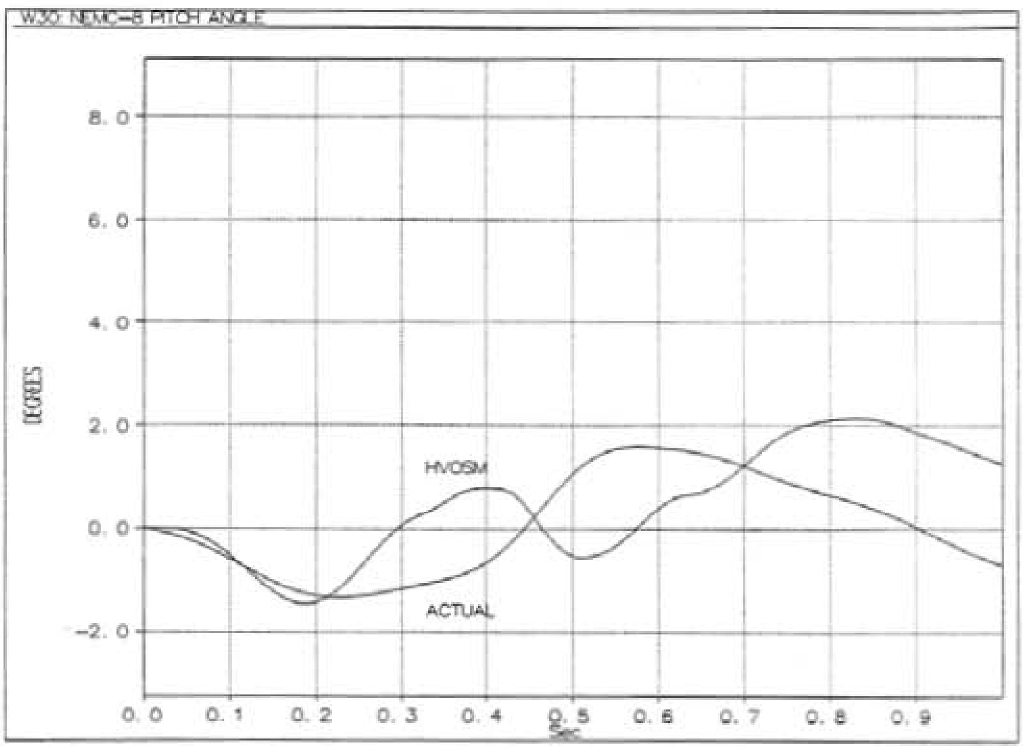

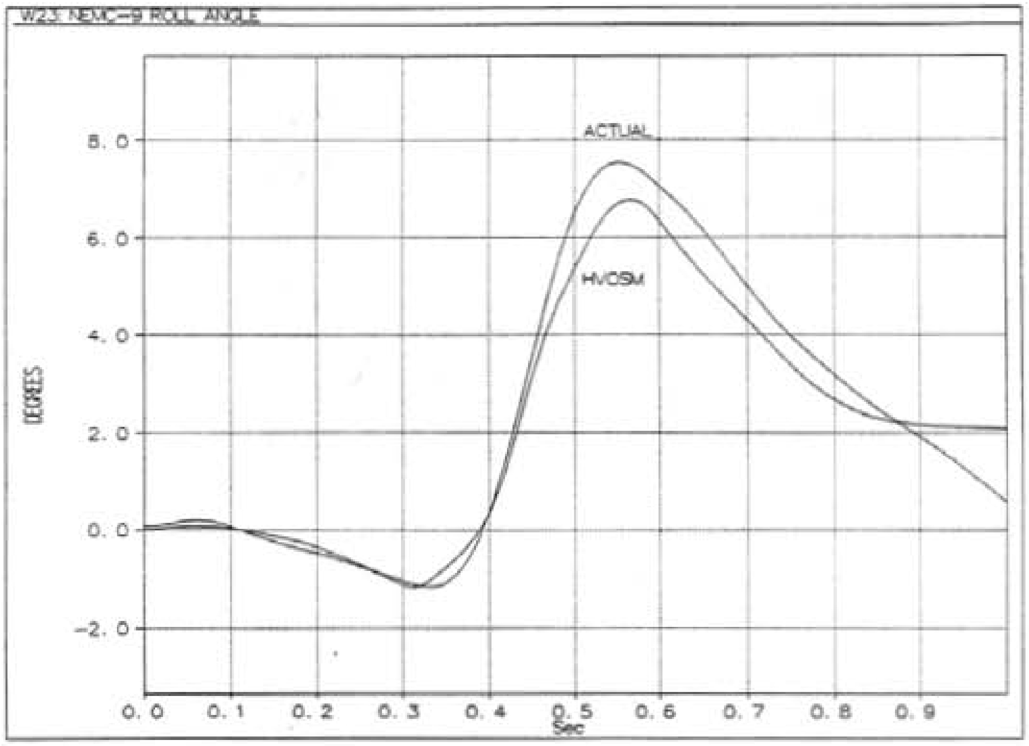

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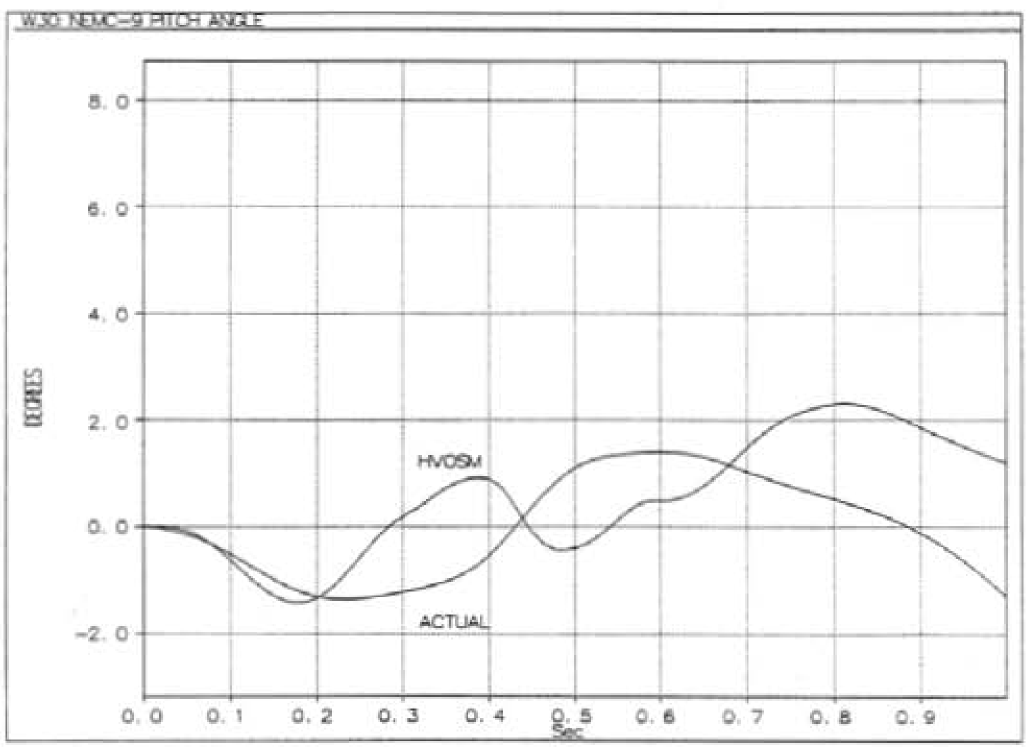

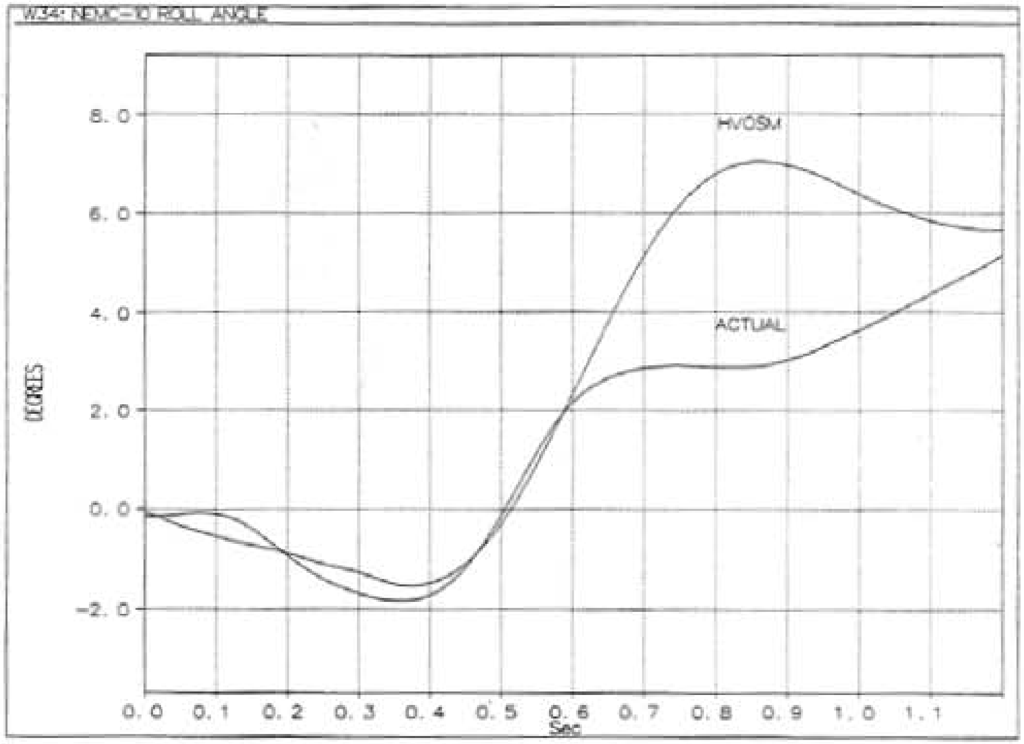

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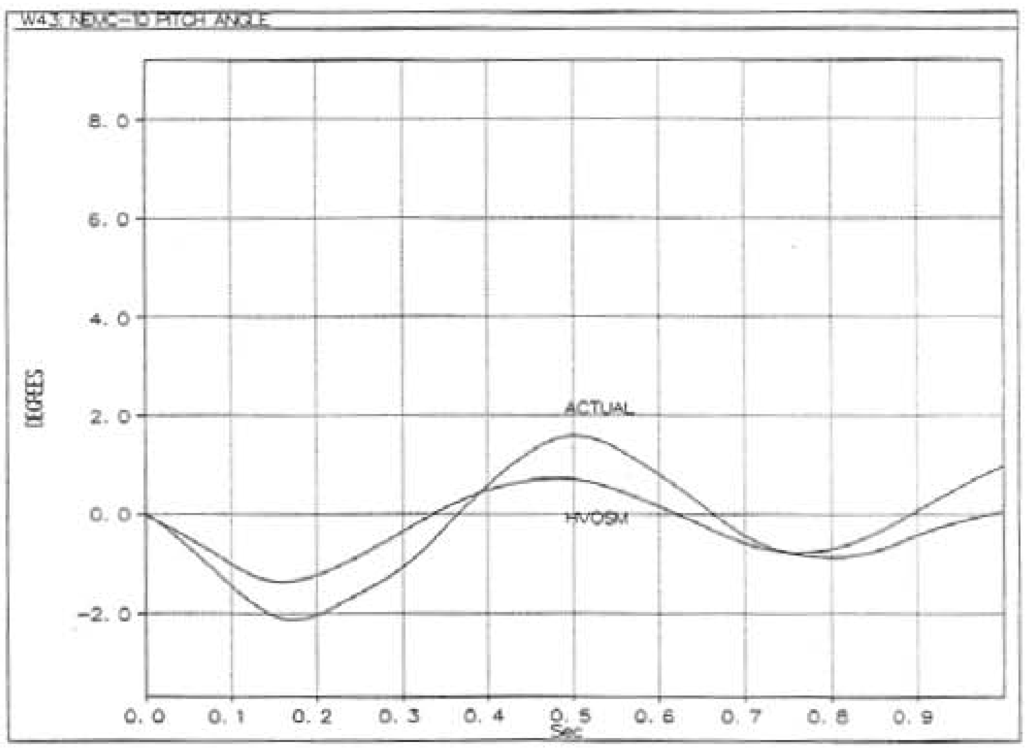

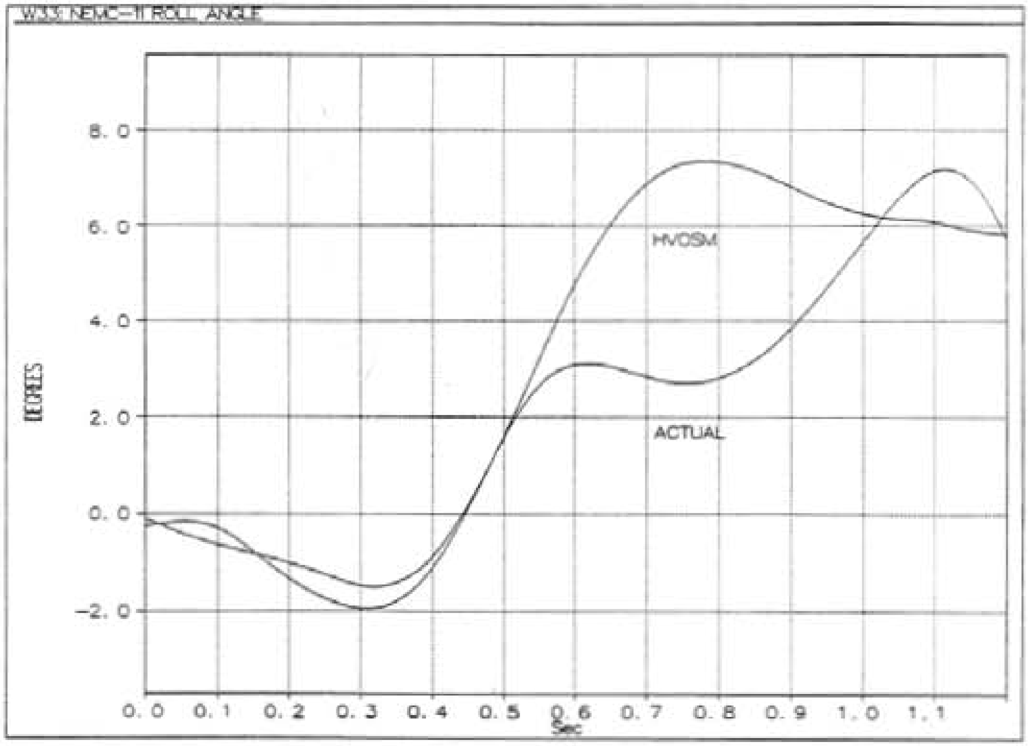

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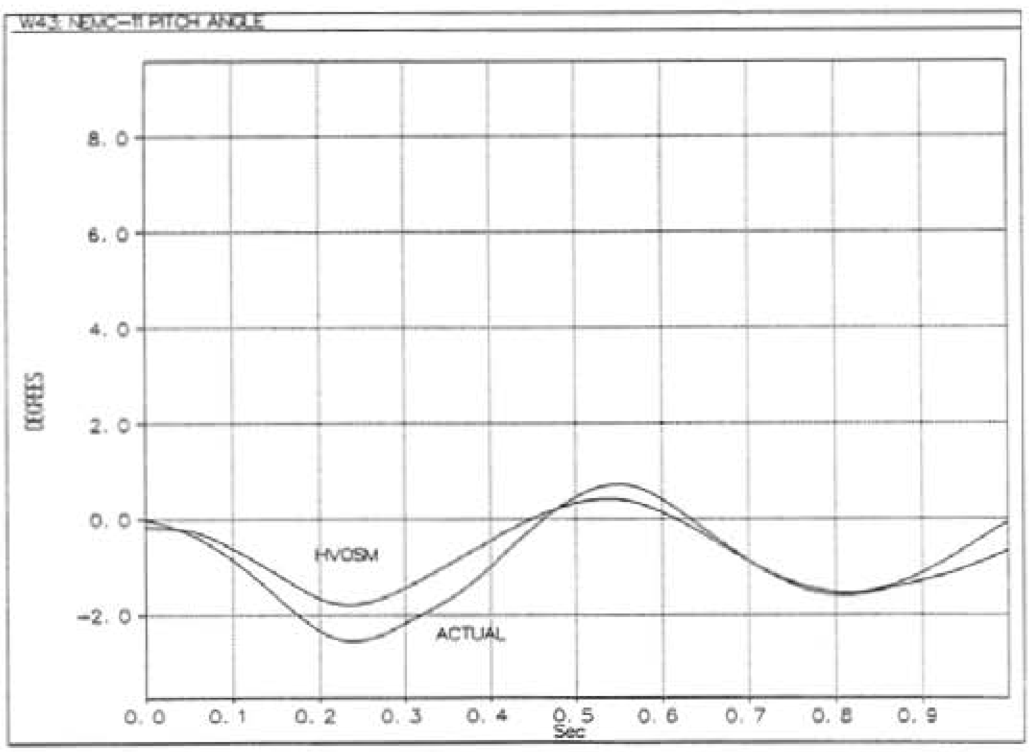

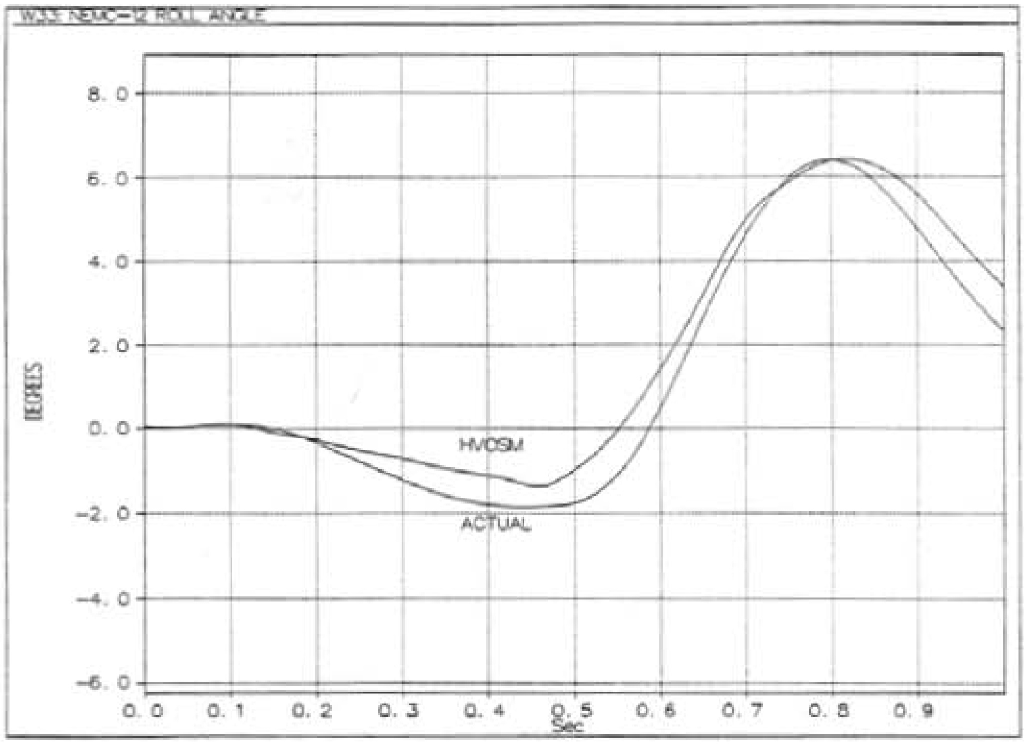

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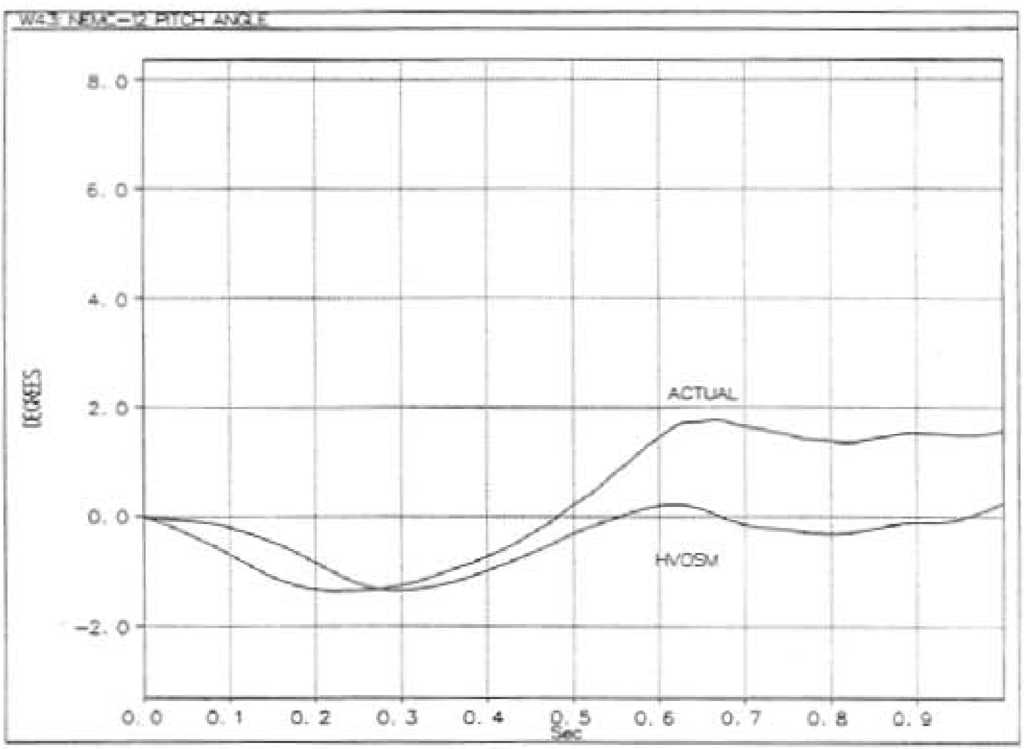

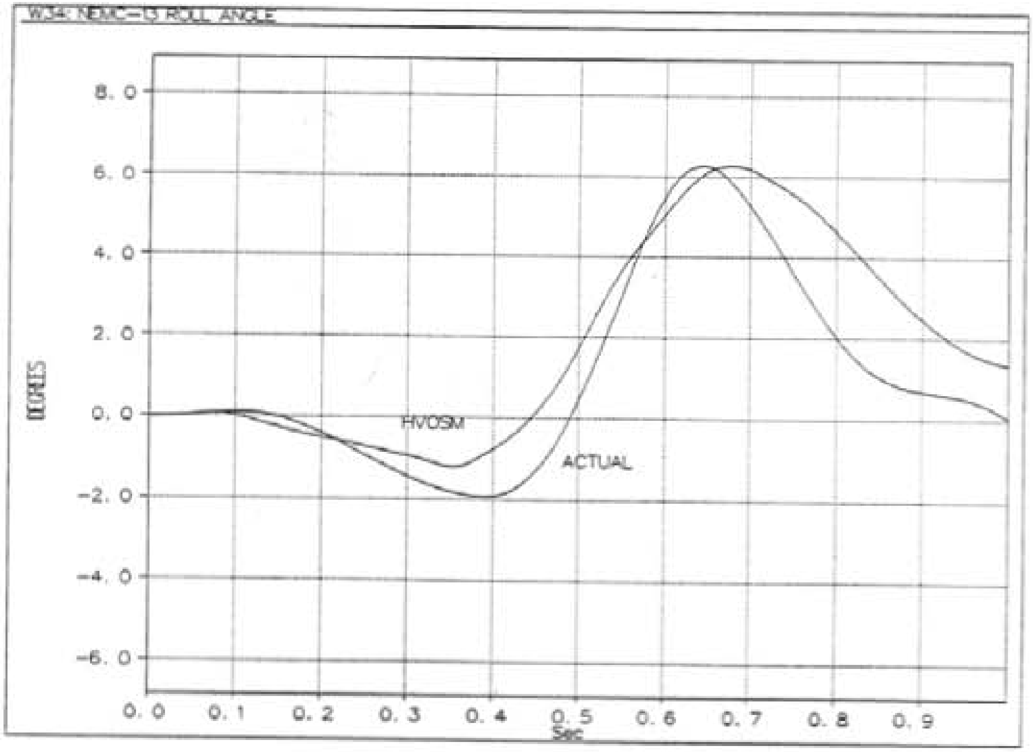

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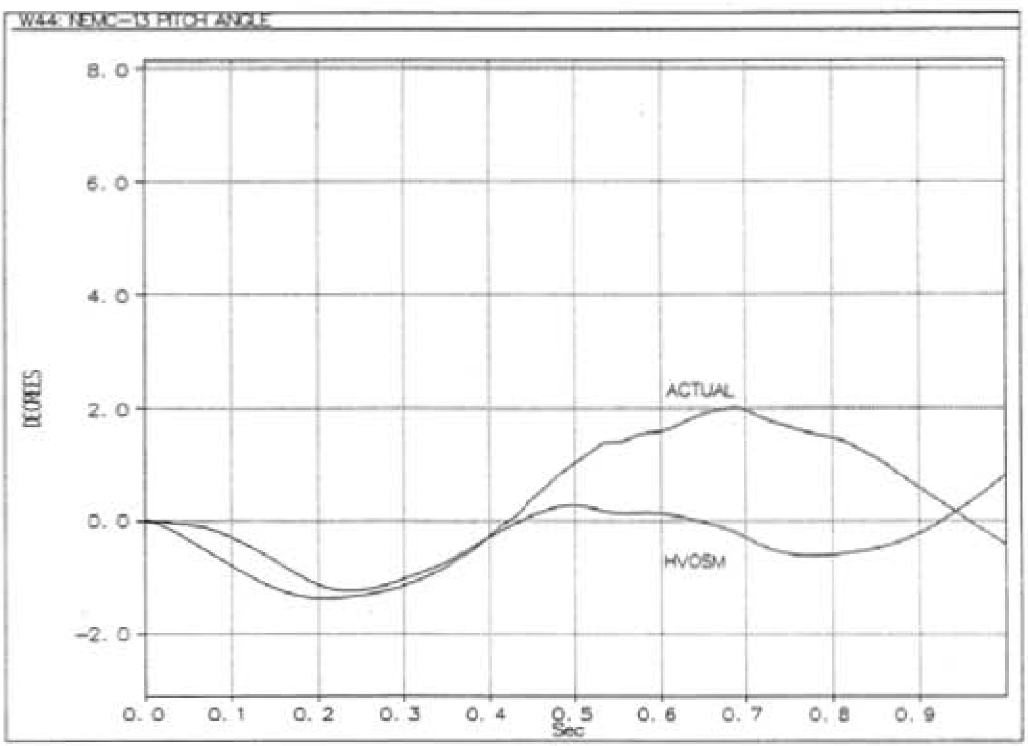

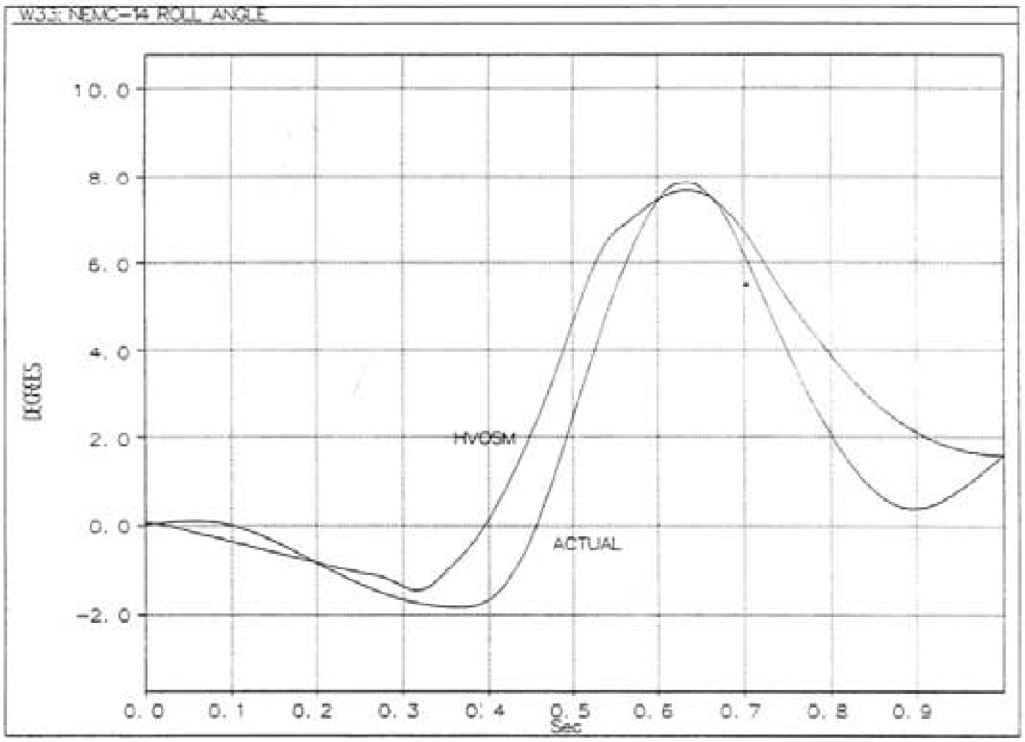

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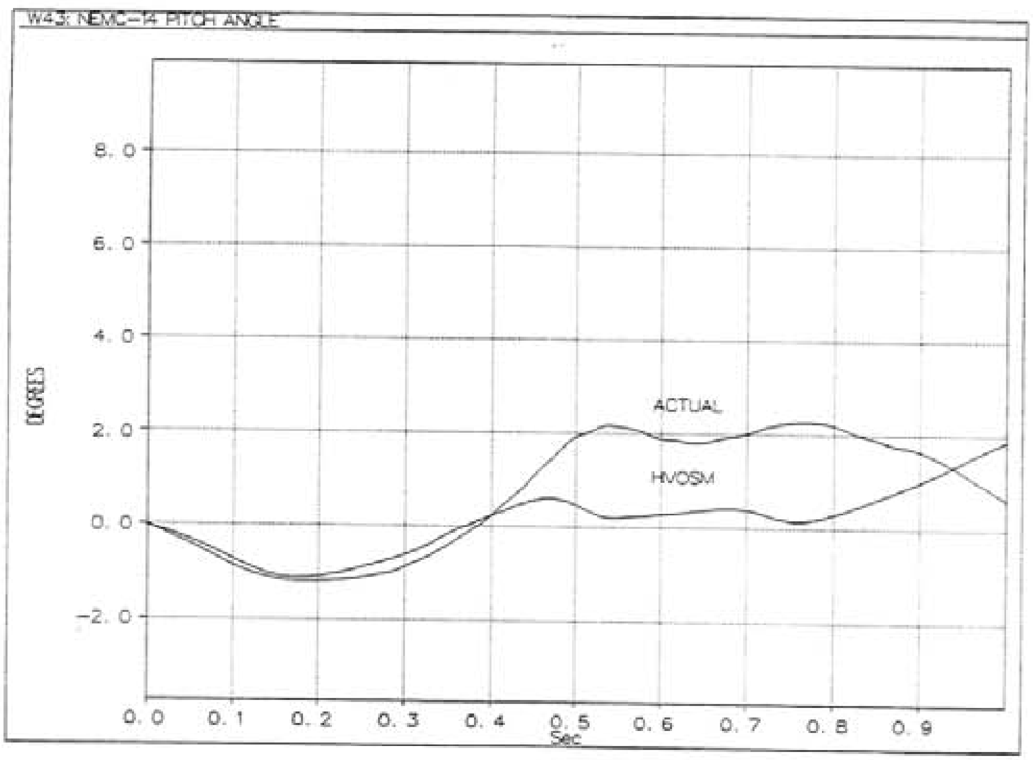

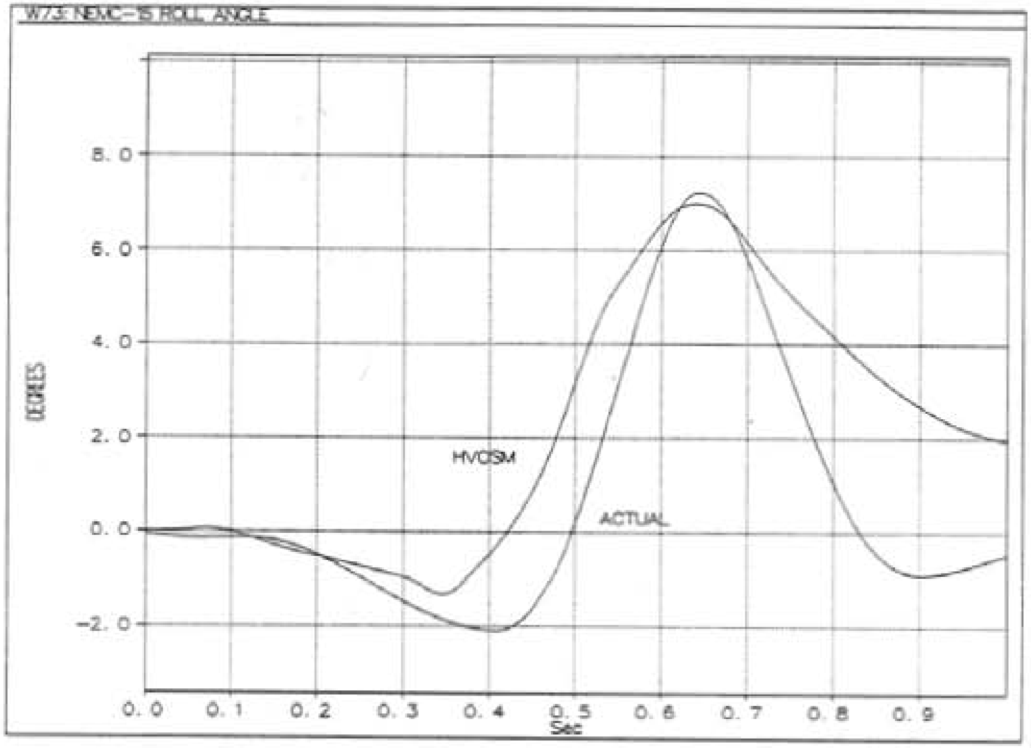

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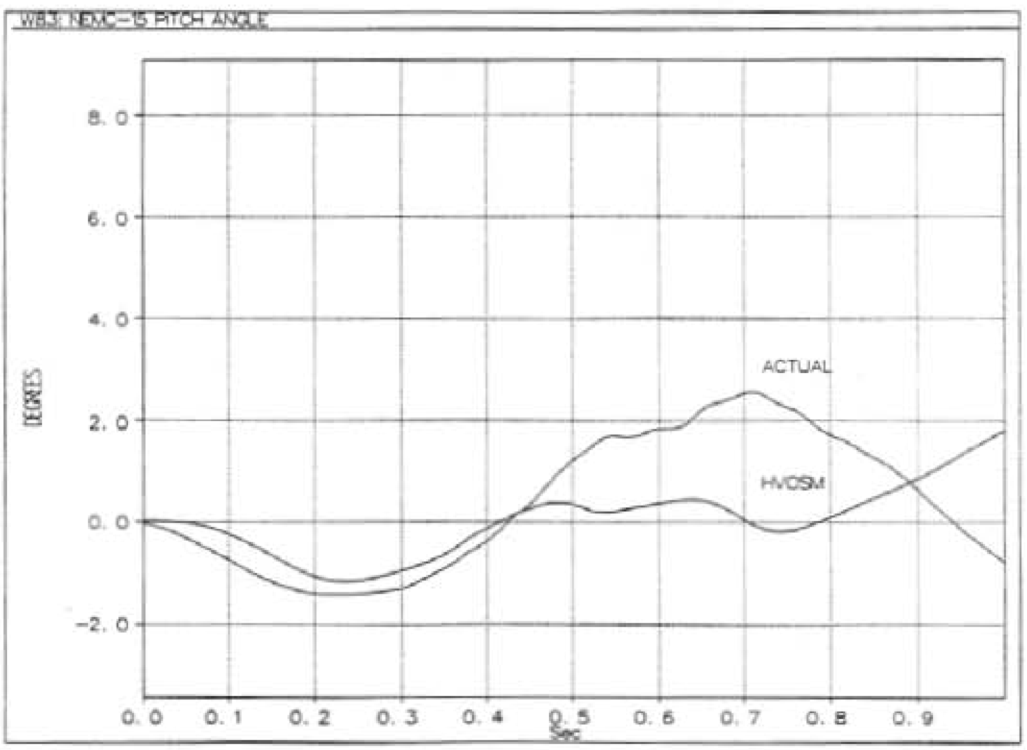

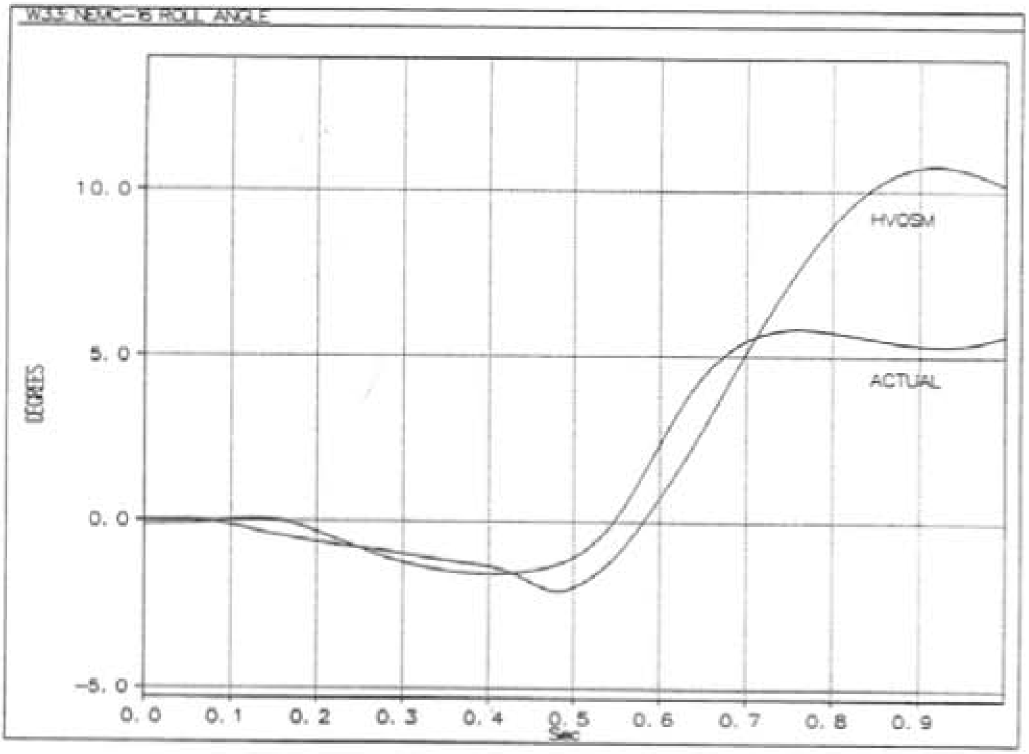

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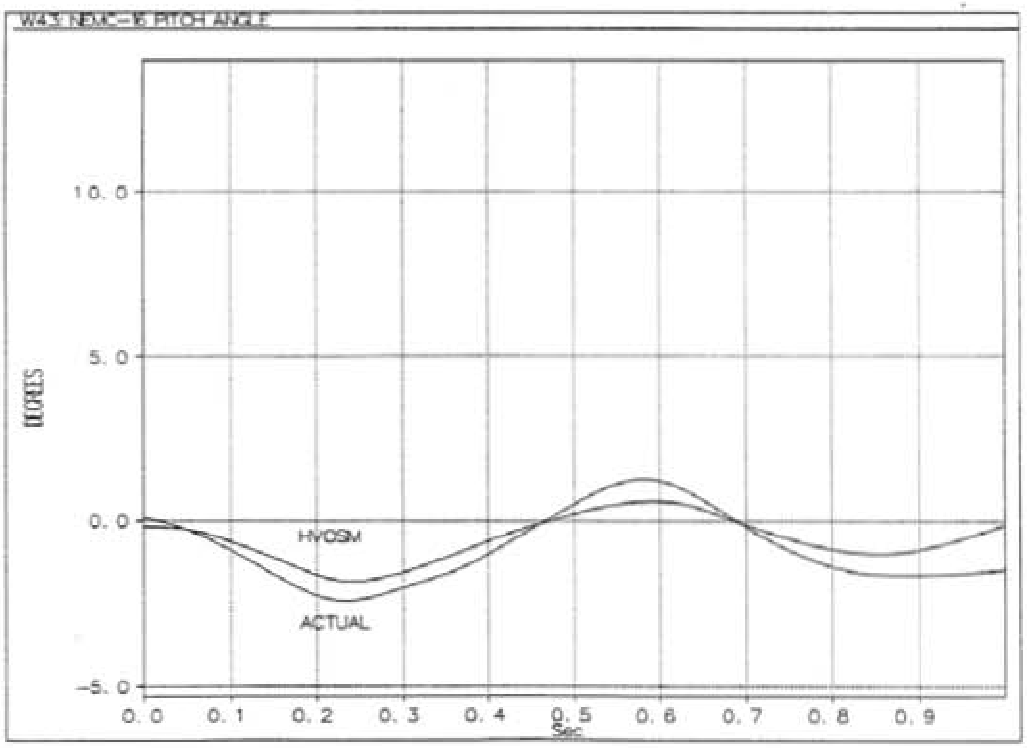

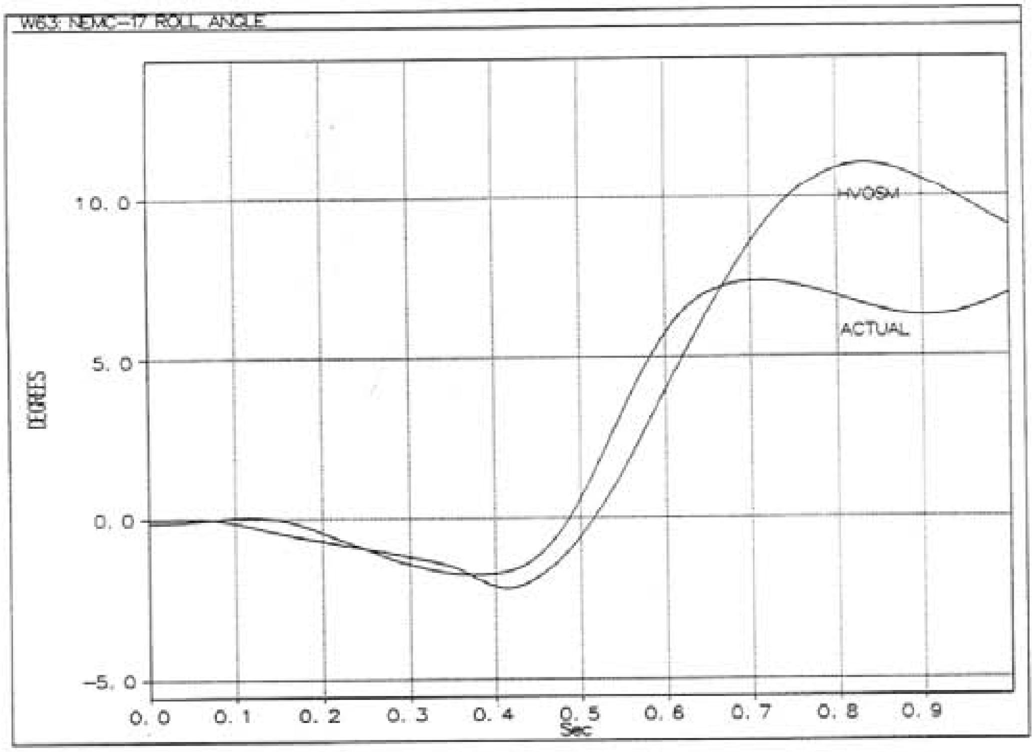

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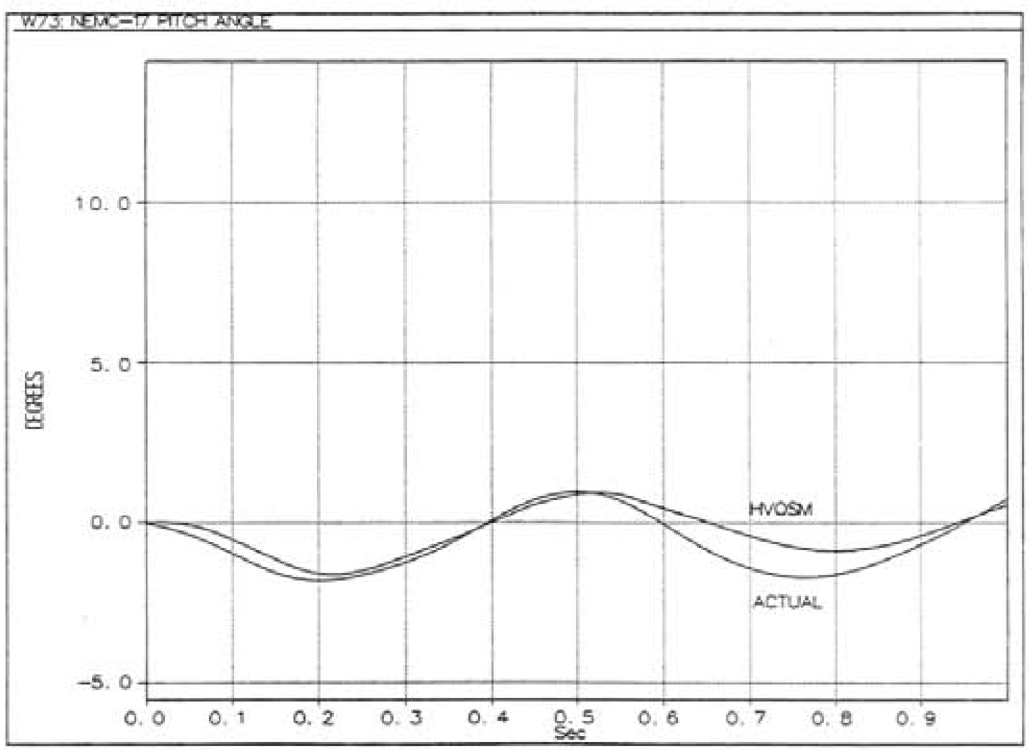

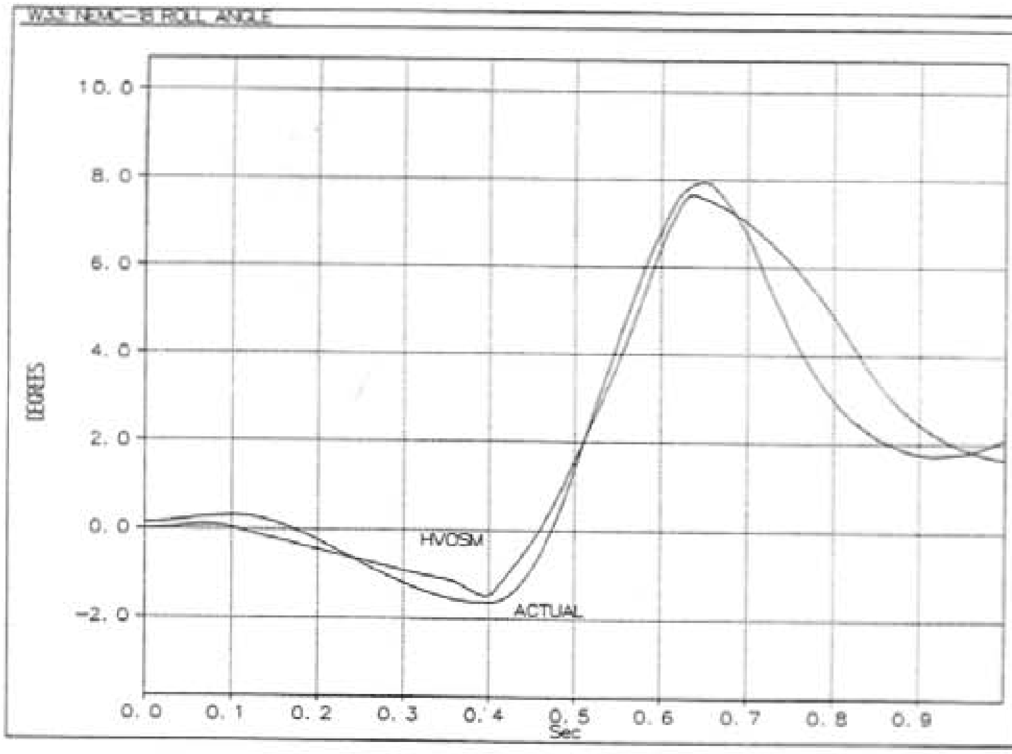

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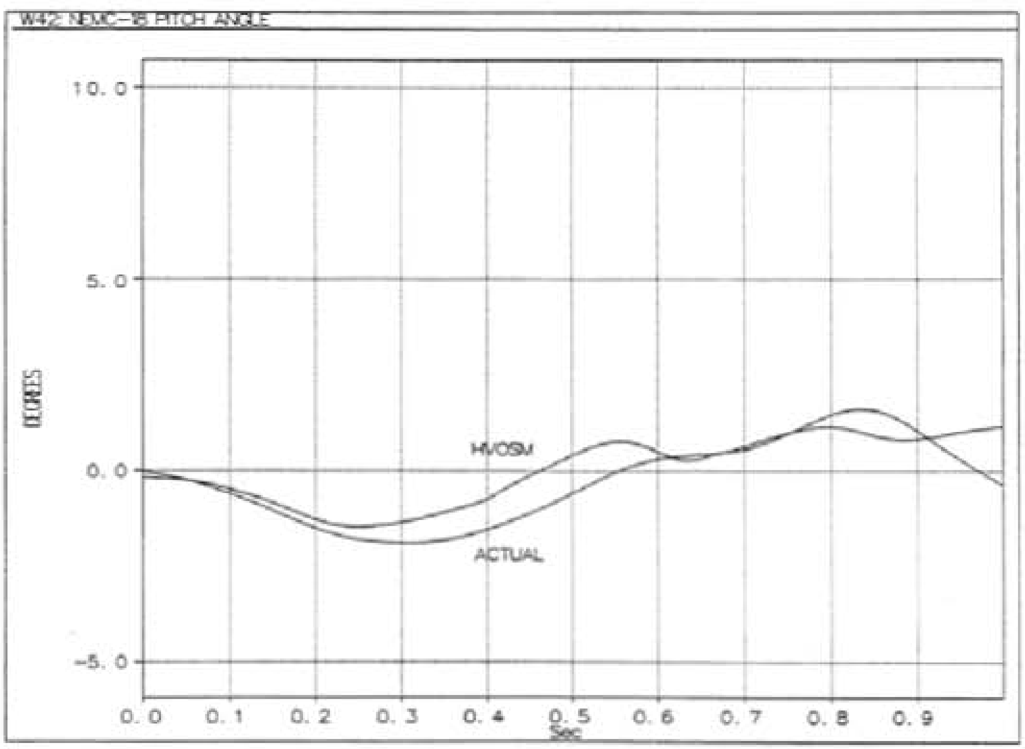

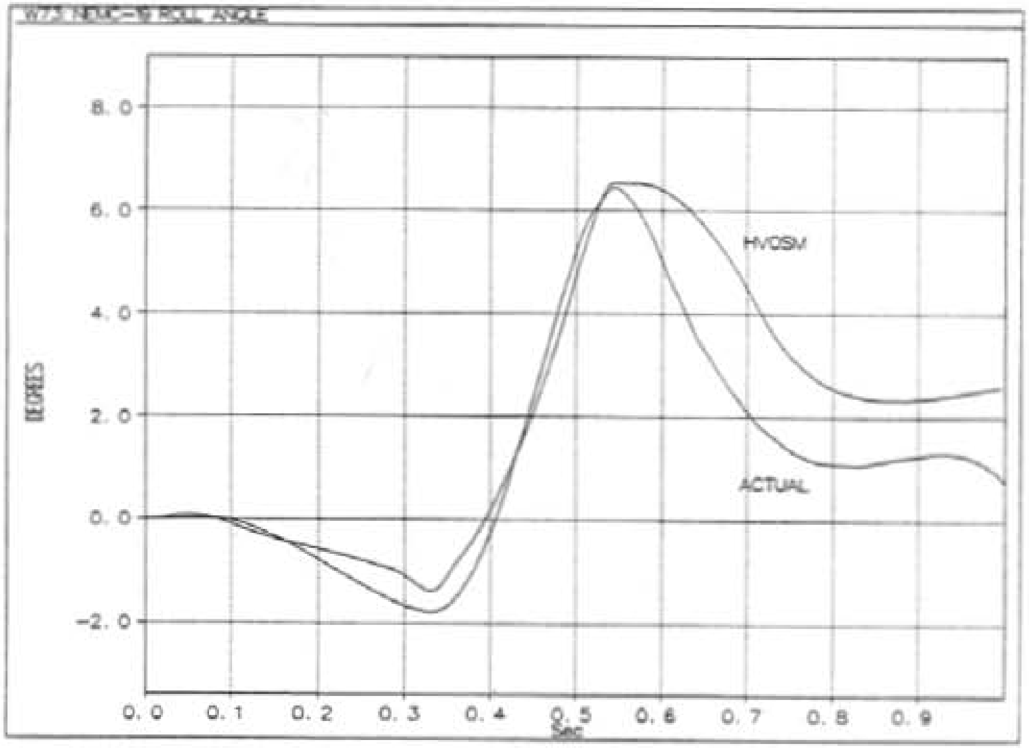

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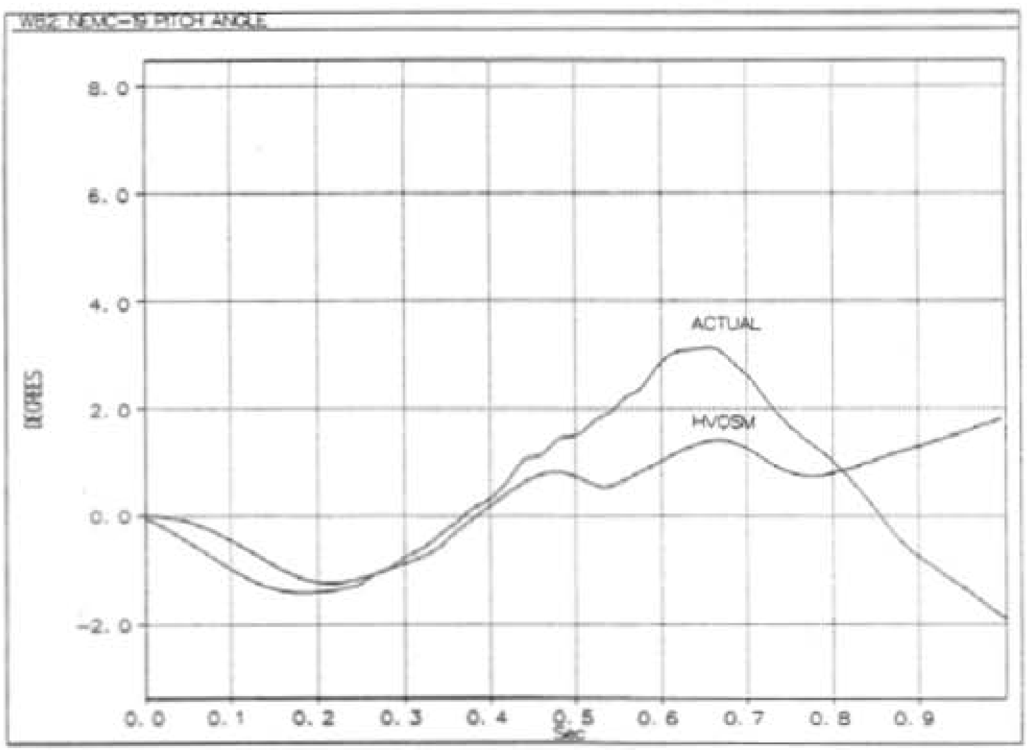

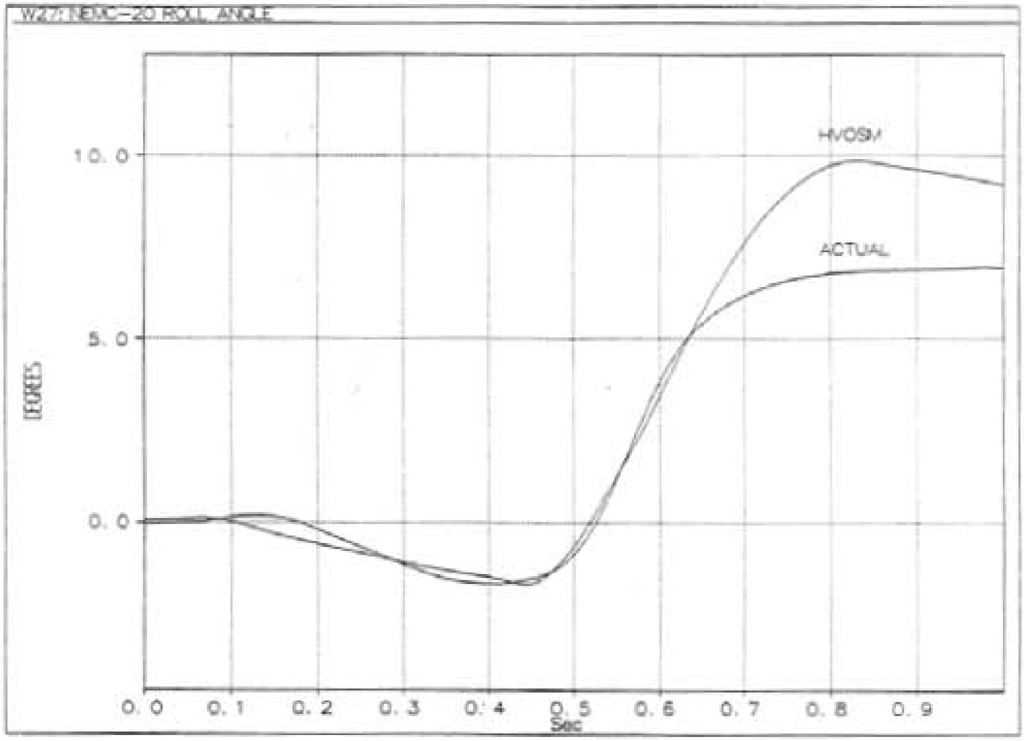

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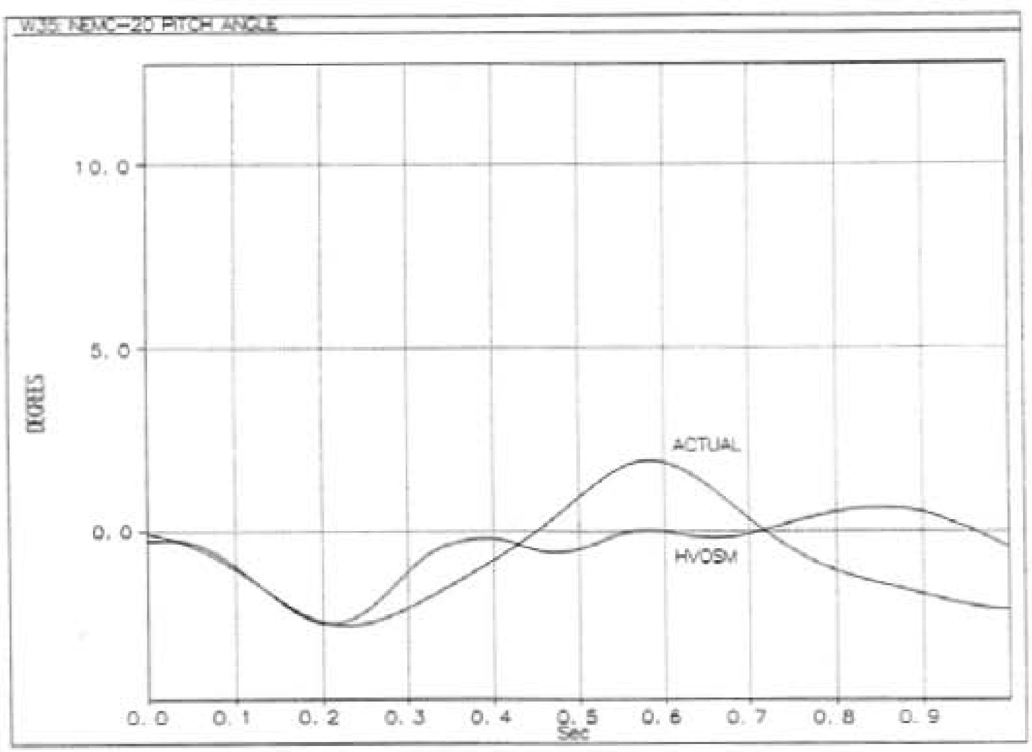

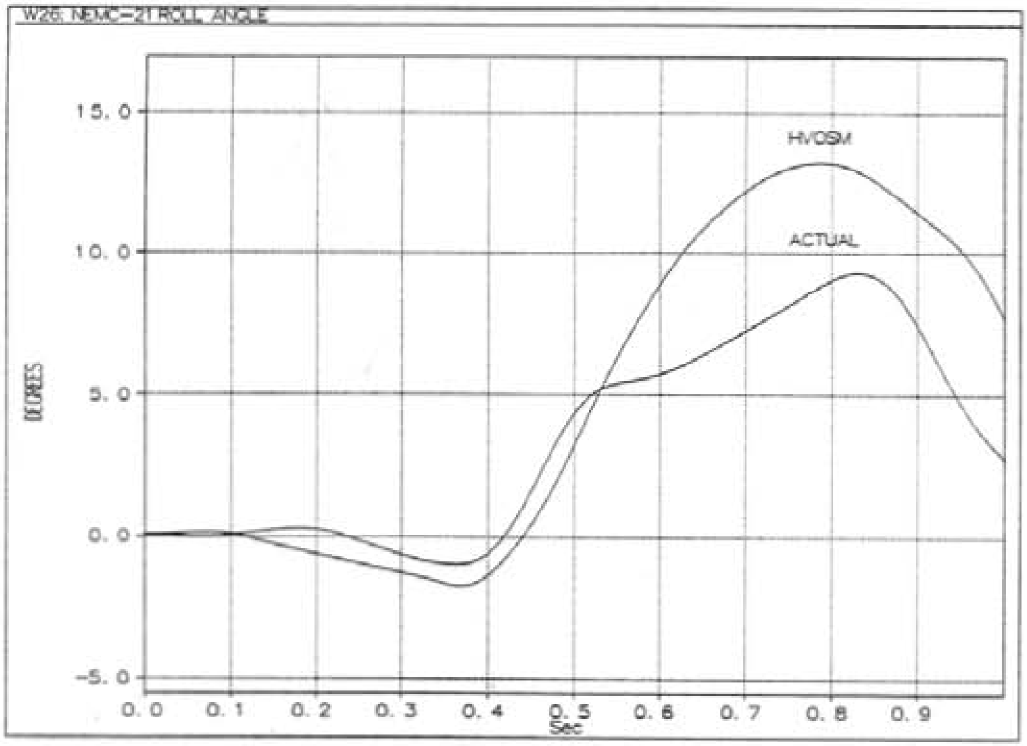

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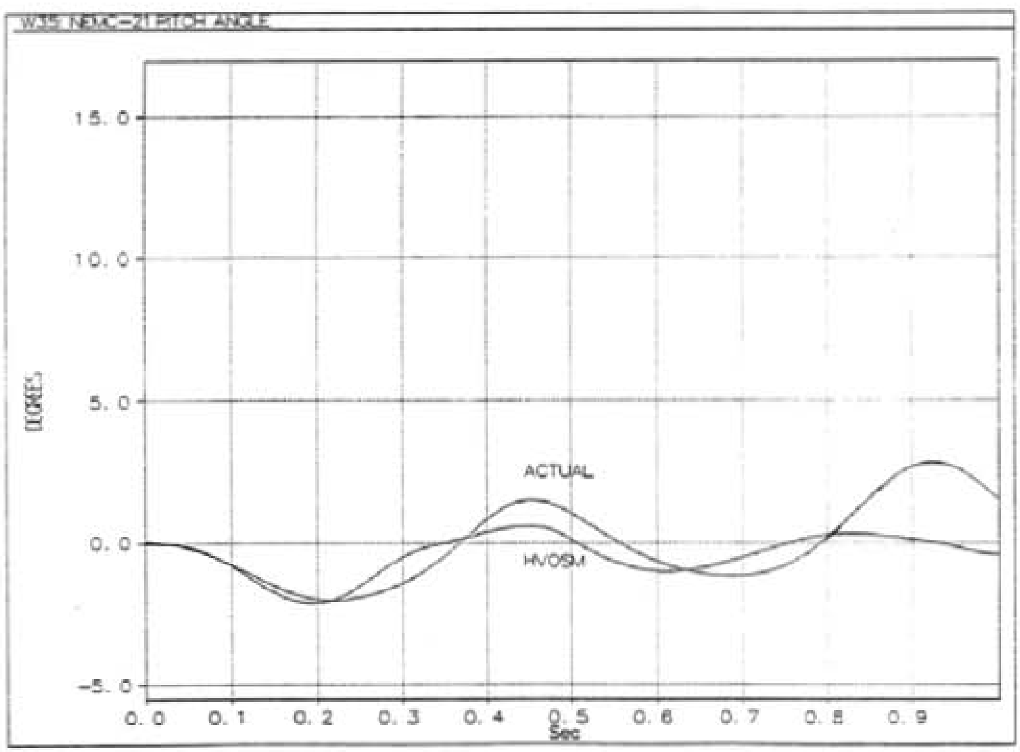
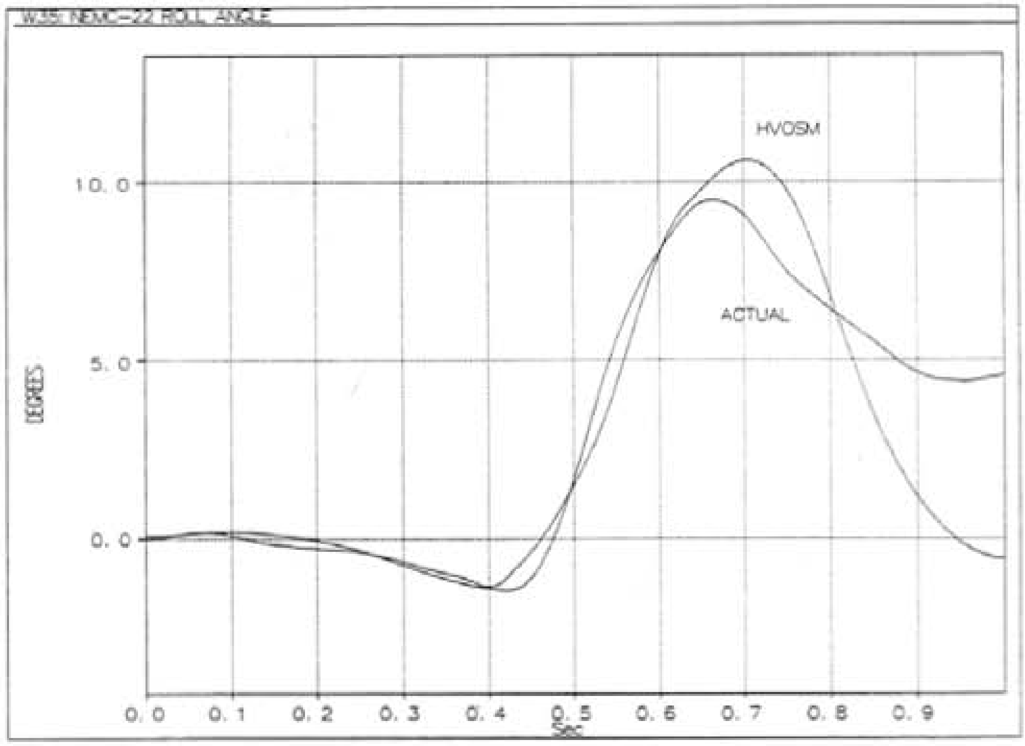
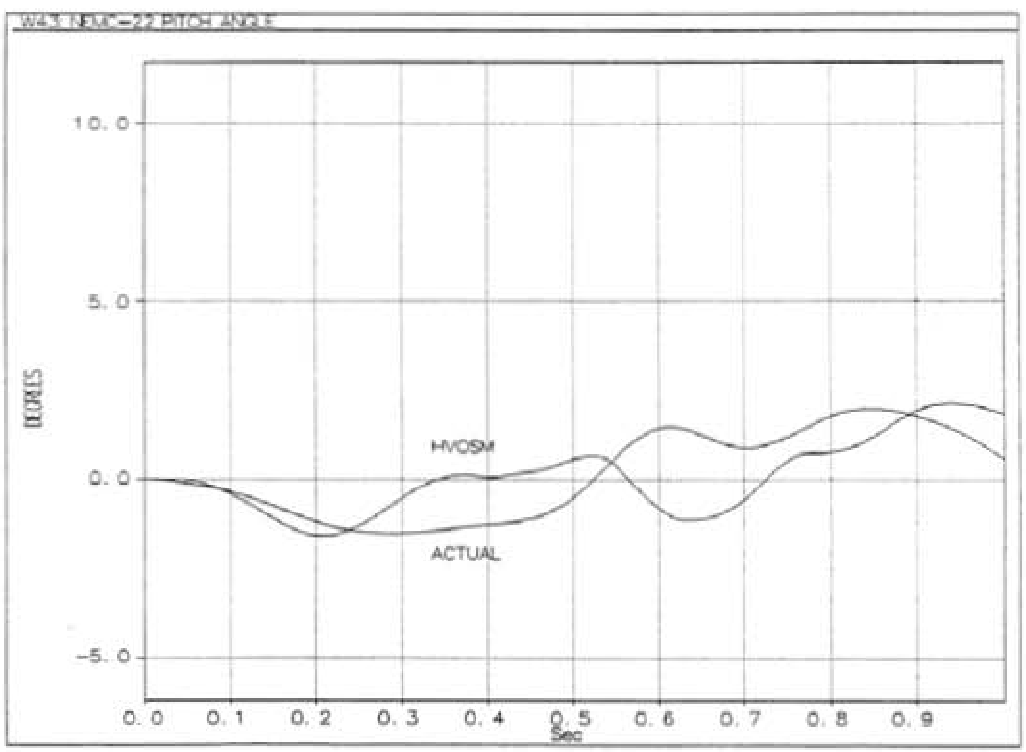
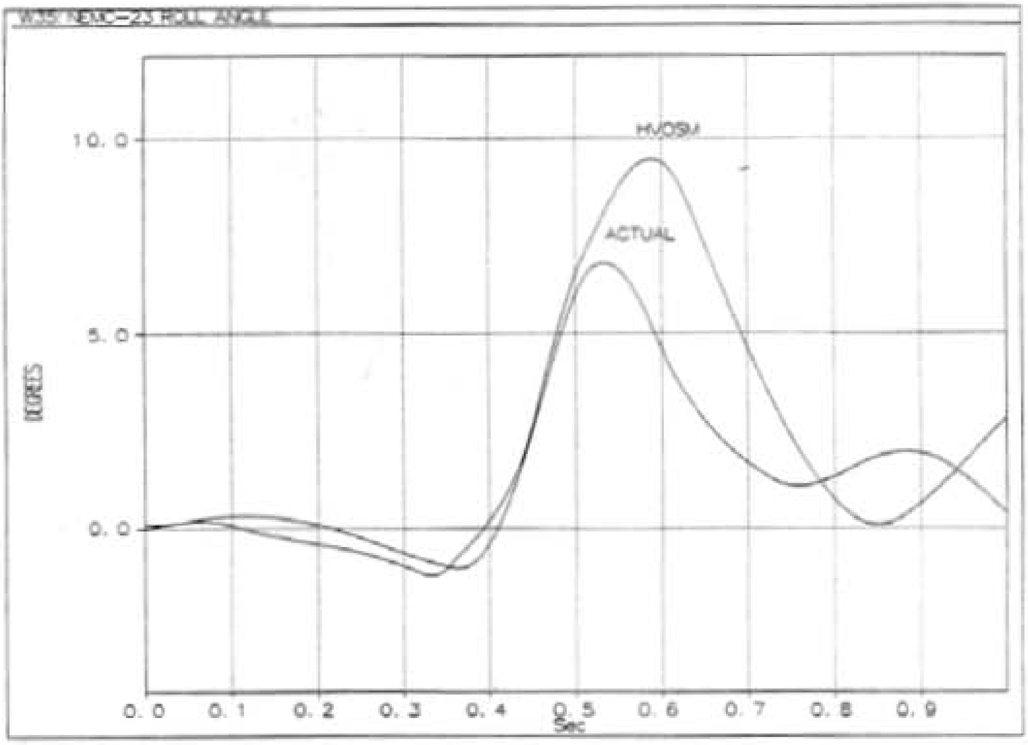


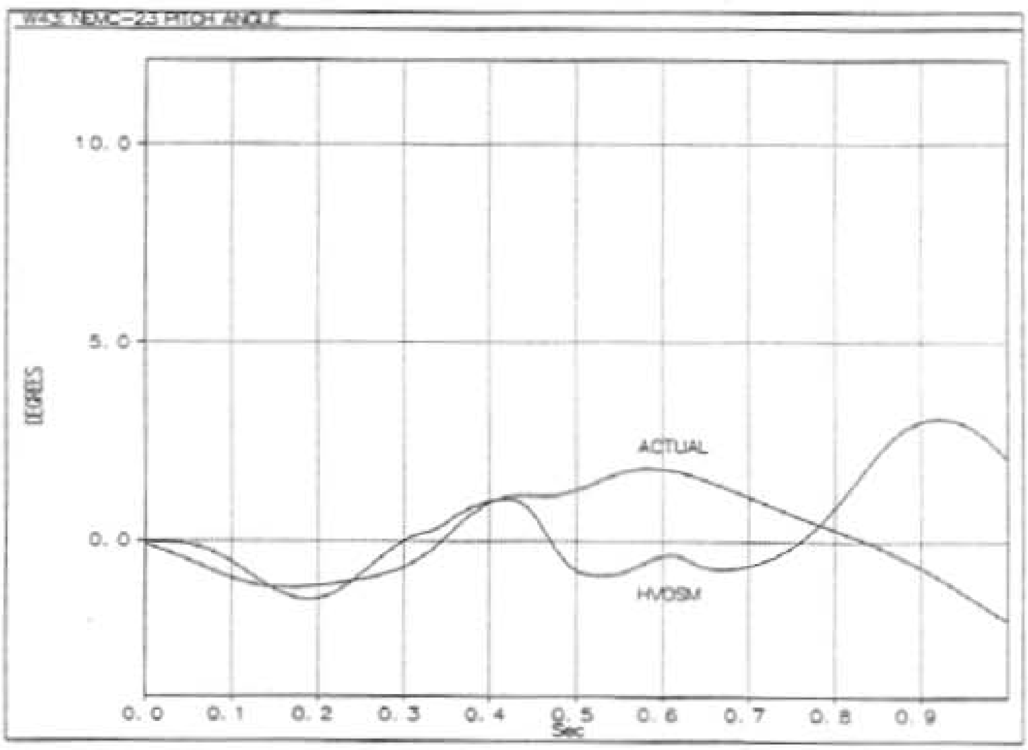


NEMC-22(6S,1800LB,18.3DEG,43.2MPH)



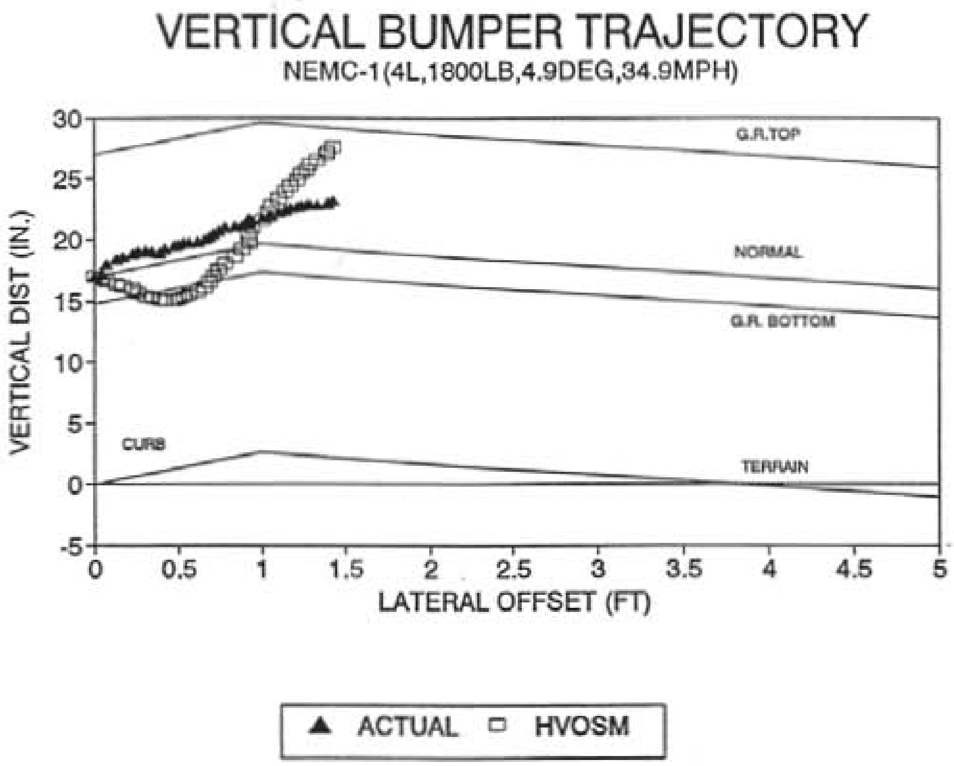


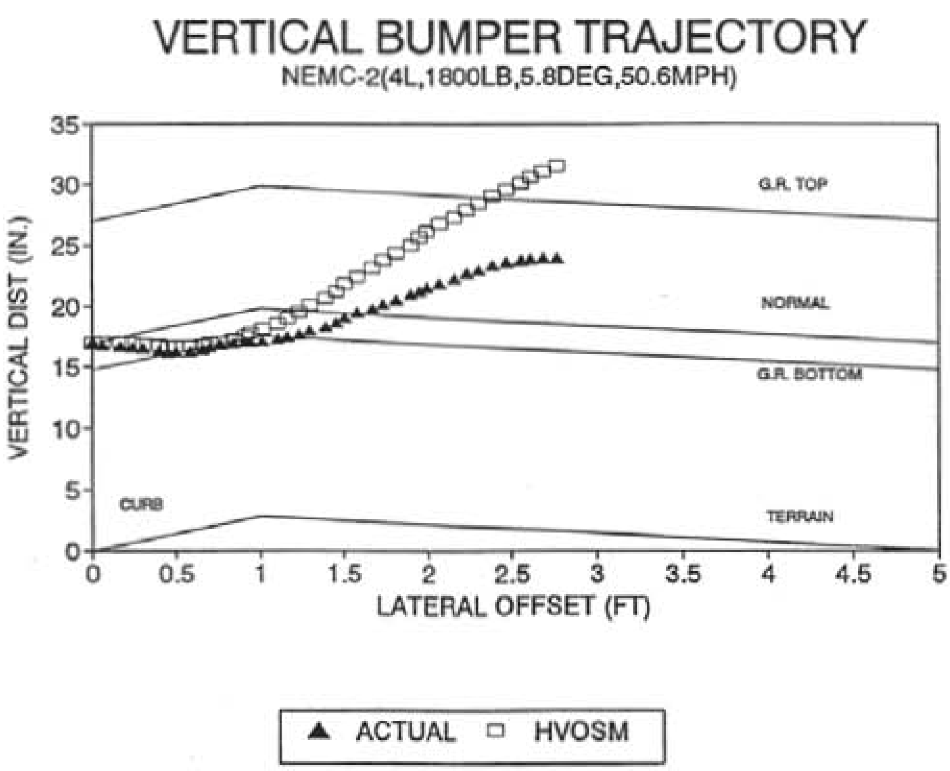
NEMC-23(6S,1800LB,20.0DEG,52.9MPH)

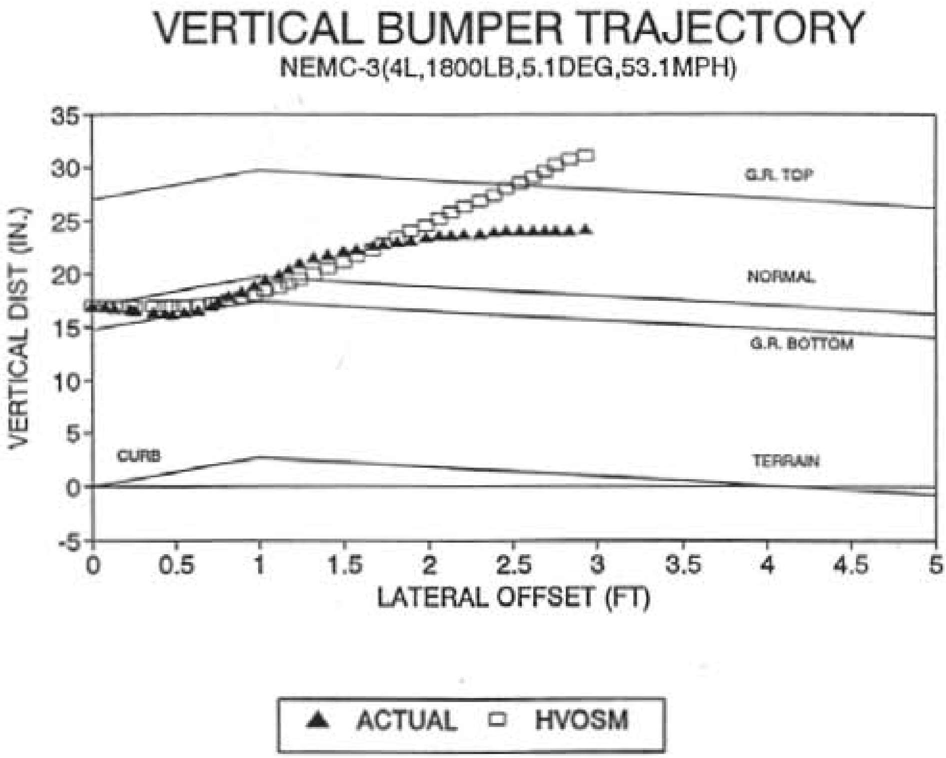


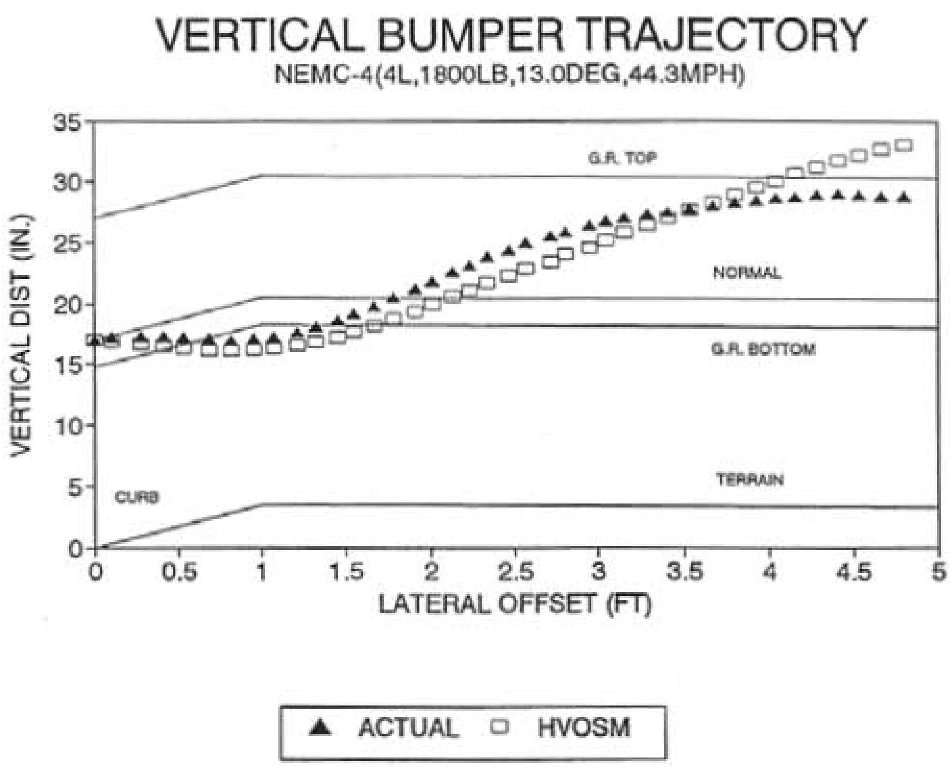
APPENDIX B:

Actual and Simulated Bumper Trajectories (NEMC 1-23)


VERTICAL BUMPER TRAJECTORY
NEMC-1(4L,1800LB,4.9DEG,34.9MPH)
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
G.R.TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
ACTUAL
HVOSM

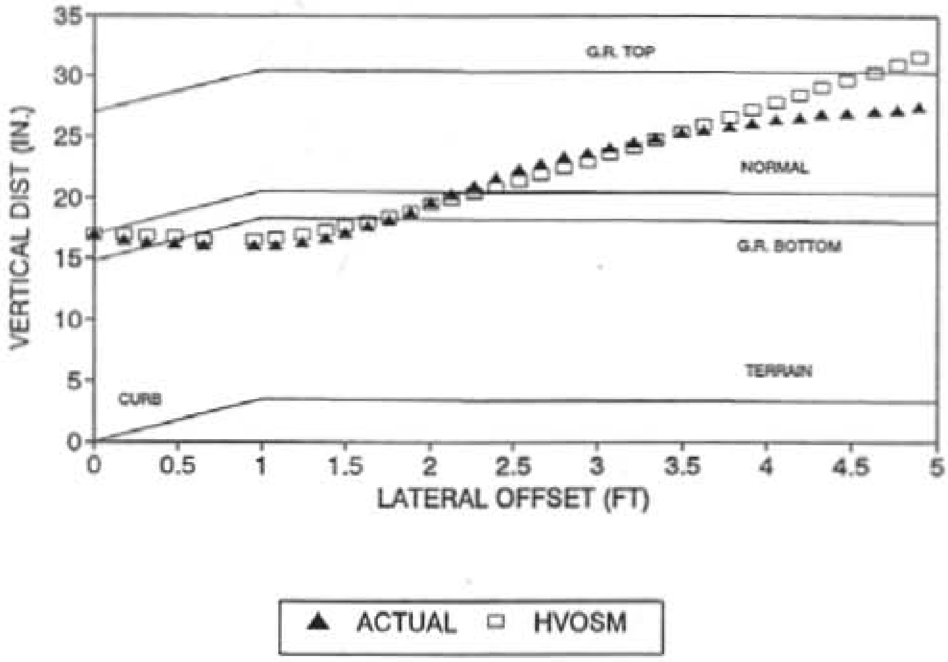

VERTICAL BUMPER TRAJECTORY
NEMC-2(4L,1800LB,5.8DEG,50.6MPH)
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
ACTUAL
HVOSM


VERTICAL BUMPER TRAJECTORY
NEMC-3(4L,1800LB,5.1DEG,53.1MPH)
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
ACTUAL
HVOSM


VERTICAL BUMPER TRAJECTORY
NEMC-4(4L,1800LB,13.0DEG,44.3MPH)
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
ACTUAL
HVOSM

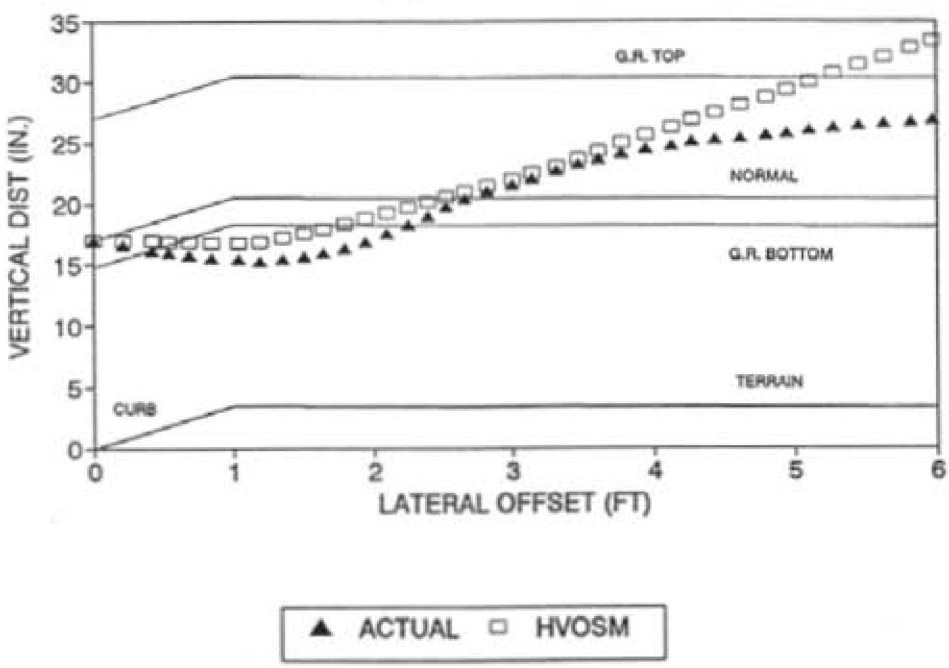
VERTICAL BUMPER TRAJECTORY

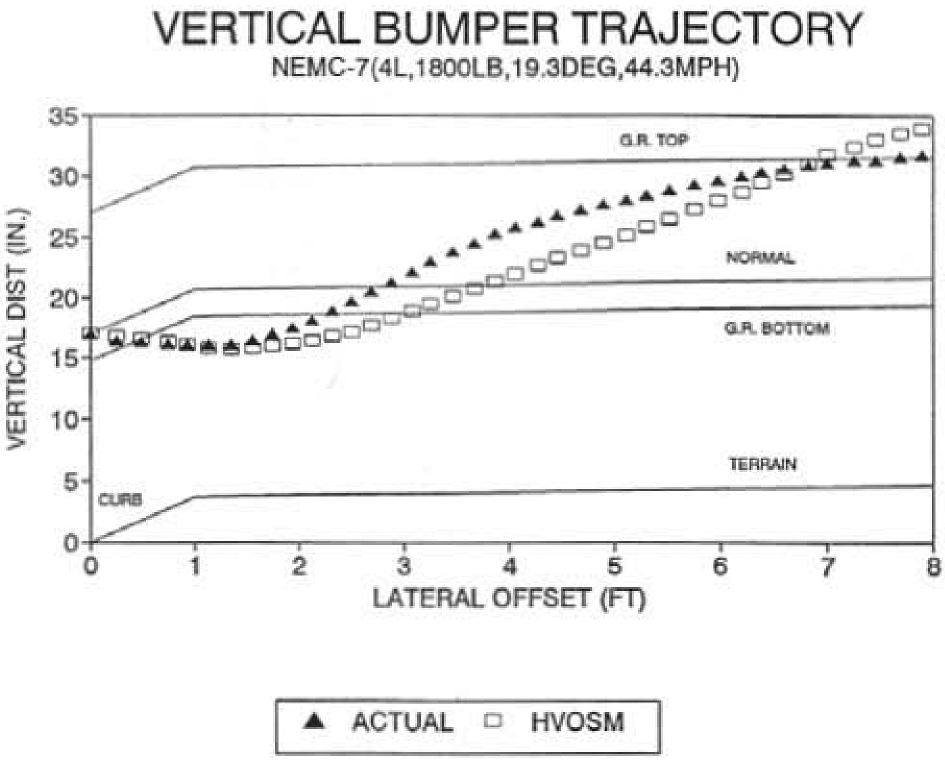
NEMC-5(4L,1800LB,13.1DEG,50.6MPH)

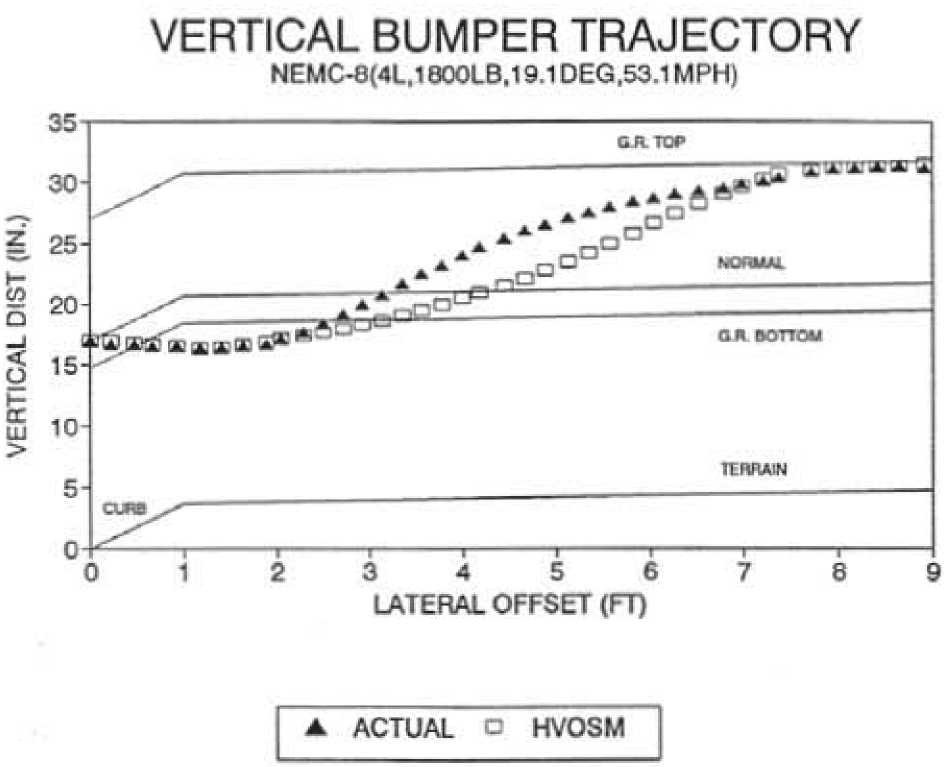


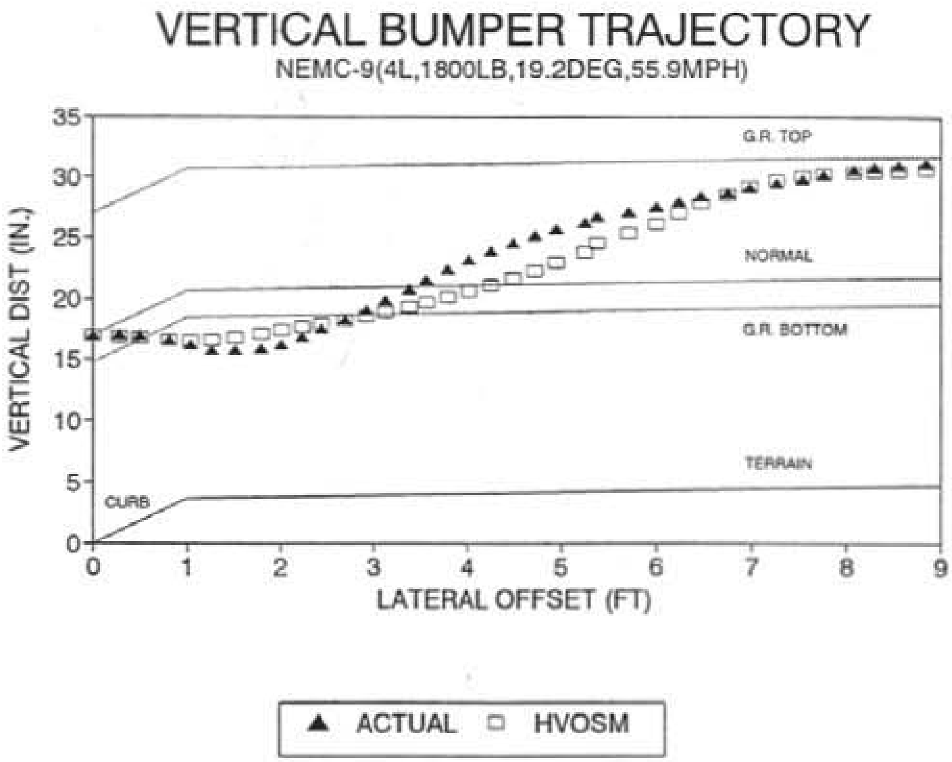
VERTICAL BUMPER TRAJECTORY

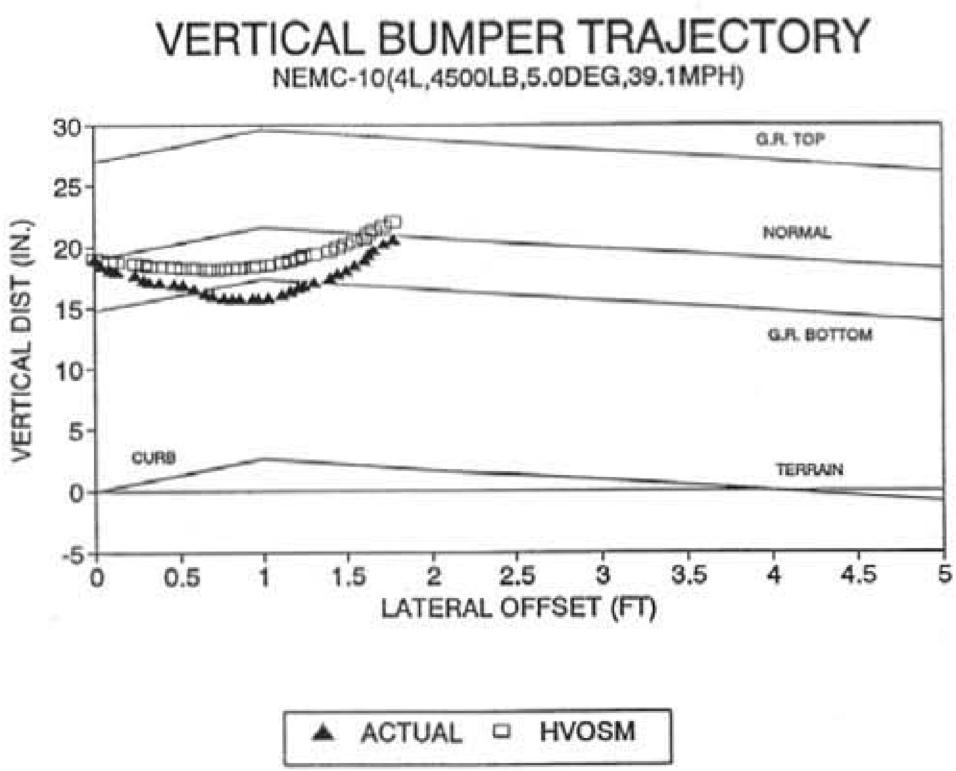
NEMC-6(4L,1800LB,13.1DEG,55.9MPH)




VERTICAL BUMPER TRAJECTORY
NEMC-7(4L,1800LB,19.3DEG,44.3MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
ACTUAL
HVOSM

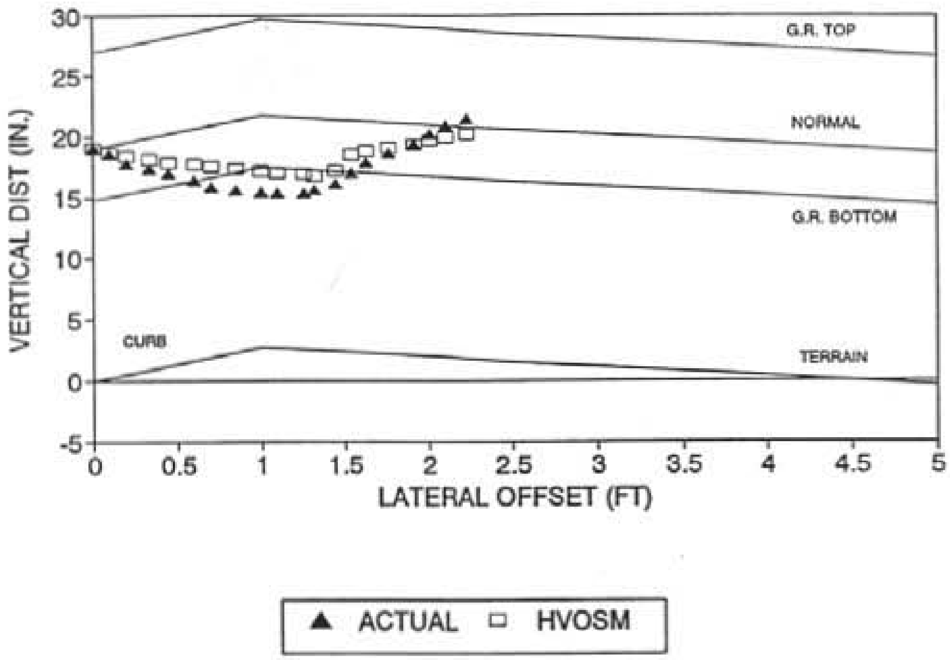

VERTICAL BUMPER TRAJECTORY
NEMC-8(4L,1800LB,19.1DEG,53.1MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
ACTUAL
HVOSM


VERTICAL BUMPER TRAJECTORY
NEMC-9(4L,1800LB,19.2DEG,55.9MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
7
8
9
ACTUAL
HVOSM


VERTICAL BUMPER TRAJECTORY
NEMC-10(4L,4500LB,5.0DEG,39.1MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
-5
0
5
10
15
20
25
30
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
ACTUAL
HVOSM

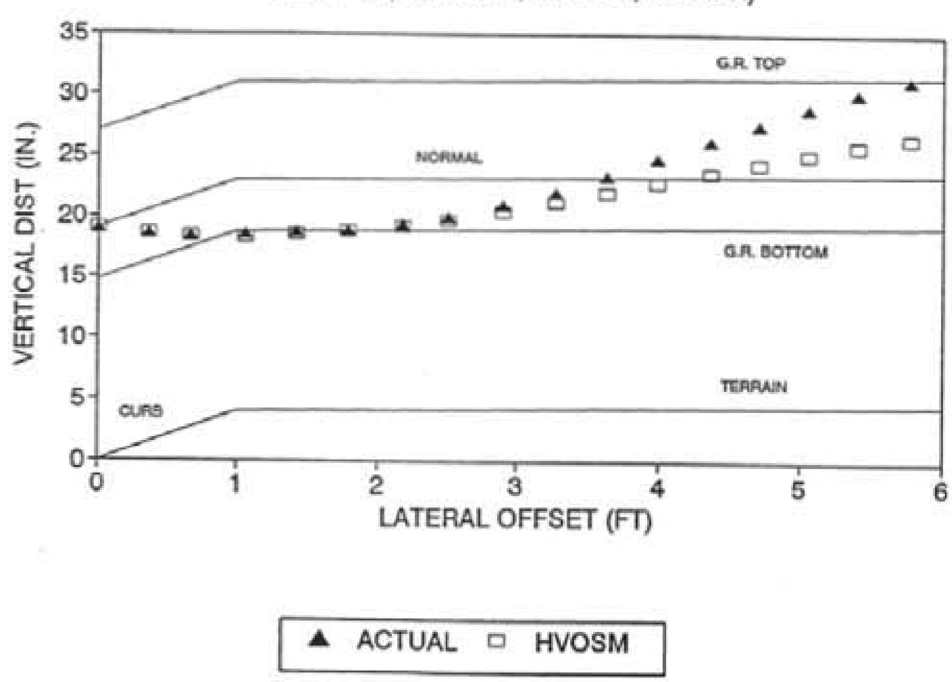
VERTICAL BUMPER TRAJECTORY

NEMC-11(4L,4500LB,5.4DEG,45.3MPH)



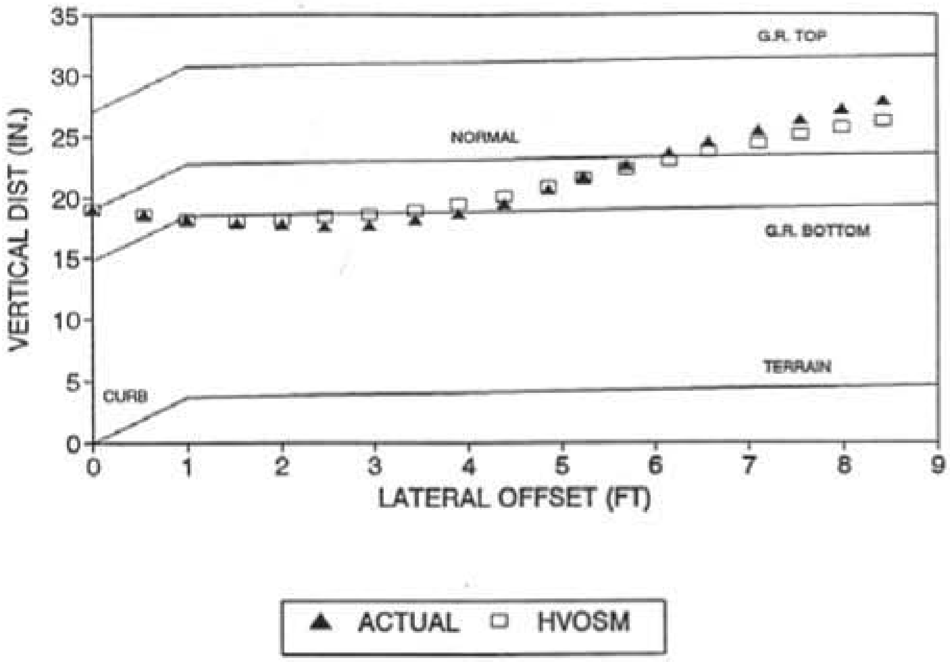
VERTICAL BUMPER TRAJECTORY

NEMC-12(4L,4500LB,19.7DEG,39.1MPH)



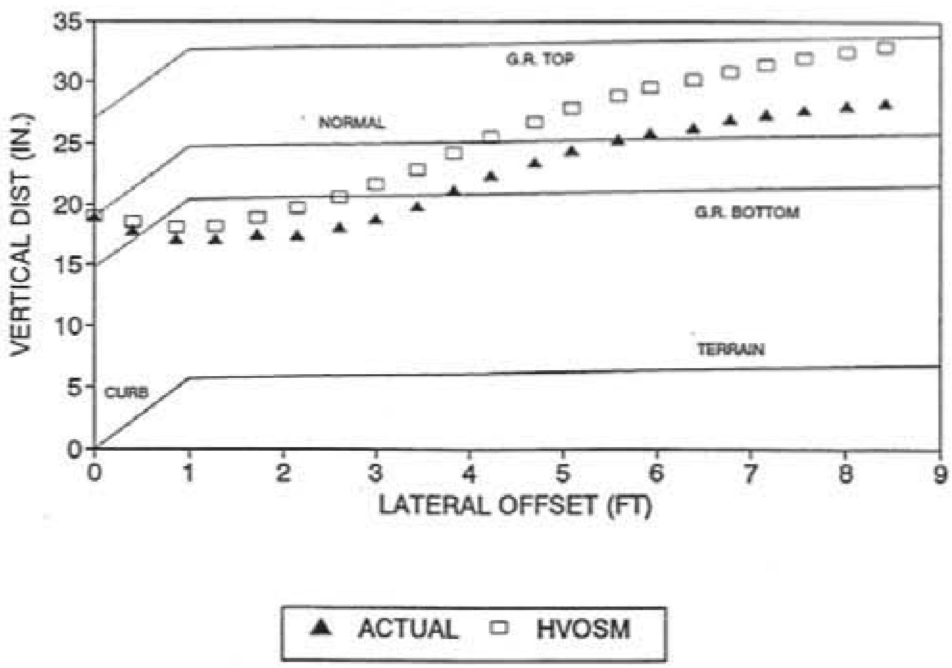
VERTICAL BUMPER TRAJECTORY

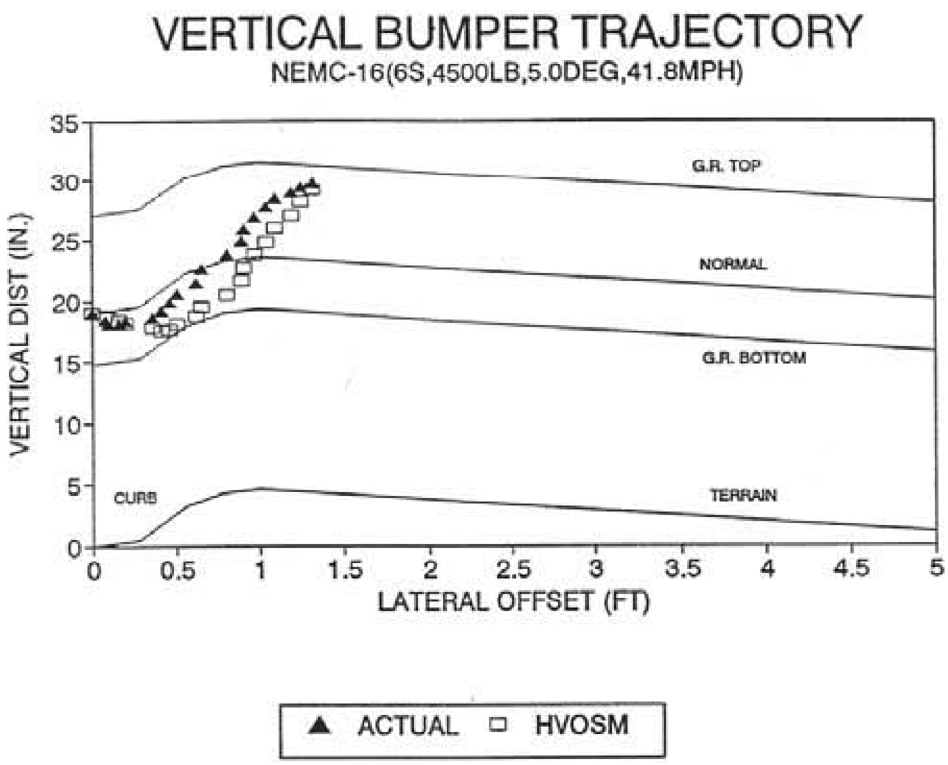
NEMC-13(4L,4500LB,19.0DEG,51.9MPH)

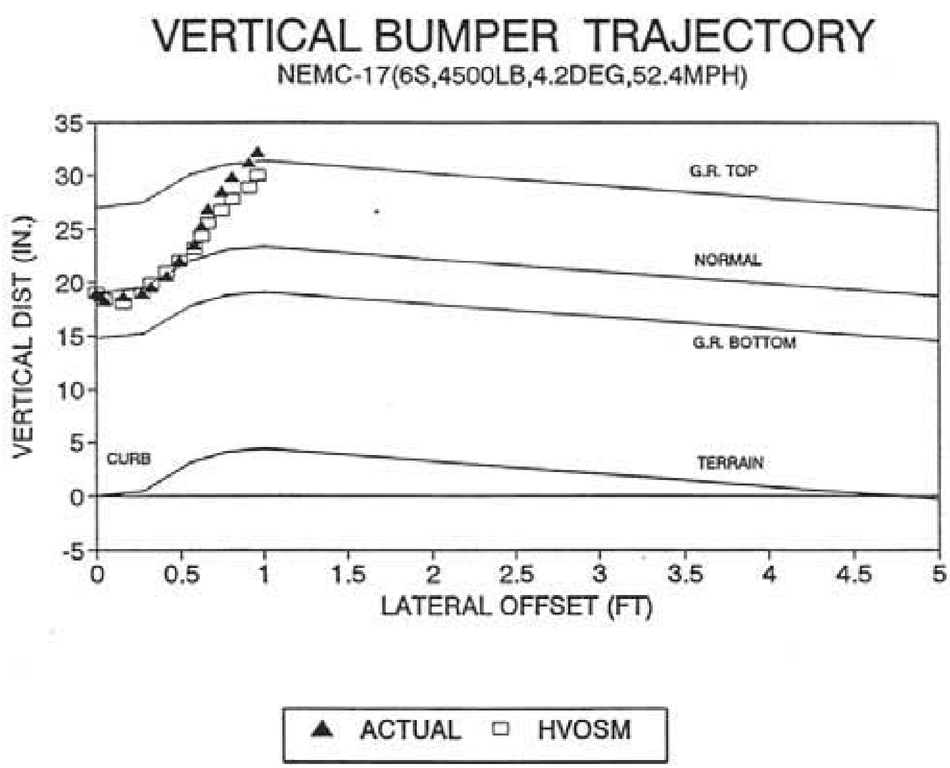


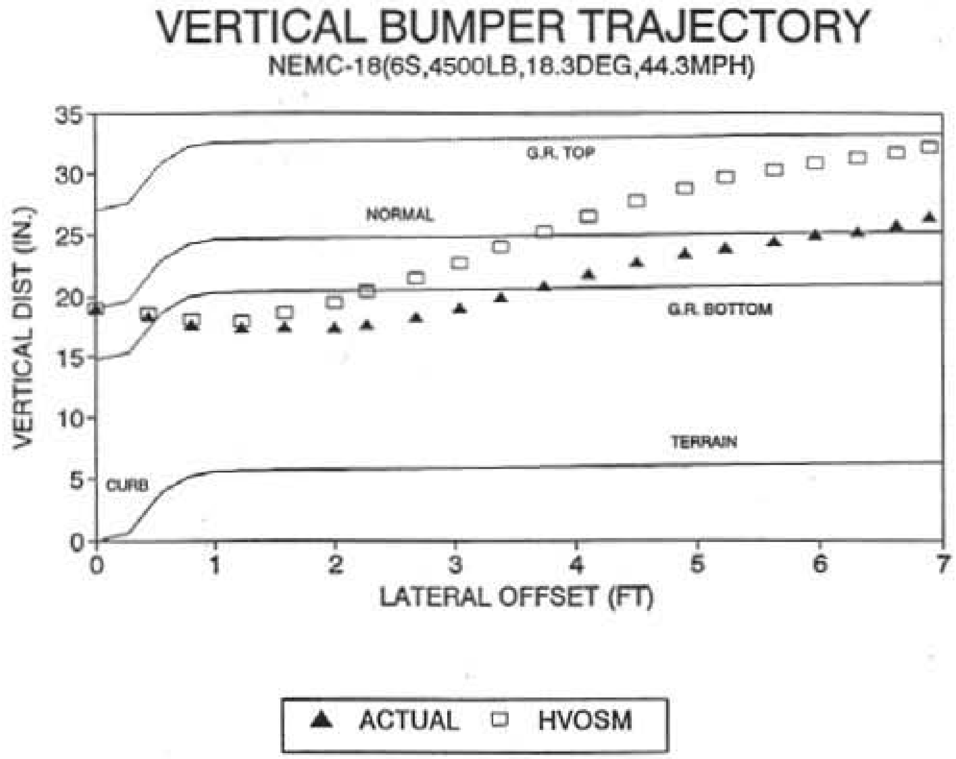
VERTICAL BUMPER TRAJECTORY

NEMC-14(6L,4500LB,19.5DEG,45.2MPH)

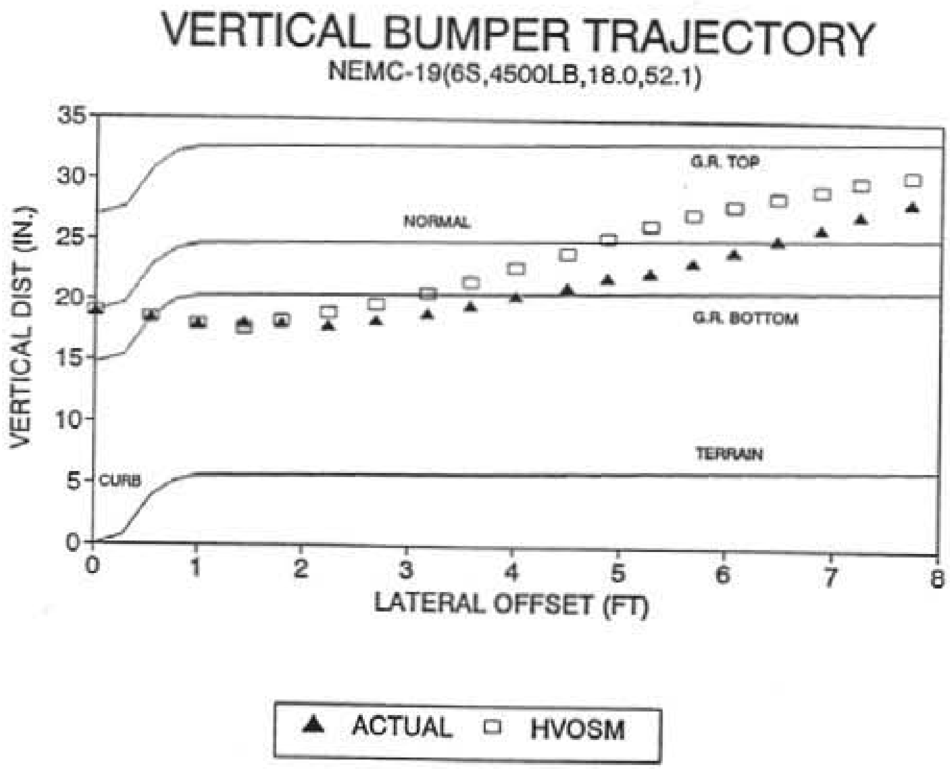



VERTICAL BUMPER TRAJECTORY
NEMC-16(6S,4500LB,5.0DEG,41.8MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
ACTUAL
HVOSM


VERTICAL BUMPER TRAJECTORY
NEMC-17(6S,4500LB,4.2DEG,52.4MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
ACTUAL
HVOSM

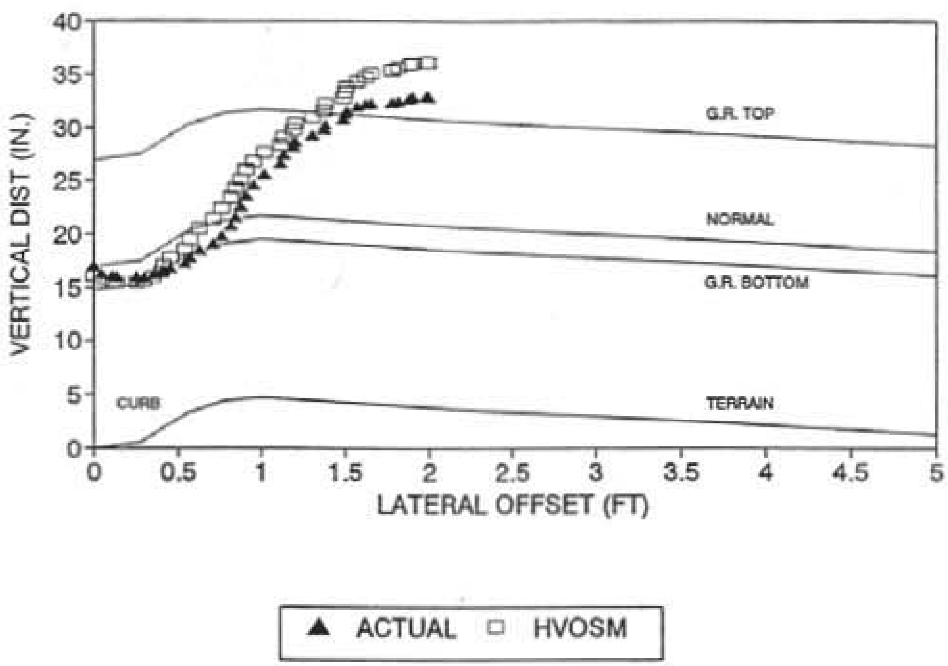


VERTICAL BUMPER TRAJECTORY
NEMC-18(6S,4500LB,18.3DEG,44.3MPH)
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
ACTUAL
HVOSM

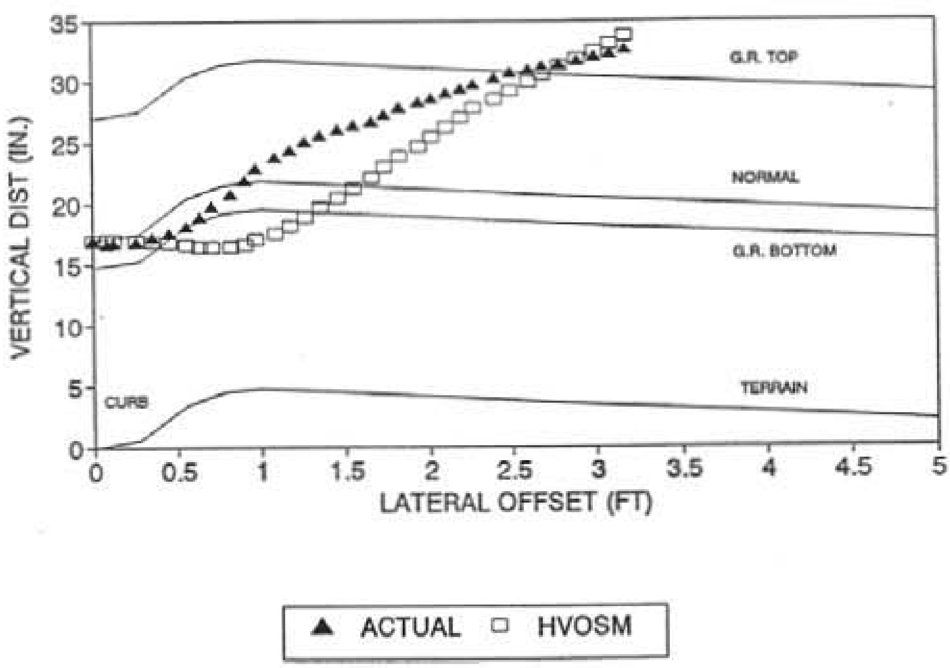


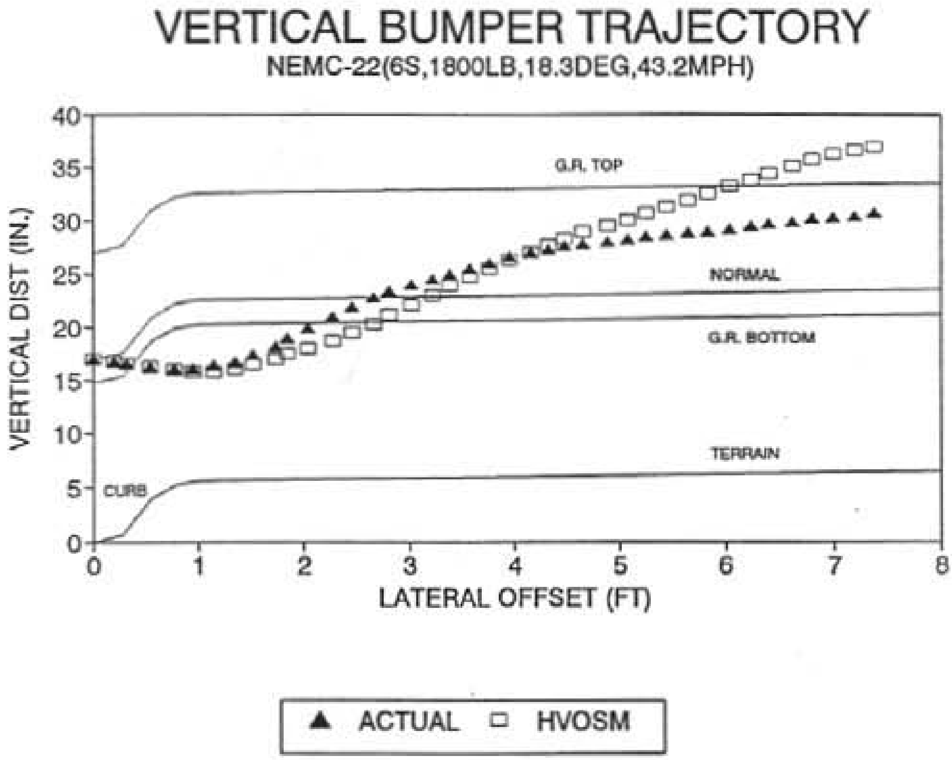
VERTICAL BUMPER TRAJECTORY
NEMC-19(6S,4500LB,18.0,52.1)
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
ACTUAL
HVOSM

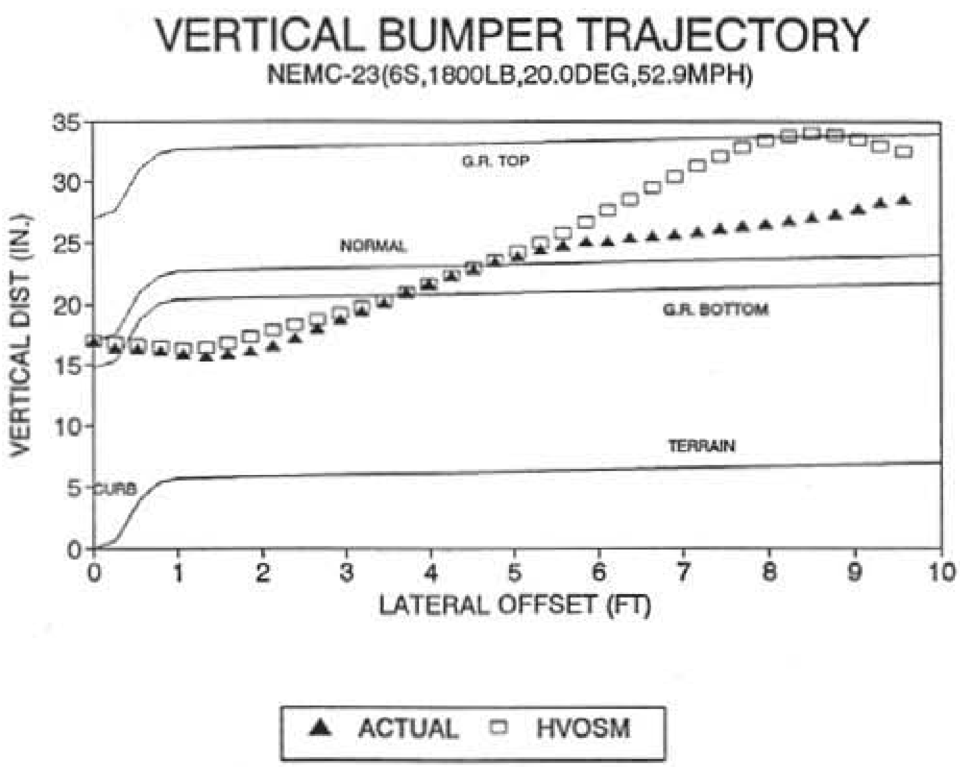
VERTICAL BUMPER TRAJECTORY
NEMC-20(6S,1800LB,5.2DEG,42.7MPH)



VERTICAL BUMPER TRAJECTORY
NEMC-21(6S,1800LB,5.9DEG,51.2MPH)




VERTICAL BUMPER TRAJECTORY
NEMC-22(6S,1800LB,18.3DEG,43.2MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
ACTUAL
HVOSM


VERTICAL BUMPER TRAJECTORY
NEMC-23(6S,1800LB,20.0DEG,52.9MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERTICAL DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
7
8
9
10
ACTUAL
HVOSM

APPENDIX C:

HVOSM Example Input Sets (NEMC-9 and NEMC-19)

NEMC-9 (4-in Lip curb/1800 lb Vehicle Model)

```
1
0nemc-9 rd2smn model                                                         0 100
00.0     1.5      .001     .001     70.0     0.0      0.0                    0 101
01.0     1.0      .001     0.0      0.0      0.0                1.0          0 102
01.0                                                                         0 103
01.0     1.0      1.0      1.0      1.0      1.0      1.0                    0 104
0VEHICLE DATA                                                                0 200
04.297   0.348    0.557    2643.81 5627.91 9118.49 0.0                       0 201
026.71   63.79    54.0     53.5                                              0 202
05.0     0.0      2.5                                 12.65    12.4          0 203
075.55   278.9    0.854    278.9    0.854    1.0      -2.05    2.0           0 204
0131.33  278.9    0.73     278.9    0.73     1.0      -3.0     3.5           0 205
06.25    12.0     3.49     20.0     3.49     31.0     0.1      1.8           0 206
08.48    5.0      19.66    12.5     8.21     30.0     19.66    1.6           0 207
06.43    5.0      4.82     12.25    3.35     32.5     0.1      1.8           0 208
010.4    12.5     4.09     20.0     4.09     30.0     10.4     1.6           0 209
013500.  30900.                                                              0 210
0200.    240.     0.40     5000.    0.075    1.10                            0 211
0-3.0    3.0      0.5                                                        0 212
0-1.5    -1.375   -1.25    -1.125   -1.0     -.625    -.375    0.0      .625 1 212
01.0     1.45     1.75     2.125                                             2 212
0-2.25   -1.85    -1.5     -1.125   -0.75    -0.25    0.25     .625    1.125 3 212
01.75    2.25     3.0      4.25                                              4 212
0-5.0    5.0      5.0                                                        0 214
00.092   0.092    0.092                                                      1 214
0TIRE DATA                                                                   0 300
01.0     1.0      1.0      1.0      6.0      0.25     0.0                    0 301
0870.    4.38     10.      148.52   12.9     2446.0   0.446    -5559.9 1.0   1 301
013.5    0.7      0.0      2000.    0.05     0.8      4.88     0.3           2 301
0GENERATED CURB SURFACE                                                      0 500
026.     0.       54.      68.      1.0                                      0 507
0-600.   -480.    0.       -600.    -120.    0.       -600.    24.      0.   1 507
0-600.   72.      0.       -600.    120.     0.       -600.    168.     0.   2 507
0-600.   180.     0.       -600.    300.     0.       -600.    480.     0.   3 507
0-360.   -480.    0.       -360.    -120.    0.       -360.    24.      0.   4 507
0-360.   72.      0.       -360.    120.     0.       -360.    168.     0.   5 507
0-360.   180.     0.       -360.    300.     0.       -360.    480.     0.   6 507
0-312.   -480.    0.       -312.    -120.    0.       -312.    24.    1.44   7 507
0-312.   72.      2.64     -312.    120.     3.12     -312.    168.   3.84   8 507
0-312.   180.     -0.16    -312.    300.     -4.96    -312.    480. -12.16   9 507
0-264.   -480.    0.       -264.    -120.    0.       -264.    24.    2.16  10 507
0-264.   72.      3.6      -264.    120.     4.56     -264.    168.   5.16  11 507
0-264.   180.     1.16     -264.    300.     -3.64    -264.    480. -10.84  12 507
0168.    -480.    0.       168.     -120.    0.       168.     24.    5.29  13 507
0168.    72.      6.25     168.     120.     7.21     168.     168.   8.17  14 507
0168.    180.     4.17     168.     300.     -0.63    168.     480.  -7.83  15 507
0600.    -480.    0.       600.     -120.    0.       600.     24.    6.96  16 507
0600.    72.      7.92     600.     120.     8.88     600.     168.   9.84  17 507
0600.    180.     5.84     600.     300.     1.04     600.     480.  -6.16  18 507
04.  4.  4.  4.  4.  4.  4.  4.  4.  3.  3.  3.  3.  3.  3.  3.  3.  3.     1 508
03.  3.  3.  3.  3.  4.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.     2 508
03.  3.  4.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  4.     3 508
03.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.                     4 508
01.  0.  2.  2.  11. 9.  10. 0.  2.  0.  3.  3.  12. 11. 11. 1.  3.  0.     1 509
04.  4.  13. 13. 12. 2.  4.  0.  5.  5.  14. 15. 13. 3.  5.  0.  6.  6.     2 509
015. 17. 14. 4.  6.  0.  7.  7.  16. 19. 15. 5.  7.  0.  8.  8.  17. 21.    3 509
016. 6.  8.  0.  9.  0.  18. 23. 17. 7.  10. 1.  11. 10. 20. 24. 19. 0.     4 509
011. 11. 21. 25. 20. 9.  11. 2.  12. 12. 21. 10. 12. 13. 22. 27. 21. 11.    5 509
012. 3.  13. 14. 22. 12. 13. 15. 23. 29. 22. 13. 13. 4.  14. 16. 23. 14.    6 509
014. 17. 24. 31. 23. 15. 14. 5.  15. 18. 24. 16. 15. 19. 25. 33. 24. 17.    7 509
015. 6.  16. 20. 25. 18. 16. 21. 26. 35. 25. 19. 16. 7.  17. 22. 26. 20.    8 509
017. 23. 27. 37. 26. 21. 17. 8.  18. 0.  27. 22. 19. 9.  20. 25. 29. 39.    9 509
028. 0.  20. 10. 21. 26. 29. 24. 21. 27. 30. 41. 29. 25. 21. 12. 22. 28.   10 509
030. 26. 22. 29. 31. 43. 30. 27. 22. 14. 23. 30. 31. 28. 23. 31. 32. 45.   11 509
031. 29. 23. 16. 24. 32. 32. 30. 24. 33. 33. 47. 32. 31. 24. 18. 25. 34.   12 509
033. 32. 25. 35. 34. 49. 33. 33. 25. 20. 26. 36. 34. 34. 26. 37. 35. 51.   13 509
034. 35. 26. 22. 27. 38. 35. 36. 27. 0.  36. 53. 35. 37. 28. 24. 29. 40.   14 509
038. 54. 37. 0.  29. 41. 39. 55. 38. 39. 29. 26. 30. 42. 39. 40. 30. 43.   15 509
040. 57. 39. 41. 30. 28. 31. 44. 40. 42. 31. 45. 41. 59. 40. 43. 31. 30.   16 509
```

```
032. 46. 41. 44. 32. 47. 42. 61. 41. 45. 32. 32. 33. 48. 42. 46. 33. 49.    17 509
043. 63. 42. 47. 33. 34. 34. 50. 43. 48. 34. 51. 44. 65. 43. 49. 34. 36.    18 509
035. 52. 44. 50. 35. 53. 45. 67. 44. 51. 35. 38. 36. 0.  45. 52. 37. 39.    19 509
038. 55. 47. 0.  46. 0.  38. 40. 39. 56. 47. 54. 39. 57. 48. 0.  47. 55.    20 509
039. 42. 40. 58. 48. 56. 40. 59. 49. 0.  48. 57. 40. 44. 41. 60. 49. 58.    21 509
041. 61. 50. 0.  49. 59. 41. 46. 42. 62. 50. 60. 42. 63. 51. 0.  50. 61.    22 509
042. 48. 43. 64. 51. 62. 43. 65. 52. 0.  51. 63. 43. 50. 44. 66. 52. 64.    23 509
044. 67. 53. 0.  52. 65. 44. 52. 45. 68. 53. 66. 45. 0.  54. 0.  53. 67.    24 509
01.  1.  2.  2.  3.  3.  4.  4.  5.  5.  6.  6.  7.  7.  8.  8.  9.  8.     1 510
018. 23. 27. 38. 36. 53. 45. 68. 54. 68. 53. 66. 52. 64. 51. 62. 50. 60.     2 510
049. 58. 48. 56. 47. 54. 46. 54. 37. 39. 28. 24. 19. 9.  10. 1.              3 510
0initial conditions                                                          0 600
0-0.07   -0.16   19.2    -0.68   -0.91   0.04    0.0     0.0                 0 601
0-480.   15.05   -25.32  986.4   0.0     0.0                                 0 602
00.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0                 0 603
0                                                                            09999
1        nemc-9 rd2smn model
         OCTOBER
    VEHICLE DATA                                TIRE DATA
    GENERATED CURB SURFACE                      initial conditions

0                        P R O G R A M   C O N T R O L   D A T A
         START TIME                       T0     =    .0000  SEC
         END TIME                         T1     =   1.5000  SEC
         INTEGRATION INCREMENT            DTCOMP =    .0010  SEC
                                                             (0=VARIABLE STEP ADAMS-MOULTON
         INTEGRATION MODE                 MODE   =   1       -)1= RUNGA-KUTTA
                                                             (2= FIXED STEP ADAMS-MOULTON
         PRINT INTERVAL                   DTPRNT =    .0010  SEC
0                                                            (0= INDEPENDENT FRONT SUSPENSION,
SOLID REAR AXLE
         SUSPENSION OPTION                ISUS   =   1       -)1= INDEPENDENT FRONT AND REAR
SUSPENSION
                                                             (2= SOLID FRONT AND REAR AXLES

                                                             (0= NO CURB, NO STEER DEGREE OF
FREEDOM
         CURB/STEER OPTION                INDCRB =   1       -)1= CURB
                                                             (-1=STEER DEGREE OF FREEDOM, NO CURB

         CURB INTEGRATION INCR.           DELTC  =   .00100  SEC
0                                                            (0= NO BARRIER
                                                             |1= RIGID BARRIER , FINITE VERT. DIM.

         BARRIER OPTION                   INDB   =   0       -)2= ''    ''   ,INFINITE ''   ''

                                                             |3= DEFORM. ''  , FINITE  ''   ''

                                                             (4=  ''    ''   ,INFINITE ''   ''

         BARRIER INTEGRATION INCR.        DELTB  =   .00000  SEC
0
         SIGN IMPACT OPTION               COLL   =   0.        ( 0 = NO : 1 = YES

0
                                                     I N I T I A L   C O N D I T I O N S

                                          XCOP   = -480.00   INCHES
    U0     =  986.40   IN/SEC
         SPRUNG MASS C.G. POSITION        YCOP   =   15.05   INCHES        SPRUNG MASS LINEAR
VELOCITY     V0    =     .00    IN/SEC
                                          ZCOP   =  -25.32   INCHES
    W0     =     .00   IN/SEC
0                                         PHI0   =    -.07   DEGREES
    P0     =    -.68   DEG/SEC
         SPRUNG MASS ORIENTATION          THETA0 =    -.16   DEGREES       SPRUNG MASS ANGULAR
VELOCITY     Q0    =    -.91    DEG/SEC
                                          PSI0   =   19.20   DEGREES
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```
   RO    =      .04   DEG/SEC
0                                              DEL10  =       .00    INCHES
  DEL10D =      .00    IN/SEC
         UNSPRUNG MASS POSITIONS               DEL20  =       .00    INCHES          UNSPRUNG MASS VELOCITIES
  DEL20D =      .00    IN/SEC
0                                              DEL30  =       .00    INCHES
  DEL30D =      .00    IN/SEC
                                               DEL40  =       .00    INCHES
  DEL40D =      .00    IN/SEC
         STEER ANGLE                           PSIFI0 =       .00    DEGREES         STEER VELOCITY
  PSIFD0 =      .00   DEG/SEC
1        nemc-9 rd2smn model
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0        SPRUNG MASS                  XMS    =      4.297 LB-SEC**2/IN    FRONT WHEEL X LOCATION
A    =   26.710 INCHES
         FRONT UNSPRUNG MASS          XMUF   =       .348 LB-SEC**2/IN    REAR WHEEL X LOCATION
B    =   63.790 INCHES
         REAR UNSPRUNG MASS           XMUR   =       .557 LB-SEC**2/IN    FRONT WHEEL Z LOCATION
ZF   =   12.650 INCHES
0        X MOMENT OF INERTIA          XIX    =  2643.810 LB-SEC**2-IN     REAR WHEEL Z LOCATION
ZR   =   12.400 INCHES
         Y MOMENT OF INERTIA          XIY    =  5627.910 LB-SEC**2-IN     FRONT WHEEL TRACK
TF   =   54.000 INCHES
         Z MOMENT OF INERTIA          XIZ    =  9118.490 LB-SEC**2-IN     REAR WHEEL TRACK
TR   =   53.500 INCHES
         XZ PRODUCT OF INERTIA        XIXZ   =      .000 LB-SEC**2-IN     FRONT ROLL AXIS
RHOF =     .000 NOT USED
0        FRONT AXLE MOMENT OF INERTIA XIF    =      .000 NOT USED         REAR ROLL AXIS
RHO  =     .000 NOT USED
         REAR AXLE MOMENT OF INERTIA  XIR    =      .000 NOT USED         FRONT SPRING TRACK
TSF  =     .000 NOT USED
         GRAVITY                      G      =   386.400 IN/SEC**2        REAR SPRING TRACK
TS   =     .000 NOT USED
0                                     X1     =      5.00 INCHES           FRONT AUX ROLL STIFFNESS
RF   = 13500.00 LB-IN/RAD
         ACCELEROMETER 1 POSITION     Y1     =       .00 INCHES           REAR AUX ROLL STIFFNESS
RR   = 30900.00 LB-IN/RAD
                                      Z1     =      2.50 INCHES           REAR ROLL-STEER COEF.
AKRS =    .0000 NOT USED
                                      X2     =       .00 INCHES
AKDS =     .000 RADIANS
         ACCELEROMETER 2 POSITION     Y2     =       .00 INCHES           REAR DEFL-STEER COEFS.
AKDS1=     .000 RAD/IN
                                      Z2     =       .00 INCHES
AKDS2=     .000 RAD/IN**2

AKDS3=     .000 RAD/IN**3
0             S T E E R I N G   S Y S T E M
         MOMENT OF INERTIA        XIPS  =   200.000 LB-SEC**2-IN
         COULOMB FRICTION TORQUE  CPSP  =   240.000 LB-IN
         FRICTION LAG             EPSP  =      .075 RAD/SEC
         ANGULAR STOP RATE        AKPS  =  5000.000 LB-IN/RAD
         ANGULAR STOP POSITION    OMGPS =      .400 RADIANS
         PNEUMATIC TRAIL          XPS   =     1.100 INCHES
0                                   FRONT SUSPENSION                      REAR SUSPENSION

         SUSPENSION RATE                AKF    =   75.550 LB/IN           AKR    =  131.330
LB/IN
         COMPRESSION STOP COEFS.        AKFC   =  278.900 LB/IN           AKRC   =  278.900
LB/IN
                                        AKFCP  =     .854 LB/IN**3        AKRCP  =     .730
LB/IN**3
0        EXTENSION STOP COEFS.          AKFE   =  278.900 LB/IN           AKRE   =  278.900
LB/IN
                                        AKFEP  =     .854 LB/IN**3        AKREP  =     .730
LB/IN**3
```

COMPRESSION STOP LOCATION OMEGFC = -2.050 INCHES OMEGRC = -3.000
INCHES
EXTENSION STOP LOCATION OMEGFE = 2.000 INCHES OMEGRE = 3.500
INCHES
0 STOP ENERGY DISSIPATION FACTOR XLAMF = 1.000 XLAMR = 1.000
COMP. VISC. DAMP. COEF. NO. 1 CFJ(1) = 6.250 LB-SEC/IN CRJ(1) = 6.430
LB-SEC/IN
VEL. AT THE CHANGE OF COEF. 1 DLFJ(1)= 12.000 IN/SEC DLRJ(1)= 5.000
IN/SEC
COMP. VISC. DAMP. COEF. NO. 2 CFJ(2) = 3.490 LB-SEC/IN CRJ(2) = 4.820
LB-SEC/IN
VEL. AT THE CHANGE OF COEF. 2 DLFJ(2)= 20.000 IN/SEC DLRJ(2)= 12.250
IN/SEC
COMP. VISC. DAMP. COEF. NO. 3 CFJ(3) = 3.490 LB-SEC/IN CRJ(3) = 3.350
LB-SEC/IN
0 EXTN. VISC. DAMP. COEF. NO. 1 CFR(1) = 8.480 LB-SEC/IN CRR(1) = 10.400
LB-SEC/IN
VEL. AT THE CHANGE OF COEF. 1 DLFR(1)= 5.000 IN/SEC DLRR(1)= 12.500
IN/SEC
EXTN. VISC. DAMP. COEF. NO. 2 CFR(2) = 19.660 LB-SEC/IN CRR(2) = 4.090
LB-SEC/IN
VEL. AT THE CHANGE OF COEF. 2 DLFR(2)= 12.500 IN/SEC DLRR(2)= 20.000
IN/SEC
EXTN. VISC. DAMP. COEF. NO. 3 CFR(3) = 8.210 LB-SEC/IN CRR(3) = 4.090
LB-SEC/IN
VEL. AT THE CHANGE OF COEF. 3 DLFR(3)= 30.000 IN/SEC DLRR(3)= 30.000
IN/SEC
0 EXTN. VISC. DAMP. COEF. NO. 4 CFR(4) = 19.660 LB-SEC/IN CRR(4) = 10.400
LB-SEC/IN
COULOMB FRICTION CFP = 31.000 LB CRP = 32.500 LB

FRICTION LAG EPSF = .100 IN/SEC EPSR = .100
IN/SEC
POWER IN POWER LAW DAMPING POWF = 1.600 POWR = 1.600
1 nemc-9 rd2smn model
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0 FRONT WHEEL CAMBER REAR WHEEL CAMBER FRONT HALF-TRACK CHANGE REAR
HALF-TRACK CHANGE
VS VS VS VS
SUSPENSION DEFLECTION SUSPENSION DEFLECTION SUSPENSION DEFLECTION SUSPENSION
DEFLECTION

DELTAF	PHIC	DELTAR	PHIRC	DELTAF	DTHF	DELTAR	DTHR
INCHES	DEGREES	INCHES	DEGREES	INCHES	INCHES	INCHES	INCHES
-3.00	-1.50	-3.00	-2.25	-3.00	.00	-3.00	.00
-2.50	-1.38	-2.50	-1.85	-2.50	.00	-2.50	.00
-2.00	-1.25	-2.00	-1.50	-2.00	.00	-2.00	.00
-1.50	-1.13	-1.50	-1.13	-1.50	.00	-1.50	.00
-1.00	-1.00	-1.00	-.75	-1.00	.00	-1.00	.00
-.50	-.63	-.50	-.25	-.50	.00	-.50	.00
.00	-.38	.00	.25	.00	.00	.00	.00
.50	.00	.50	.63	.50	.00	.50	.00
1.00	.63	1.00	1.13	1.00	.00	1.00	.00
1.50	1.00	1.50	1.75	1.50	.00	1.50	.00

	2.00	1.45	2.00	2.25	2.00	.00	2.00
.00							
	2.50	1.75	2.50	3.00	2.50	.00	2.50
.00							
	3.00	2.13	3.00	4.25	3.00	.00	3.00
.00							

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0 T I R E D A T A

				RF	LF	RR	LR	
0	TIRE LINEAR SPRING RATE	AKT	=	870.000	870.000	870.000	870.000	
LB/IN	DEFL. FOR INCREASED RATE	SIGT	=	4.380	4.380	4.380	4.380	
INCHES	SPRING RATE INCREASING FACTOR	XLAMT	=	10.000	10.000	10.000	10.000	
		A0	=	148.520	148.520	148.520	148.520	
		A1	=	12.900	12.900	12.900	12.900	
	SIDE FORCE COEFFICIENTS	A2	=	2446.000	2446.000	2446.000	2446.000	
		A3	=	.446	.446	.446	.446	
		A4	=	-5559.900	-5559.900	-5559.900	-5559.900	
	TIRE OVERLOAD FACTOR	OMEGT	=	1.000	1.000	1.000	1.000	
	TIRE UNDEFLECTED RADIUS	RW	=	13.500	13.500	13.500	13.500	
INCHES	TIRE / GROUND FRICTION COEF.	AMU	=	.700	.700	.700	.700	
	TIRE DAMPING PARAMETER	AMUT	=	.000	.000	.000	.000	SEC
	TIRE RIM STIFFNESS TERM	AKTR	=	2000.000	2000.000	2000.000	2000.000	
LB/IN	RIM FORCE VELOCITY COEF.	CTR	=	.050	.050	.050	.050	
	RIM FORCE POWER TERM	PTR	=	.800	.800	.800	.800	
	TIRE DEFLECTION TO THE RIM	RDR	=	4.880	4.880	4.880	4.880	
INCHES	RIM / CURB FRICTION COEFF.	AMURC	=	.300	.300	.300	.300	
	FRICTION LAG FOR RIM FRICION	EPSVR	=	.000				

0 ANTI-PITCH TABLES FOR CIRCUMFERENTIAL TIRE FORCE

FRONT WHEEL DEFL. - IN.	APF LB/LB-FT	REAR WHEEL DEFL.- IN.	APR LB/LB-FT
		-5.0000	.0920
		.0000	.0920
		5.0000	.0920

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0 C U R B / B A R R I E R D A T A

CURB FRICTION COEFFICIENT FACTOR AMUC = 1.000

NODE LOCATIONS & NO. OF NODES CONNECTED

NODE NO.	X'(INCHES)	LOCATION Y'(INCHES)	Z'(INCHES)	NO. OF NODES CONNECTED
1	-600.00	-480.00	.00	2
2	-600.00	-120.00	.00	3
3	-600.00	24.00	.00	3
4	-600.00	72.00	.00	3
5	-600.00	120.00	.00	3
6	-600.00	168.00	.00	3
7	-600.00	180.00	.00	3

8	-600.00	300.00	.00	3
9	-600.00	480.00	.00	2
10	-360.00	-480.00	.00	3
11	-360.00	-120.00	.00	5
12	-360.00	24.00	.00	5
13	-360.00	72.00	.00	5
14	-360.00	120.00	.00	5
15	-360.00	168.00	.00	5
16	-360.00	180.00	.00	5
17	-360.00	300.00	.00	5
18	-360.00	480.00	.00	3
19	-312.00	-480.00	.00	3
20	-312.00	-120.00	.00	4
21	-312.00	24.00	1.44	6
22	-312.00	72.00	2.64	6
23	-312.00	120.00	3.12	6
24	-312.00	168.00	3.84	6
25	-312.00	180.00	-.16	6
26	-312.00	300.00	-4.96	6
27	-312.00	480.00	-12.16	5
28	-264.00	-480.00	.00	3
29	-264.00	-120.00	.00	6
30	-264.00	24.00	2.16	6
31	-264.00	72.00	3.60	6
32	-264.00	120.00	4.56	6
33	-264.00	168.00	5.16	6
34	-264.00	180.00	1.16	6
35	-264.00	300.00	-3.64	6
36	-264.00	480.00	-10.84	3
37	168.00	-480.00	.00	3
38	168.00	-120.00	.00	4
39	168.00	24.00	5.29	6
40	168.00	72.00	6.25	6
41	168.00	120.00	7.21	6
42	168.00	168.00	8.17	6
43	168.00	180.00	4.17	6
44	168.00	300.00	-.63	6
45	168.00	480.00	-7.83	5
46	600.00	-480.00	.00	2
47	600.00	-120.00	.00	4
48	600.00	24.00	6.96	4
49	600.00	72.00	7.92	4
50	600.00	120.00	8.88	4
51	600.00	168.00	9.84	4
52	600.00	180.00	5.84	4
53	600.00	300.00	1.04	4
54	600.00	480.00	-6.16	2

ELEMENT SLOPES, ORIENTATIONS AND NO. OF SIDES

ELEM. NO.	SLOPE,PHIS (DEG.)	ORIENTN.,PSIS (DEG.)	NO. OF SIDES
1	.00	.00	4
2	.00	.00	4
3	.00	.00	4
4	.00	.00	4
5	.00	.00	4
6	.00	.00	4
7	.00	.00	4
8	.00	.00	4
9	.00	.00	4
10	-.57	180.00	3
11	-1.72	90.00	3
12	-2.24	129.81	3
13	-3.15	90.00	3
14	-3.20	100.30	3
15	-3.72	90.00	3

16	-3.82	102.99	3
17	-4.57	90.00	3
18	-18.92	13.50	3
19	-.19	-90.00	3
20	-2.30	-4.76	3
21	-5.90	-90.00	3
22	-6.32	-68.84	3
23	-14.22	-90.00	3
24	.00	.00	4
25	-.57	180.00	3
26	-1.22	135.00	3
27	-1.67	149.04	3
28	-2.06	146.31	3
29	-1.28	116.57	3
30	-2.06	123.69	3
31	-1.92	116.57	3
32	-1.73	114.44	3
33	-18.49	4.72	3
34	-18.49	4.72	3
35	-2.78	34.51	3
36	-2.78	34.51	3
37	-2.78	34.51	3
38	-2.78	34.51	3
39	.00	.00	4
40	-2.10	180.00	3
41	-.95	154.22	3
42	-1.22	160.09	3
43	-1.75	168.44	3
44	-1.20	162.95	3
45	-1.20	162.95	3
46	-1.20	162.95	3
47	-.82	150.86	3
48	-18.44	1.20	3
49	-18.44	1.20	3
50	-2.33	9.88	3
51	-2.33	9.88	3
52	-2.33	9.88	3
53	-2.33	9.88	3
54	.00	.00	4
55	-2.10	180.00	3
56	-2.78	175.43	3
57	-1.17	169.06	3
58	-1.17	169.06	3
59	-1.17	169.06	3
60	-1.17	169.06	3
61	-1.17	169.06	3
62	-1.17	169.06	3
63	-18.44	.66	3
64	-18.44	.66	3
65	-2.30	5.52	3
66	-2.30	5.52	3
67	-2.30	5.52	3
68	-2.30	5.52	3

ELEMENT NODE NUMBERS

ELEMENT NO.	NODES IN COUNTERCLOCKWISE SEQUENCE			
1	1	2	11	10
2	2	3	12	11
3	3	4	13	12
4	4	5	14	13
5	5	6	15	14
6	6	7	16	15
7	7	8	17	16
8	8	9	18	17
9	10	11	20	19
10	11	21	20	

11	11	12	21	
12	12	22	21	
13	12	13	22	
14	13	23	22	
15	13	14	23	
16	14	24	23	
17	14	15	24	
18	15	25	24	
19	15	16	25	
20	16	26	25	
21	16	17	26	
22	17	27	26	
23	17	18	27	
24	19	20	29	28
25	20	21	29	
26	21	30	29	
27	21	22	30	
28	22	31	30	
29	22	23	31	
30	23	32	31	
31	23	24	32	
32	24	33	32	
33	24	25	33	
34	25	34	33	
35	25	26	34	
36	26	35	34	
37	26	27	35	
38	27	36	35	
39	28	29	38	37
40	29	39	38	
41	29	30	39	
42	30	40	39	
43	30	31	40	
44	31	41	40	
45	31	32	41	
46	32	42	41	
47	32	33	42	
48	33	43	42	
49	33	34	43	
50	34	44	43	
51	34	35	44	
52	35	45	44	
53	35	36	45	
54	37	38	47	46
55	38	39	47	
56	39	48	47	
57	39	40	48	
58	40	49	48	
59	40	41	49	
60	41	50	49	
61	41	42	50	
62	42	51	50	
63	42	43	51	
64	43	52	51	
65	43	44	52	
66	44	53	52	
67	44	45	53	
68	45	54	53	

NODAL CONNECTIVITY

NODE NO.	NODES CONNECTED IN COUNTERCLOCKWISE SEQUENCE		
1	2	10	
2	3	11	1
3	4	12	2
4	5	13	3
5	6	14	4

6	7	15	5			
7	8	16	6			
8	9	17	7			
9	18	8				
10	1	11	19			
11	2	12	21	20	10	
12	3	13	22	21	11	
13	4	14	23	22	12	
14	5	15	24	23	13	
15	6	16	25	24	14	
16	7	17	26	25	15	
17	8	18	27	26	16	
18	27	17	9			
19	10	20	28			
20	11	21	29	19		
21	11	12	22	30	29	20
22	12	13	23	31	30	21
23	13	14	24	32	31	22
24	14	15	25	33	32	23
25	15	16	26	34	33	24
26	16	17	27	35	34	25
27	36	35	26	17	18	
28	19	29	37			
29	20	21	30	39	38	28
30	21	22	31	40	39	29
31	22	23	32	41	40	30
32	23	24	33	42	41	31
33	24	25	34	43	42	32
34	25	26	35	44	43	33
35	26	27	36	45	44	34
36	45	35	27			
37	28	38	46			
38	29	39	47	37		
39	29	30	40	48	47	38
40	30	31	41	49	48	39
41	31	32	42	50	49	40
42	32	33	43	51	50	41
43	33	34	44	52	51	42
44	34	35	45	53	52	43
45	54	53	44	35	36	
46	37	47				
47	46	38	39	48		
48	47	39	40	49		
49	48	40	41	50		
50	49	41	42	51		
51	50	42	43	52		
52	51	43	44	53		
53	52	44	45	54		
54	53	45				

ELEMENT CONNECTIVITY (0 = OUTSIDE EDGE)

ELEMENT NO. ELEMENTS CONNECTED TO EACH SIDE IN COUNTERCLOCKWISE SEQUENCE (SIDE 1 STARTS FROM NODE 1)

1	0	2	9	0
2	0	3	11	1
3	0	4	13	2
4	0	5	15	3
5	0	6	17	4
6	0	7	19	5
7	0	8	21	6
8	0	0	23	7
9	1	10	24	0
10	11	25	9	
11	2	12	10	
12	13	27	11	
13	3	14	12	

14	15	29	13	
15	4	16	14	
16	17	31	15	
17	5	18	16	
18	19	33	17	
19	6	20	18	
20	21	35	19	
21	7	22	20	
22	23	37	21	
23	8	0	22	
24	9	25	39	0
25	10	26	24	
26	27	41	25	
27	12	28	26	
28	29	43	27	
29	14	30	28	
30	31	45	29	
31	16	32	30	
32	33	47	31	
33	18	34	32	
34	35	49	33	
35	20	36	34	
36	37	51	35	
37	22	38	36	
38	0	53	37	
39	24	40	54	0
40	41	55	39	
41	26	42	40	
42	43	57	41	
43	28	44	42	
44	45	59	43	
45	30	46	44	
46	47	61	45	
47	32	48	46	
48	49	63	47	
49	34	50	48	
50	51	65	49	
51	36	52	50	
52	53	67	51	
53	38	0	52	
54	39	55	0	0
55	40	56	54	
56	57	0	55	
57	42	58	56	
58	59	0	57	
59	44	60	58	
60	61	0	59	
61	46	62	60	
62	63	0	61	
63	48	64	62	
64	65	0	63	
65	50	66	64	
66	67	0	65	
67	52	68	66	
68	0	0	67	

OUTSIDE CURB NODE NUMBERS IN COUNTERCLOCKWISE SEQUENCE

1 2 3 4 5 6 7 8 9 18 27
36 45 54 53
52 51 50 49 48 47 46 37 28 19 10

OUTSIDE CURB ELEMENTS IN COUNTERCLOCKWISE ,SEQUENCE STARTING FROM OUTSIDE CURB NODE NO. 1

1 2 3 4 5 6 7 8 8 23 38
53 68 68 66
64 62 60 58 56 54 54 39 24 9 1

OUTSIDE BARRIER NODE NUMBERS IN COUNTERCLOCKWISE SEQUENCE

WHEEL RADIUS-RADIAL SPRING FOR TABLE
RWHJB(BEGIN) = .000 INCHES
RWHJE(END) = 6.000 ''
DRWHJ(INCRE.) = .250 ''

0	RW-HJ IN.	FJP. LBS. RF	FJP. LBS. LF	FJP. LBS. RR	FJP. LBS. LR
0	.000	.000	.000	.000	.000
0	.250	59.0	59.0	59.0	59.0
0	.500	71.0	71.0	71.0	71.0
0	.750	86.1	86.1	86.1	86.1
0	1.00	100.	100.	100.	100.
0	1.25	116.	116.	116.	116.
0	1.50	124.	124.	124.	124.
0	1.75	131.	131.	131.	131.
0	2.00	151.	151.	151.	151.
0	2.25	142.	142.	142.	142.
0	2.50	173.	173.	173.	173.
0	2.75	159.	159.	159.	159.
0	3.00	184.	184.	184.	184.
0	3.25	185.	185.	185.	185.
0	3.50	191.	191.	191.	191.
0	3.75	202.	202.	202.	202.
0	4.00	206.	206.	206.	206.
0	4.25	209.	209.	209.	209.
0	4.50	438.	438.	438.	438.
0	4.75	693.	693.	693.	693.
0	5.00	822.	822.	822.	822.
0	5.25	937.	937.	937.	937.
0	5.50	.103E+04	.103E+04	.103E+04	.103E+04
0	5.75	.114E+04	.114E+04	.114E+04	.114E+04
0	6.00	.123E+04	.123E+04	.123E+04	.123E+04

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1
UNEXPECTED END OF FILE ENCOUNTERED IN STMT NO. 1 OF SUBROUTINE INPUT. LAST CARD READ WAS9999

NEMC-19 (6-in Type I curb/4500 lb Vehicle Model)

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1
Onemc 19 RD2SMN model                                                                0 100
00.0      1.5       .001      .001      70.0      0.0       0.0                      0 101
00.0      1.0       .001      0.0       0.0       0.0                         0.0    0 102
01.0                                                                                 0 103
01.0      1.0       1.0       1.0       1.0       1.0       1.0                      0 104
OVEHICLE DATA                                                                        0 200
09.934    0.619     0.989     4640.02 24622.    33387.    0.0       667.47           0 201
046.83    67.17     62.25     62.0      0.0       36.5                               0 202
0-3.17    0.0       1.62      0.0       0.0       0.0       11.62     11.62          0 203
0106.2    162.0     250.      162.0     20000.    0.5       -5.05     4.33           0 204
0169.3    185.0     200.      185.0     20000.    0.5       -8.76     5.05           0 205
03.66     5.00      12.1      10.2      1.17      36.0      0.1       1.0            0 206
05.30     12.5      1.94      20.0      1.94      30.0      5.30      1.8            0 207
04.00     5.0       9.99      10.1      1.61      50.0      0.1       1.0            0 208
06.67     12.5      1.62      20.0      1.62      30.0      6.67      1.8            0 209
0253362. 40000.                                                                      0 210
04920.    600.      0.40      5000.     0.075     1.50                               0 211
0-4.00    4.00      1.00      0.0       0.0                                          0 212
00.28     0.61      0.73      0.75      0.50      0.0       -0.83     -1.68     -2.0 1 212
OTIRE DATA                                                                           0 300
01.0      1.0       1.0       1.0       6.0       0.25                             0 301
01038.    5.55      10.       7404.61 6.69      2751.61 0.533     -6420.4 0.75     1 301
013.5     0.7       0.0       2000.     0.05      0.8       6.05      0.3            2 301
OGENERATED CURB SURFACE                                                              0 500
032.      0.        72.       95.       1.0                                          0 507
0-600.    -480.     0.        -600.     -120.     0.        -600.     24.       0.   1 507
0-600.    72.       0.        -600.     120.      0.        -600.     168.      0.   2 507
0-600.    171.36    0.        -600.     174.72    0.        -600.     177.76    0.   3 507
0-600.    180.      0.        -600.     300.      0.        -600.     480.      0.   4 507
0-360.    -480.     0.        -360.     -120.     0.        -360.     24.       0.   5 507
0-360.    72.       0.        -360.     120.      0.        -360.     168.      0.   6 507
0-360.    171.36    0.        -360.     174.72    0.        -360.     177.76    0.   7 507
0-360.    180.      0.        -360.     300.      0.        -360.     480.      0.   8 507
0-312.    -480.     0.        -312.     -120.     0.        -312.     24.       1.44 9 507
0-312.    72.       2.64      -312.     120.      3.12      -312.     168.      3.84 10 507
0-312.    171.36    3.12      -312      174.72    -0.36     -312.     177.76    -1.68 11 507
0-312.    180.      -2.16     -312.     300.      -6.96     -312.     480.      -14.16 12 507
0-264.    -480.     0.        -264.     -120.     0.        -264.     24.       2.16 13 507
0-264.    72.       3.6       -264.     120.      4.56      -264.     168.      5.16 14 507
0-264.    171.36    4.44      -264.     174.72    0.96      -264.     177.76    -0.36 15 507
0-264.    180.      -0.84     -264.     300.      -5.64     -264.     480.      -12.84 16 507
0168.     -480.     0.        168.      -120.     0.        168.      24.       5.29 17 507
0168.     72.       6.25      168.      120.      7.21      168.      168.      8.17 18 507
0168.     171.36    7.45      168.      174.72    3.97      168.      177.76    2.65 19 507
0168.     180.      2.17      168.      300.      -2.63     168.      480.      -9.83 20 507
0600.     -480.     0.        600.      -120.     0.        600.      24.       6.96 21 507
0600.     72.       7.92      600.      120.      8.88      600.      168.      9.84 22 507
0600.     171.36    9.12      600.      174.72    5.64      600.      177.76    4.32 23 507
0600.     180.      3.84      600.      300.      -0.96     600.      480.      -8.16 24 507
04.  4.   4.  4.  4.  4.  4.  4.  4.  4.  4.  4.  3.  3.  3.  3.  3.  3.          1 508
03.  3.   3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  4.  3.  3.  3.          2 508
03.  3.   3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  4.          3 508
03.  3.   3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.          4 508
03.  3.   4.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.          5 508
03.  3.   3.  3.  3.                                                              6 508
01.  0.   2.  2.  14. 12. 13. 0.  2.  0.  3.  3.  15. 14. 14. 1.  3.  0.          1 509
04.  4.   16. 16. 15. 2.  4.  0.  5.  5.  17. 18. 16. 3.  5.  0.  6.  6.          2 509
018. 20. 17. 4.  6.  0.  7.  7.  19. 22. 18. 5.  7.  0.  8.  8.  20. 24.          3 509
019. 6.  8.  0.  9.  9.  21. 26. 20. 7.  9.  0.  10. 10. 22. 28. 21. 8.           4 509
010. 0.  11. 11. 23. 30. 22. 9.  11. 0.  12. 0.  24. 32. 23. 10. 13. 1.           5 509
014. 13. 26. 33. 25. 0.  14. 14. 27. 34. 26. 12. 14. 2.  15. 15. 27. 13.          6 509
015. 16. 28. 36. 27. 14. 15. 3.  16. 17. 28. 15. 16. 18. 29. 38. 28. 16.          7 509
016. 4.  17. 19. 29. 17. 17. 20. 30. 40. 29. 18. 17. 5.  18. 21. 30. 19.          8 509
018. 22. 31. 42. 30. 20. 18. 6.  19. 23. 31. 21. 19. 24. 32. 44. 31. 22.          9 509
019. 7.  20. 25. 32. 23. 20. 26. 33. 46. 32. 24. 20. 8.  21. 27. 33. 25.         10 509
021. 28. 34. 48. 33. 26. 21. 9.  22. 29. 34. 27. 22. 30. 35. 50. 34. 28.         11 509
022. 10. 23. 31. 35. 29. 23. 32. 36. 52. 35. 30. 23. 11. 24. 0.  36. 31.         12 509
025. 12. 26. 34. 38. 54. 37. 0.  26. 13. 27. 35. 38. 33. 27. 36. 39. 56.         13 509
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038. 34. 27. 15. 28. 37. 39. 35. 28. 38. 40. 58. 39. 36. 28. 17. 29. 39.     14 509
040. 37. 29. 40. 41. 60. 40. 38. 29. 19. 30. 41. 41. 39. 30. 42. 42. 62.     15 509
041. 40. 30. 21. 31. 43. 42. 41. 31. 44. 43. 64. 42. 42. 31. 23. 32. 45.     16 509
043. 43. 32. 46. 44. 66. 43. 44. 32. 25. 33. 47. 44. 45. 33. 48. 45. 68.     17 509
044. 46. 33. 27. 34. 49. 45. 47. 34. 50. 46. 70. 45. 48. 34. 29. 35. 51.     18 509
046. 49. 35. 52. 47. 72. 46. 50. 35. 31. 36. 53. 47. 51. 36. 0.  48. 74.     19 509
047. 52. 37. 33. 38. 55. 50. 75. 49. 0.  38. 56. 51. 76. 50. 54. 38. 35.     20 509
039. 57. 51. 55. 39. 58. 52. 78. 51. 56. 39. 37. 40. 59. 52. 57. 40. 60.     21 509
053. 80. 52. 58. 40. 39. 41. 61. 53. 59. 41. 62. 54. 82. 53. 60. 41. 41.     22 509
042. 63. 54. 61. 42. 64. 55. 84. 54. 62. 42. 43. 43. 65. 55. 63. 43. 66.     23 509
056. 86. 55. 64. 43. 45. 44. 67. 56. 65. 44. 68. 57. 88. 56. 66. 44. 47.     24 509
045. 69. 57. 67. 45. 70. 58. 90. 57. 68. 45. 49. 46. 71. 58. 69. 46. 72.     25 509
059. 92. 58. 70. 46. 51. 47. 73. 59. 71. 47. 74. 60. 94. 59. 72. 47. 53.     26 509
048. 0.  60. 73. 49. 54. 50. 76. 62. 0.  61. 0.  50. 55. 51. 77. 62. 75.     27 509
051. 78. 63. 0.  62. 76. 51. 57. 52. 79. 63. 77. 52. 80. 64. 0.  63. 78.     28 509
052. 59. 53. 81. 64. 79. 53. 82. 65. 0.  64. 80. 53. 61. 54. 83. 65. 81.     29 509
054. 84. 66. 0.  65. 82. 54. 63. 55. 85. 66. 83. 55. 86. 67. 0.  66. 84.     30 509
055. 65. 56. 87. 67. 85. 56. 88. 68. 0.  67. 86. 56. 67. 57. 89. 68. 87.     31 509
057. 90. 69. 0.  68. 88. 57. 69. 58. 91. 69. 89. 58. 92. 70. 0.  69. 90.     32 509
058. 71. 59. 93. 70. 91. 59. 94. 71. 0.  70. 92. 59. 73. 60. 95. 71. 93.     33 509
060. 0.  72. 0.  71. 94.                                                     34 509
01.  1.  2.  2.  3.  3.  4.  4.  5.  5.  6.  6.  7.  7.  8.  8.  9.  9.      1 510
010. 10. 11. 11. 12. 11. 24. 32. 36. 53. 48. 74. 60. 95. 72. 95. 71. 93.      2 510
070. 91. 69. 89. 68. 87. 67. 85. 66. 83. 65. 81. 64. 79. 63. 77. 62. 75.      3 510
061. 75. 49. 54. 37. 33. 25. 12. 13. 1.                                       4 510
0initial conditions                                                           0 600
00.0     -0.15    18.3     0.0      -0.1     0.0      0.0      0.0            0 601
0-480.   17.29    -24.     919.2    0.0      0.0                              0 602
00.0     0.0      0.0      0.0      0.0      0.0      0.0      0.0            0 603
0                                                                             09999
1         nemc 19 RD2SMN model
          OCTOBER
    VEHICLE DATA                               TIRE DATA
    GENERATED CURB SURFACE                     initial conditions

0                    P R O G R A M   C O N T R O L   D A T A
         START TIME                    T0     =     .0000  SEC
         END TIME                      T1     =    1.5000  SEC
         INTEGRATION INCREMENT         DTCOMP =     .0010  SEC
                                                            (0=VARIABLE STEP ADAMS-MOULTON
         INTEGRATION MODE              MODE   =    1        -)1= RUNGA-KUTTA
                                                            (2= FIXED STEP ADAMS-MOULTON
         PRINT INTERVAL                DTPRNT =     .0010  SEC
0                                                           (0= INDEPENDENT FRONT SUSPENSION,
SOLID REAR AXLE
         SUSPENSION OPTION             ISUS   =    0        -)1= INDEPENDENT FRONT AND REAR
SUSPENSION
                                                            (2= SOLID FRONT AND REAR AXLES

                                                            (0= NO CURB, NO STEER DEGREE OF
FREEDOM
         CURB/STEER OPTION             INDCRB =    1        -)1= CURB
                                                            (-1=STEER DEGREE OF FREEDOM, NO CURB

         CURB INTEGRATION INCR.        DELTC  =   .00100  SEC
0                                                           (0= NO BARRIER
                                                            |1= RIGID BARRIER , FINITE VERT. DIM.

         BARRIER OPTION                INDB   =    0        -)2=  ''     ''   ,INFINITE  ''    ''

                                                            |3= DEFORM. ''    , FINITE   ''    ''

                                                            (4=   ''     ''   ,INFINITE  ''    ''

         BARRIER INTEGRATION INCR.     DELTB  =   .00000  SEC
0
         SIGN IMPACT OPTION            COLL   =   0.         ( 0 = NO : 1 = YES

0
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                                                   I N I T I A L   C O N D I T I O N S

                                         XCOP   = -480.00   INCHES
   U0    =  919.20    IN/SEC
          SPRUNG MASS C.G. POSITION      YCOP   =   17.29   INCHES        SPRUNG MASS LINEAR
VELOCITY    V0   =      .00    IN/SEC
                                         ZCOP   =  -24.00   INCHES
   W0    =     .00    IN/SEC
0                                        PHI0   =     .00   DEGREES
   P0    =     .00   DEG/SEC
          SPRUNG MASS ORIENTATION        THETA0 =    -.15   DEGREES       SPRUNG MASS ANGULAR
VELOCITY    Q0   =     -.10    DEG/SEC
                                         PSI0   =   18.30   DEGREES
   R0    =     .00   DEG/SEC
0                                        DEL10  =     .00   INCHES
  DEL10D =     .00    IN/SEC
          UNSPRUNG MASS POSITIONS        DEL20  =     .00   INCHES        UNSPRUNG MASS VELOCITIES
  DEL20D =     .00    IN/SEC
0                                        DEL30  =     .00   INCHES
  DEL30D =     .00    IN/SEC
                                         PHIR0  =     .00   DEGREES
  PHIR0D =     .00   DEG/SEC
          STEER ANGLE                    PSIFI0 =     .00   DEGREES       STEER VELOCITY
  PSIFD0 =     .00   DEG/SEC
1         nemc 19 RD2SMN model
          OCTOBER
    VEHICLE DATA                             TIRE DATA
    GENERATED CURB SURFACE                   initial conditions

0         SPRUNG MASS                    XMS    =      9.934 LB-SEC**2/IN   FRONT WHEEL X LOCATION
A     =   46.830 INCHES
          FRONT UNSPRUNG MASS            XMUF   =       .619 LB-SEC**2/IN   REAR WHEEL X LOCATION
B     =   67.170 INCHES
          REAR UNSPRUNG MASS             XMUR   =       .989 LB-SEC**2/IN   FRONT WHEEL Z LOCATION
ZF    =   11.620 INCHES
0         X MOMENT OF INERTIA            XIX    =   4640.020 LB-SEC**2-IN   REAR WHEEL Z LOCATION
ZR    =   11.620 INCHES
          Y MOMENT OF INERTIA            XIY    =  24622.000 LB-SEC**2-IN   FRONT WHEEL TRACK
TF    =   62.250 INCHES
          Z MOMENT OF INERTIA            XIZ    =  33387.000 LB-SEC**2-IN   REAR WHEEL TRACK
TR    =   62.000 INCHES
          XZ PRODUCT OF INERTIA          XIXZ   =       .000 LB-SEC**2-IN   FRONT ROLL AXIS
RHOF  =     .000 NOT USED
0         FRONT AXLE MOMENT OF INERTIA   XIF    =       .000 NOT USED       REAR ROLL AXIS
RHO   =     .000 INCHES
          REAR AXLE MOMENT OF INERTIA    XIR    =    667.470 LB-SEC**2-IN   FRONT SPRING TRACK
TSF   =     .000 NOT USED
          GRAVITY                        G      =    386.400 IN/SEC**2      REAR SPRING TRACK
TS    =   36.500 INCHES
0                                        X1     =      -3.17 INCHES         FRONT AUX ROLL STIFFNESS
RF    = 253362.00 LB-IN/RAD
          ACCELEROMETER 1 POSITION       Y1     =        .00 INCHES         REAR AUX ROLL STIFFNESS
RR    =  40000.00 LB-IN/RAD
                                         Z1     =       1.62 INCHES         REAR ROLL-STEER COEF.
AKRS  =    .0000 RAD/RAD
                                         X2     =        .00 INCHES
AKDS  =     .000 NOT USED
          ACCELEROMETER 2 POSITION       Y2     =        .00 INCHES         REAR DEFL-STEER COEFS.
AKDS1=      .000 NOT USED
                                         Z2     =        .00 INCHES
AKDS2=      .000 NOT USED

AKDS3=      .000 NOT USED
0              S T E E R I N G   S Y S T E M
          MOMENT OF INERTIA          XIPS  =  4920.000 LB-SEC**2-IN
          COULOMB FRICTION TORQUE    CPSP  =   600.000 LB-IN
          FRICTION LAG               EPSP  =      .075 RAD/SEC
          ANGULAR STOP RATE          AKPS  =  5000.000 LB-IN/RAD
          ANGULAR STOP POSITION      OMGPS =      .400 RADIANS
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          PNEUMATIC TRAIL          XPS    =     1.500 INCHES
0                                        FRONT SUSPENSION                          REAR SUSPENSION

          SUSPENSION RATE                     AKF     =    106.200 LB/IN          AKR     =    169.300
LB/IN
          COMPRESSION STOP COEFS.             AKFC    =    162.000 LB/IN          AKRC    =    185.000
LB/IN
                                              AKFCP   =    250.000 LB/IN**3       AKRCP   =    200.000
LB/IN**3
0         EXTENSION STOP COEFS.               AKFE    =    162.000 LB/IN          AKRE    =    185.000
LB/IN
                                              AKFEP   = 20000.000 LB/IN**3        AKREP   = 20000.000
LB/IN**3
          COMPRESSION STOP LOCATION           OMEGFC =     -5.050 INCHES          OMEGRC =      -8.760
INCHES
          EXTENSION STOP LOCATION             OMEGFE =      4.330 INCHES          OMEGRE =       5.050
INCHES
0         STOP ENERGY DISSIPATION FACTOR      XLAMF   =      .500                 XLAMR   =       .500
          COMP. VISC. DAMP. COEF. NO. 1       CFJ(1) =      3.660 LB-SEC/IN       CRJ(1) =       4.000
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 1       DLFJ(1)=      5.000 IN/SEC          DLRJ(1)=       5.000
IN/SEC
          COMP. VISC. DAMP. COEF. NO. 2       CFJ(2) =     12.100 LB-SEC/IN       CRJ(2) =       9.990
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 2       DLFJ(2)=     10.200 IN/SEC          DLRJ(2)=      10.100
IN/SEC
          COMP. VISC. DAMP. COEF. NO. 3       CFJ(3) =      1.170 LB-SEC/IN       CRJ(3) =       1.610
LB-SEC/IN
0          EXTN. VISC. DAMP. COEF. NO. 1       CFR(1) =      5.300 LB-SEC/IN       CRR(1) =       6.670
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 1       DLFR(1)=     12.500 IN/SEC          DLRR(1)=      12.500
IN/SEC
          EXTN. VISC. DAMP. COEF. NO. 2       CFR(2) =      1.940 LB-SEC/IN       CRR(2) =       1.620
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 2       DLFR(2)=     20.000 IN/SEC          DLRR(2)=      20.000
IN/SEC
          EXTN. VISC. DAMP. COEF. NO. 3       CFR(3) =      1.940 LB-SEC/IN       CRR(3) =       1.620
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 3       DLFR(3)=     30.000 IN/SEC          DLRR(3)=      30.000
IN/SEC
0          EXTN. VISC. DAMP. COEF. NO. 4       CFR(4) =      5.300 LB-SEC/IN       CRR(4) =       6.670
LB-SEC/IN
          COULOMB FRICTION                    CFP     =     36.000 LB             CRP     =     50.000 LB

          FRICTION LAG                        EPSF    =       .100 IN/SEC         EPSR    =       .100
IN/SEC
          POWER IN POWER LAW DAMPING          POWF    =     1.800                 POWR    =      1.800
1         nemc 19 RD2SMN model
          OCTOBER
     VEHICLE DATA                                  TIRE DATA
     GENERATED CURB SURFACE                        initial conditions

0          FRONT WHEEL CAMBER        REAR WHEEL CAMBER       FRONT HALF-TRACK CHANGE     REAR
HALF-TRACK CHANGE
                  VS                         VS                         VS                        VS
         SUSPENSION DEFLECTION     SUSPENSION DEFLECTION     SUSPENSION DEFLECTION      SUSPENSION
DEFLECTION

           DELTAF      PHIC         DELTAR     PHIRC          DELTAF      DTHF            DELTAR
DTHR
           INCHES     DEGREES       NOT USED  NOT USED        INCHES     INCHES          NOT USED
NOT USED
0          -4.00        .28          -4.00       .00          -4.00        .00            -4.00
.00
           -3.00        .61          -3.00       .00          -3.00        .00            -3.00
.00
           -2.00        .73          -2.00       .00          -2.00        .00            -2.00
.00
           -1.00        .75          -1.00       .00          -1.00        .00            -1.00
```

```
.00
         .00     .50        .00     .00         .00     .00        .00
.00
        1.00     .00       1.00     .00        1.00     .00       1.00
.00
        2.00    -.83       2.00     .00        2.00     .00       2.00
.00
        3.00   -1.68       3.00     .00        3.00     .00       3.00
.00
        4.00   -2.00       4.00     .00        4.00     .00       4.00
.00
1        nemc 19 RD2SMN model
         OCTOBER
    VEHICLE DATA                          TIRE DATA
    GENERATED CURB SURFACE                initial conditions

0                                                    T I R E   D A T A
                                                RF          LF          RR          LR
0        TIRE LINEAR SPRING RATE      AKT   =  1038.000    1038.000    1038.000    1038.000
LB/IN
         DEFL. FOR INCREASED RATE     SIGT  =     5.550       5.550       5.550       5.550
INCHES
         SPRING RATE INCREASING FACTOR XLAMT =   10.000      10.000      10.000      10.000
                                      A0    =  7404.610    7404.610    7404.610    7404.610
                                      A1    =     6.690       6.690       6.690       6.690
         SIDE FORCE COEFFICIENTS      A2    =  2751.610    2751.610    2751.610    2751.610
                                      A3    =      .533        .533        .533        .533
                                      A4    = -6420.400   -6420.400   -6420.400   -6420.400
         TIRE OVERLOAD FACTOR         OMEGT =      .750        .750        .750        .750
         TIRE UNDEFLECTED RADIUS      RW    =    13.500      13.500      13.500      13.500
INCHES
         TIRE / GROUND FRICTION COEF. AMU   =      .700        .700        .700        .700
         TIRE DAMPING PARAMETER       ANUT  =      .000        .000        .000        .000  SEC
         TIRE RIM STIFFNESS TERM      AKTR  =  2000.000    2000.000    2000.000    2000.000
LB/IN
         RIM FORCE VELOCITY COEF.     CTR   =      .050        .050        .050        .050
         RIM FORCE POWER TERM         PTR   =      .800        .800        .800        .800
         TIRE DEFLECTION TO THE RIM   RDR   =     6.050       6.050       6.050       6.050
INCHES
         RIM / CURB FRICTION COEFF.   AMURC =      .300        .300        .300        .300
         FRICTION LAG FOR RIM FRICION EPSVR =      .000

0NO ANTI-PITCH TABLES
1        nemc 19 RD2SMN model
         OCTOBER
    VEHICLE DATA                          TIRE DATA
    GENERATED CURB SURFACE                initial conditions

0             C U R B / B A R R I E R   D A T A


         CURB FRICTION COEFFICIENT FACTOR    AMUC  =   1.000


         NODE LOCATIONS & NO. OF NODES CONNECTED


         NODE                    LOCATION                  NO. OF NODES
         NO.      X'(INCHES)    Y'(INCHES)    Z'(INCHES)    CONNECTED

          1        -600.00       -480.00         .00         2
          2        -600.00       -120.00         .00         3
          3        -600.00         24.00         .00         3
          4        -600.00         72.00         .00         3
          5        -600.00        120.00         .00         3
          6        -600.00        168.00         .00         3
          7        -600.00        171.36         .00         3
          8        -600.00        174.72         .00         3
          9        -600.00        177.76         .00         3
```

10	-600.00	180.00	.00	3
11	-600.00	300.00	.00	3
12	-600.00	480.00	.00	2
13	-360.00	-480.00	.00	3
14	-360.00	-120.00	.00	5
15	-360.00	24.00	.00	5
16	-360.00	72.00	.00	5
17	-360.00	120.00	.00	5
18	-360.00	168.00	.00	5
19	-360.00	171.36	.00	5
20	-360.00	174.72	.00	5
21	-360.00	177.76	.00	5
22	-360.00	180.00	.00	5
23	-360.00	300.00	.00	5
24	-360.00	480.00	.00	3
25	-312.00	-480.00	.00	3
26	-312.00	-120.00	.00	4
27	-312.00	24.00	1.44	6
28	-312.00	72.00	2.64	6
29	-312.00	120.00	3.12	6
30	-312.00	168.00	3.84	6
31	-312.00	171.36	3.12	6
32	-312.00	174.72	-.36	6
33	-312.00	177.76	-1.68	6
34	-312.00	180.00	-2.16	6
35	-312.00	300.00	-6.96	6
36	-312.00	480.00	-14.16	5
37	-264.00	-480.00	.00	3
38	-264.00	-120.00	.00	6
39	-264.00	24.00	2.16	6
40	-264.00	72.00	3.60	6
41	-264.00	120.00	4.56	6
42	-264.00	168.00	5.16	6
43	-264.00	171.36	4.44	6
44	-264.00	174.72	.96	6
45	-264.00	177.76	-.36	6
46	-264.00	180.00	-.84	6
47	-264.00	300.00	-5.64	6
48	-264.00	480.00	-12.84	3
49	168.00	-480.00	.00	3
50	168.00	-120.00	.00	4
51	168.00	24.00	5.29	6
52	168.00	72.00	6.25	6
53	168.00	120.00	7.21	6
54	168.00	168.00	8.17	6
55	168.00	171.36	7.45	6
56	168.00	174.72	3.97	6
57	168.00	177.76	2.65	6
58	168.00	180.00	2.17	6
59	168.00	300.00	-2.63	6
60	168.00	480.00	-9.83	5
61	600.00	-480.00	.00	2
62	600.00	-120.00	.00	4
63	600.00	24.00	6.96	4
64	600.00	72.00	7.92	4
65	600.00	120.00	8.88	4
66	600.00	168.00	9.84	4
67	600.00	171.36	9.12	4
68	600.00	174.72	5.64	4
69	600.00	177.76	4.32	4
70	600.00	180.00	3.84	4
71	600.00	300.00	-.96	4
72	600.00	480.00	-8.16	2

ELEMENT SLOPES, ORIENTATIONS AND NO. OF SIDES

ELEM. NO.	SLOPE,PHIS (DEG.)	ORIENTN.,PSIS (DEG.)	NO. OF SIDES

1	.00	.00	4
2	.00	.00	4
3	.00	.00	4
4	.00	.00	4
5	.00	.00	4
6	.00	.00	4
7	.00	.00	4
8	.00	.00	4
9	.00	.00	4
10	.00	.00	4
11	.00	.00	4
12	.00	.00	4
13	-.57	180.00	3
14	-1.72	90.00	3
15	-2.24	129.81	3
16	-3.15	90.00	3
17	-3.20	100.30	3
18	-3.72	90.00	3
19	-3.82	102.99	3
20	-4.57	90.00	3
21	-12.88	20.47	3
22	-3.72	90.00	3
23	-46.06	3.59	3
24	-.43	-90.00	3
25	-23.47	-.99	3
26	-2.00	-90.00	3
27	-12.25	-9.28	3
28	-2.58	-90.00	3
29	-3.45	-48.37	3
30	-8.25	-90.00	3
31	-8.55	-74.58	3
32	-16.44	-90.00	3
33	.00	.00	4
34	-.57	180.00	3
35	-1.22	135.00	3
36	-1.67	149.04	3
37	-2.06	146.31	3
38	-1.28	116.57	3
39	-2.06	123.69	3
40	-1.92	116.57	3
41	-1.73	114.44	3
42	-12.19	7.31	3
43	-12.19	7.31	3
44	-46.02	1.52	3
45	-46.02	1.52	3
46	-23.51	3.62	3
47	-23.51	3.62	3
48	-12.19	7.31	3
49	-12.19	7.31	3
50	-2.78	34.51	3
51	-2.78	34.51	3
52	-2.78	34.51	3
53	-2.78	34.51	3
54	.00	.00	4
55	-2.10	180.00	3
56	-.95	154.22	3
57	-1.22	160.09	3
58	-1.75	168.44	3
59	-1.20	162.95	3
60	-1.20	162.95	3
61	-1.20	162.95	3
62	-.82	150.86	3
63	-12.10	1.86	3
64	-12.10	1.86	3
65	-46.01	.39	3
66	-46.01	.39	3
67	-23.47	.92	3
68	-23.47	.92	3
69	-12.10	1.86	3

70	-12.10	1.86	3
71	-2.33	9.88	3
72	-2.33	9.88	3
73	-2.33	9.88	3
74	-2.33	9.88	3
75	.00	.00	4
76	-2.10	180.00	3
77	-2.78	175.43	3
78	-1.17	169.06	3
79	-1.17	169.06	3
80	-1.17	169.06	3
81	-1.17	169.06	3
82	-1.17	169.06	3
83	-1.17	169.06	3
84	-12.10	1.03	3
85	-12.10	1.03	3
86	-46.01	.21	3
87	-46.01	.21	3
88	-23.47	.51	3
89	-23.47	.51	3
90	-12.10	1.03	3
91	-12.10	1.03	3
92	-2.30	5.52	3
93	-2.30	5.52	3
94	-2.30	5.52	3
95	-2.30	5.52	3

ELEMENT NODE NUMBERS

ELEMENT NO.	NODES IN COUNTERCLOCKWISE SEQUENCE			
1	1	2	14	13
2	2	3	15	14
3	3	4	16	15
4	4	5	17	16
5	5	6	18	17
6	6	7	19	18
7	7	8	20	19
8	8	9	21	20
9	9	10	22	21
10	10	11	23	22
11	11	12	24	23
12	13	14	26	25
13	14	27	26	
14	14	15	27	
15	15	28	27	
16	15	16	28	
17	16	29	28	
18	16	17	29	
19	17	30	29	
20	17	18	30	
21	18	31	30	
22	18	19	31	
23	19	32	31	
24	19	20	32	
25	20	33	32	
26	20	21	33	
27	21	34	33	
28	21	22	34	
29	22	35	34	
30	22	23	35	
31	23	36	35	
32	23	24	36	
33	25	26	38	37
34	26	27	38	
35	27	39	38	
36	27	28	39	
37	28	40	39	

38	28	29	40	
39	29	41	40	
40	29	30	41	
41	30	42	41	
42	30	31	42	
43	31	43	42	
44	31	32	43	
45	32	44	43	
46	32	33	44	
47	33	45	44	
48	33	34	45	
49	34	46	45	
50	34	35	46	
51	35	47	46	
52	35	36	47	
53	36	48	47	
54	37	38	50	49
55	38	51	50	
56	38	39	51	
57	39	52	51	
58	39	40	52	
59	40	53	52	
60	40	41	53	
61	41	54	53	
62	41	42	54	
63	42	55	54	
64	42	43	55	
65	43	56	55	
66	43	44	56	
67	44	57	56	
68	44	45	57	
69	45	58	57	
70	45	46	58	
71	46	59	58	
72	46	47	59	
73	47	60	59	
74	47	48	60	
75	49	50	62	61
76	50	51	62	
77	51	63	62	
78	51	52	63	
79	52	64	63	
80	52	53	64	
81	53	65	64	
82	53	54	65	
83	54	66	65	
84	54	55	66	
85	55	67	66	
86	55	56	67	
87	56	68	67	
88	56	57	68	
89	57	69	68	
90	57	58	69	
91	58	70	69	
92	58	59	70	
93	59	71	70	
94	59	60	71	
95	60	72	71	

NODAL CONNECTIVITY

NODE NO.	NODES CONNECTED IN COUNTERCLOCKWISE SEQUENCE		
1	2	13	
2	3	14	1
3	4	15	2
4	5	16	3
5	6	17	4

6	7	18	5			
7	8	19	6			
8	9	20	7			
9	10	21	8			
10	11	22	9			
11	12	23	10			
12	24	11				
13	1	14	25			
14	2	15	27	26	13	
15	3	16	28	27	14	
16	4	17	29	28	15	
17	5	18	30	29	16	
18	6	19	31	30	17	
19	7	20	32	31	18	
20	8	21	33	32	19	
21	9	22	34	33	20	
22	10	23	35	34	21	
23	11	24	36	35	22	
24	36	23	12			
25	13	26	37			
26	14	27	38	25		
27	14	15	28	39	38	26
28	15	16	29	40	39	27
29	16	17	30	41	40	28
30	17	18	31	42	41	29
31	18	19	32	43	42	30
32	19	20	33	44	43	31
33	20	21	34	45	44	32
34	21	22	35	46	45	33
35	22	23	36	47	46	34
36	48	47	35	23	24	
37	25	38	49			
38	26	27	39	51	50	37
39	27	28	40	52	51	38
40	28	29	41	53	52	39
41	29	30	42	54	53	40
42	30	31	43	55	54	41
43	31	32	44	56	55	42
44	32	33	45	57	56	43
45	33	34	46	58	57	44
46	34	35	47	59	58	45
47	35	36	48	60	59	46
48	60	47	36			
49	37	50	61			
50	38	51	62	49		
51	38	39	52	63	62	50
52	39	40	53	64	63	51
53	40	41	54	65	64	52
54	41	42	55	66	65	53
55	42	43	56	67	66	54
56	43	44	57	68	67	55
57	44	45	58	69	68	56
58	45	46	59	70	69	57
59	46	47	60	71	70	58
60	72	71	59	47	48	
61	49	62				
62	61	50	51	63		
63	62	51	52	64		
64	63	52	53	65		
65	64	53	54	66		
66	65	54	55	67		
67	66	55	56	68		
68	67	56	57	69		
69	68	57	58	70		
70	69	58	59	71		
71	70	59	60	72		
72	71	60				

ELEMENT CONNECTIVITY (0 = OUTSIDE EDGE)

ELEMENT NO. ELEMENTS CONNECTED TO EACH SIDE IN COUNTERCLOCKWISE SEQUENCE (SIDE 1 STARTS FROM NODE 1)

1	0	2	12	0
2	0	3	14	1
3	0	4	16	2
4	0	5	18	3
5	0	6	20	4
6	0	7	22	5
7	0	8	24	6
8	0	9	26	7
9	0	10	28	8
10	0	11	30	9
11	0	0	32	10
12	1	13	33	0
13	14	34	12	
14	2	15	13	
15	16	36	14	
16	3	17	15	
17	18	38	16	
18	4	19	17	
19	20	40	18	
20	5	21	19	
21	22	42	20	
22	6	23	21	
23	24	44	22	
24	7	25	23	
25	26	46	24	
26	8	27	25	
27	28	48	26	
28	9	29	27	
29	30	50	28	
30	10	31	29	
31	32	52	30	
32	11	0	31	
33	12	34	54	0
34	13	35	33	
35	36	56	34	
36	15	37	35	
37	38	58	36	
38	17	39	37	
39	40	60	38	
40	19	41	39	
41	42	62	40	
42	21	43	41	
43	44	64	42	
44	23	45	43	
45	46	66	44	
46	25	47	45	
47	48	68	46	
48	27	49	47	
49	50	70	48	
50	29	51	49	
51	52	72	50	
52	31	53	51	
53	0	74	52	
54	33	55	75	0
55	56	76	54	
56	35	57	55	
57	58	78	56	
58	37	59	57	
59	60	80	58	
60	39	61	59	
61	62	82	60	
62	41	63	61	
63	64	84	62	
64	43	65	63	

65	66	86	64	
66	45	67	65	
67	68	88	66	
68	47	69	67	
69	70	90	68	
70	49	71	69	
71	72	92	70	
72	51	73	71	
73	74	94	72	
74	53	0	73	
75	54	76	0	0
76	55	77	75	
77	78	0	76	
78	57	79	77	
79	80	0	78	
80	59	81	79	
81	82	0	80	
82	61	83	81	
83	84	0	82	
84	63	85	83	
85	86	0	84	
86	65	87	85	
87	88	0	86	
88	67	89	87	
89	90	0	88	
90	69	91	89	
91	92	0	90	
92	71	93	91	
93	94	0	92	
94	73	95	93	
95	0	0	94	

OUTSIDE CURB NODE NUMBERS IN COUNTERCLOCKWISE SEQUENCE

```
              1      2      3      4      5      6      7      8      9     10     11
12     24     36     48
       60     72     71     70     69     68     67     66     65     64     63     62
61     49     37
       25     13
```

OUTSIDE CURB ELEMENTS IN COUNTERCLOCKWISE ,SEQUENCE STARTING FROM OUTSIDE CURB NODE NO. 1

```
              1      2      3      4      5      6      7      8      9     10     11
11     32     53     74
       95     95     93     91     89     87     85     83     81     79     77     75
75     54     33
       12      1
```

OUTSIDE BARRIER NODE NUMBERS IN COUNTERCLOCKWISE SEQUENCE

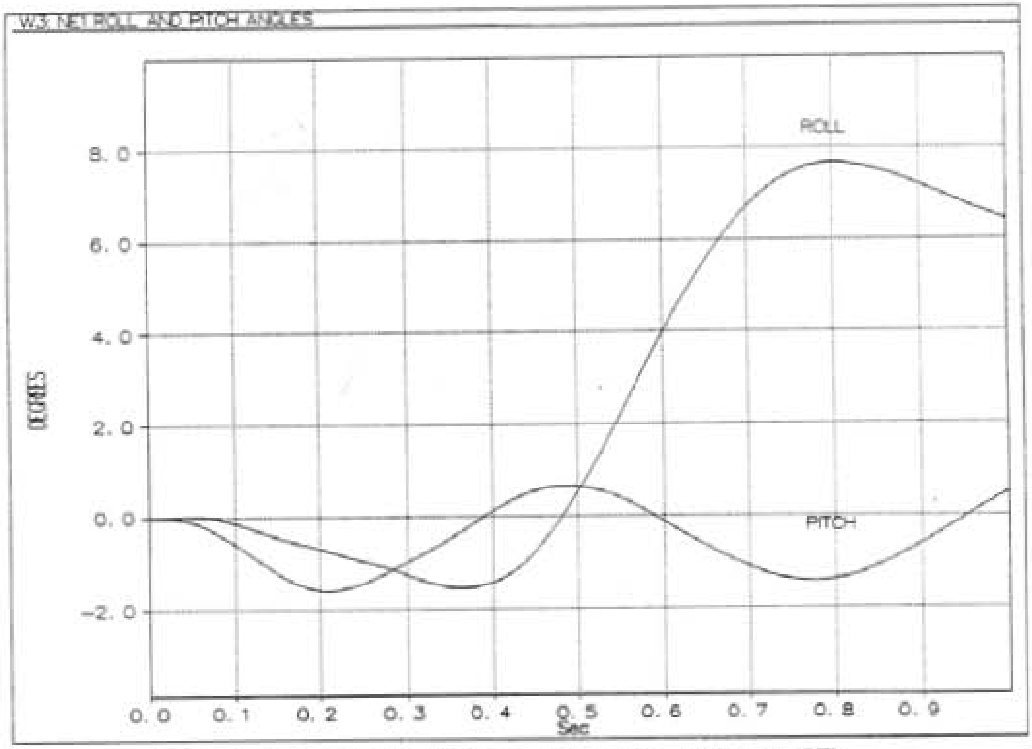
WHEEL RADIUS-RADIAL SPRING FOR TABLE
RWHJB(BEGIN) = .000 INCHES
RWHJE(END) = 6.000 ''
DRWHJ(INCRE.) = .250 ''

0	RW-HJ IN.	FJP. LBS. RF	FJP. LBS. LF	FJP. LBS. RR	FJP. LBS. LR
0	.000	.000	.000	.000	.000
0	.250	70.4	70.4	70.4	70.4
0	.500	84.7	84.7	84.7	84.7

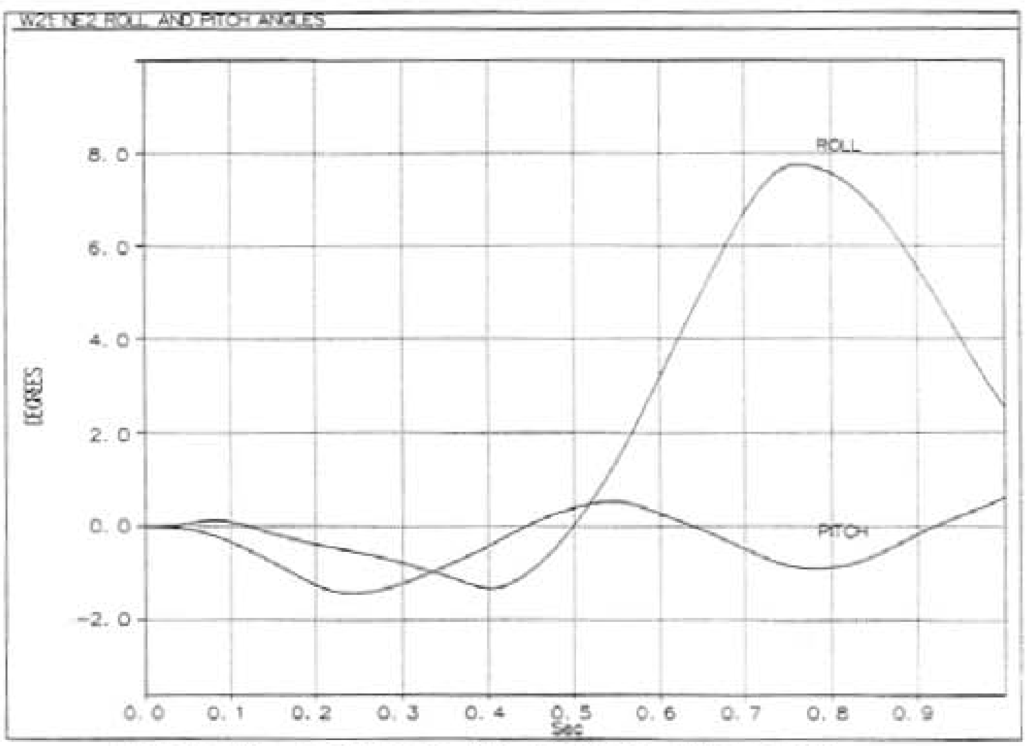
```
0 .750     103.      103.      103.      103.
0 1.00     119.      119.      119.      119.
0 1.25     139.      139.      139.      139.
0 1.50     148.      148.      148.      148.
0 1.75     156.      156.      156.      156.
0 2.00     180.      180.      180.      180.
0 2.25     170.      170.      170.      170.
0 2.50     206.      206.      206.      206.
0 2.75     189.      189.      189.      189.
0 3.00     219.      219.      219.      219.
0 3.25     220.      220.      220.      220.
0 3.50     228.      228.      228.      228.
0 3.75     240.      240.      240.      240.
0 4.00     246.      246.      246.      246.
0 4.25     249.      249.      249.      249.
0 4.50     272.      272.      272.      272.
0 4.75     260.      260.      260.      260.
0 5.00     280.      280.      280.      280.
0 5.25     286.      286.      286.      286.
0 5.50     285.      285.      285.      285.
0 5.75     694.      694.      694.      694.
0 6.00     871.      871.      871.      871.
1
1
 UNEXPECTED END OF FILE ENCOUNTERED IN STMT NO. 1 OF SUBROUTINE INPUT.  LAST CARD READ WAS9999
```

APPENDIX D:

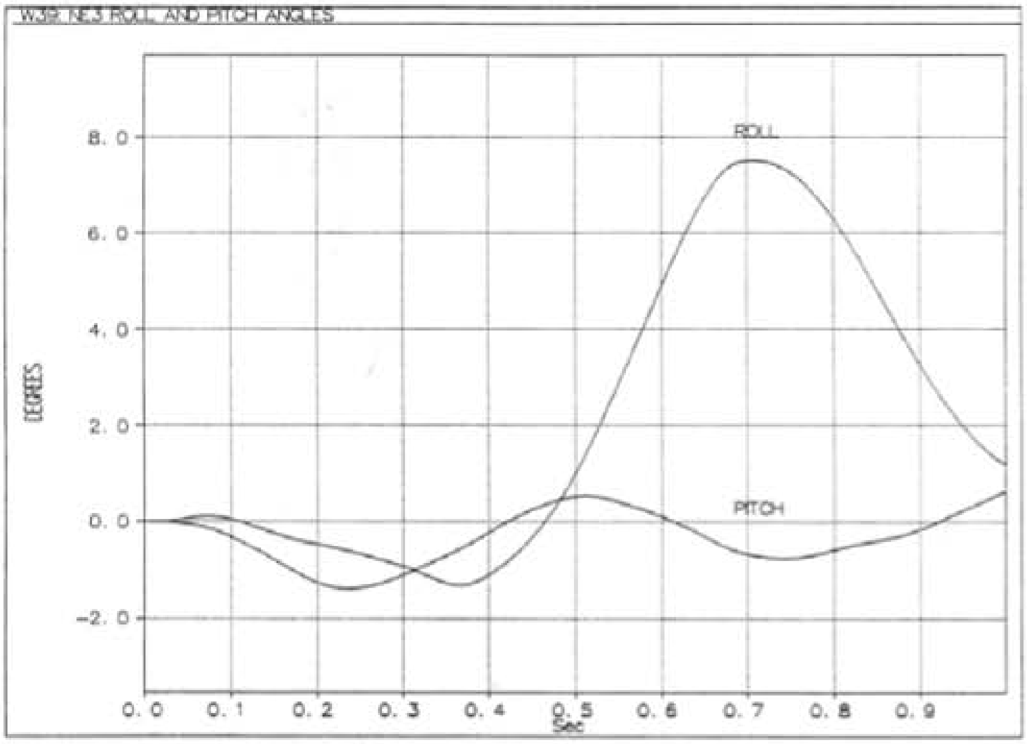
Simulated Angular Displacements (NE 1-31)



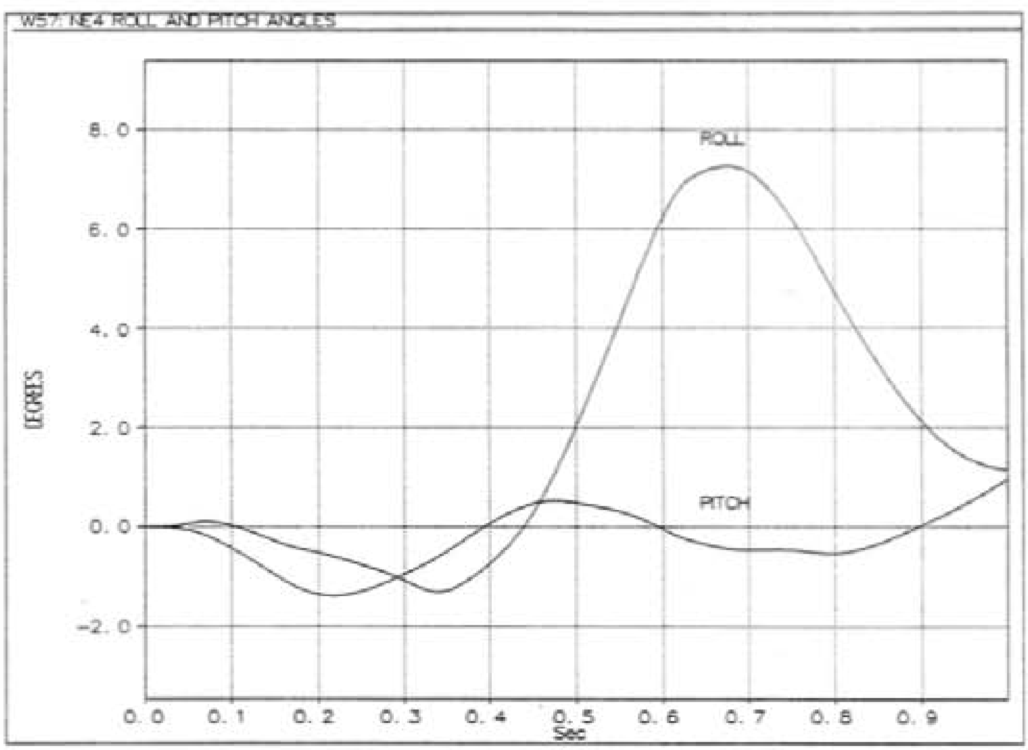
NE1(4L,4500LB,5.0DEG,55MPH)



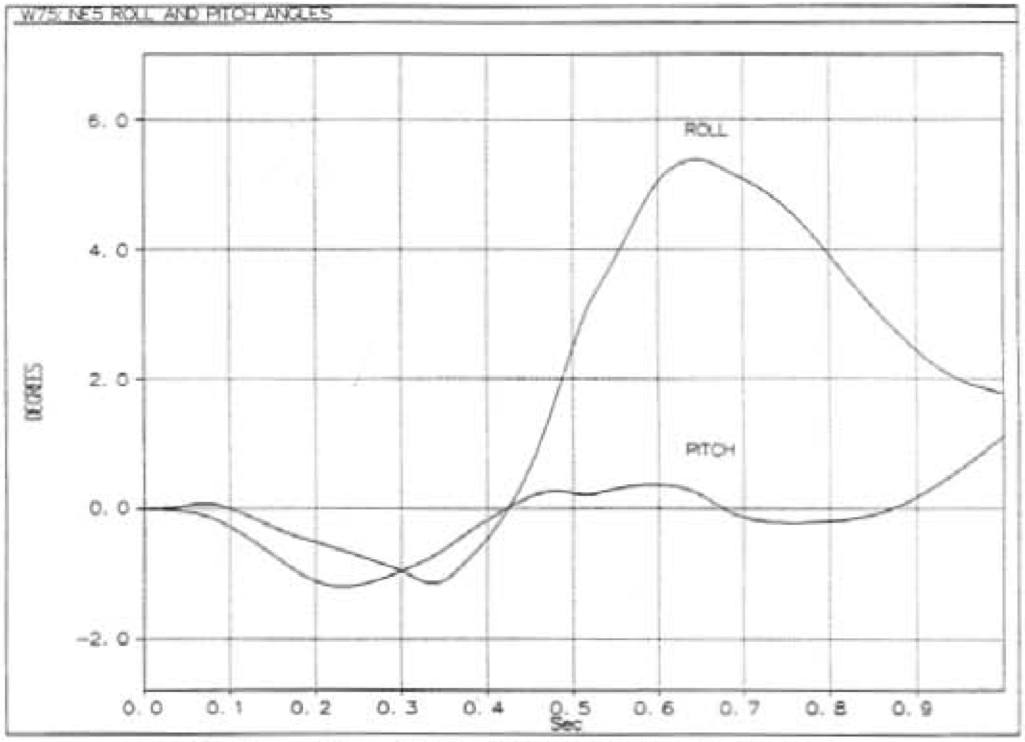
NE2(4L,4500LB,12.5DEG,45MPH)



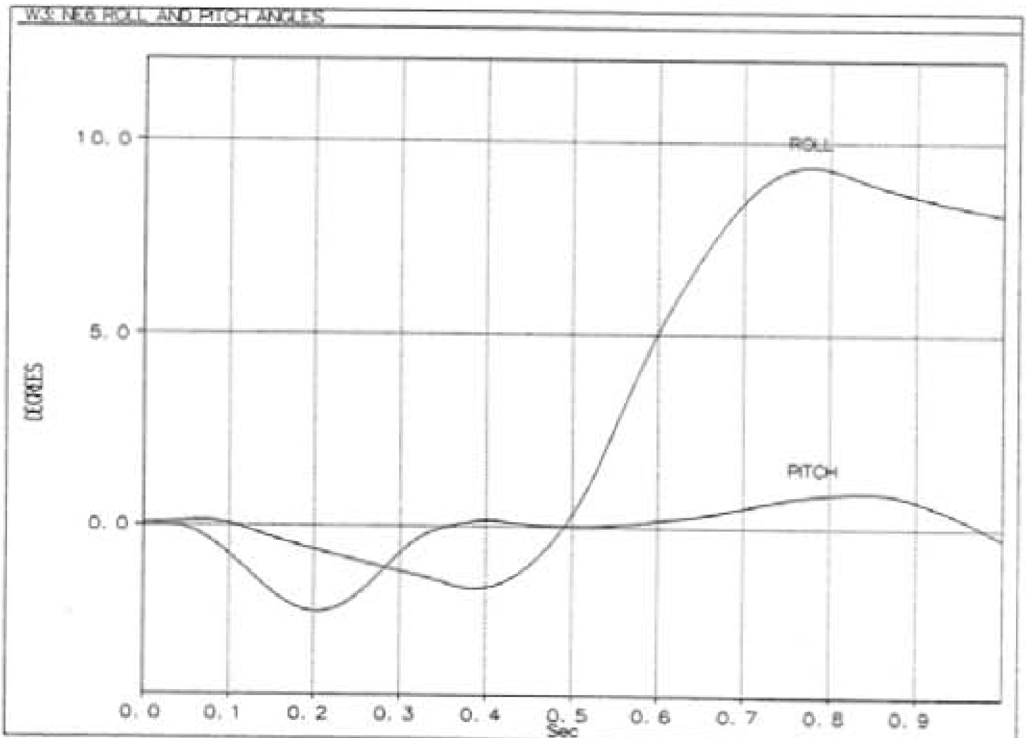
NE3(4L,4500LB,12.5DEG,50MPH)



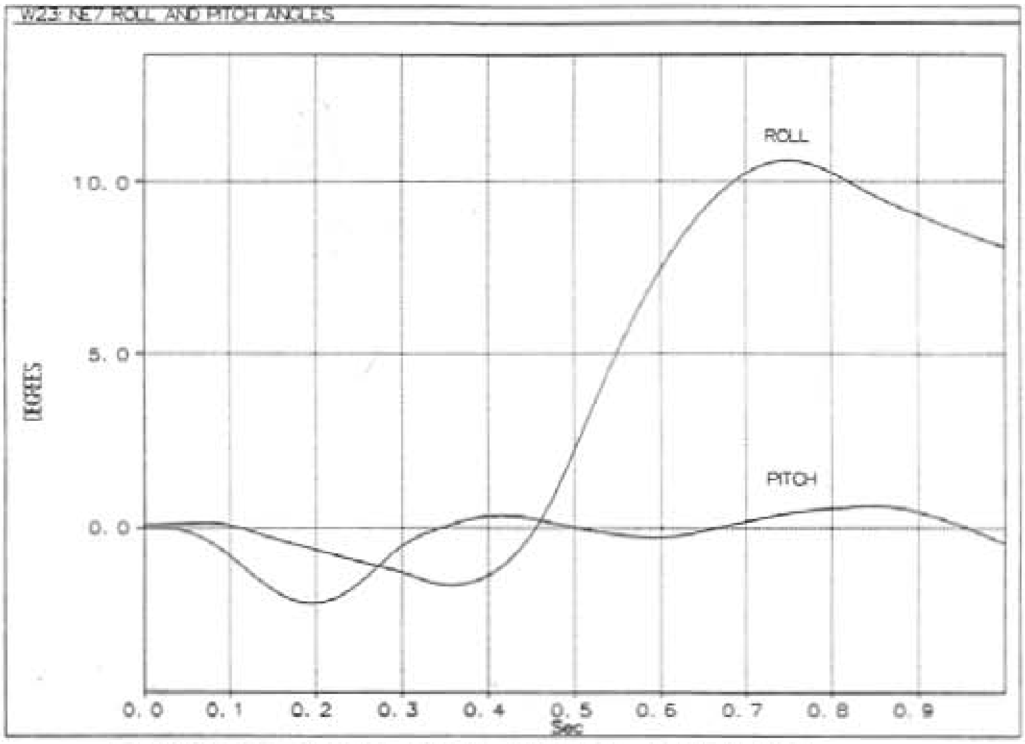
NE4(4L,4500LB,12.5DEG,55MPH)



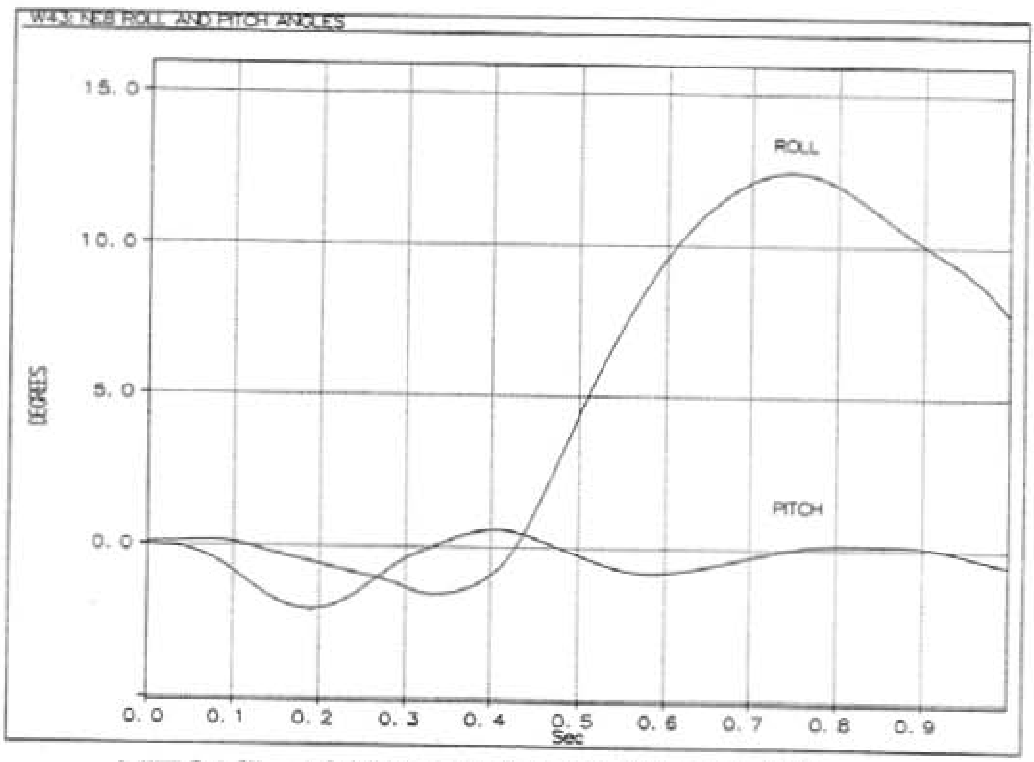
NE5(4L,4500LB,20.0DEG,55MPH)



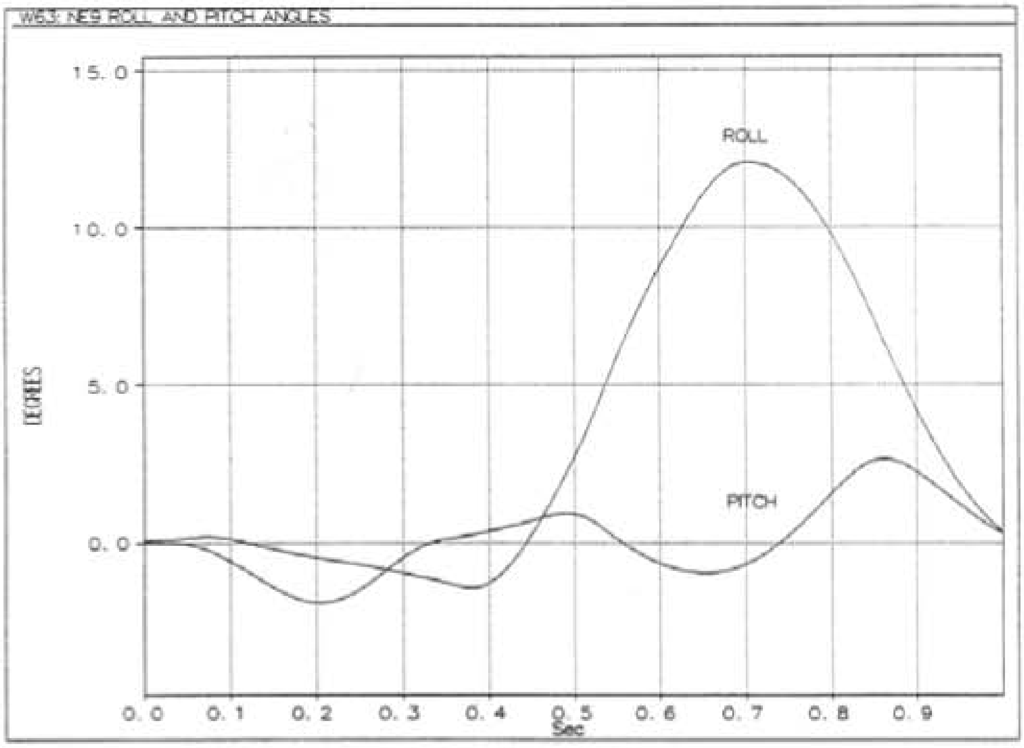
NE6(6L,1800LB,5.0DEG,45MPH)



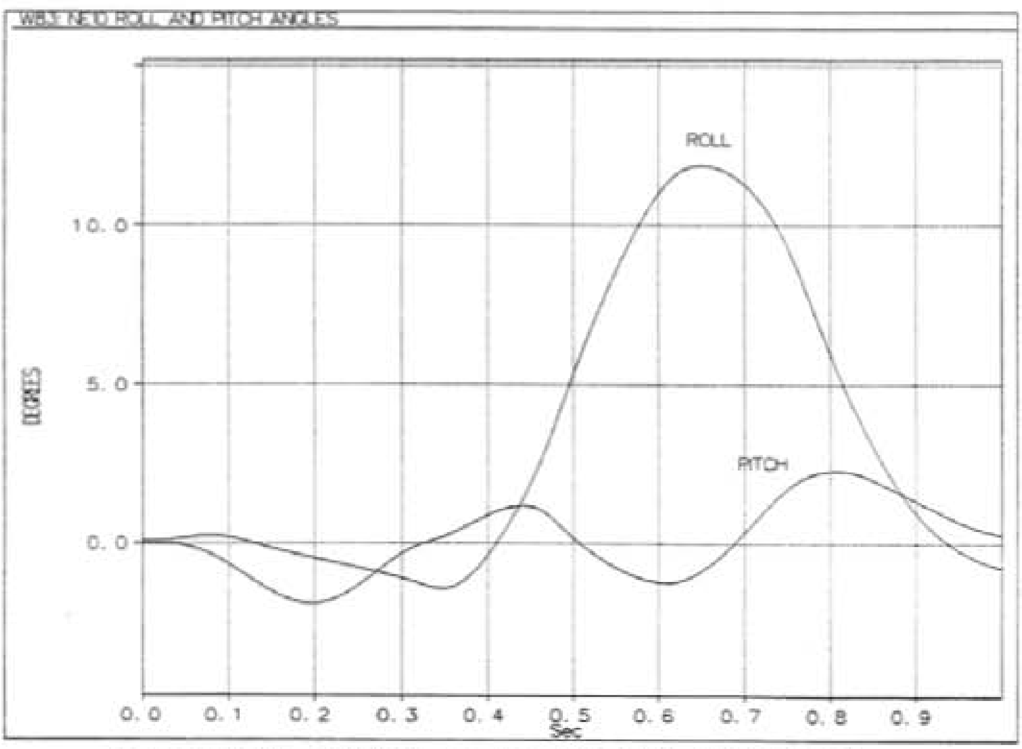
NE7(6L,1800LB,5.0DEG,50MPH)



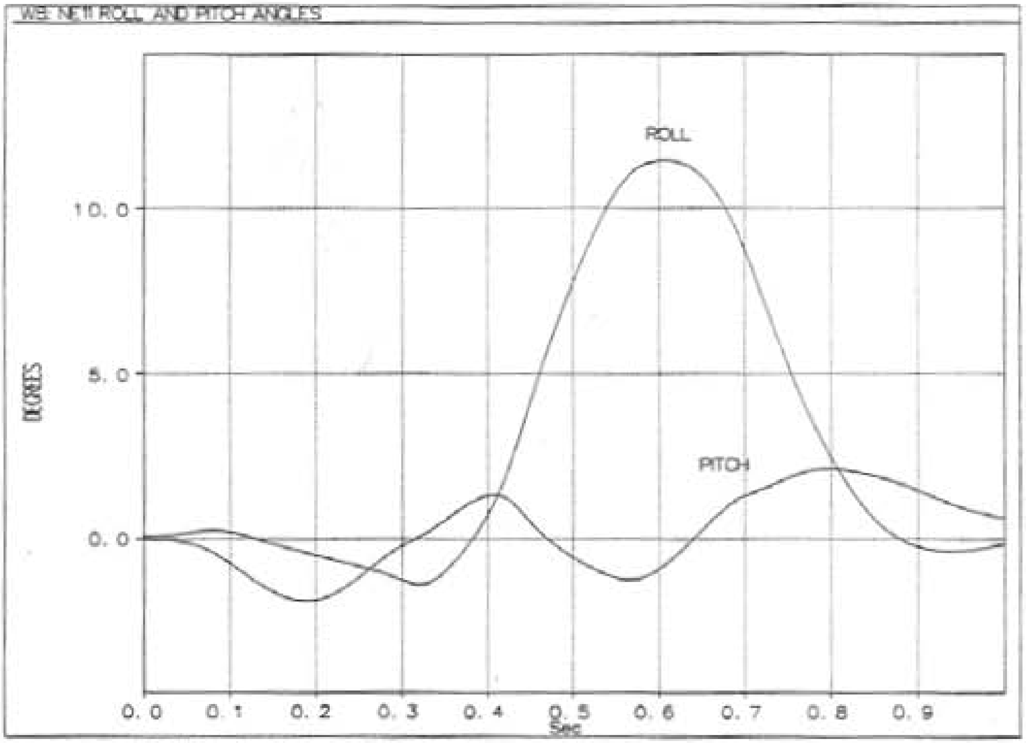
NE8(6L,1800LB,5.0DEG,55MPH)



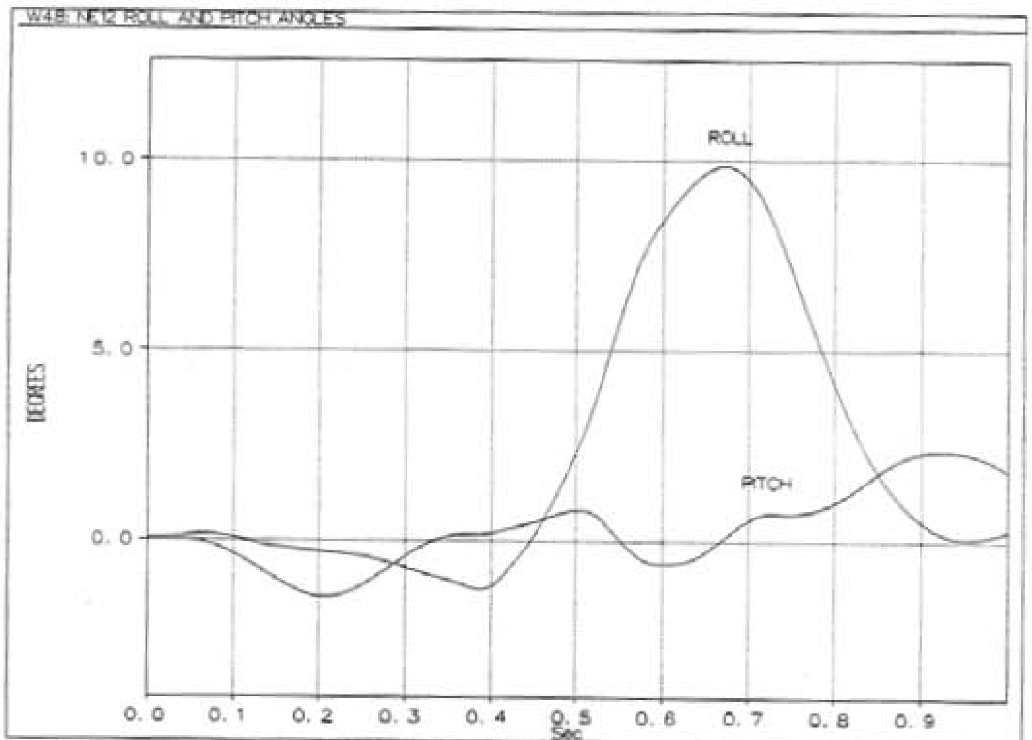
NE9(6L,1800LB,12.5DEG,45MPH)



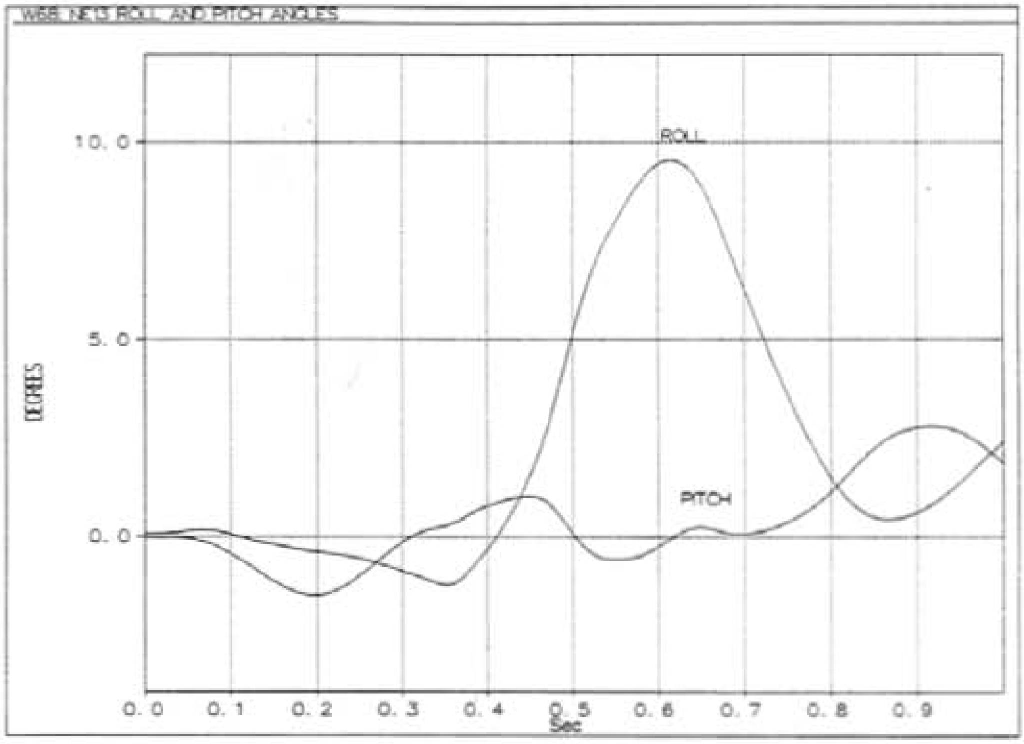
NE10(6L,1800LB,12.5DEG,50MPH)



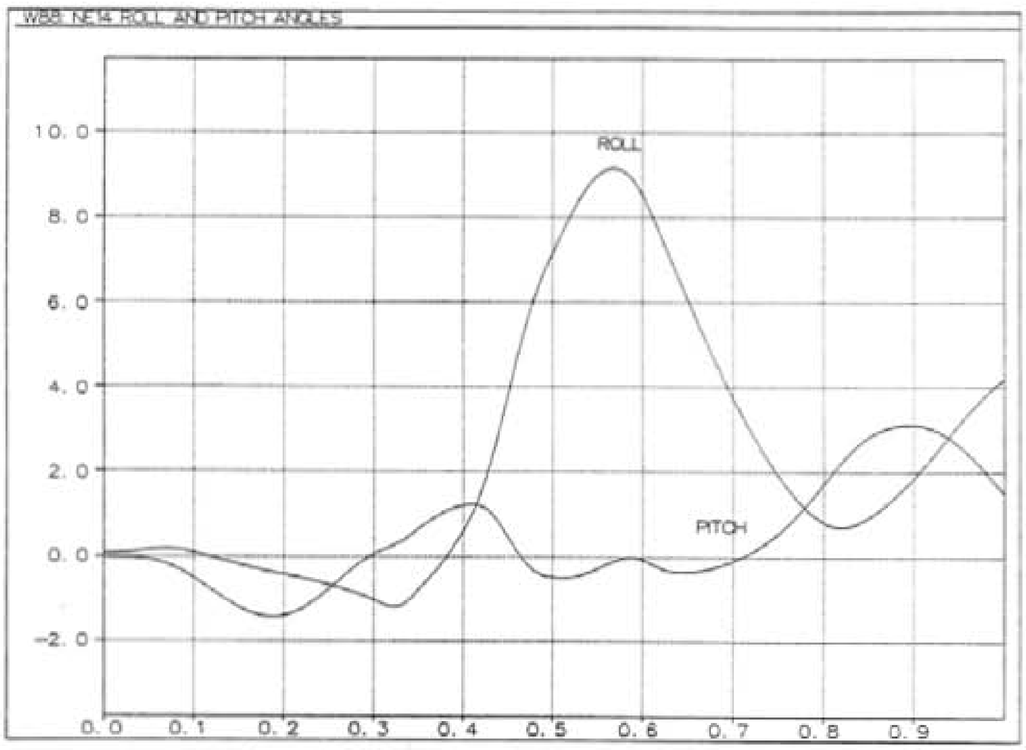
NE11(6L,1800LB,12.5DEG,55MPH)



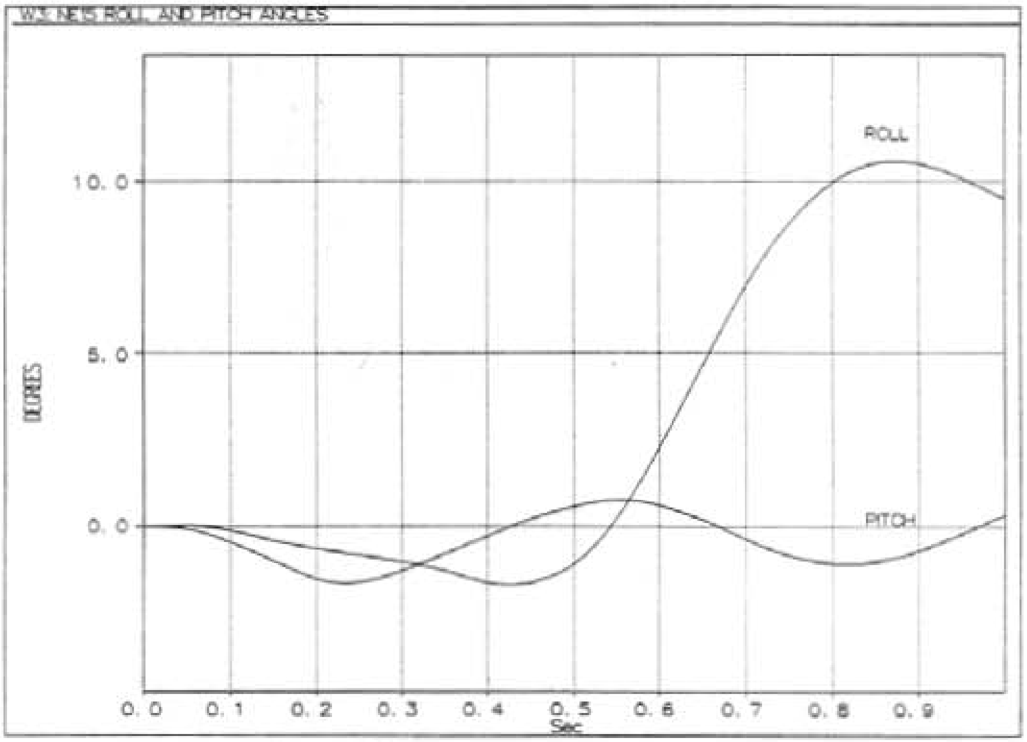
NE12(6L,1800LB,20.0DEG,45MPH)



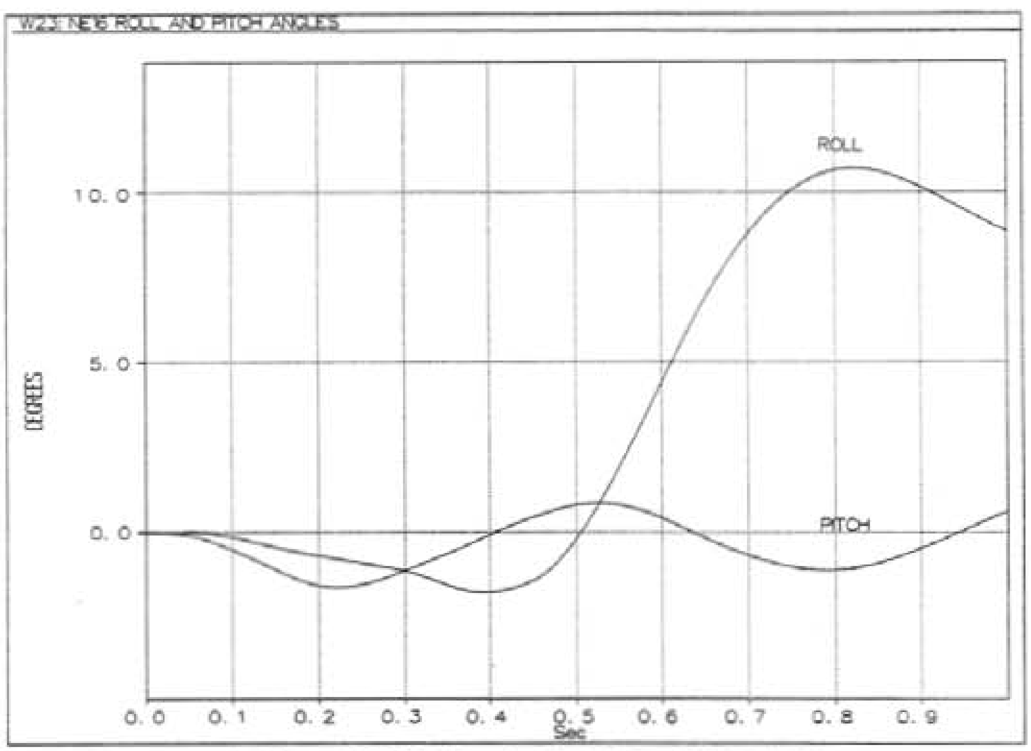
NE13(6L,1800LB,20.0DEG,50MPH)



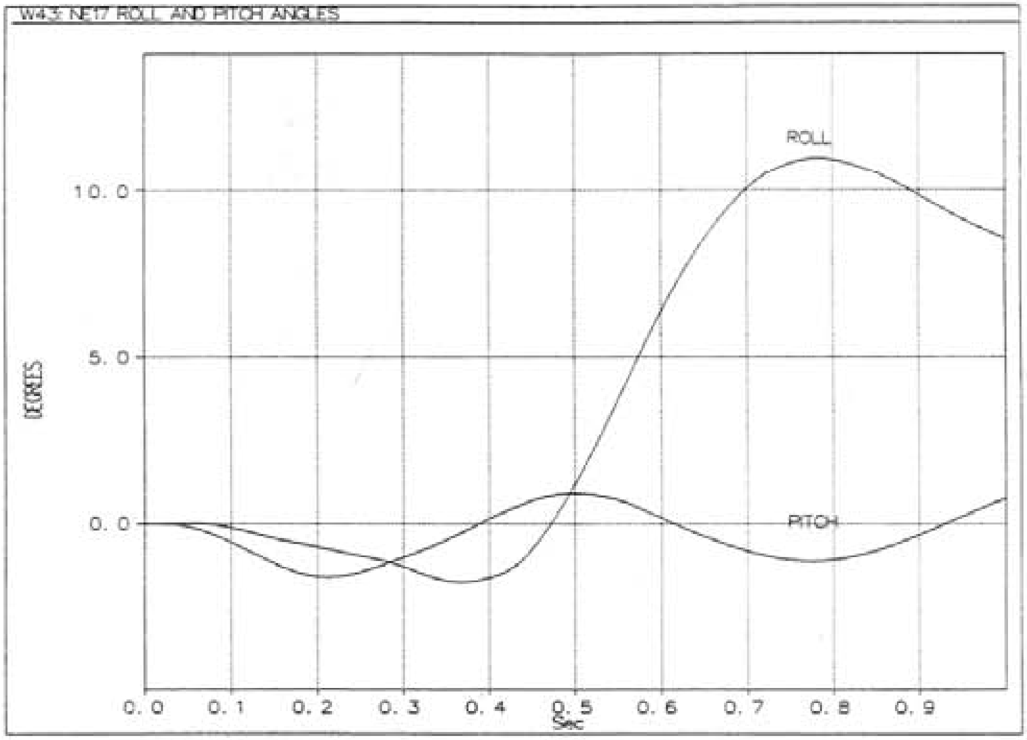
NE14(6L,1800LB,20.0DEG,55MPH)



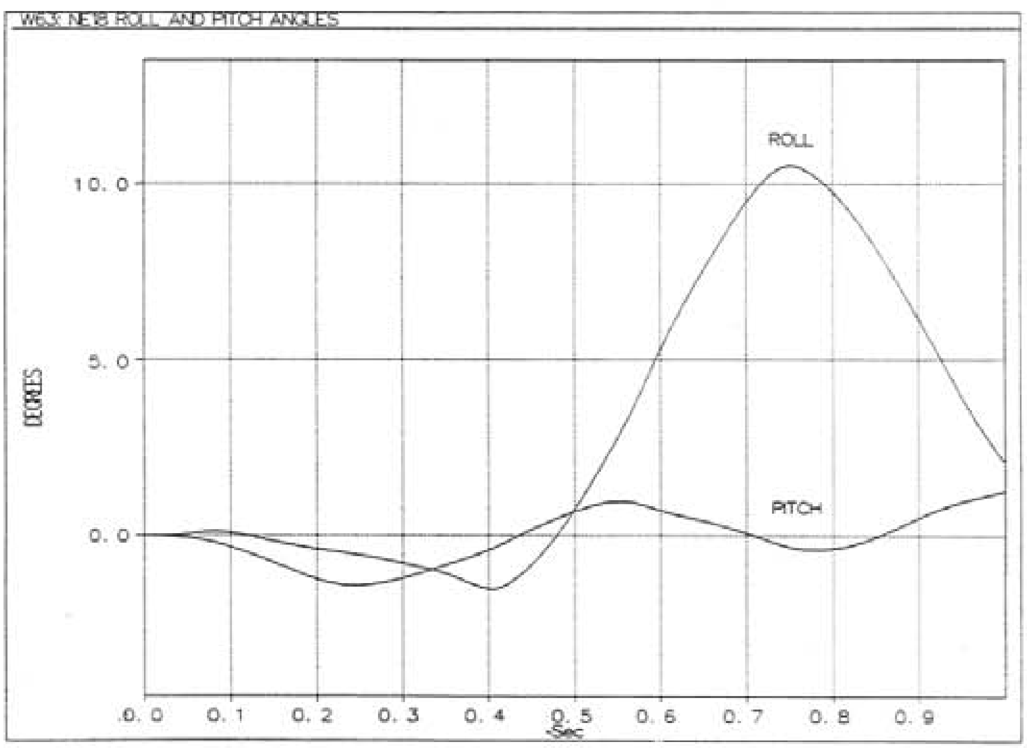
NE15(6L,4500LB,5.0DEG,45MPH)



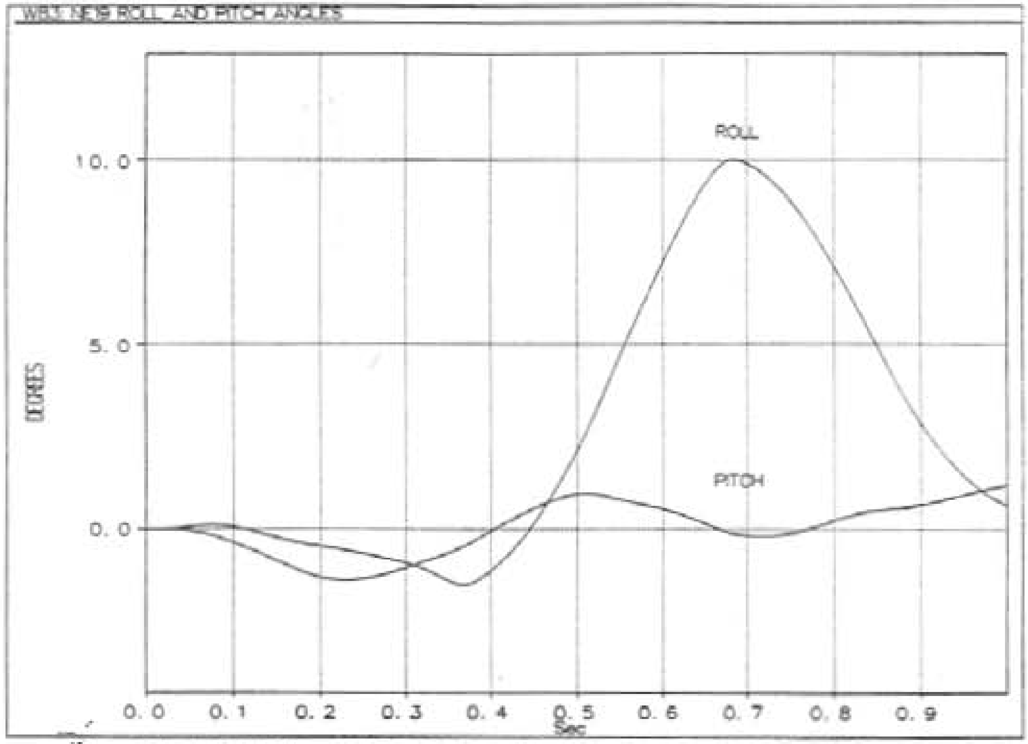
NE16(6L,4500LB,5.0DEG,50MPH)



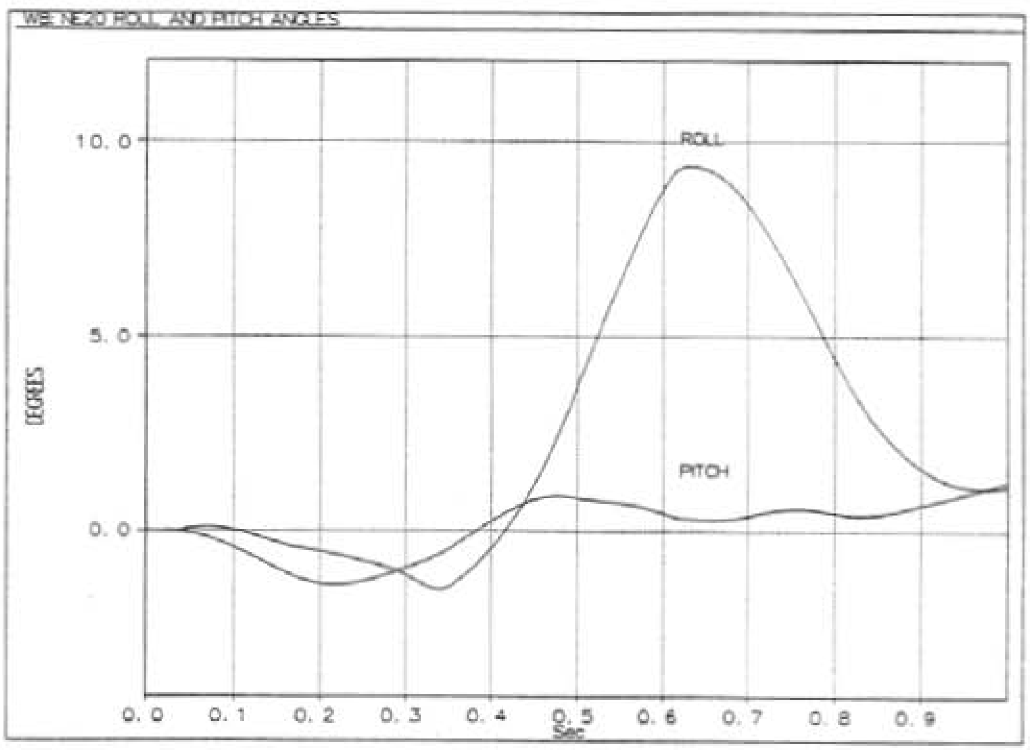
NE17(6L,4500LB,5.0DEG,55MPH)



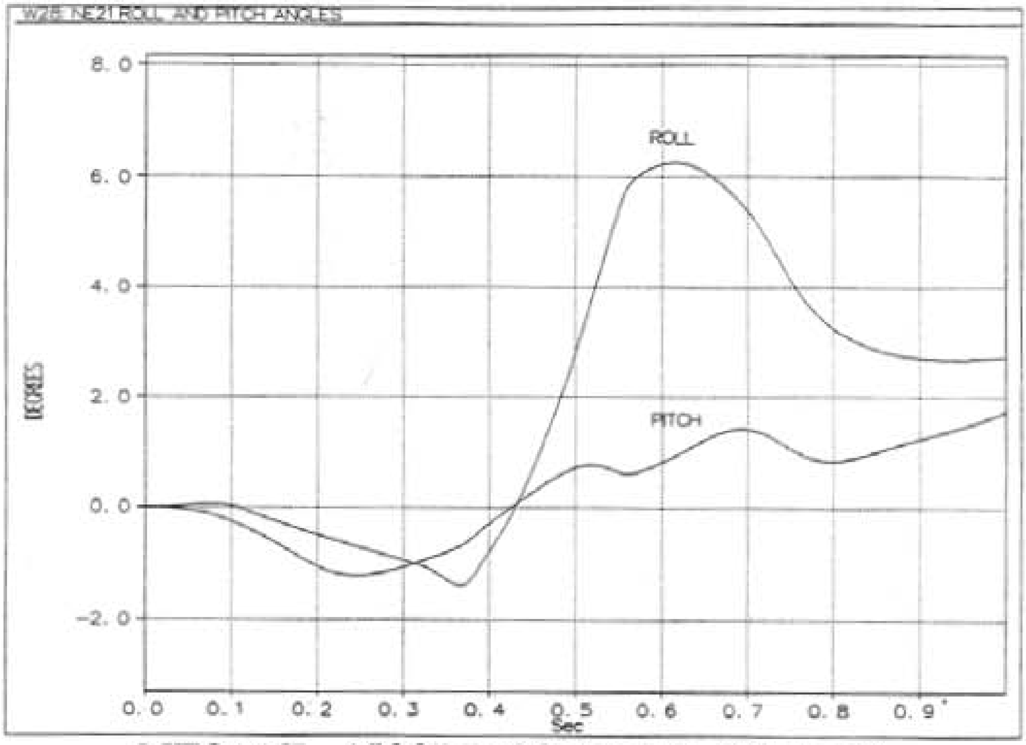
NE18(6L,4500LB,12.5DEG,45MPH)



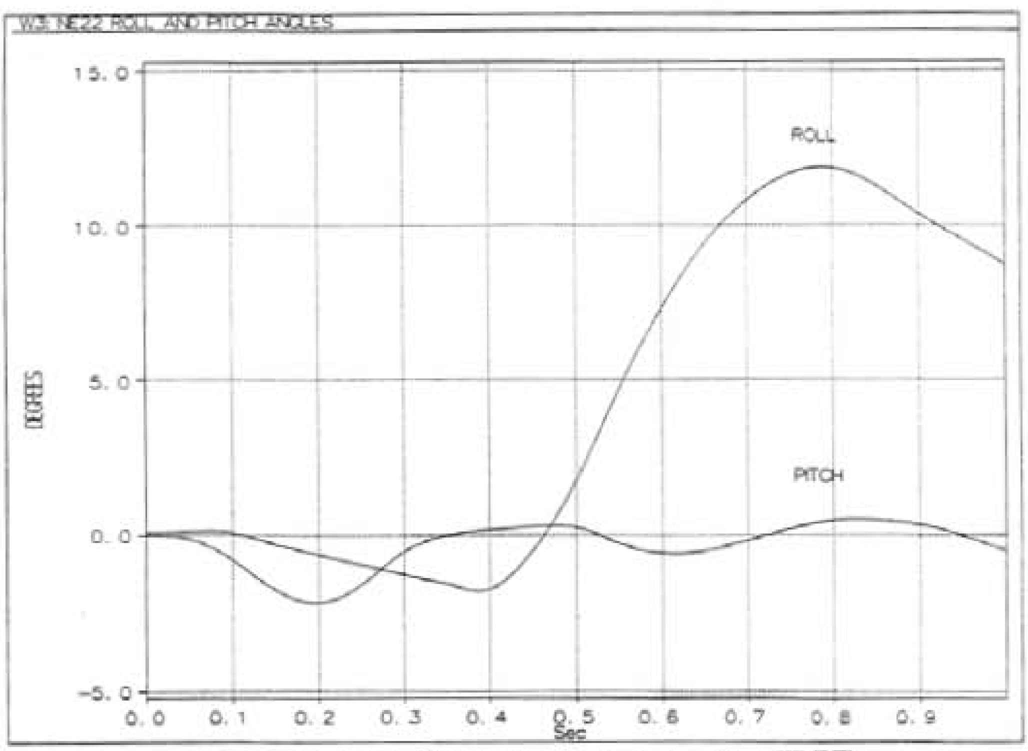
NE19(6L,4500LB,12.5DEG,50MPH)



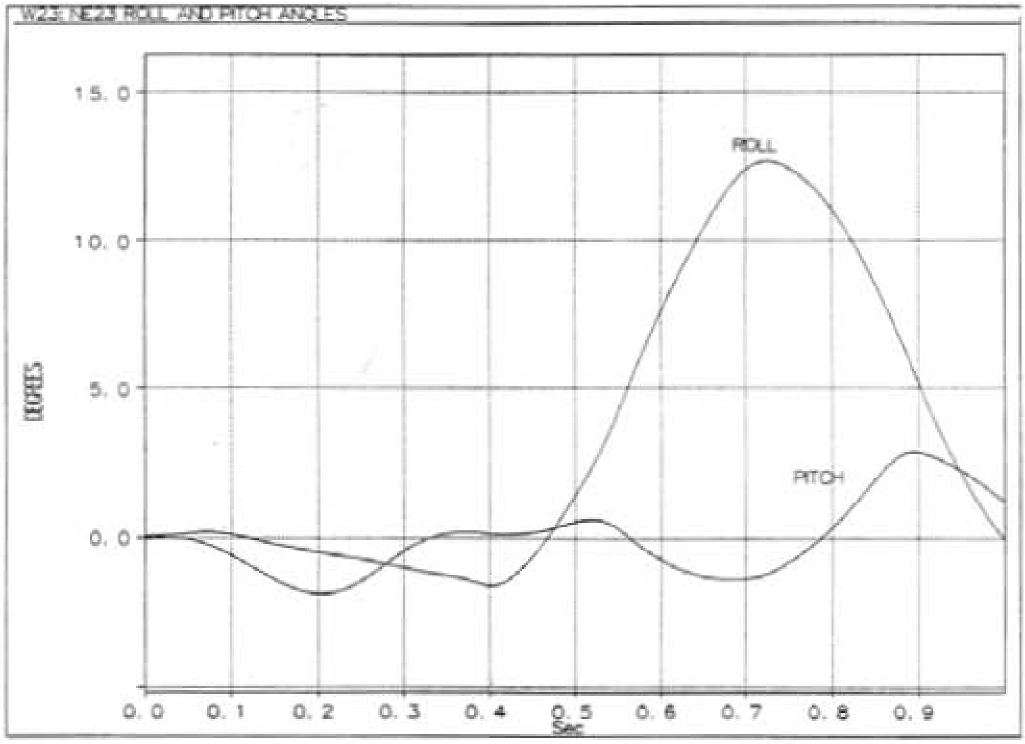
NE20(6L,4500LB,12.5DEG,55MPH)



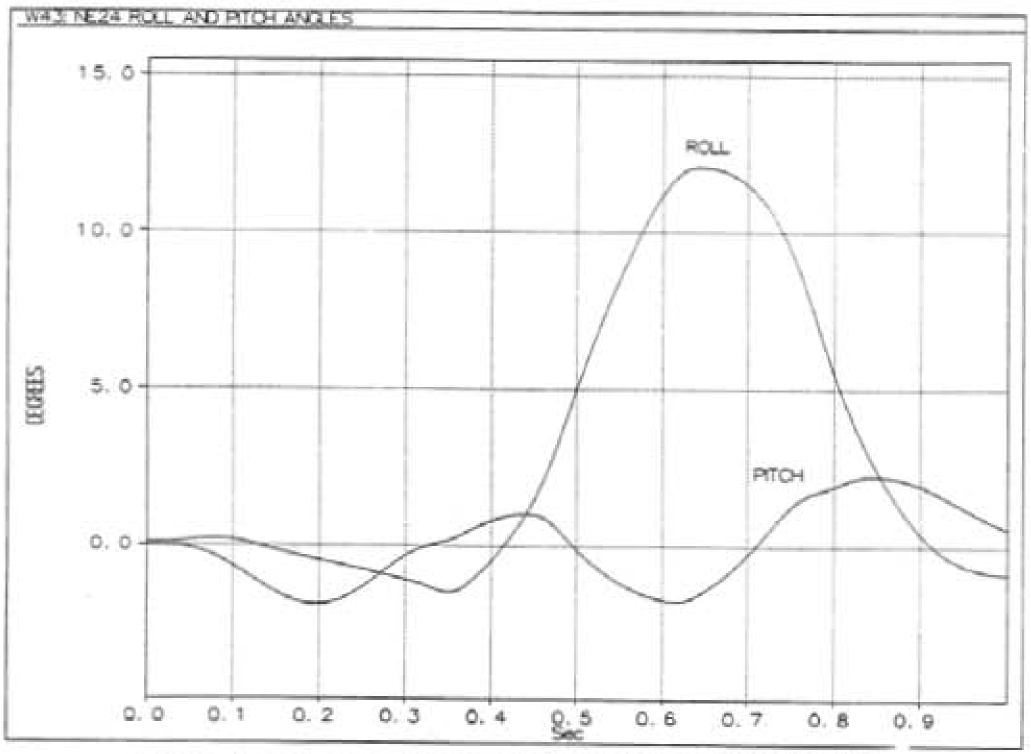
NE21(6L,4500LB,20.0DEG,50MPH)



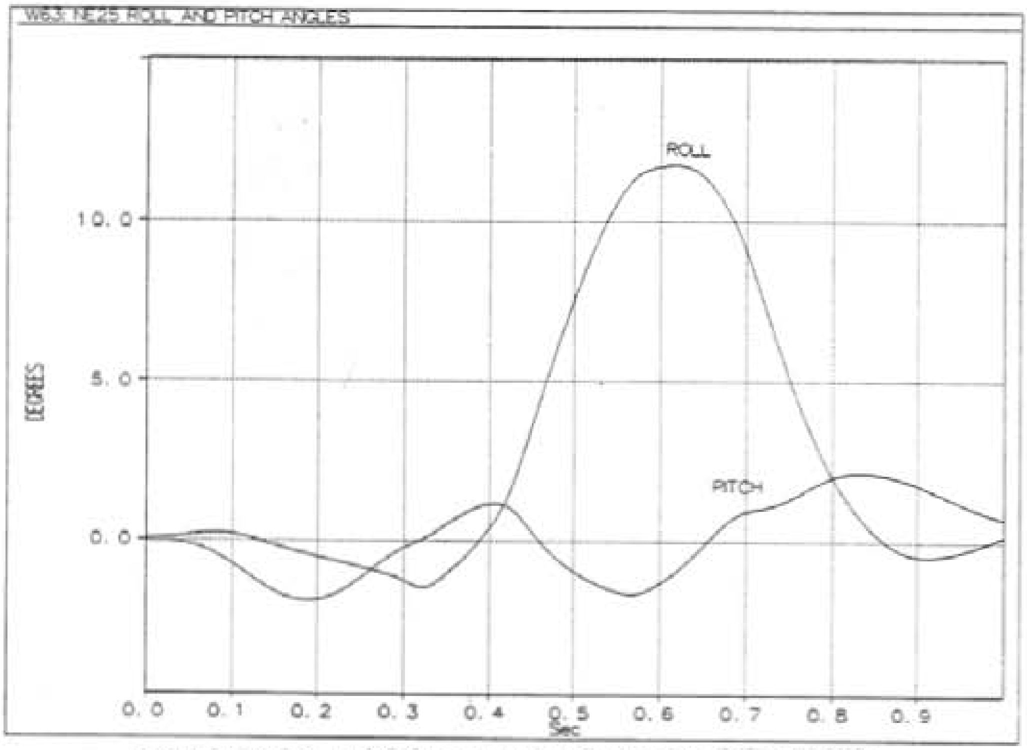
NE22(6S,1800LB,5.0DEG,50MPH)



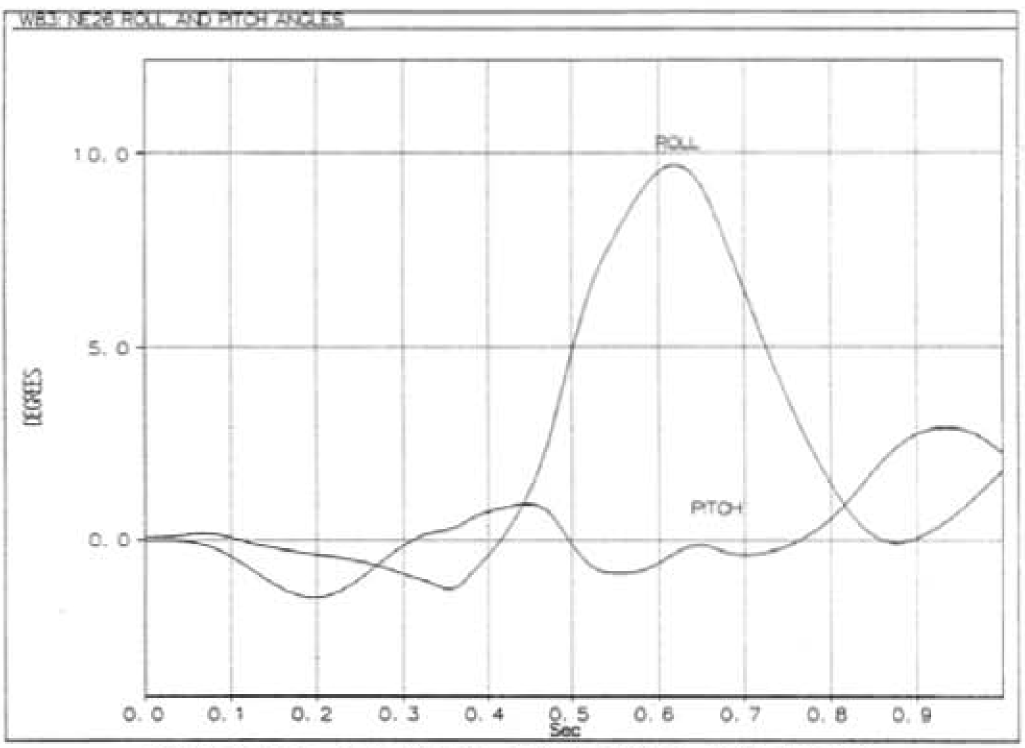
NE23(6S,1800LB,12.5DEG,45MPH)



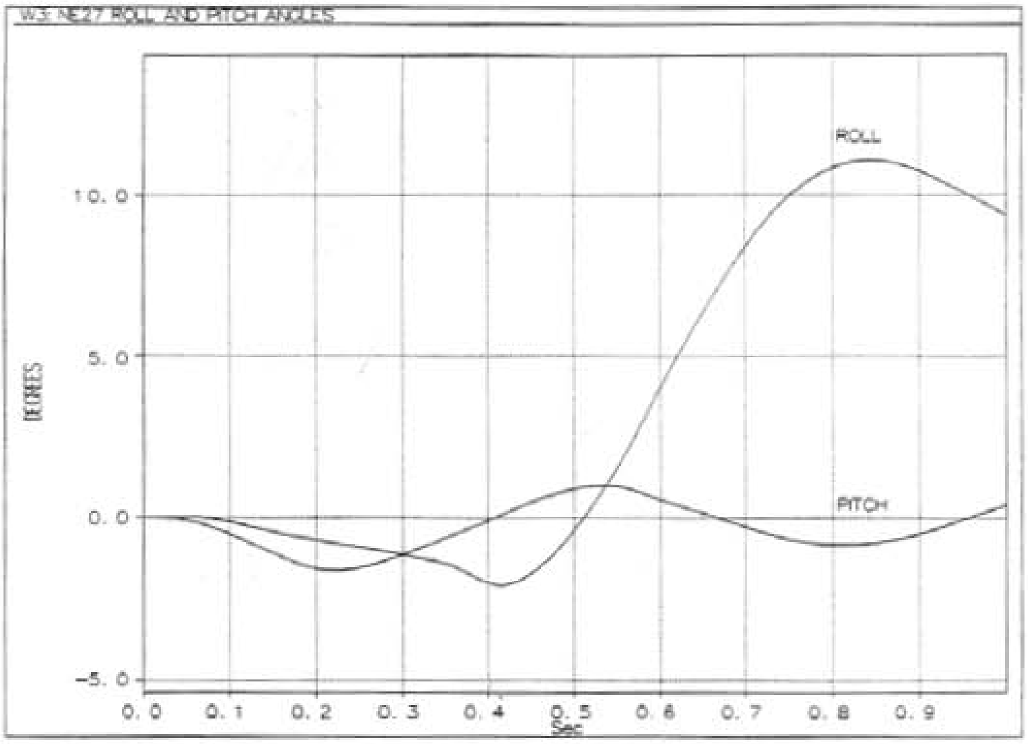
NE24(6S,1800LB,12.5DEG,50MPH)



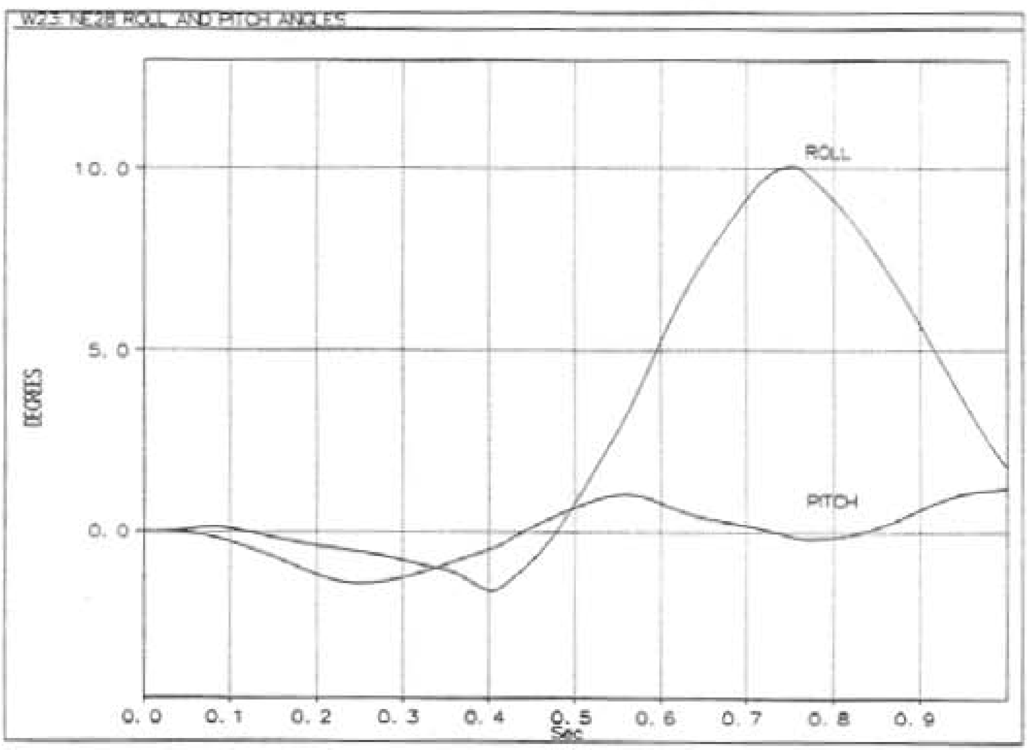
NE25(6S,1800LB,12.5DEG,55MPH)



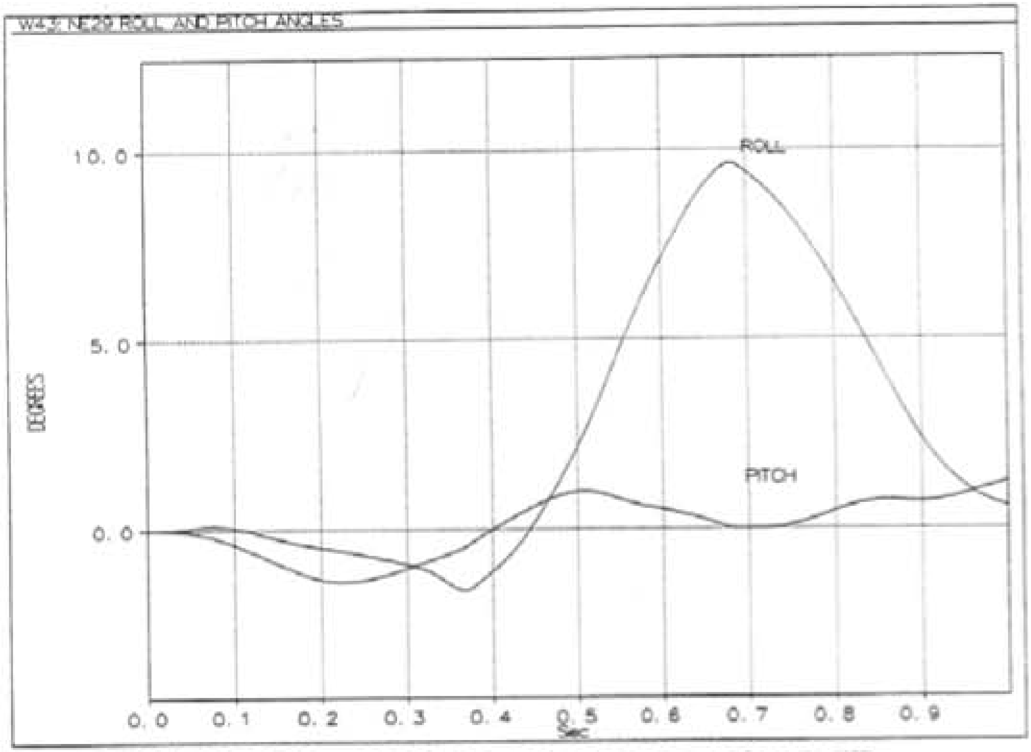
NE26(6S,1800LB,20.0DEG,50MPH)



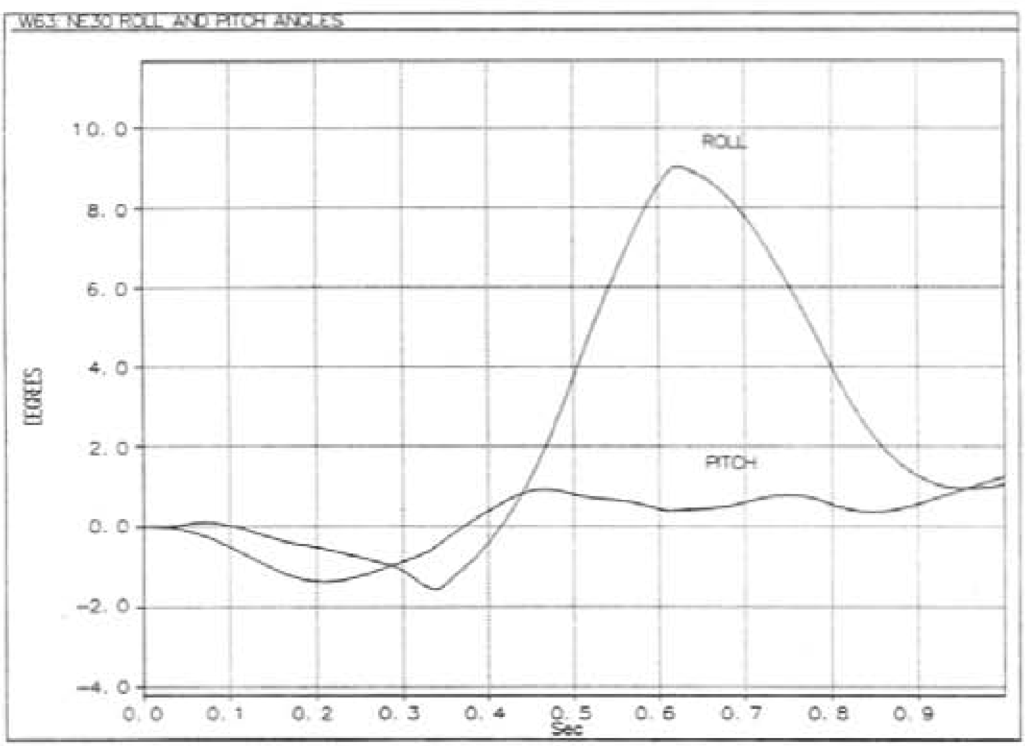
NE27(6S,4500LB,5.0DEG,50MPH)



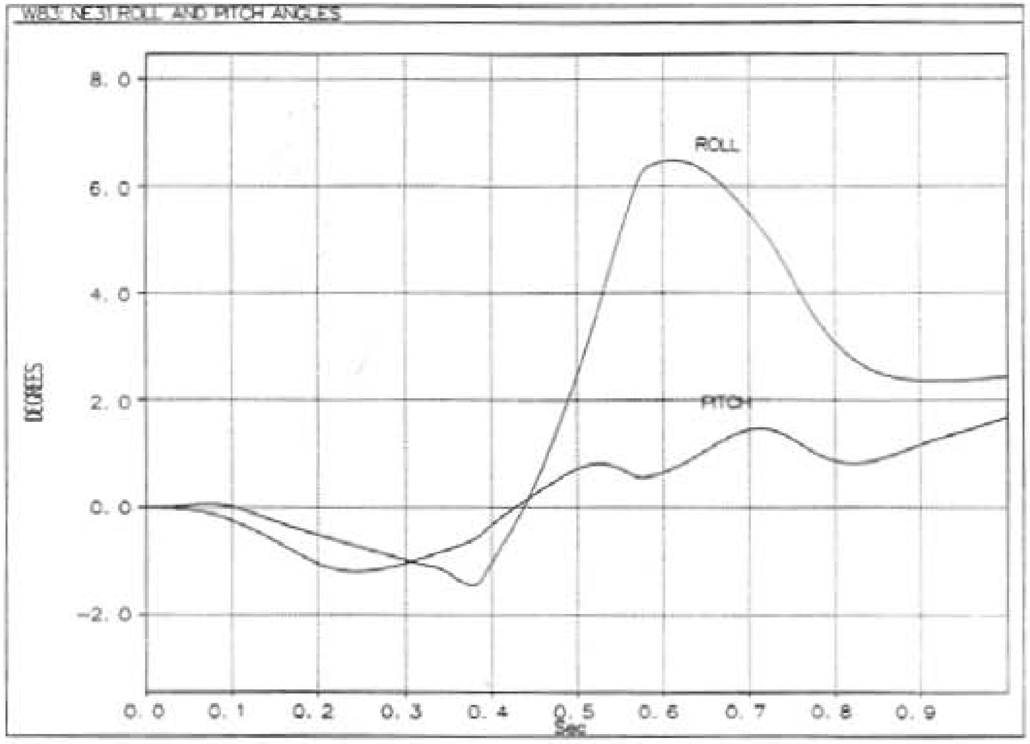
NE28(6S,4500LB,12.5DEG,45MPH)



NE29(6S,4500LB,12.5DEG,50MPH)



NE30(6S,4500LB,12.5DEG,55MPH)



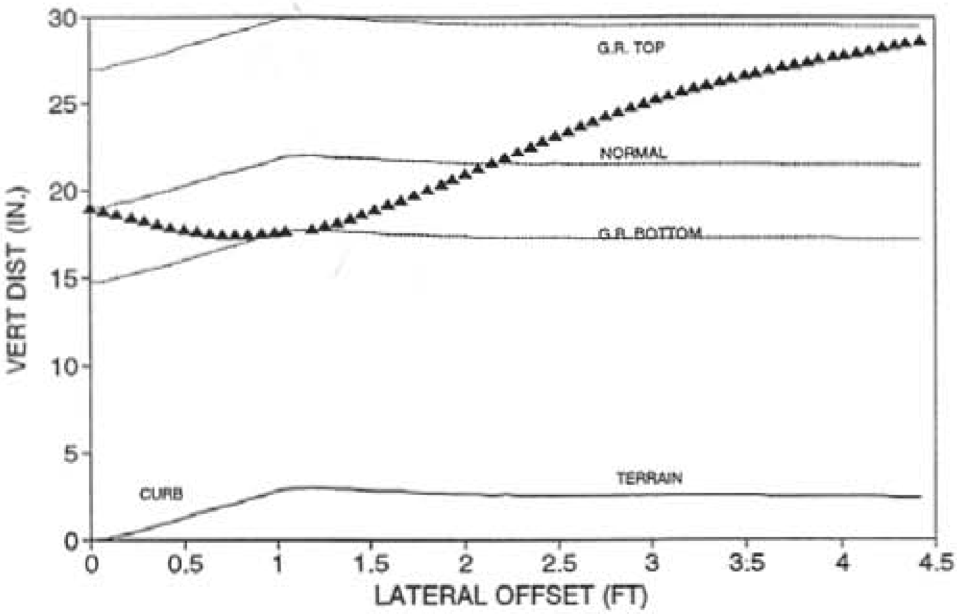
NE31(6S,4500LB,20.0DEG,50MPH)

APPENDIX E:

Simulated Bumper Trajectories (NE 1-31)

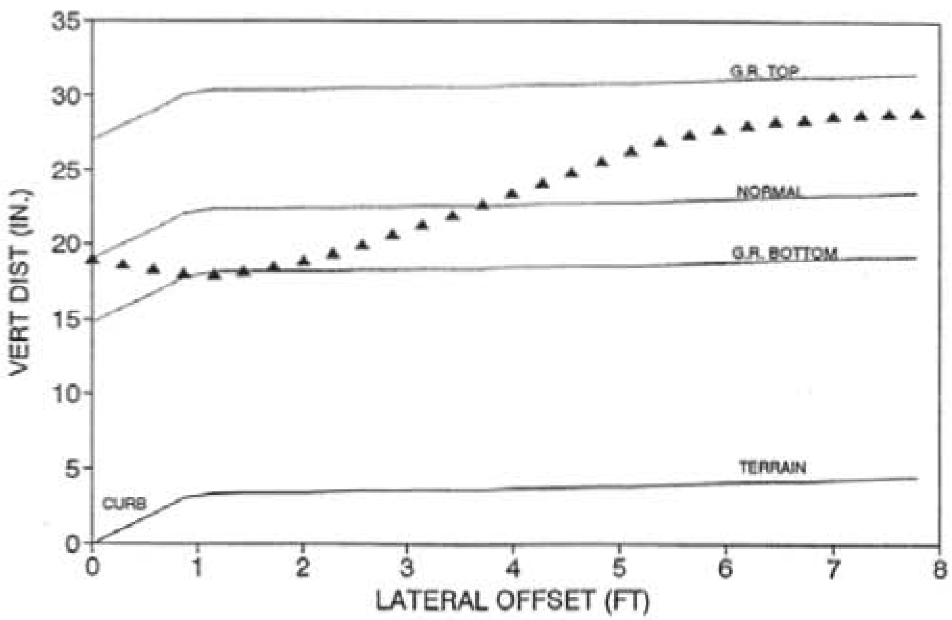
SIMULATED BUMPER TRAJECTORY

NE1(4L,4500LB,5.0DEG,55MPH)



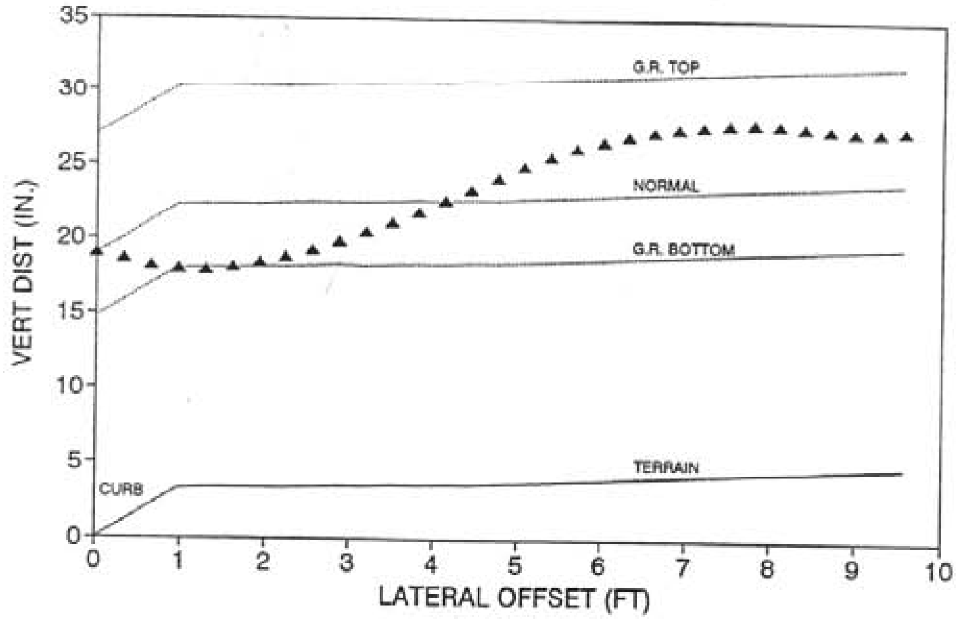
SIMULATED BUMPER TRAJECTORY

NE2(4L,4500LB,12.5DEG,45MPH)



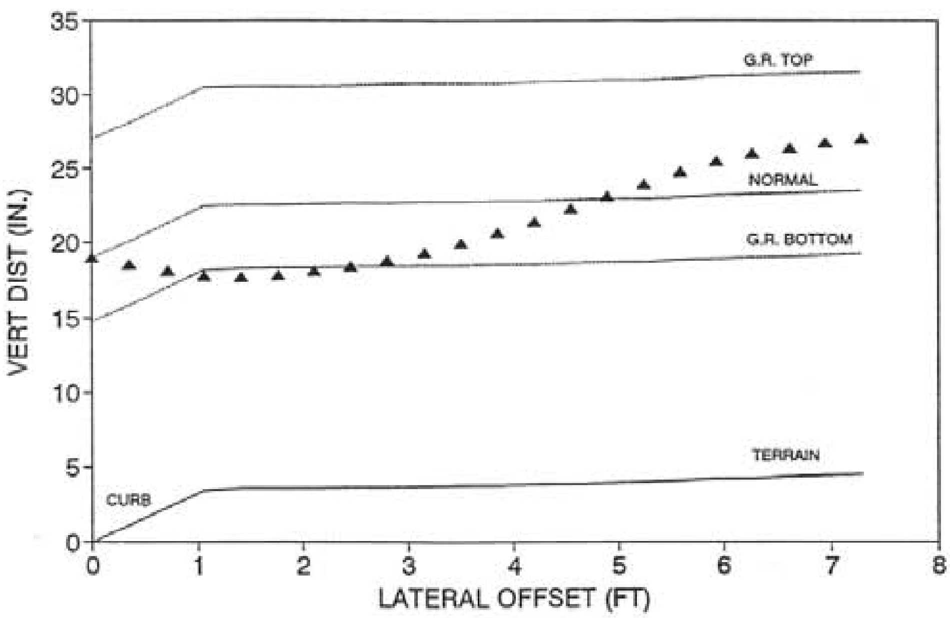
SIMULATED BUMPER TRAJECTORY

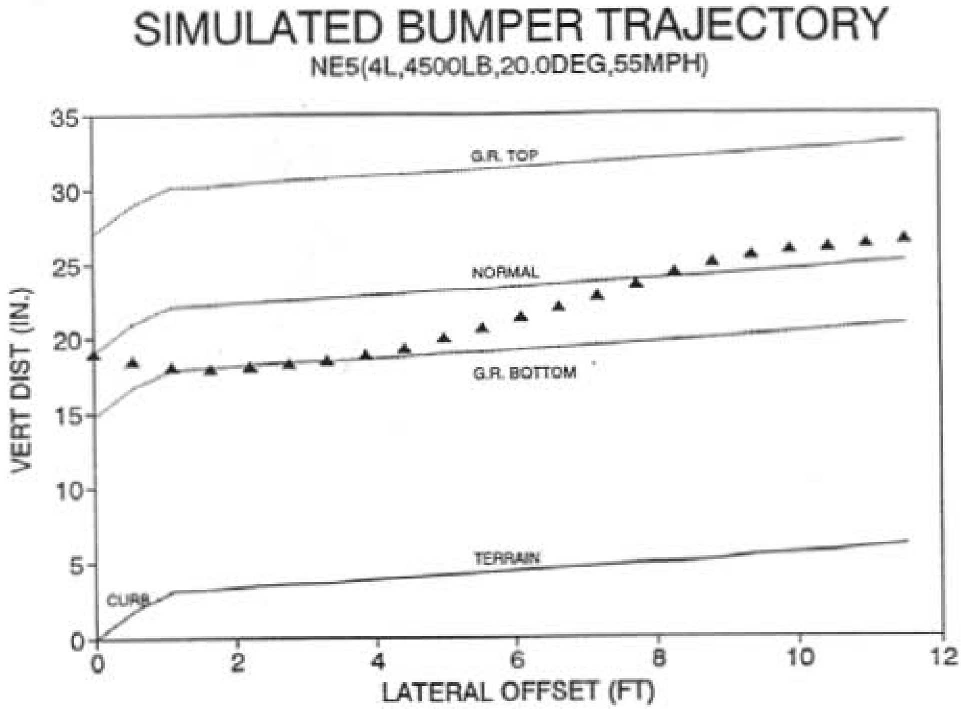
NE3(4L,4500LB,12.5DEG,50MPH)

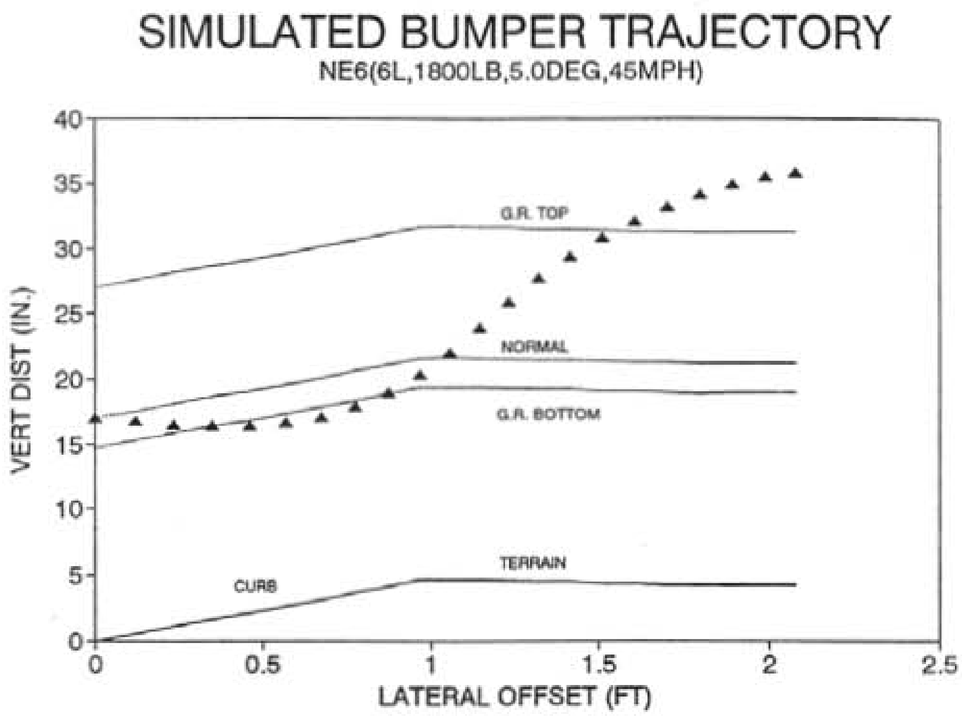


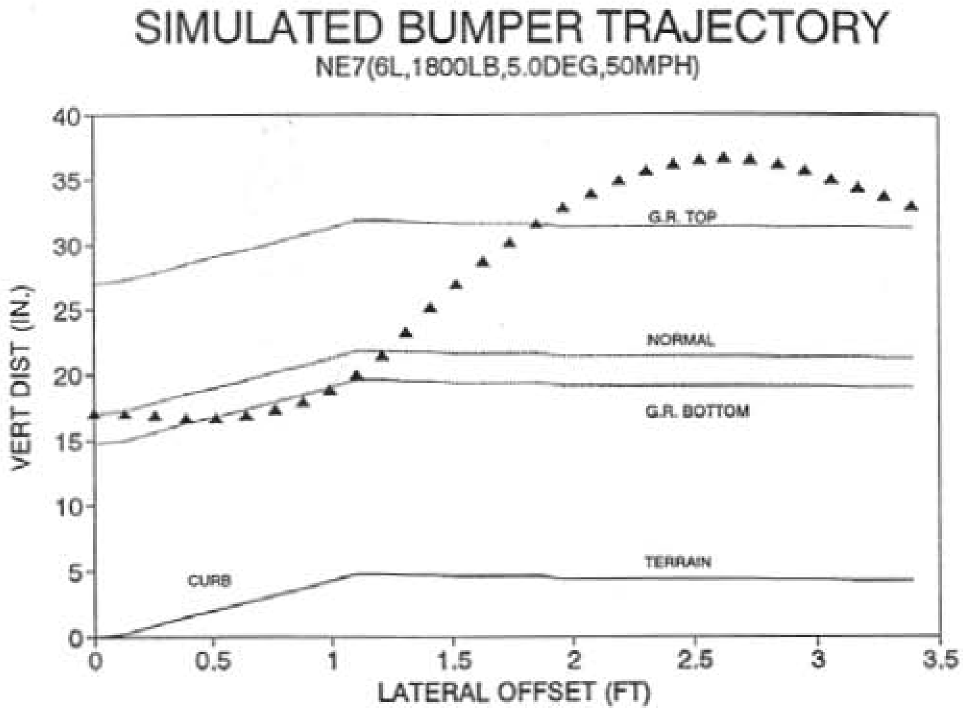
SIMULATED BUMPER TRAJECTORY

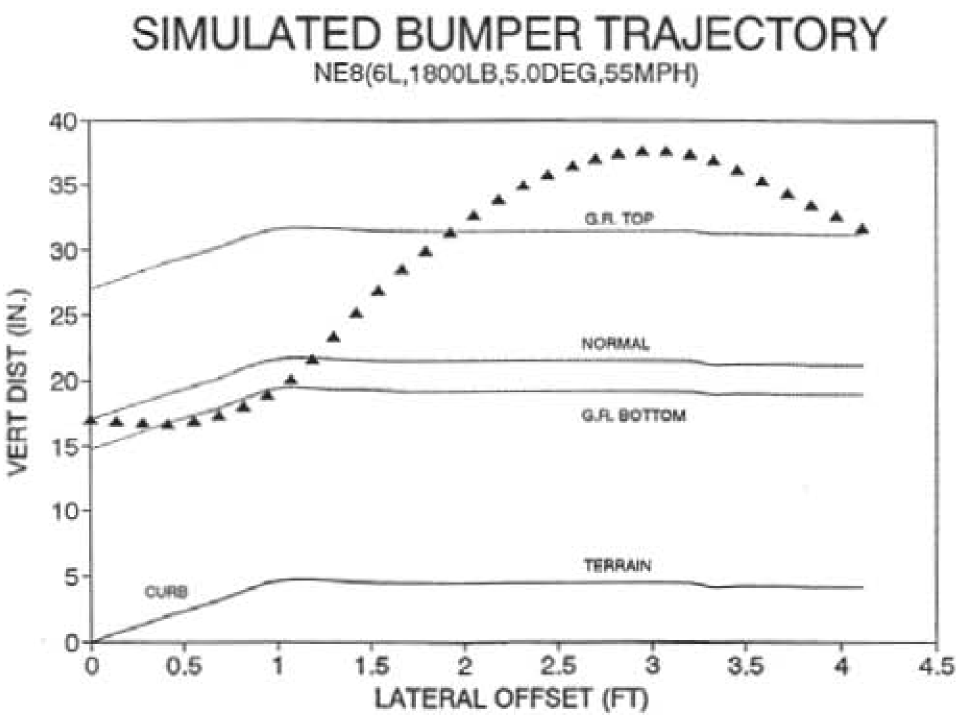
NE4(4L,4500LB,12.5DEG,55MPH)




SIMULATED BUMPER TRAJECTORY
NE5(4L,4500LB,20.0DEG,55MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12

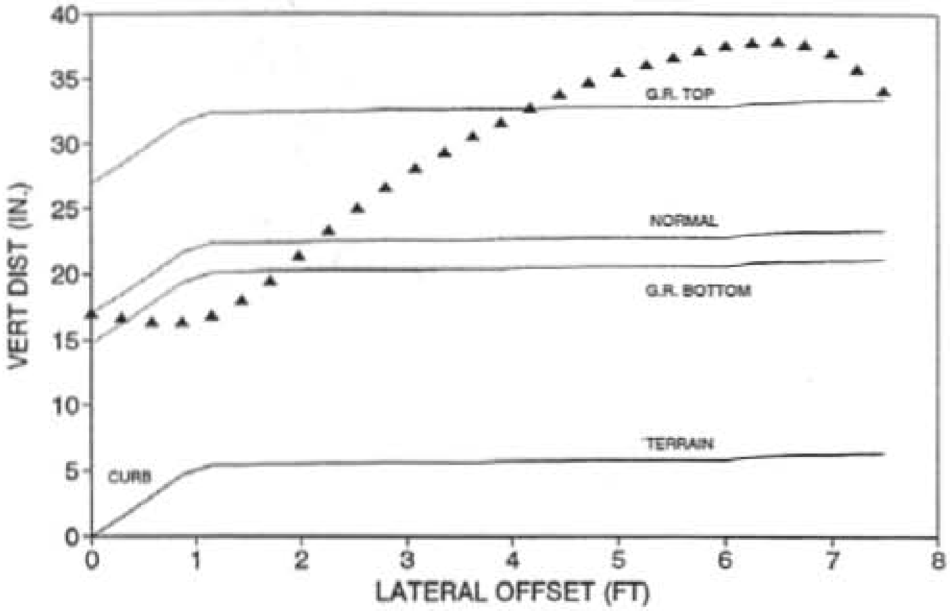

SIMULATED BUMPER TRAJECTORY
NE6(6L,1800LB,5.0DEG,45MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
0
0.5
1
1.5
2
2.5


SIMULATED BUMPER TRAJECTORY
NE7(6L,1800LB,5.0DEG,50MPH)
VERT DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
0
5
10
15
20
25
30
35
40
0
0.5
1
1.5
2
2.5
3
3.5


SIMULATED BUMPER TRAJECTORY
NE8(6L,1800LB,5.0DEG,55MPH)
VERT DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
CURB
TERRAIN
0
5
10
15
20
25
30
35
40
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

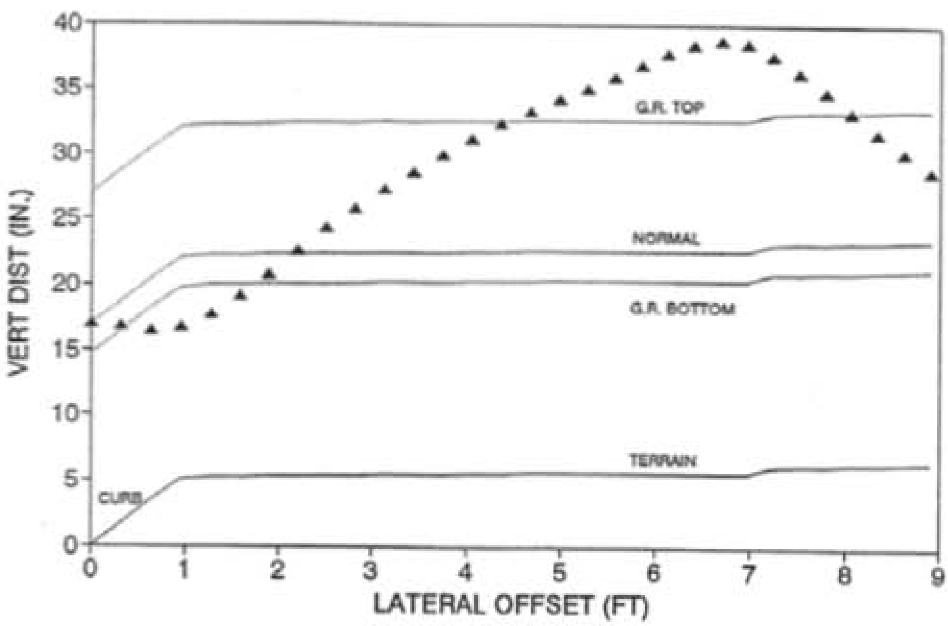
SIMULATED BUMPER TRAJECTORY

NE9(6L,1800LB,12.5DEG,45MPH)



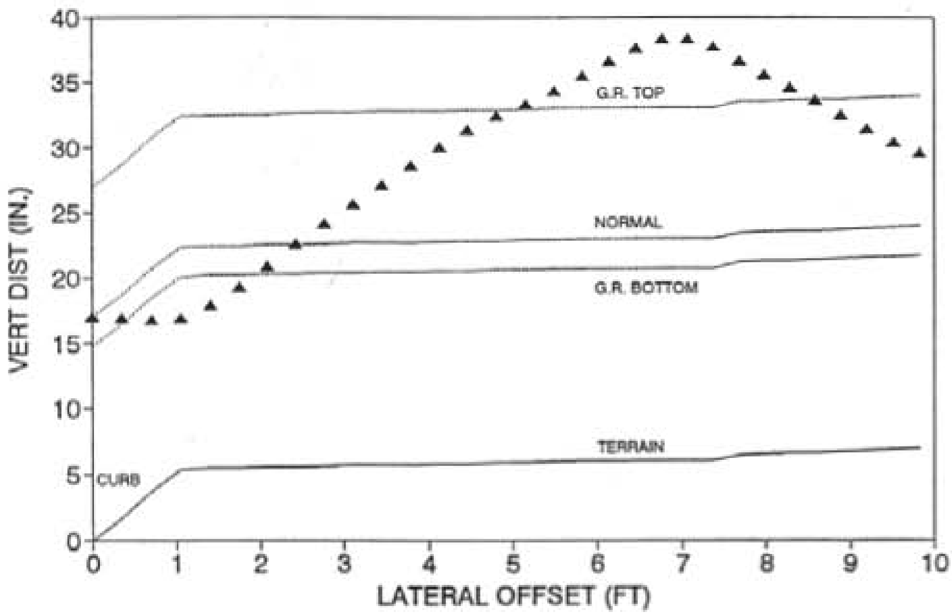
SIMULATED BUMPER TRAJECTORY

NE10(6L,1800LB,12.5DEG,50MPH)



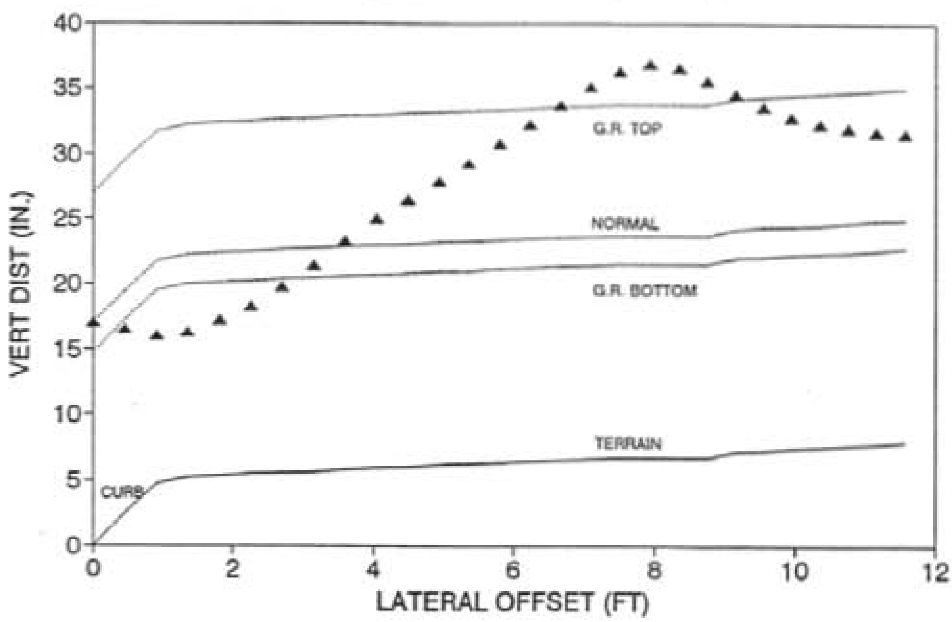
SIMULATED BUMPER TRAJECTORY

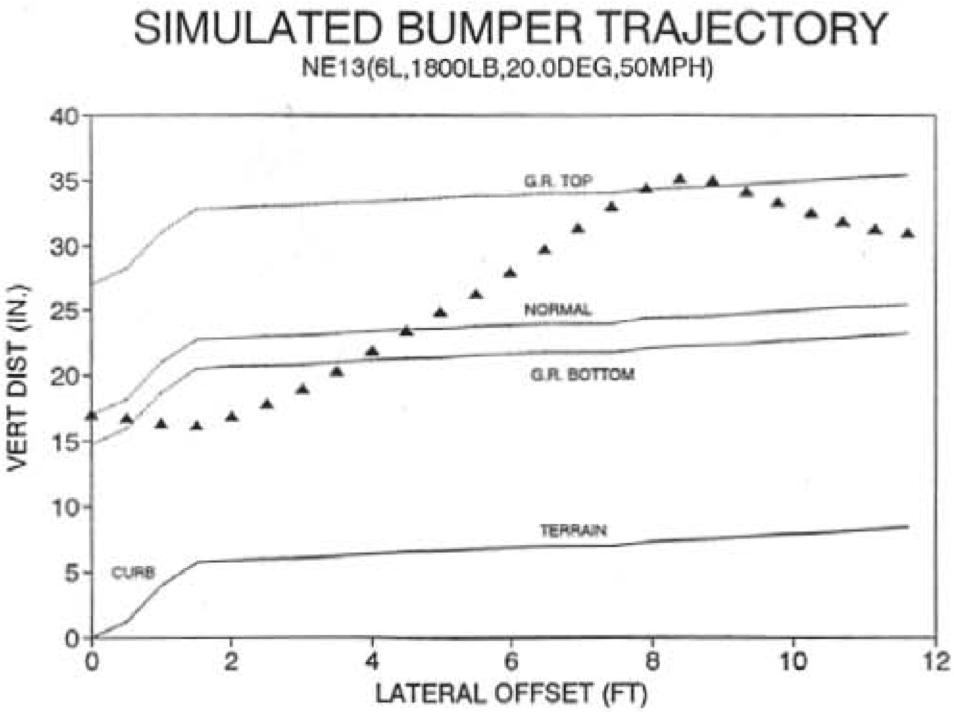
NE11(6L,1800LB,12.5DEG,55MPH)

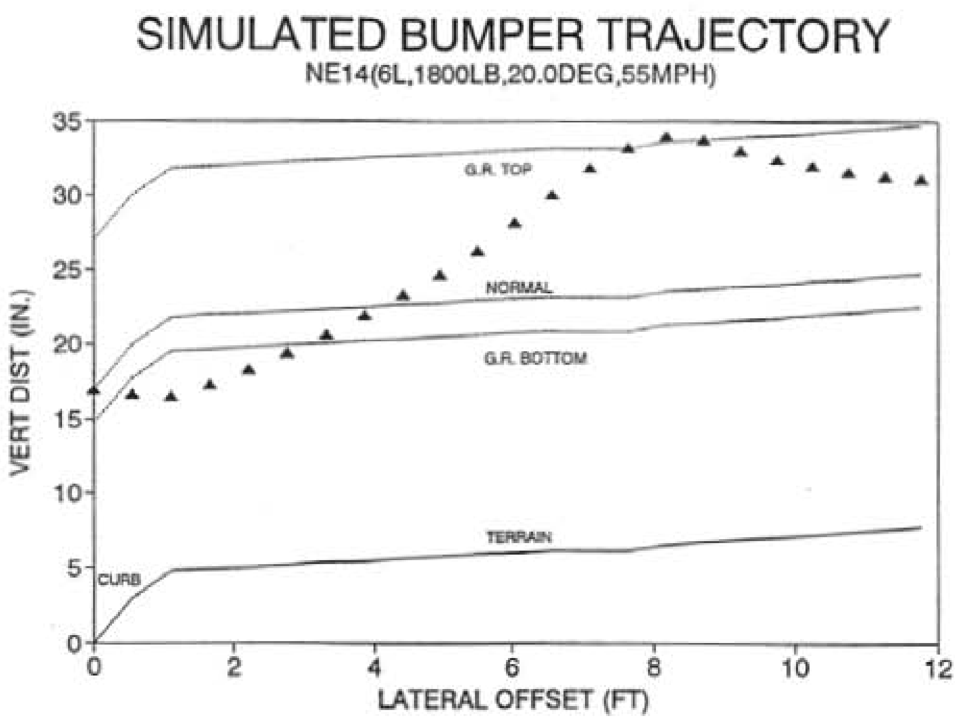


SIMULATED BUMPER TRAJECTORY

NE12(6L,1800LB,20.0DEG,45MPH)

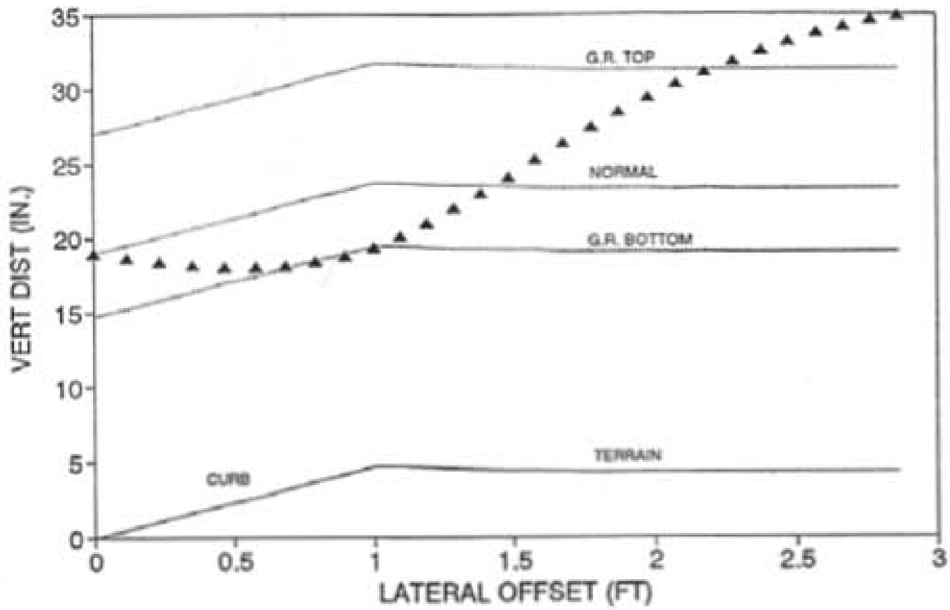



SIMULATED BUMPER TRAJECTORY
NE13(6L,1800LB,20.0DEG,50MPH)
VERT DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12


SIMULATED BUMPER TRAJECTORY
NE14(6L,1800LB,20.0DEG,55MPH)
VERT DIST (IN.)
LATERAL OFFSET (FT)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12

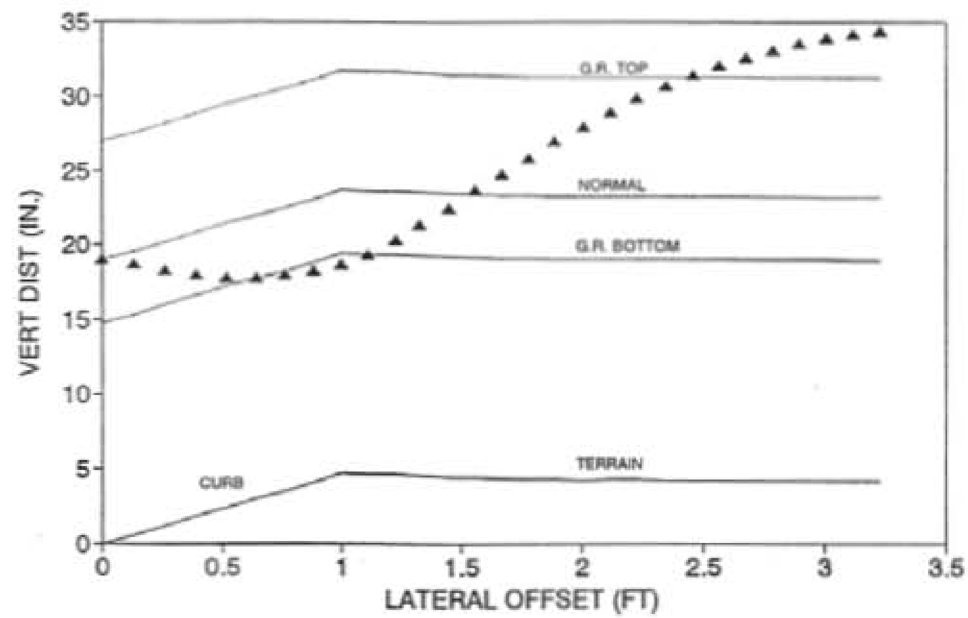
SIMULATED BUMPER TRAJECTORY

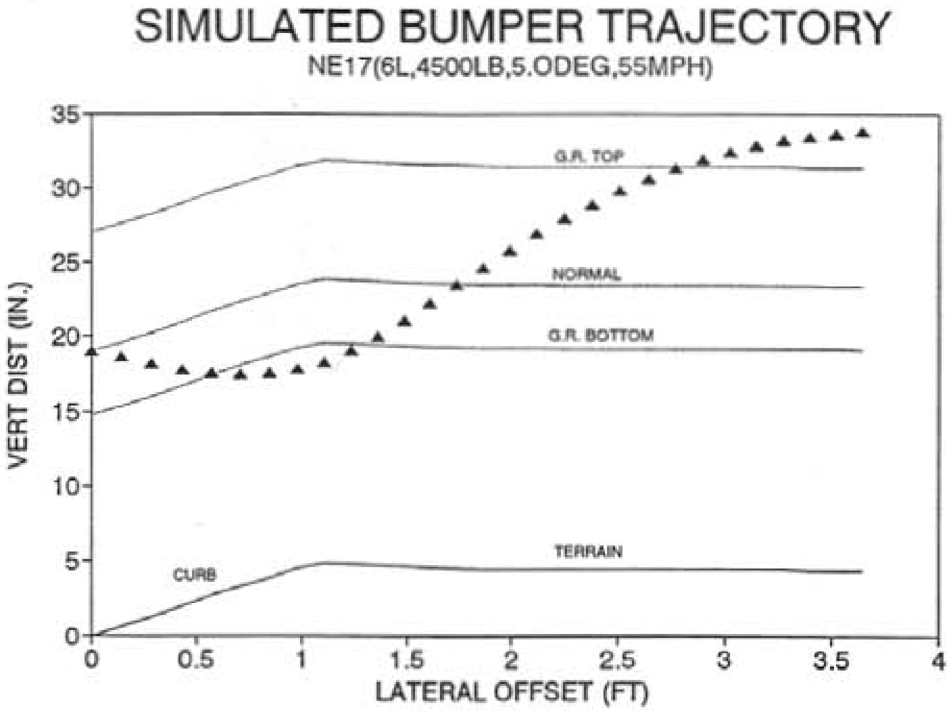
NE15(6L,4500LB,5.0DEG,45MPH)

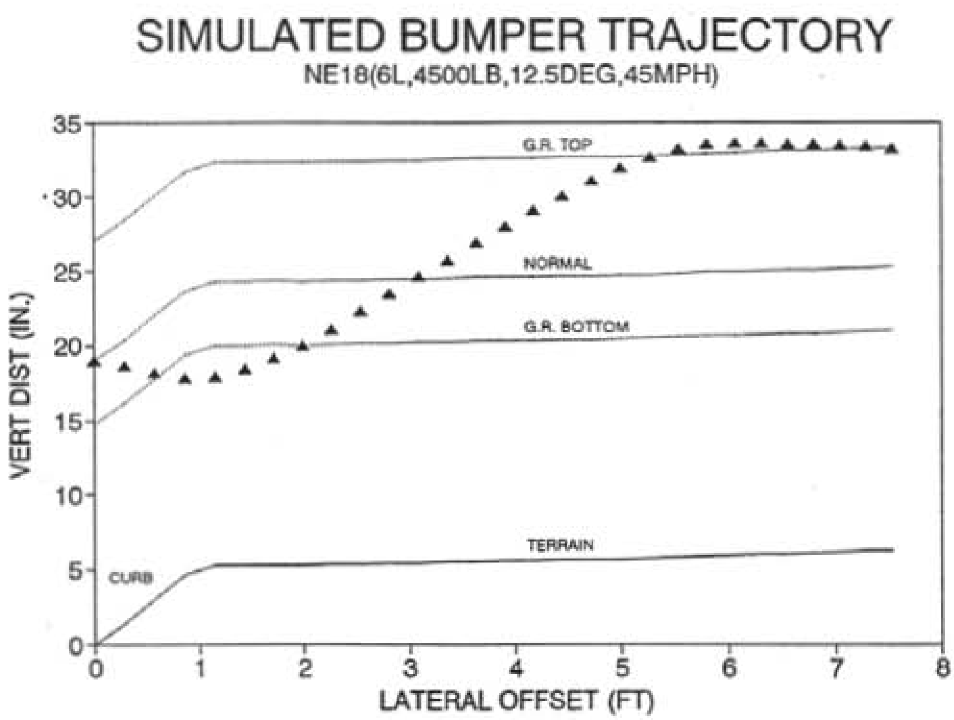


SIMULATED BUMPER TRAJECTORY

NE16(6L,4500LB,5.0DEG,50MPH)

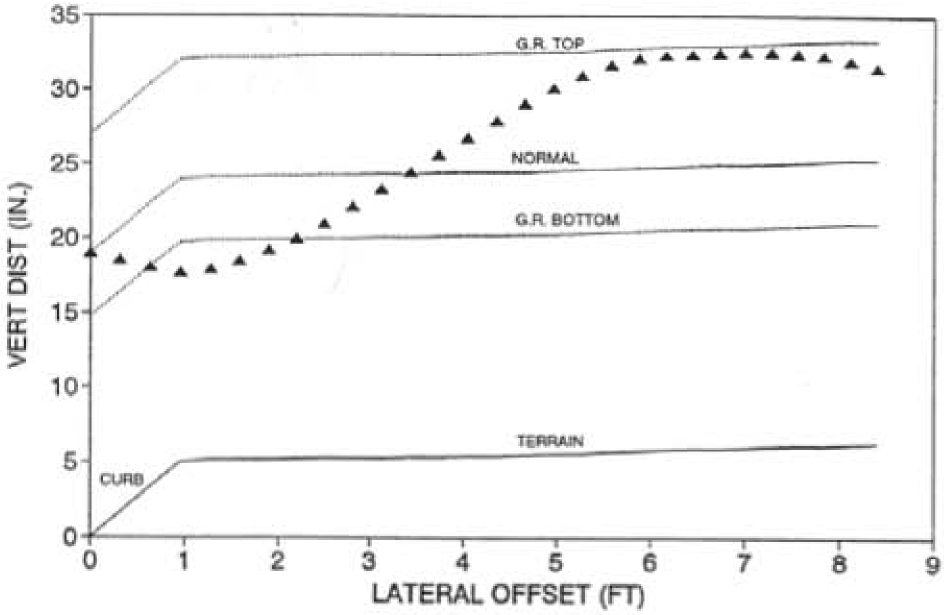



SIMULATED BUMPER TRAJECTORY
NE17(6L,4500LB,5.0DEG,55MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)


SIMULATED BUMPER TRAJECTORY
NE18(6L,4500LB,12.5DEG,45MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)

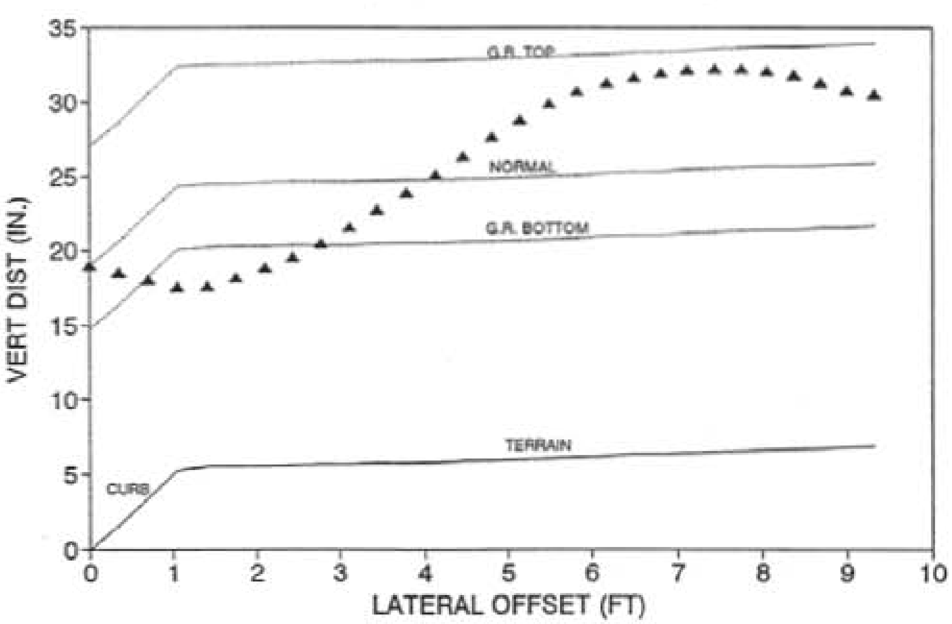
SIMULATED BUMPER TRAJECTORY

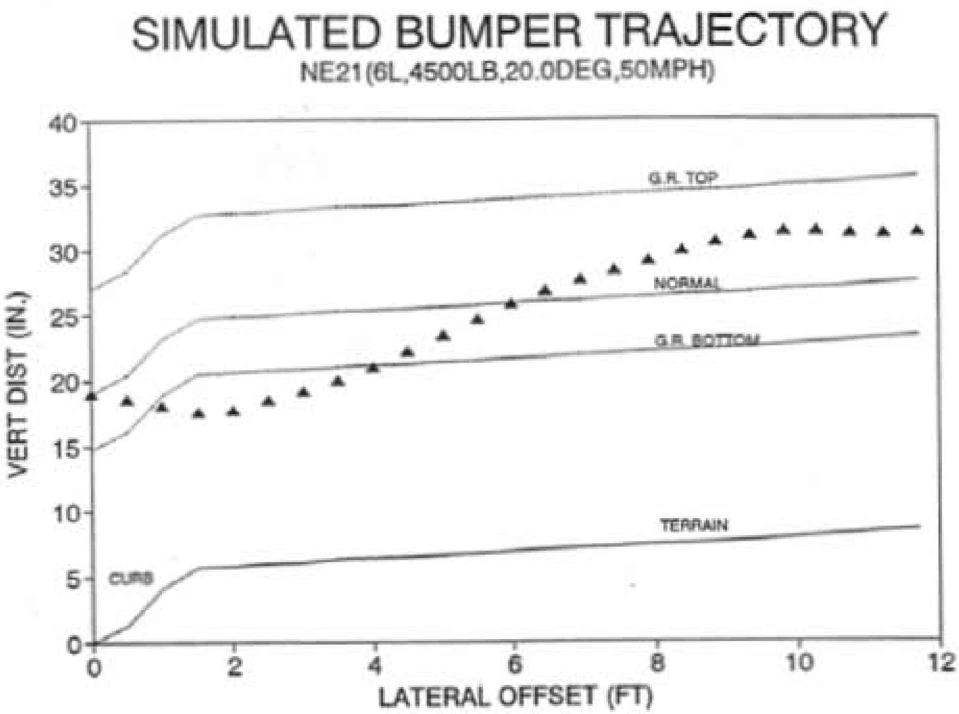
NE19(6L,4500LB,12.5DEG,50MPH)

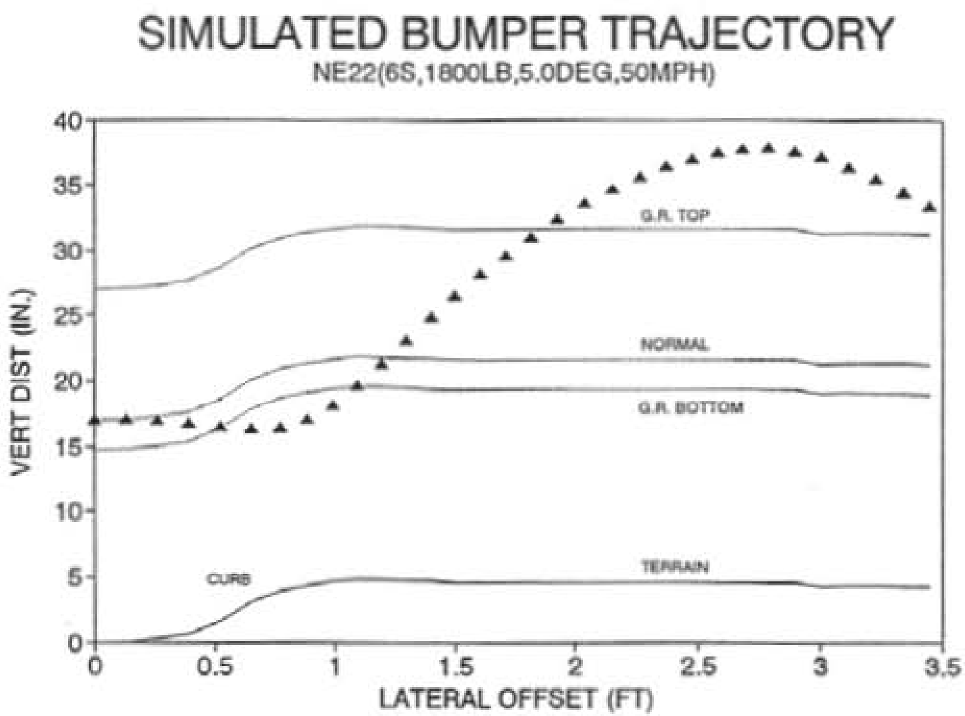


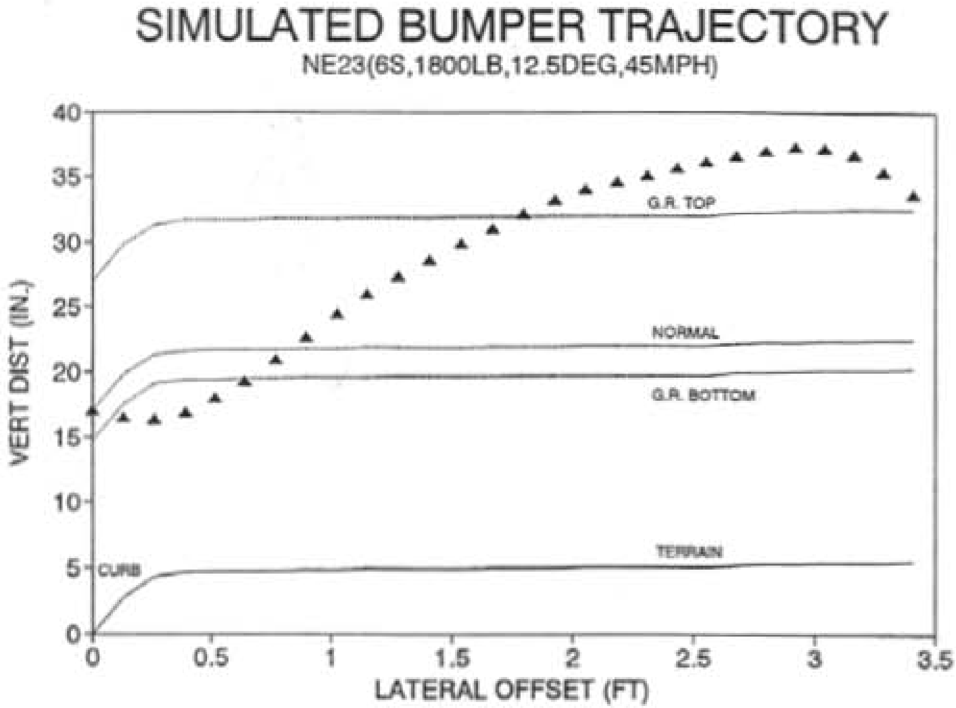
SIMULATED BUMPER TRAJECTORY

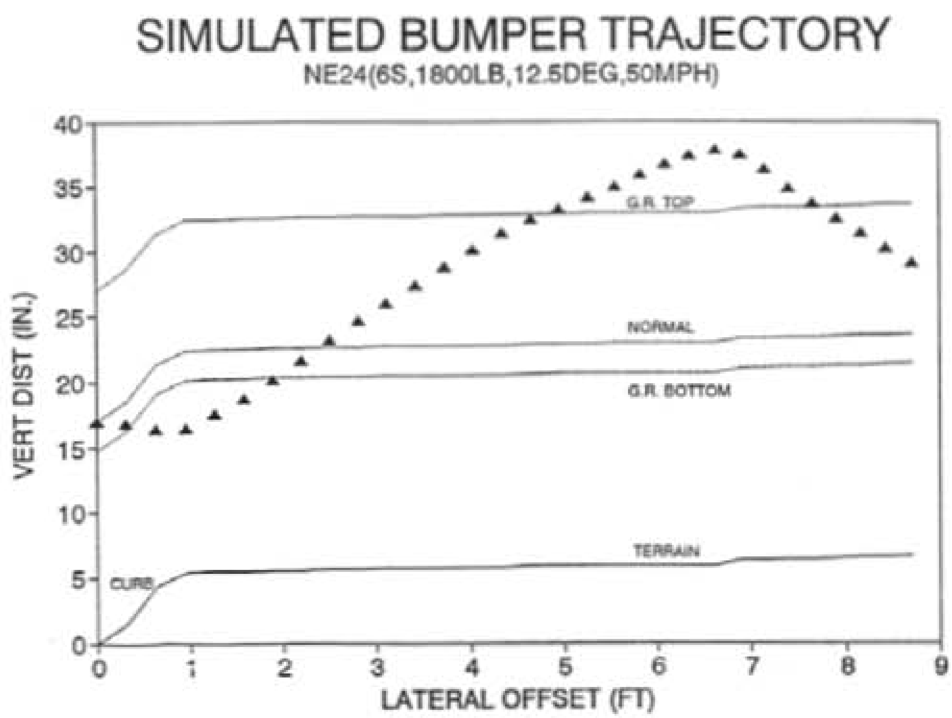
NE20(6L,4500LB,12.5DEG,55MPH)




SIMULATED BUMPER TRAJECTORY
NE21(6L,4500LB,20.0DEG,50MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12

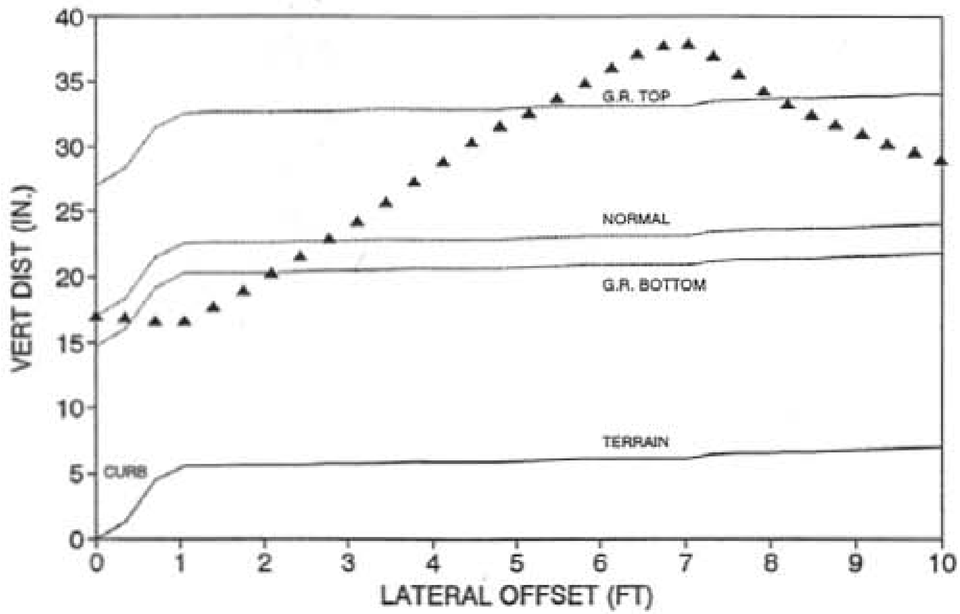

SIMULATED BUMPER TRAJECTORY
NE22(6S,1800LB,5.0DEG,50MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
0
0.5
1
1.5
2
2.5
3
3.5


SIMULATED BUMPER TRAJECTORY
NE23(6S,1800LB,12.5DEG,45MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
0.5
1
1.5
2
2.5
3
3.5


SIMULATED BUMPER TRAJECTORY
NE24(6S,1800LB,12.5DEG,50MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9

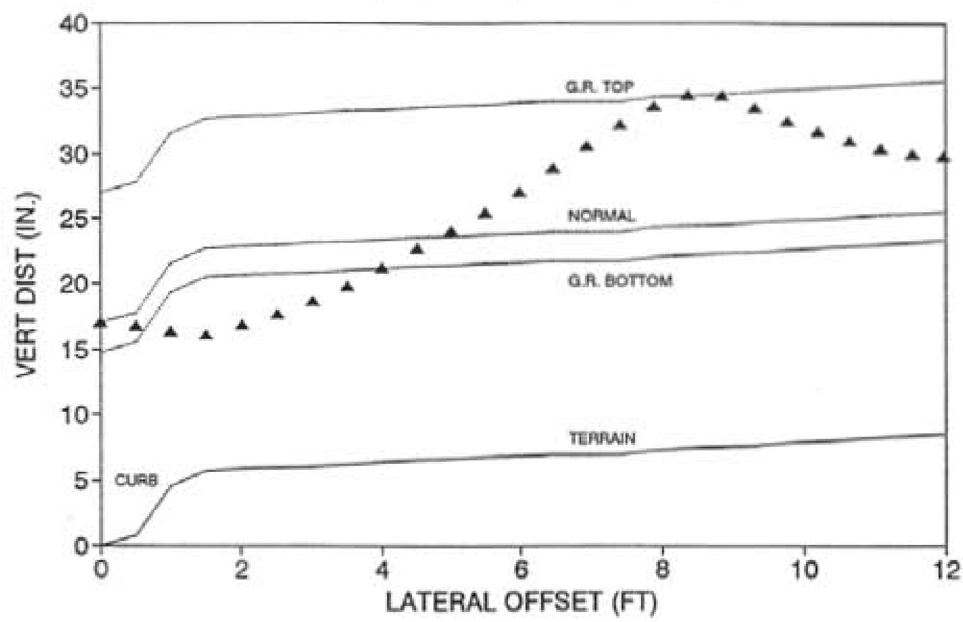
SIMULATED BUMPER TRAJECTORY

NE25(6S,1800LB,12.5DEG,55MPH)



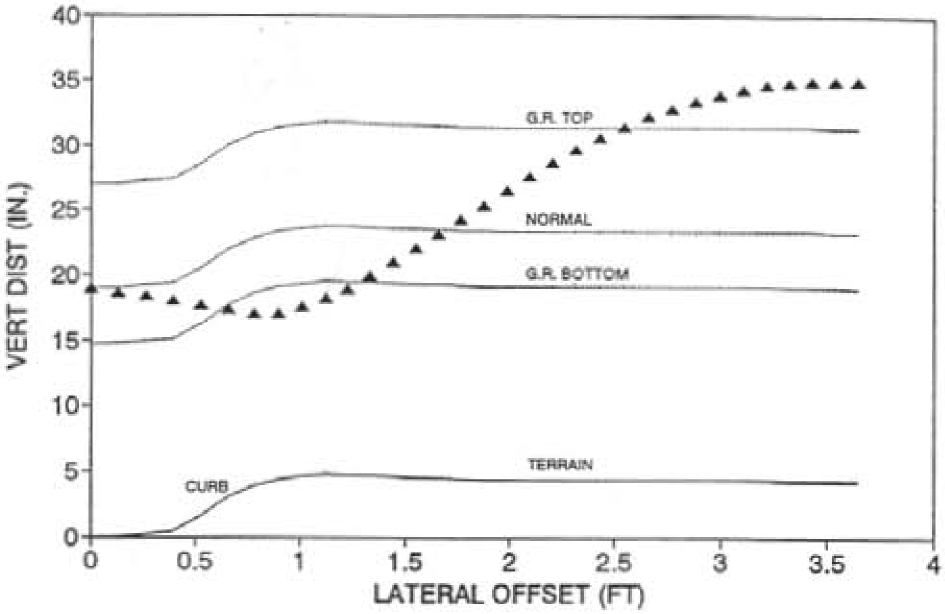
SIMULATED BUMPER TRAJECTORY

NE26(6S,1800LB,20.0DEG,50MPH)



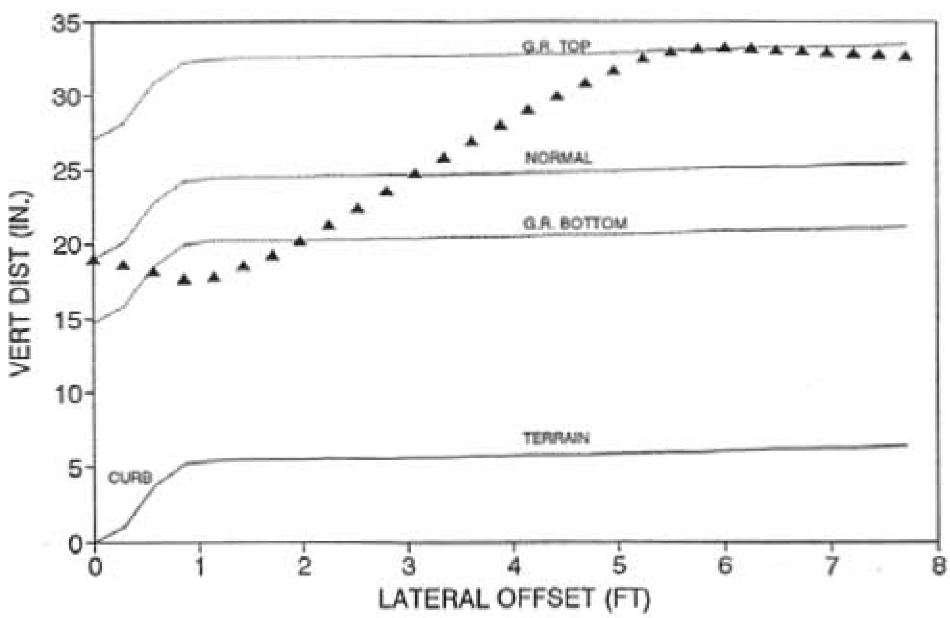
SIMULATED BUMPER TRAJECTORY

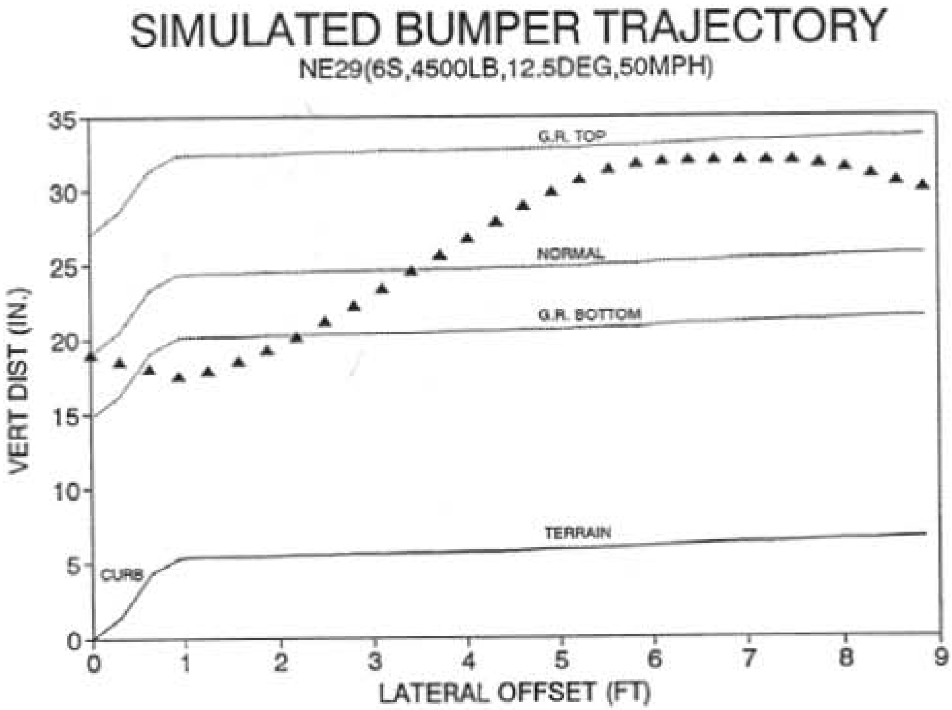
NE27(6S,4500LB,5.0DEG,50MPH)

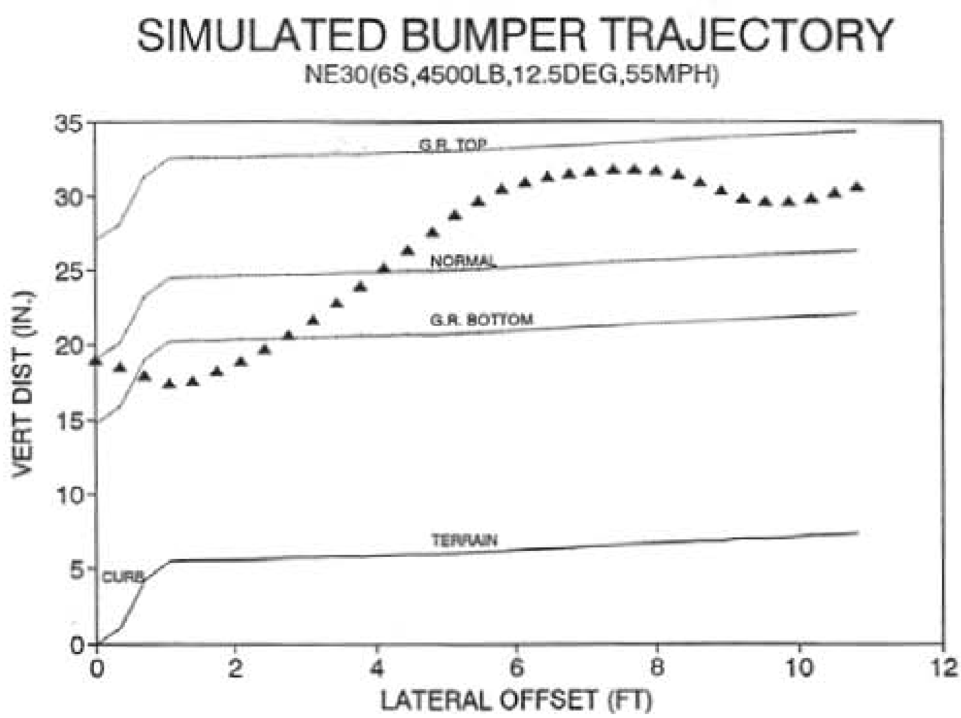


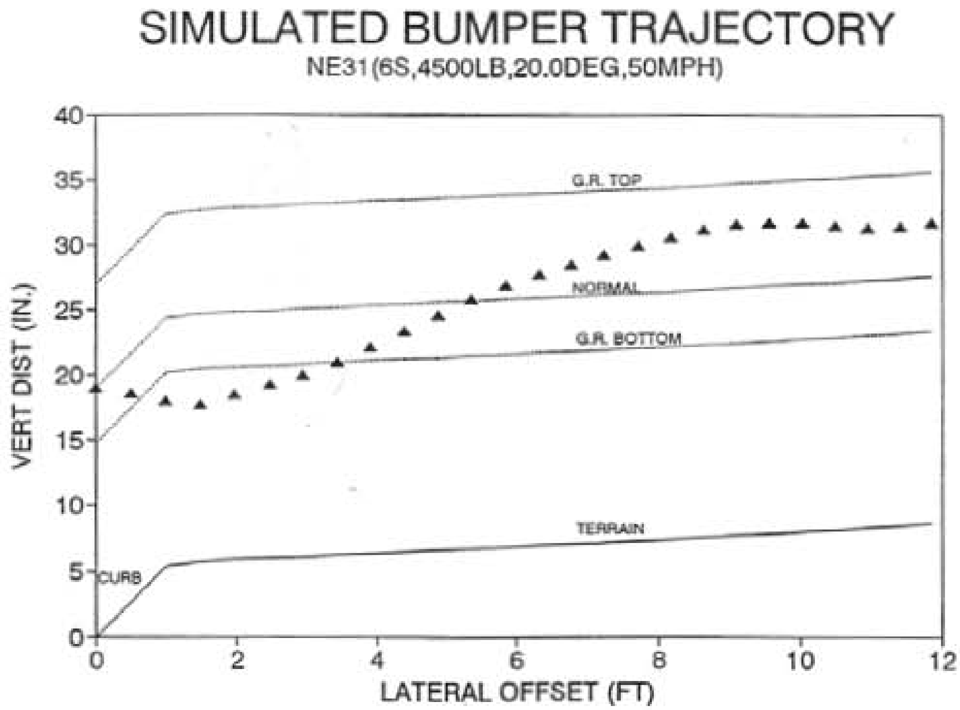
SIMULATED BUMPER TRAJECTORY

NE28(6S,4500LB,12.5DEG,45MPH)




SIMULATED BUMPER TRAJECTORY
NE29(6S,4500LB,12.5DEG,50MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
7
8
9


SIMULATED BUMPER TRAJECTORY
NE30(6S,4500LB,12.5DEG,55MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12


SIMULATED BUMPER TRAJECTORY
NE31(6S,4500LB,20.0DEG,50MPH)
G.R. TOP
NORMAL
G.R. BOTTOM
TERRAIN
CURB
VERT DIST (IN.)
LATERAL OFFSET (FT)
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12

APPENDIX F:

"Non-Tracking" Example Input Set (NT27)

(6-in Type I Curb, 180 deg yaw, 1800 lb Vehicle)

```
1
0(nt27, 1800 lb, 180 deg impact, 6-in S)                                  0 100
00.0     2.5     .001    .005    70.0    0.0     0.0                      0 101
01.0     1.0     .001    0.0     0.0     0.0                     0.0      0 102
01.0                                                                      0 103
01.0     1.0     1.0     1.0     1.0     1.0     1.0                      0 104
0VEHICLE DATA                                                             0 200
04.297   0.348   0.557   2643.81 5627.91 9118.49 0.0                      0 201
026.71   63.79   54.0    53.5                                             0 202
05.0     0.0     2.5                             12.65   12.4             0 203
075.55   278.9   0.854   278.9   0.854   1.0     -2.05   2.0              0 204
0131.33  278.9   0.73    278.9   0.73    1.0     -3.0    3.5              0 205
06.25    12.0    3.49    20.0    3.49    31.0    0.1     1.8              0 206
08.48    5.0     19.66   12.5    8.21    30.0    19.66   1.6              0 207
06.43    5.0     4.82    12.25   3.35    32.5    0.1     1.8              0 208
010.4    12.5    4.09    20.0    4.09    30.0    10.4    1.6              0 209
013500.  30900.                                                           0 210
0200.    240.    0.40    5000.   0.075   1.10                             0 211
0-3.0    3.0     0.5                                                      0 212
0-1.5    -1.375  -1.25   -1.125  -1.0    -.625   -.375   0.0     .625     1 212
01.0     1.45    1.75    2.125                                            2 212
0-2.25   -1.85   -1.5    -1.125  -0.75   -0.25   0.25    .625    1.125    3 212
01.75    2.25    3.0     4.25                                             4 212
0-5.0    5.0     5.0                                                      0 214
00.092   0.092   0.092                                                    1 214
0TIRE DATA                                                                0 300
01.0     1.0     1.0     1.0     6.0     0.25    0.0                      0 301
0870.    4.38    10.     148.52  12.9    2446.0  0.446   -5559.9 1.0      1 301
013.5    0.7     0.0     2000.   0.05    0.8     4.88    0.3              2 301
0VEHICLE CONTROL                                                          0 400
00.0     9.8     .2      1.0     0.0     0.0                              0 401
09.0     1.8     3.6     5.4     7.2     9.0     9.0     9.0     9.0      1 401
09.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0      2 401
09.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0      3 401
09.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0      4 401
09.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0     9.0      5 401
09.0     9.0     9.0     9.0                                              6 401
0GENERATED CURB SURFACE                                                   0 500
032.     0.      72.     87.     1.0                                      0 507
0-600.   -480.   0.      -600.   -120.   0.      -600.   24.     0.       1 507
0-600.   72.     0.      -600.   120.    0.      -600.   168.    0.       2 507
0-600.   171.36  0.      -600.   174.72  0.      -600.   177.76  0.       3 507
0-600.   180.    0.      -600.   300.    0.      -600.   2480.   0.       4 507
0-360.   -480.   0.      -360.   -120.   0.      -360.   24.     0.       5 507
0-360.   72.     0.      -360.   120.    0.      -360.   168.    0.       6 507
0-360.   171.36  0.      -360.   174.72  0.      -360.   177.76  0.       7 507
0-360.   180.    0.      -360.   300.    0.      -360.   2480.   0.       8 507
0-312.   -480.   0.      -312.   -120.   0.      -312.   24.     0.       9 507
0-312.   72.     0.96    -312.   120.    1.92    -312.   168.    2.88    10 507
0-312.   171.36  2.16    -312    174.72  -1.32   -312.   177.76  -2.64   11 507
0-312.   180.    -3.12   -312.   300.    -7.92   -312.   2480.   -2.52   12 507
0-264.   -480.   0.      -264.   -120.   0.      -264.   24.     0.      13 507
0-264.   72.     0.96    -264.   120.    1.92    -264.   168.    2.88    14 507
0-264.   171.36  2.16    -264.   174.72  -1.32   -264.   177.76  -2.64   15 507
0-264.   180.    -3.12   -264.   300.    -7.92   -264.   2480.   -2.52   16 507
0168.    -480.   0.      168.    -120.   0.      168.    24.     0.      17 507
0168.    72.     0.96    168.    120.    1.92    168.    168.    2.88    18 507
0168.    171.36  2.16    168.    174.72  -1.32   168.    177.76  -2.64   19 507
0168.    180.    -3.12   168.    300.    -7.92   168.    2480.   -2.52   20 507
02600.   -480.   0.      2600.   -120.   0.      2600.   24.     0.0     21 507
02600.   72.     0.96    2600.   120.    1.92    2600.   168.    2.88    22 507
02600.   171.36  2.16    2600.   174.72  -1.32   2600.   177.76  -2.64   23 507
02600.   180.    -3.12   2600.   300.    -7.92   2600.   2480.   -2.52   24 507
04.  4.  4.  4.  4.  4.  4.  4.  4.  4.  4.  4.  3.  3.  3.  3.  3.  3.   1 508
03.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  4.  3.  3.  3.   2 508
03.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  3.  4.   3 508
03.  3.  3.  3.  3.  3.  3.  3.  4.  4.  4.  4.  3.  3.  3.  3.  4.  3.   4 508
03.  3.  3.  3.  3.  3.  3.  4.  4.  4.  4.  3.  3.  3.  3.               5 508
01.  0.  2.  2.  14. 12. 13. 0.  2.  0.  3.  3.  15. 14. 14. 1.  3.  0.   1 509
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04.  4.  16. 16. 15. 2.  4.  0.  5.  5.  17. 18. 16. 3.  5.  0.  6.  6.      2 509
018. 20. 17. 4.  6.  0.  7.  7.  19. 22. 18. 5.  7.  0.  8.  8.  20. 24.     3 509
019. 6.  8.  0.  9.  9.  21. 26. 20. 7.  9.  0.  10. 10. 22. 28. 21. 8.      4 509
010. 0.  11. 11. 23. 30. 22. 9.  11. 0.  12. 0.  24. 32. 23. 10. 13. 1.      5 509
014. 13. 26. 33. 25. 0.  14. 14. 27. 34. 26. 12. 14. 2.  15. 15. 27. 13.     6 509
015. 16. 28. 36. 27. 14. 15. 3.  16. 17. 28. 15. 16. 18. 29. 38. 28. 16.     7 509
016. 4.  17. 19. 29. 17. 17. 20. 30. 40. 29. 18. 17. 5.  18. 21. 30. 19.     8 509
018. 22. 31. 42. 30. 20. 18. 6.  19. 23. 31. 21. 19. 24. 32. 44. 31. 22.     9 509
019. 7.  20. 25. 32. 23. 20. 26. 33. 46. 32. 24. 20. 8.  21. 27. 33. 25.    10 509
021. 28. 34. 48. 33. 26. 21. 9.  22. 29. 34. 27. 22. 30. 35. 50. 34. 28.    11 509
022. 10. 23. 31. 35. 29. 23. 32. 36. 52. 35. 30. 23. 11. 24. 0.  36. 31.    12 509
025. 12. 26. 34. 38. 54. 37. 0.  26. 13. 27. 35. 38. 33. 27. 36. 39. 56.    13 509
038. 34. 27. 15. 28. 37. 39. 35. 28. 38. 40. 58. 39. 36. 28. 17. 29. 39.    14 509
040. 37. 29. 40. 41. 60. 40. 38. 29. 19. 30. 41. 41. 39. 30. 42. 42. 62.    15 509
041. 40. 30. 21. 31. 43. 42. 41. 31. 44. 43. 63. 42. 42. 31. 23. 32. 45.    16 509
043. 43. 32. 46. 44. 64. 43. 44. 32. 25. 33. 47. 44. 45. 33. 48. 45. 65.    17 509
044. 46. 33. 27. 34. 49. 45. 47. 34. 50. 46. 66. 45. 48. 34. 29. 35. 51.    18 509
046. 49. 35. 52. 47. 68. 46. 50. 35. 31. 36. 53. 47. 51. 36. 0.  48. 70.    19 509
047. 52. 37. 33. 38. 55. 50. 71. 49. 0.  38. 56. 51. 72. 50. 54. 38. 35.    20 509
039. 57. 51. 55. 39. 58. 52. 74. 51. 56. 39. 37. 40. 59. 52. 57. 40. 60.    21 509
053. 76. 52. 58. 40. 39. 41. 61. 53. 59. 41. 62. 54. 78. 53. 60. 41. 41.    22 509
042. 63. 54. 61. 42. 43. 43. 64. 55. 80. 54. 62. 43. 45. 44. 65. 56. 81.    23 509
055. 63. 44. 47. 45. 66. 57. 82. 56. 64. 45. 49. 46. 67. 58. 83. 57. 65.    24 509
046. 68. 59. 84. 58. 66. 46. 51. 47. 69. 59. 67. 47. 70. 60. 86. 59. 68.    25 509
047. 53. 48. 0.  60. 69. 49. 54. 50. 72. 62. 0.  61. 0.  50. 55. 51. 73.    26 509
062. 71. 51. 74. 63. 0.  62. 72. 51. 57. 52. 75. 63. 73. 52. 76. 64. 0.     27 509
063. 74. 52. 59. 53. 77. 64. 75. 53. 78. 65. 0.  64. 76. 53. 61. 54. 79.    28 509
065. 77. 54. 80. 66. 0.  65. 78. 54. 63. 55. 81. 67. 0.  66. 79. 55. 64.    29 509
056. 82. 68. 0.  67. 80. 56. 65. 57. 83. 69. 0.  68. 81. 57. 66. 58. 84.    30 509
070. 0.  69. 82. 58. 67. 59. 85. 70. 83. 59. 86. 71. 0.  70. 84. 59. 69.    31 509
060. 87. 71. 85. 60. 0.  72. 0.  71. 86.                                    32 509
01.  1.  2.  2.  3.  3.  4.  4.  5.  5.  6.  6.  7.  7.  8.  8.  9.  9.      1 510
010. 10. 11. 11. 12. 11. 24. 32. 36. 53. 48. 70. 60. 87. 72. 87. 71. 85.     2 510
070. 83. 69. 82. 68. 81. 67. 80. 66. 79. 65. 77. 64. 75. 63. 73. 62. 71.     3 510
061. 71. 49. 54. 37. 33. 25. 12. 13. 1.                                      4 510
0INITIAL CONDITIONS                                                          0 600
0-5.13   -1.21   155.58  15.66   -4.71   49.8    9.0     0.0                 0 601
00.0     -50.0   -26.52  -579.36 -765.48 -49.8                               0 602
02.66    -1.56   2.19    .13     -8.11   .28     -.28    .96                 0 603
0                                                                            09999
1         (nt27, 1800 lb, 180 deg impact, 6-in S)
          OCTOBER
    VEHICLE DATA                              TIRE DATA                              VEHICLE CONTROL

    GENERATED CURB SURFACE                    INITIAL CONDITIONS

0                       P R O G R A M   C O N T R O L   D A T A
          START TIME                    T0     =    .0000  SEC
          END TIME                      T1     =   2.5000  SEC
          INTEGRATION INCREMENT         DTCOMP =    .0010  SEC
                                                              (0=VARIABLE STEP ADAMS-MOULTON
          INTEGRATION MODE              MODE   =    1        -)1= RUNGA-KUTTA
                                                              (2= FIXED STEP ADAMS-MOULTON
          PRINT INTERVAL                DTPRNT =    .0050  SEC
0                                                             (0= INDEPENDENT FRONT SUSPENSION,
SOLID REAR AXLE
          SUSPENSION OPTION             ISUS   =    1        -)1= INDEPENDENT FRONT AND REAR
SUSPENSION
                                                              (2= SOLID FRONT AND REAR AXLES

                                                              (0= NO CURB, NO STEER DEGREE OF
FREEDOM
          CURB/STEER OPTION             INDCRB =    1        -)1= CURB
                                                              (-1=STEER DEGREE OF FREEDOM, NO CURB

          CURB INTEGRATION INCR.        DELTC  =    .00100 SEC
0                                                             (0= NO BARRIER
                                                              |1= RIGID BARRIER , FINITE VERT. DIM.
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        BARRIER OPTION             INDB   =    0        -)2=  ''      '' ,INFINITE  ''    ''
                                                         |3= DEFORM. ''  , FINITE  ''    ''
                                                         (4=  ''      '' ,INFINITE  ''    ''
        BARRIER INTEGRATION INCR.  DELTB  =    .00000  SEC
0
        SIGN IMPACT OPTION         COLL   =   0.        ( 0 = NO : 1 = YES
0
                                          I N I T I A L   C O N D I T I O N S
                                   XCOP   =     .00   INCHES
   U0   = -579.36   IN/SEC
        SPRUNG MASS C.G. POSITION  YCOP   =  -50.00   INCHES      SPRUNG MASS LINEAR
VELOCITY    V0   = -765.48   IN/SEC
                                   ZCOP   =  -26.52   INCHES
   W0   =  -49.80   IN/SEC
0                                  PHI0   =   -5.13   DEGREES
   P0   =   15.66   DEG/SEC
        SPRUNG MASS ORIENTATION    THETA0 =   -1.21   DEGREES     SPRUNG MASS ANGULAR
VELOCITY    Q0   =   -4.71   DEG/SEC
                                   PSI0   =  155.58   DEGREES
   R0   =   49.80   DEG/SEC
0                                  DEL10  =    2.66   INCHES
  DEL10D =   -8.11   IN/SEC
        UNSPRUNG MASS POSITIONS    DEL20  =   -1.56   INCHES      UNSPRUNG MASS VELOCITIES
  DEL20D =     .28   IN/SEC
0                                  DEL30  =    2.19   INCHES
  DEL30D =    -.28   IN/SEC
                                   DEL40  =     .13   INCHES
  DEL40D =     .96   IN/SEC
        STEER ANGLE                PSIFI0 =    9.00   DEGREES     STEER VELOCITY
  PSIFD0 =     .00   DEG/SEC
1       (nt27, 1800 lb, 180 deg impact, 6-in S)
        OCTOBER
    VEHICLE DATA                          TIRE DATA                        VEHICLE CONTROL

    GENERATED CURB SURFACE                INITIAL CONDITIONS

0       SPRUNG MASS                XMS   =     4.297 LB-SEC**2/IN    FRONT WHEEL X LOCATION
A    =  26.710 INCHES
        FRONT UNSPRUNG MASS        XMUF  =      .348 LB-SEC**2/IN    REAR WHEEL X LOCATION
B    =  63.790 INCHES
        REAR UNSPRUNG MASS         XMUR  =      .557 LB-SEC**2/IN    FRONT WHEEL Z LOCATION
ZF   =  12.650 INCHES
0       X MOMENT OF INERTIA        XIX   =  2643.810 LB-SEC**2-IN    REAR WHEEL Z LOCATION
ZR   =  12.400 INCHES
        Y MOMENT OF INERTIA        XIY   =  5627.910 LB-SEC**2-IN    FRONT WHEEL TRACK
TF   =  54.000 INCHES
        Z MOMENT OF INERTIA        XIZ   =  9118.490 LB-SEC**2-IN    REAR WHEEL TRACK
TR   =  53.500 INCHES
        XZ PRODUCT OF INERTIA      XIXZ  =      .000 LB-SEC**2-IN    FRONT ROLL AXIS
RHOF =    .000 NOT USED
0       FRONT AXLE MOMENT OF INERTIA XIF =      .000 NOT USED        REAR ROLL AXIS
RHO  =    .000 NOT USED
        REAR AXLE MOMENT OF INERTIA  XIR =      .000 NOT USED        FRONT SPRING TRACK
TSF  =    .000 NOT USED
        GRAVITY                    G     =   386.400 IN/SEC**2       REAR SPRING TRACK
TS   =    .000 NOT USED
0                                  X1    =      5.00 INCHES          FRONT AUX ROLL STIFFNESS
RF   = 13500.00 LB-IN/RAD
        ACCELEROMETER 1 POSITION   Y1    =       .00 INCHES          REAR AUX ROLL STIFFNESS
RR   = 30900.00 LB-IN/RAD
                                   Z1    =      2.50 INCHES          REAR ROLL-STEER COEF.
AKRS =    .0000 NOT USED
                                   X2    =       .00 INCHES
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AKDS =     .000 RADIANS
          ACCELEROMETER 2 POSITION      Y2    =     .00 INCHES         REAR DEFL-STEER COEFS.
AKDS1=     .000 RAD/IN
                                        Z2    =     .00 INCHES
AKDS2=     .000 RAD/IN**2

AKDS3=     .000 RAD/IN**3
0              S T E E R I N G   S Y S T E M
          MOMENT OF INERTIA       XIPS  =   200.000 LB-SEC**2-IN
          COULOMB FRICTION TORQUE CPSP  =   240.000 LB-IN
          FRICTION LAG            EPSP  =      .075 RAD/SEC
          ANGULAR STOP RATE       AKPS  =  5000.000 LB-IN/RAD
          ANGULAR STOP POSITION   OMGPS =      .400 RADIANS
          PNEUMATIC TRAIL         XPS   =     1.100 INCHES
0                                   FRONT SUSPENSION                   REAR SUSPENSION

          SUSPENSION RATE                 AKF    =   75.550 LB/IN        AKR    =  131.330
LB/IN
          COMPRESSION STOP COEFS.         AKFC   =  278.900 LB/IN        AKRC   =  278.900
LB/IN
                                          AKFCP  =     .854 LB/IN**3     AKRCP  =     .730
LB/IN**3
0         EXTENSION STOP COEFS.           AKFE   =  278.900 LB/IN        AKRE   =  278.900
LB/IN
                                          AKFEP  =     .854 LB/IN**3     AKREP  =     .730
LB/IN**3
          COMPRESSION STOP LOCATION       OMEGFC =   -2.050 INCHES       OMEGRC =   -3.000
INCHES
          EXTENSION STOP LOCATION         OMEGFE =    2.000 INCHES       OMEGRE =    3.500
INCHES
0         STOP ENERGY DISSIPATION FACTOR  XLAMF  =    1.000              XLAMR  =    1.000
          COMP. VISC. DAMP. COEF. NO. 1   CFJ(1) =    6.250 LB-SEC/IN    CRJ(1) =    6.430
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 1   DLFJ(1)=   12.000 IN/SEC       DLRJ(1)=    5.000
IN/SEC
          COMP. VISC. DAMP. COEF. NO. 2   CFJ(2) =    3.490 LB-SEC/IN    CRJ(2) =    4.820
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 2   DLFJ(2)=   20.000 IN/SEC       DLRJ(2)=   12.250
IN/SEC
          COMP. VISC. DAMP. COEF. NO. 3   CFJ(3) =    3.490 LB-SEC/IN    CRJ(3) =    3.350
LB-SEC/IN
0          EXTN. VISC. DAMP. COEF. NO. 1   CFR(1) =    8.480 LB-SEC/IN    CRR(1) =   10.400
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 1   DLFR(1)=    5.000 IN/SEC       DLRR(1)=   12.500
IN/SEC
          EXTN. VISC. DAMP. COEF. NO. 2   CFR(2) =   19.660 LB-SEC/IN    CRR(2) =    4.090
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 2   DLFR(2)=   12.500 IN/SEC       DLRR(2)=   20.000
IN/SEC
          EXTN. VISC. DAMP. COEF. NO. 3   CFR(3) =    8.210 LB-SEC/IN    CRR(3) =    4.090
LB-SEC/IN
          VEL. AT THE CHANGE OF COEF. 3   DLFR(3)=   30.000 IN/SEC       DLRR(3)=   30.000
IN/SEC
0          EXTN. VISC. DAMP. COEF. NO. 4   CFR(4) =   19.660 LB-SEC/IN    CRR(4) =   10.400
LB-SEC/IN
          COULOMB FRICTION                CFP    =   31.000 LB           CRP    =   32.500 LB

          FRICTION LAG                    EPSF   =     .100 IN/SEC       EPSR   =     .100
IN/SEC
          POWER IN POWER LAW DAMPING      POWF   =    1.600              POWR   =    1.600
1         (nt27, 1800 lb, 180 deg impact, 6-in S)
          OCTOBER
    VEHICLE DATA                          TIRE DATA                              VEHICLE CONTROL

    GENERATED CURB SURFACE                INITIAL CONDITIONS

0          FRONT WHEEL CAMBER       REAR WHEEL CAMBER      FRONT HALF-TRACK CHANGE    REAR
HALF-TRACK CHANGE
                 VS                        VS                        VS                       VS
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SUSPENSION DEFLECTION		SUSPENSION DEFLECTION		SUSPENSION DEFLECTION		SUSPENSION DEFLECTION	
DELTAF	PHIC	DELTAR	PHIRC	DELTAF	DTHF	DELTAR	DTHR
INCHES	DEGREES	INCHES	DEGREES	INCHES	INCHES	INCHES	INCHES
-3.00	-1.50	-3.00	-2.25	-3.00	.00	-3.00	.00
-2.50	-1.38	-2.50	-1.85	-2.50	.00	-2.50	.00
-2.00	-1.25	-2.00	-1.50	-2.00	.00	-2.00	.00
-1.50	-1.13	-1.50	-1.13	-1.50	.00	-1.50	.00
-1.00	-1.00	-1.00	-.75	-1.00	.00	-1.00	.00
-.50	-.63	-.50	-.25	-.50	.00	-.50	.00
.00	-.38	.00	.25	.00	.00	.00	.00
.50	.00	.50	.63	.50	.00	.50	.00
1.00	.63	1.00	1.13	1.00	.00	1.00	.00
1.50	1.00	1.50	1.75	1.50	.00	1.50	.00
2.00	1.45	2.00	2.25	2.00	.00	2.00	.00
2.50	1.75	2.50	3.00	2.50	.00	2.50	.00
3.00	2.13	3.00	4.25	3.00	.00	3.00	.00

0

DRIVER CONTROL TABLES

T	PSIF	TQF	TQR	T	PSIF	TQF	TQR	T	PSIF	TQF	TQR	T	PSIF	TQF	TQR
SEC	DEG	LB-FT	LB-FT	SEC	DEG	LB-FT	LB-FT	SEC	DEG	LB-FT	LB-FT	SEC	DEG	LB-FT	LB-FT
.000	9.000	.0	.0	2.600	9.000	.0	.0	5.200	9.000	.0	.0	7.800	9.000	.0	.0
.200	1.800	.0	.0	2.800	9.000	.0	.0	5.400	9.000	.0	.0	8.000	9.000	.0	.0
.400	3.600	.0	.0	3.000	9.000	.0	.0	5.600	9.000	.0	.0	8.200	9.000	.0	.0
.600	5.400	.0	.0	3.200	9.000	.0	.0	5.800	9.000	.0	.0	8.400	9.000	.0	.0
.800	7.200	.0	.0	3.400	9.000	.0	.0	6.000	9.000	.0	.0	8.600	9.000	.0	.0
1.000	9.000	.0	.0	3.600	9.000	.0	.0	6.200	9.000	.0	.0	8.800	9.000	.0	.0
1.200	9.000	.0	.0	3.800	9.000	.0	.0	6.400	9.000	.0	.0	9.000	9.000	.0	.0
1.400	9.000	.0	.0	4.000	9.000	.0	.0	6.600	9.000	.0	.0	9.200	9.000	.0	.0
1.600	9.000	.0	.0	4.200	9.000	.0	.0	6.800	9.000	.0	.0	9.400	9.000	.0	.0
1.800	9.000	.0	.0	4.400	9.000	.0	.0	7.000	9.000	.0	.0	9.600	9.000	.0	.0
2.000	9.000	.0	.0	4.600	9.000	.0	.0	7.200	9.000	.0	.0	9.800	.000	.0	.0
2.200	9.000	.0	.0	4.800	9.000	.0	.0	7.400	9.000	.0	.0				
2.400	9.000	.0	.0	5.000	9.000	.0	.0	7.600	9.000	.0	.0				

1 (nt27, 1800 lb, 180 deg impact, 6-in S)
OCTOBER
VEHICLE DATA TIRE DATA VEHICLE CONTROL

GENERATED CURB SURFACE INITIAL CONDITIONS

0 T I R E D A T A

				RF	LF	RR	LR	
0 LB/IN	TIRE LINEAR SPRING RATE	AKT	=	870.000	870.000	870.000	870.000	
INCHES	DEFL. FOR INCREASED RATE	SIGT	=	4.380	4.380	4.380	4.380	
	SPRING RATE INCREASING FACTOR	XLAMT	=	10.000	10.000	10.000	10.000	
		A0	=	148.520	148.520	148.520	148.520	
		A1	=	12.900	12.900	12.900	12.900	
	SIDE FORCE COEFFICIENTS	A2	=	2446.000	2446.000	2446.000	2446.000	
		A3	=	.446	.446	.446	.446	
		A4	=	-5559.900	-5559.900	-5559.900	-5559.900	
	TIRE OVERLOAD FACTOR	OMEGT	=	1.000	1.000	1.000	1.000	
INCHES	TIRE UNDEFLECTED RADIUS	RW	=	13.500	13.500	13.500	13.500	
	TIRE / GROUND FRICTION COEF.	AMU	=	.700	.700	.700	.700	
	TIRE DAMPING PARAMETER	AMUT	=	.000	.000	.000	.000	SEC
LB/IN	TIRE RIM STIFFNESS TERM	AKTR	=	2000.000	2000.000	2000.000	2000.000	
	RIM FORCE VELOCITY COEF.	CTR	=	.050	.050	.050	.050	
	RIM FORCE POWER TERM	PTR	=	.800	.800	.800	.800	
INCHES	TIRE DEFLECTION TO THE RIM	RDR	=	4.880	4.880	4.880	4.880	
	RIM / CURB FRICTION COEFF.	AMURC	=	.300	.300	.300	.300	
	FRICTION LAG FOR RIM FRICION	EPSVR	=	.000				

0 ANTI-PITCH TABLES FOR CIRCUMFERENTIAL TIRE FORCE

FRONT WHEEL DEFL. - IN.	APF LB/LB-FT	REAR WHEEL DEFL.- IN.	APR LB/LB-FT
		-5.0000	.0920
		.0000	.0920
		5.0000	.0920

1 (nt27, 1800 lb, 180 deg impact, 6-in S)
OCTOBER
VEHICLE DATA TIRE DATA VEHICLE CONTROL

GENERATED CURB SURFACE INITIAL CONDITIONS

0 C U R B / B A R R I E R D A T A

CURB FRICTION COEFFICIENT FACTOR AMUC = 1.000

NODE LOCATIONS & NO. OF NODES CONNECTED

NODE NO.	X'(INCHES)	LOCATION Y'(INCHES)	Z'(INCHES)	NO. OF NODES CONNECTED
1	-600.00	-480.00	.00	2
2	-600.00	-120.00	.00	3
3	-600.00	24.00	.00	3
4	-600.00	72.00	.00	3
5	-600.00	120.00	.00	3
6	-600.00	168.00	.00	3
7	-600.00	171.36	.00	3
8	-600.00	174.72	.00	3
9	-600.00	177.76	.00	3
10	-600.00	180.00	.00	3
11	-600.00	300.00	.00	3
12	-600.00	2480.00	.00	2
13	-360.00	-480.00	.00	3
14	-360.00	-120.00	.00	5

15	-360.00	24.00	.00	5
16	-360.00	72.00	.00	5
17	-360.00	120.00	.00	5
18	-360.00	168.00	.00	5
19	-360.00	171.36	.00	5
20	-360.00	174.72	.00	5
21	-360.00	177.76	.00	5
22	-360.00	180.00	.00	5
23	-360.00	300.00	.00	5
24	-360.00	2480.00	.00	3
25	-312.00	-480.00	.00	3
26	-312.00	-120.00	.00	4
27	-312.00	24.00	.00	6
28	-312.00	72.00	.96	6
29	-312.00	120.00	1.92	6
30	-312.00	168.00	2.88	6
31	-312.00	171.36	2.16	6
32	-312.00	174.72	-1.32	6
33	-312.00	177.76	-2.64	6
34	-312.00	180.00	-3.12	6
35	-312.00	300.00	-7.92	6
36	-312.00	2480.00	-2.52	5
37	-264.00	-480.00	.00	3
38	-264.00	-120.00	.00	6
39	-264.00	24.00	.00	6
40	-264.00	72.00	.96	6
41	-264.00	120.00	1.92	6
42	-264.00	168.00	2.88	5
43	-264.00	171.36	2.16	5
44	-264.00	174.72	-1.32	5
45	-264.00	177.76	-2.64	5
46	-264.00	180.00	-3.12	6
47	-264.00	300.00	-7.92	6
48	-264.00	2480.00	-2.52	3
49	168.00	-480.00	.00	3
50	168.00	-120.00	.00	4
51	168.00	24.00	.00	6
52	168.00	72.00	.96	6
53	168.00	120.00	1.92	6
54	168.00	168.00	2.88	6
55	168.00	171.36	2.16	4
56	168.00	174.72	-1.32	4
57	168.00	177.76	-2.64	4
58	168.00	180.00	-3.12	4
59	168.00	300.00	-7.92	6
60	168.00	2480.00	-2.52	5
61	2600.00	-480.00	.00	2
62	2600.00	-120.00	.00	4
63	2600.00	24.00	.00	4
64	2600.00	72.00	.96	4
65	2600.00	120.00	1.92	4
66	2600.00	168.00	2.88	3
67	2600.00	171.36	2.16	3
68	2600.00	174.72	-1.32	3
69	2600.00	177.76	-2.64	3
70	2600.00	180.00	-3.12	4
71	2600.00	300.00	-7.92	4
72	2600.00	2480.00	-2.52	2

ELEMENT SLOPES, ORIENTATIONS AND NO. OF SIDES

ELEM. NO.	SLOPE,PHIS (DEG.)	ORIENTN.,PSIS (DEG.)	NO. OF SIDES
1	.00	.00	4
2	.00	.00	4
3	.00	.00	4
4	.00	.00	4

5	.00	.00	4
6	.00	.00	4
7	.00	.00	4
8	.00	.00	4
9	.00	.00	4
10	.00	.00	4
11	.00	.00	4
12	.00	.00	4
13	.00	.00	3
14	.00	.00	3
15	-1.15	180.00	3
16	-1.15	90.00	3
17	-1.62	135.00	3
18	-2.29	90.00	3
19	-2.56	116.57	3
20	-3.43	90.00	3
21	-12.55	15.64	3
22	-2.58	90.00	3
23	-46.03	2.49	3
24	-1.58	-90.00	3
25	-23.51	-3.62	3
26	-3.15	-90.00	3
27	-12.47	-14.40	3
28	-3.72	-90.00	3
29	-4.36	-58.39	3
30	-9.37	-90.00	3
31	-9.37	-90.86	3
32	-3.01	-90.00	3
33	.00	.00	4
34	.00	.00	3
35	.00	.00	3
36	-1.15	180.00	3
37	-1.15	180.00	3
38	-1.15	180.00	3
39	-1.15	180.00	3
40	-1.15	180.00	3
41	-1.15	180.00	3
42	-12.09	.00	3
43	-12.09	.00	3
44	-46.01	.00	3
45	-46.01	.00	3
46	-23.47	.00	3
47	-23.47	.00	3
48	-12.09	.00	3
49	-12.09	.00	3
50	-2.29	.00	3
51	-2.29	.00	3
52	-.14	180.00	3
53	-.14	180.00	3
54	.00	.00	4
55	.00	.00	3
56	.00	.00	3
57	-1.15	180.00	3
58	-1.15	180.00	3
59	-1.15	180.00	3
60	-1.15	180.00	3
61	-1.15	180.00	3
62	-1.15	180.00	3
63	-12.09	.00	4
64	-46.01	.00	4
65	-23.47	.00	4
66	-12.09	.00	4
67	-2.29	.00	3
68	-2.29	.00	3
69	-.14	180.00	3
70	-.14	180.00	3
71	.00	.00	4
72	.00	.00	3
73	.00	.00	3

74	-1.15	180.00	3
75	-1.15	180.00	3
76	-1.15	180.00	3
77	-1.15	180.00	3
78	-1.15	180.00	3
79	-1.15	180.00	3
80	-12.09	.00	4
81	-46.01	.00	4
82	-23.47	.00	4
83	-12.09	.00	4
84	-2.29	.00	3
85	-2.29	.00	3
86	-.14	180.00	3
87	-.14	180.00	3

ELEMENT NODE NUMBERS

ELEMENT NO.	NODES IN COUNTERCLOCKWISE SEQUENCE			
1	1	2	14	13
2	2	3	15	14
3	3	4	16	15
4	4	5	17	16
5	5	6	18	17
6	6	7	19	18
7	7	8	20	19
8	8	9	21	20
9	9	10	22	21
10	10	11	23	22
11	11	12	24	23
12	13	14	26	25
13	14	27	26	
14	14	15	27	
15	15	28	27	
16	15	16	28	
17	16	29	28	
18	16	17	29	
19	17	30	29	
20	17	18	30	
21	18	31	30	
22	18	19	31	
23	19	32	31	
24	19	20	32	
25	20	33	32	
26	20	21	33	
27	21	34	33	
28	21	22	34	
29	22	35	34	
30	22	23	35	
31	23	36	35	
32	23	24	36	
33	25	26	38	37
34	26	27	38	
35	27	39	38	
36	27	28	39	
37	28	40	39	
38	28	29	40	
39	29	41	40	
40	29	30	41	
41	30	42	41	
42	30	31	42	
43	31	43	42	
44	31	32	43	
45	32	44	43	
46	32	33	44	
47	33	45	44	
48	33	34	45	
49	34	46	45	

50	34	35	46	
51	35	47	46	
52	35	36	47	
53	36	48	47	
54	37	38	50	49
55	38	51	50	
56	38	39	51	
57	39	52	51	
58	39	40	52	
59	40	53	52	
60	40	41	53	
61	41	54	53	
62	41	42	54	
63	42	43	55	54
64	43	44	56	55
65	44	45	57	56
66	45	46	58	57
67	46	59	58	
68	46	47	59	
69	47	60	59	
70	47	48	60	
71	49	50	62	61
72	50	51	62	
73	51	63	62	
74	51	52	63	
75	52	64	63	
76	52	53	64	
77	53	65	64	
78	53	54	65	
79	54	66	65	
80	54	55	67	66
81	55	56	68	67
82	56	57	69	68
83	57	58	70	69
84	58	59	70	
85	59	71	70	
86	59	60	71	
87	60	72	71	

NODAL CONNECTIVITY

NODE NO.	NODES CONNECTED IN COUNTERCLOCKWISE SEQUENCE				
1	2	13			
2	3	14	1		
3	4	15	2		
4	5	16	3		
5	6	17	4		
6	7	18	5		
7	8	19	6		
8	9	20	7		
9	10	21	8		
10	11	22	9		
11	12	23	10		
12	24	11			
13	1	14	25		
14	2	15	27	26	13
15	3	16	28	27	14
16	4	17	29	28	15
17	5	18	30	29	16
18	6	19	31	30	17
19	7	20	32	31	18
20	8	21	33	32	19
21	9	22	34	33	20
22	10	23	35	34	21
23	11	24	36	35	22
24	36	23	12		
25	13	26	37		

26	14	27	38	25		
27	14	15	28	39	38	26
28	15	16	29	40	39	27
29	16	17	30	41	40	28
30	17	18	31	42	41	29
31	18	19	32	43	42	30
32	19	20	33	44	43	31
33	20	21	34	45	44	32
34	21	22	35	46	45	33
35	22	23	36	47	46	34
36	48	47	35	23	24	
37	25	38	49			
38	26	27	39	51	50	37
39	27	28	40	52	51	38
40	28	29	41	53	52	39
41	29	30	42	54	53	40
42	30	31	43	54	41	
43	31	32	44	55	42	
44	32	33	45	56	43	
45	33	34	46	57	44	
46	34	35	47	59	58	45
47	35	36	48	60	59	46
48	60	47	36			
49	37	50	61			
50	38	51	62	49		
51	38	39	52	63	62	50
52	39	40	53	64	63	51
53	40	41	54	65	64	52
54	41	42	55	66	65	53
55	43	56	67	54		
56	44	57	68	55		
57	45	58	69	56		
58	46	59	70	57		
59	46	47	60	71	70	58
60	72	71	59	47	48	
61	49	62				
62	61	50	51	63		
63	62	51	52	64		
64	63	52	53	65		
65	64	53	54	66		
66	65	54	67			
67	66	55	68			
68	67	56	69			
69	68	57	70			
70	69	58	59	71		
71	70	59	60	72		
72	71	60				

ELEMENT CONNECTIVITY (0 = OUTSIDE EDGE)

ELEMENT NO. ELEMENTS CONNECTED TO EACH SIDE IN COUNTERCLOCKWISE SEQUENCE (SIDE 1 STARTS FROM NODE 1)

1	0	2	12	0
2	0	3	14	1
3	0	4	16	2
4	0	5	18	3
5	0	6	20	4
6	0	7	22	5
7	0	8	24	6
8	0	9	26	7
9	0	10	28	8
10	0	11	30	9
11	0	0	32	10
12	1	13	33	0
13	14	34	12	
14	2	15	13	
15	16	36	14	

16	3	17	15	
17	18	38	16	
18	4	19	17	
19	20	40	18	
20	5	21	19	
21	22	42	20	
22	6	23	21	
23	24	44	22	
24	7	25	23	
25	26	46	24	
26	8	27	25	
27	28	48	26	
28	9	29	27	
29	30	50	28	
30	10	31	29	
31	32	52	30	
32	11	0	31	
33	12	34	54	0
34	13	35	33	
35	36	56	34	
36	15	37	35	
37	38	58	36	
38	17	39	37	
39	40	60	38	
40	19	41	39	
41	42	62	40	
42	21	43	41	
43	44	63	42	
44	23	45	43	
45	46	64	44	
46	25	47	45	
47	48	65	46	
48	27	49	47	
49	50	66	48	
50	29	51	49	
51	52	68	50	
52	31	53	51	
53	0	70	52	
54	33	55	71	0
55	56	72	54	
56	35	57	55	
57	58	74	56	
58	37	59	57	
59	60	76	58	
60	39	61	59	
61	62	78	60	
62	41	63	61	
63	43	64	80	62
64	45	65	81	63
65	47	66	82	64
66	49	67	83	65
67	68	84	66	
68	51	69	67	
69	70	86	68	
70	53	0	69	
71	54	72	0	0
72	55	73	71	
73	74	0	72	
74	57	75	73	
75	76	0	74	
76	59	77	75	
77	78	0	76	
78	61	79	77	
79	80	0	78	
80	63	81	0	79
81	64	82	0	80
82	65	83	0	81
83	66	84	0	82
84	67	85	83	

85	86	0	84
86	69	87	85
87	0	0	86

OUTSIDE CURB NODE NUMBERS IN COUNTERCLOCKWISE SEQUENCE

```
          1      2      3      4      5      6      7      8      9     10     11
12     24     36     48
    60     72     71     70     69     68     67     66     65     64     63     62
61     49     37
    25     13
```

OUTSIDE CURB ELEMENTS IN COUNTERCLOCKWISE ,SEQUENCE STARTING FROM OUTSIDE CURB NODE NO. 1

```
          1      2      3      4      5      6      7      8      9     10     11
11     32     53     70
    87     87     85     83     82     81     80     79     77     75     73     71
71     54     33
    12      1
```

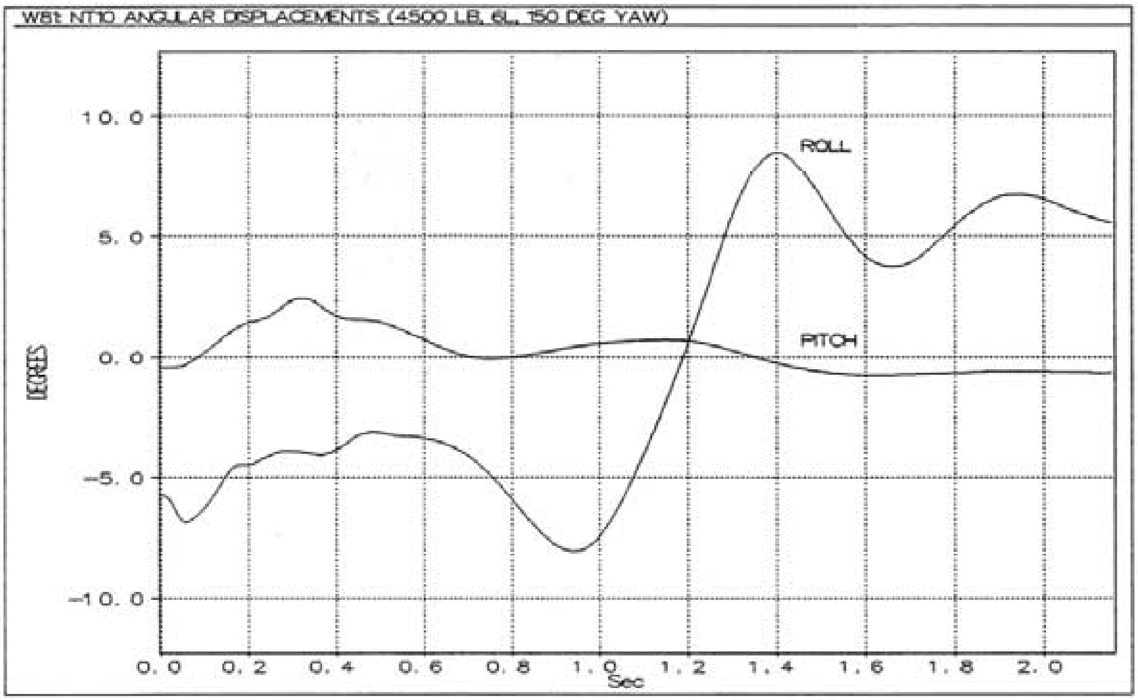
OUTSIDE BARRIER NODE NUMBERS IN COUNTERCLOCKWISE SEQUENCE

WHEEL RADIUS-RADIAL SPRING FOR TABLE
RWHJB(BEGIN) = .000 INCHES
RWHJE(END) = 6.000 ''
DRWHJ(INCRE.) = .250 ''

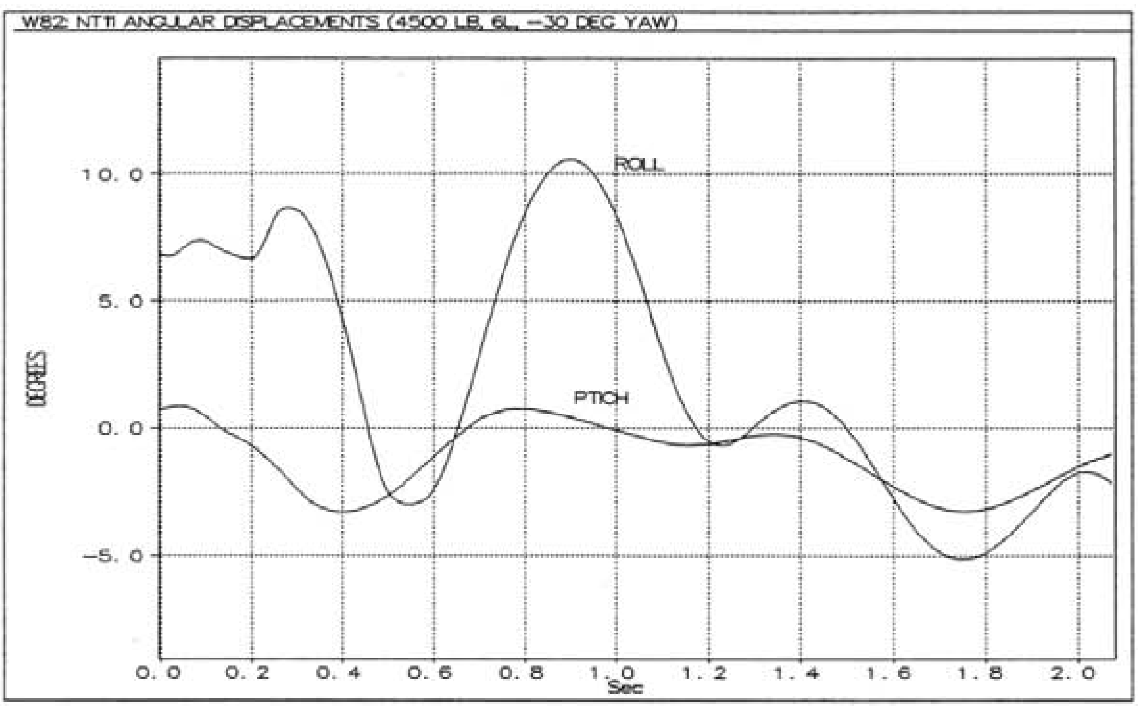
0 RW-HJ IN.	FJP. LBS. RF	FJP. LBS. LF	FJP. LBS. RR	FJP. LBS. LR
0 .000	.000	.000	.000	.000
0 .250	59.0	59.0	59.0	59.0
0 .500	71.0	71.0	71.0	71.0
0 .750	86.1	86.1	86.1	86.1
0 1.00	100.	100.	100.	100.
0 1.25	116.	116.	116.	116.
0 1.50	124.	124.	124.	124.
0 1.75	131.	131.	131.	131.
0 2.00	151.	151.	151.	151.
0 2.25	142.	142.	142.	142.
0 2.50	173.	173.	173.	173.
0 2.75	159.	159.	159.	159.
0 3.00	184.	184.	184.	184.
0 3.25	185.	185.	185.	

APPENDIX G:

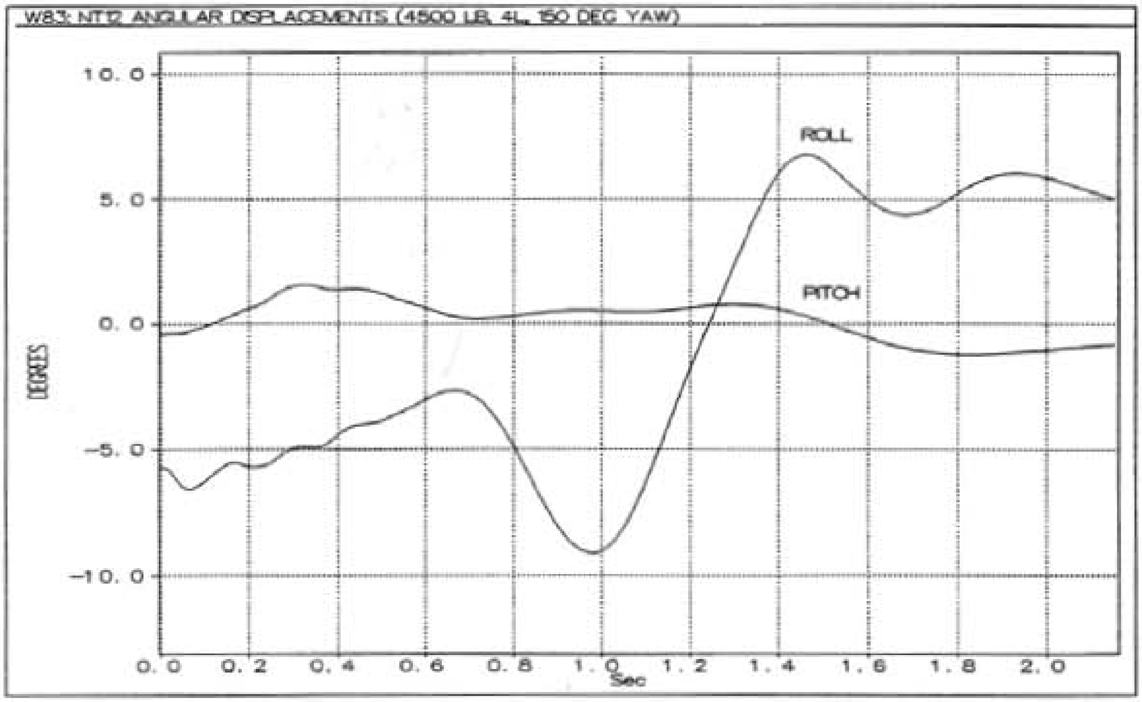
Simulated Angular Displacements (NT10-27)



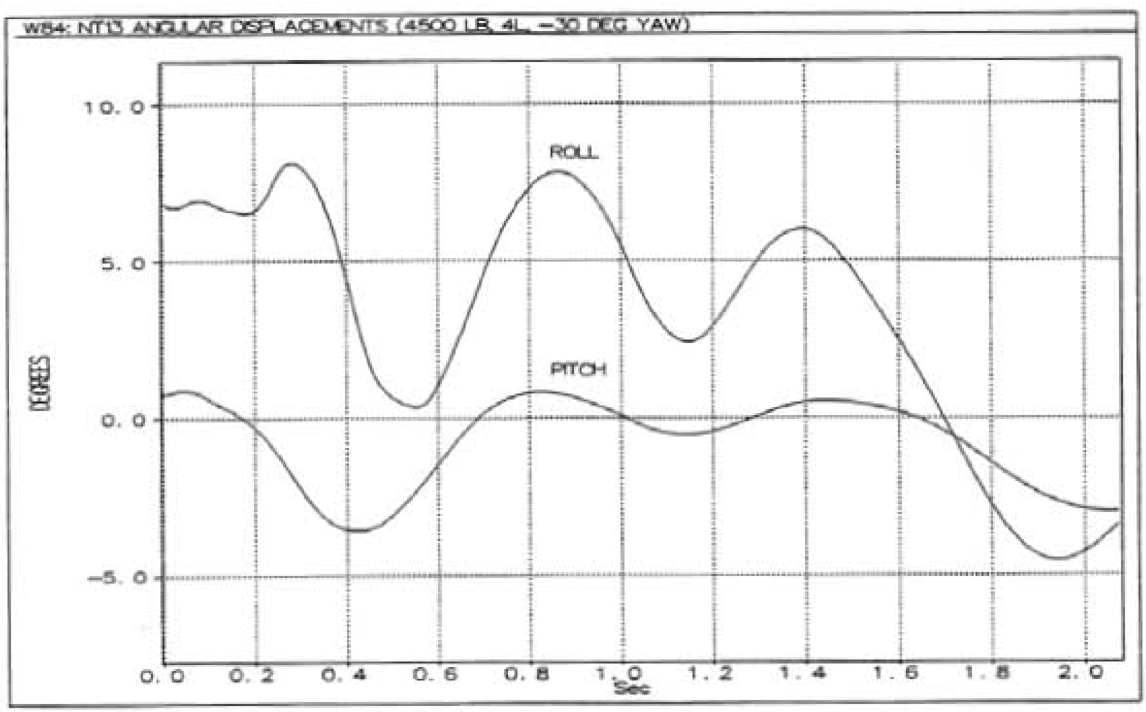
NT10 (6L, 4500LB, 150 DEG YAW)



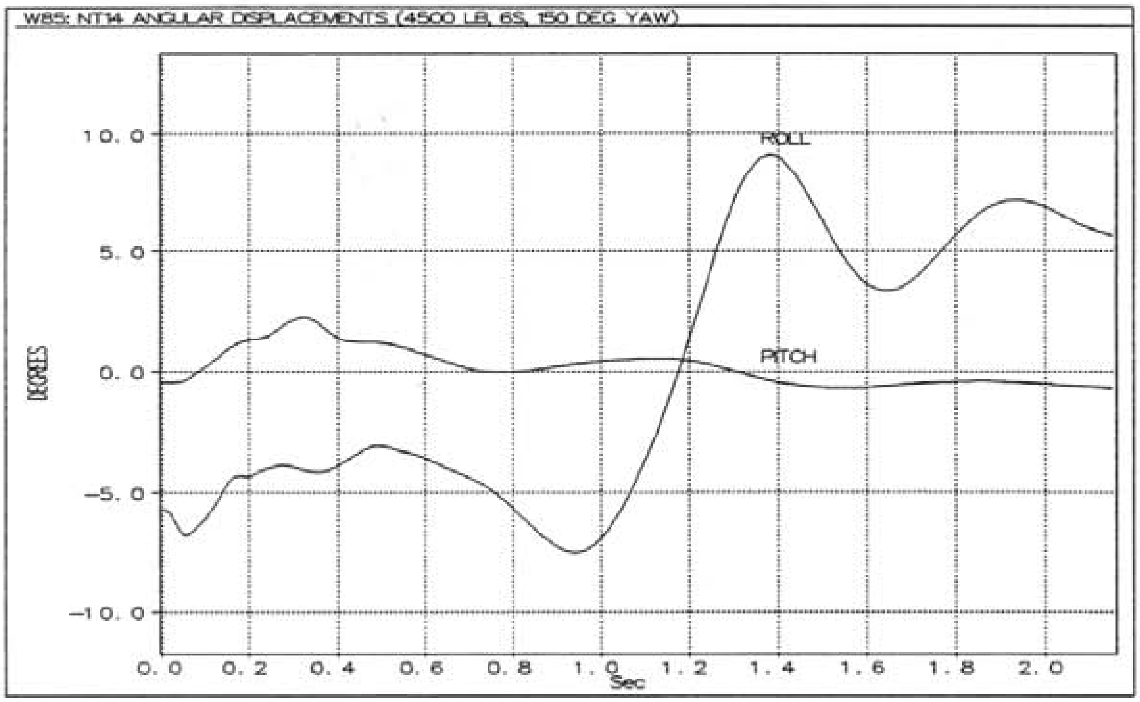
NT11 (6L, 4500LB, -30 DEG YAW)



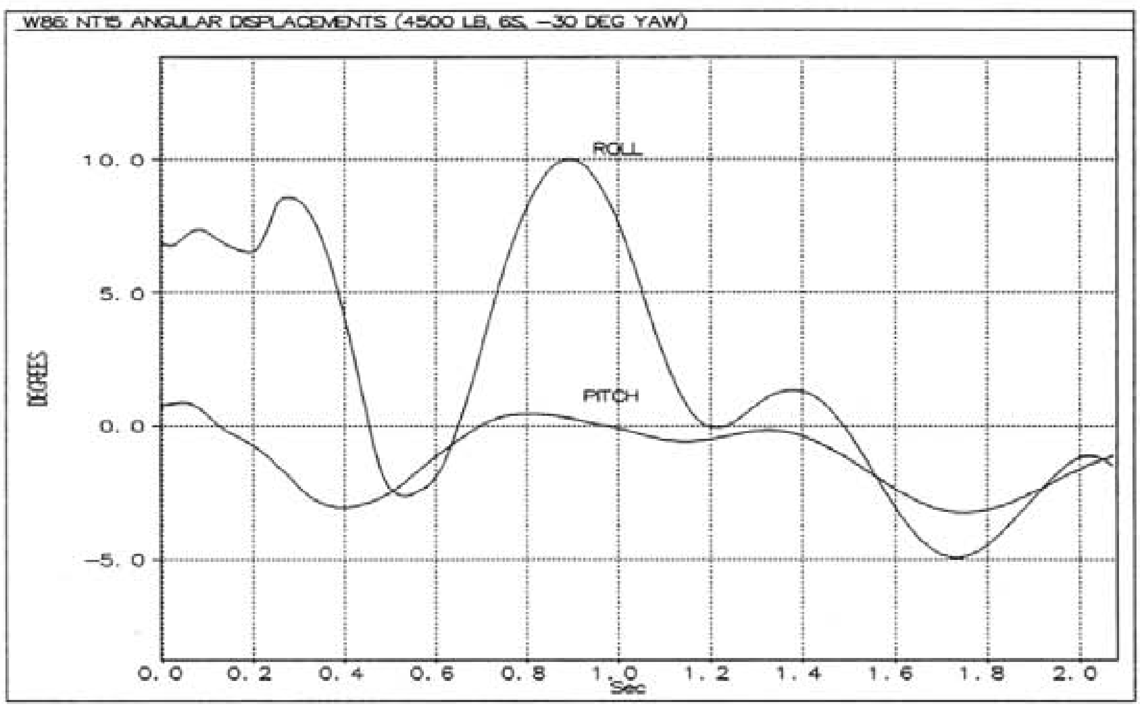
NT12 (4L, 4500LB, 150 DEG YAW)



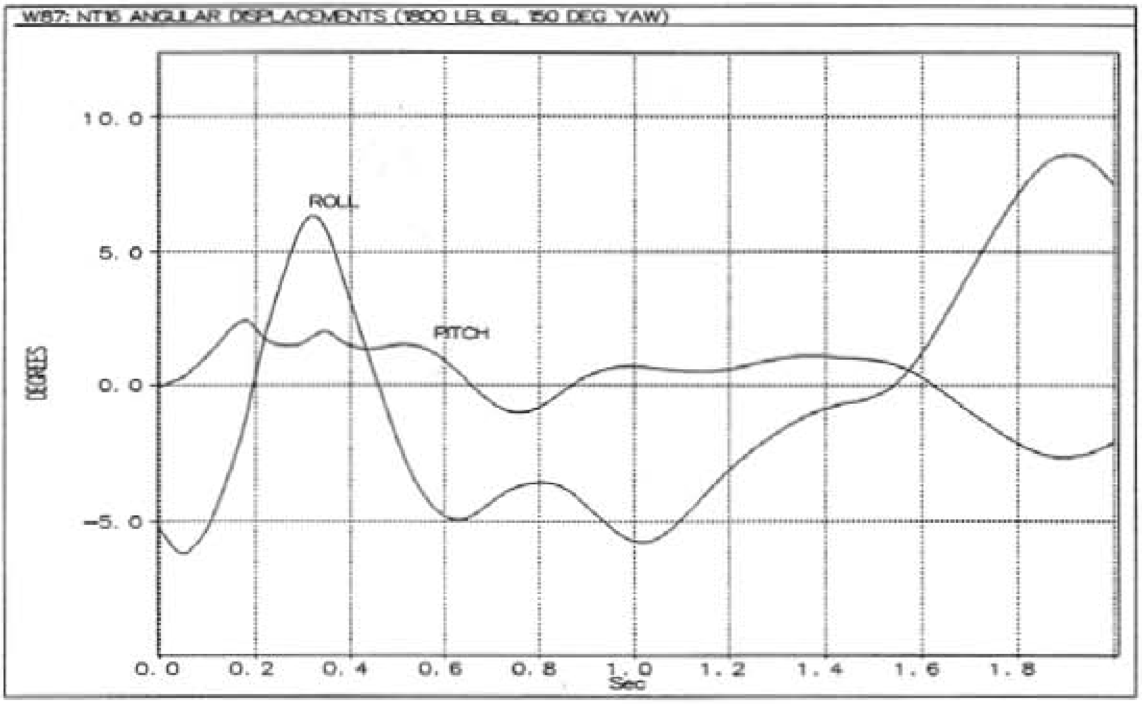
NT13 (4L, 4500LB, -30 DEG YAW)



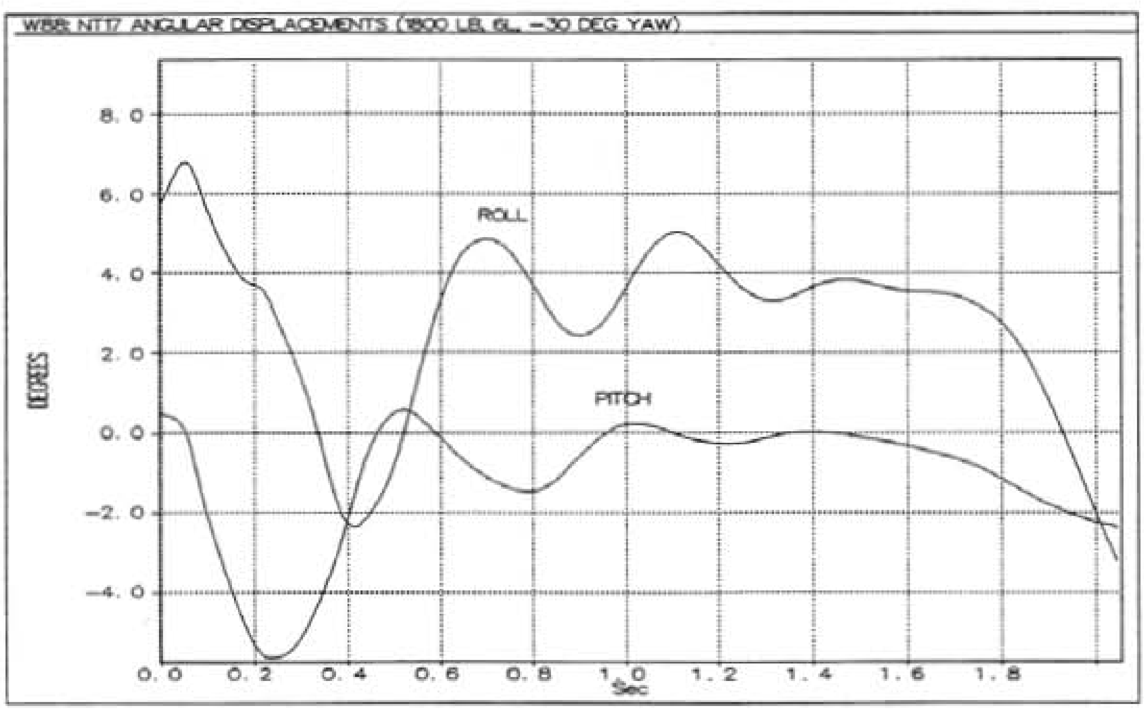
NT14 (6S, 4500LB, 150 DEG YAW)



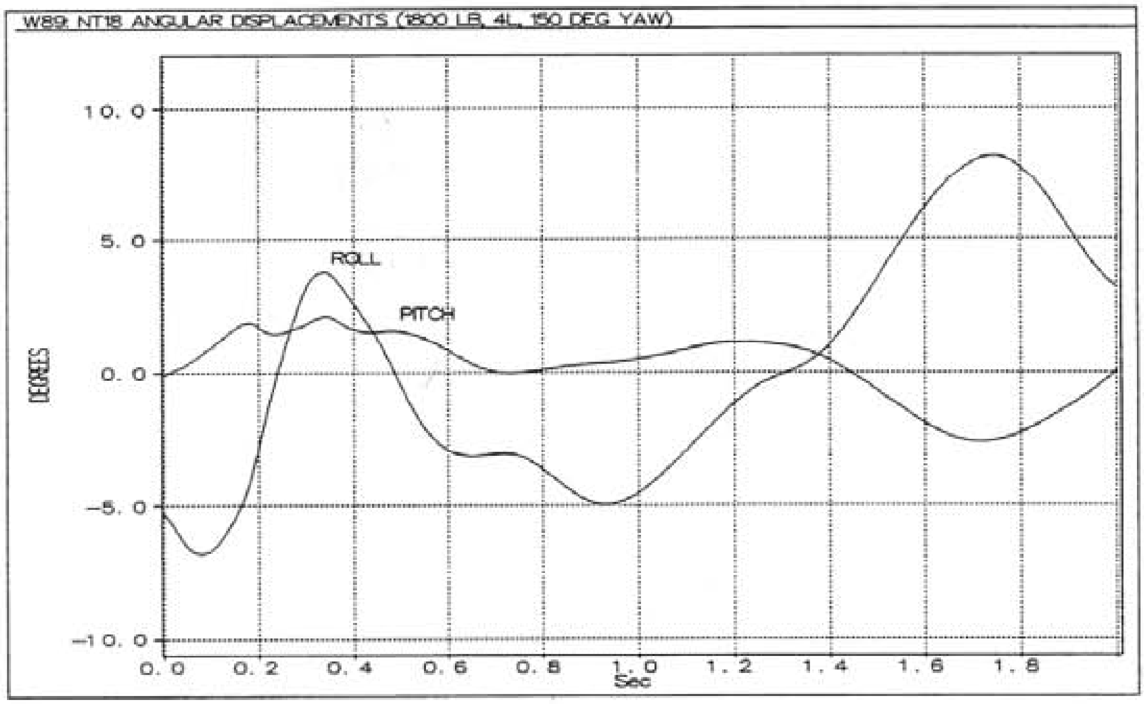
NT15 (6S, 4500LB, -30 DEG YAW)



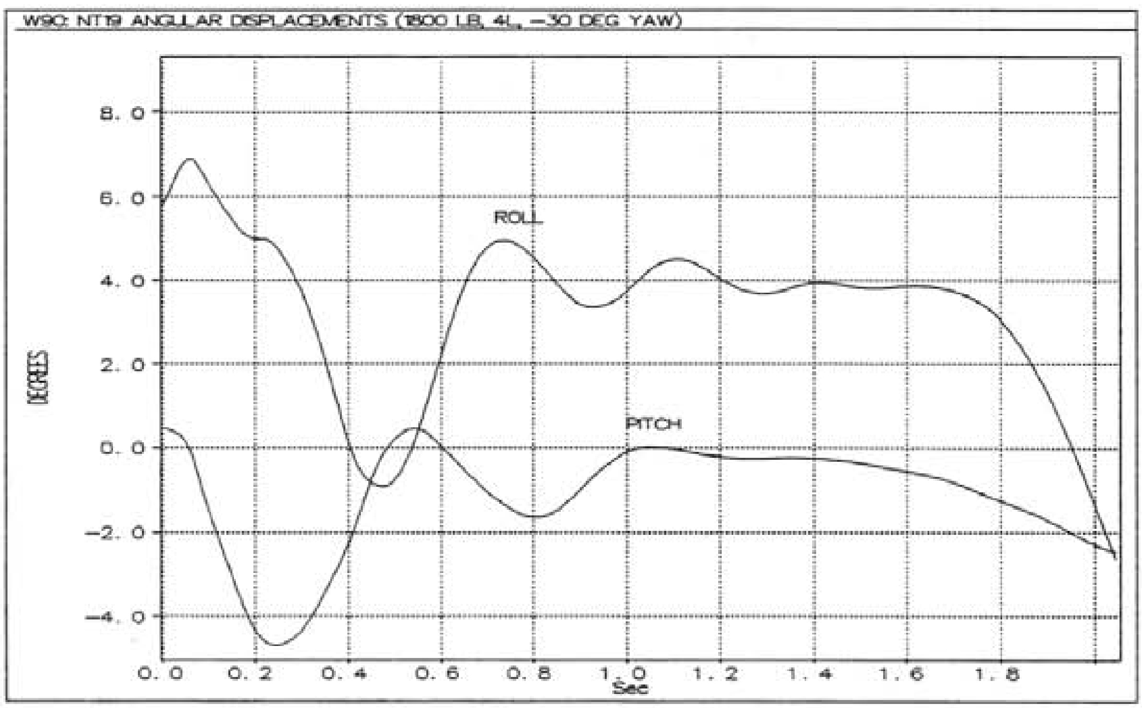
NT16 (6L, 1800 LB, 150 DEG YAW)



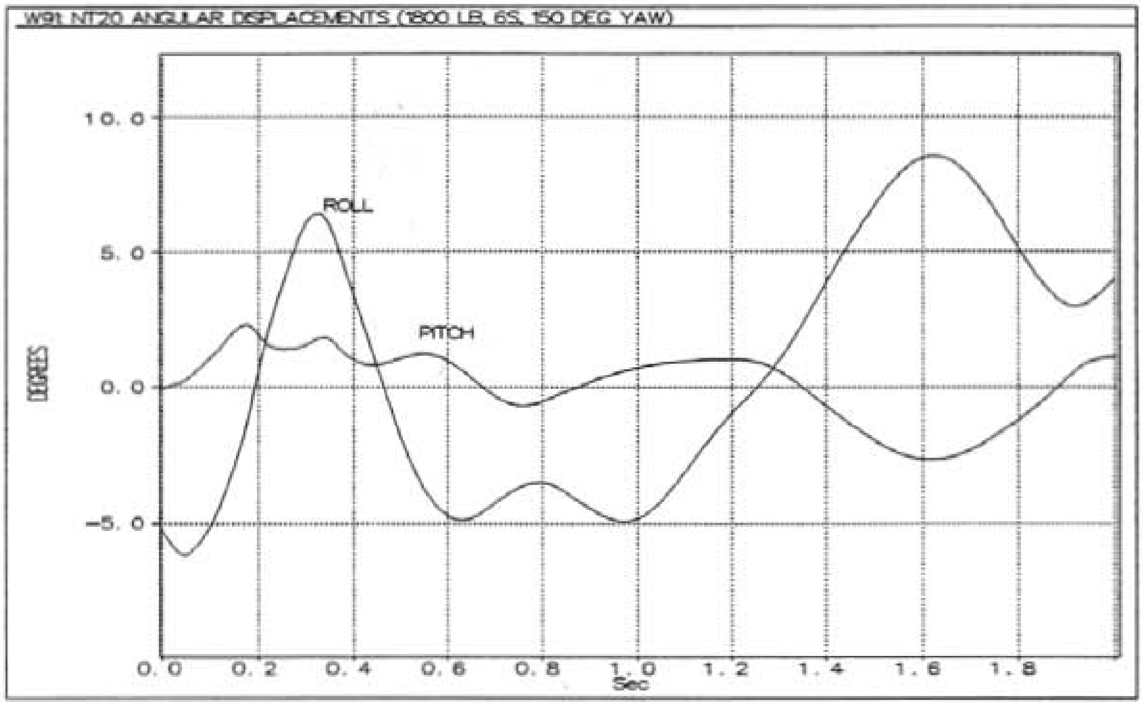
NT17 (6L, 1800 LB, -30 DEG YAW)



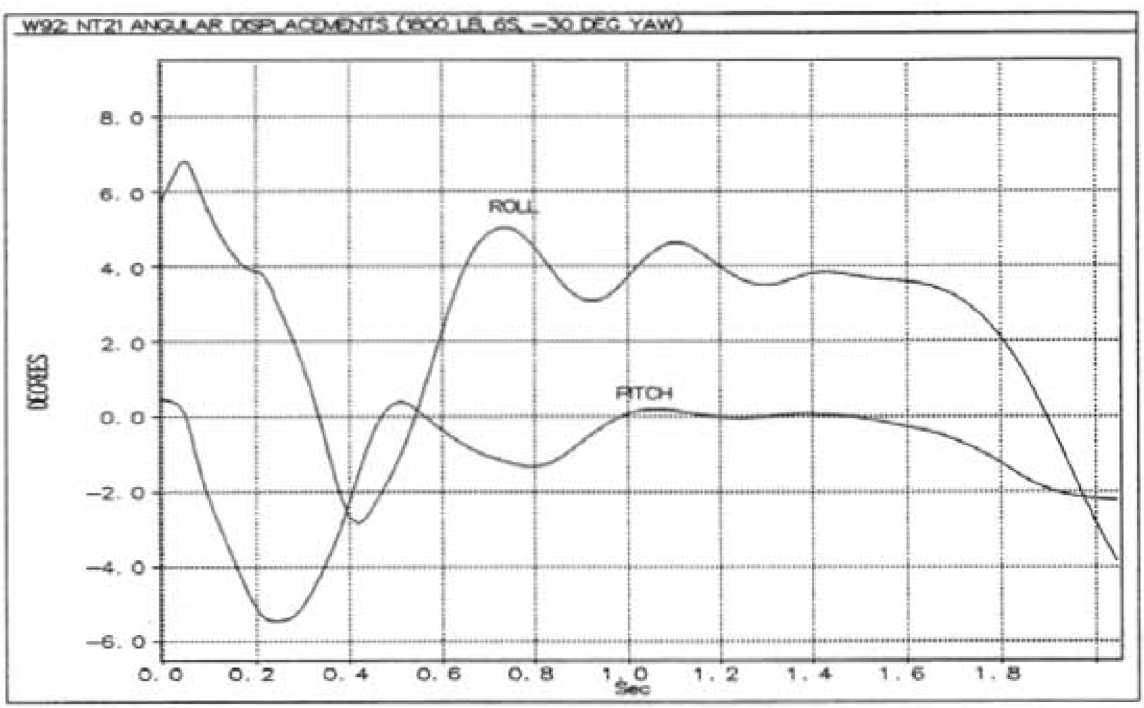
NT18 (4L, 1800 LB, 150 DEG YAW)



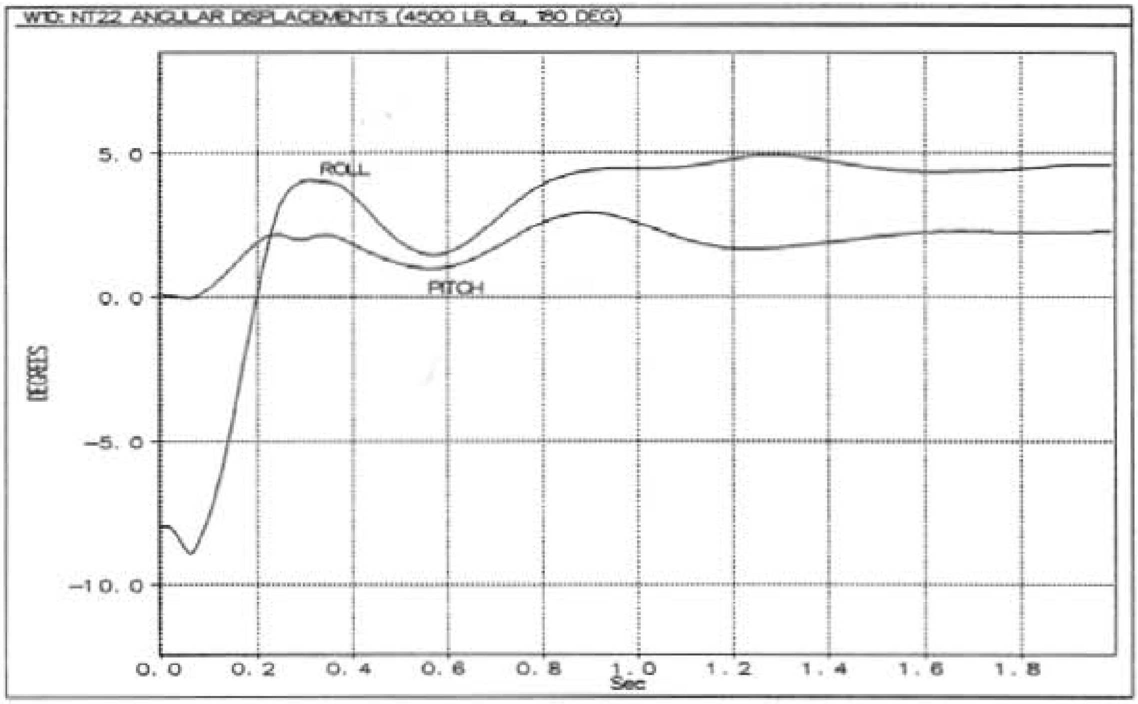
NT19 (4L, 1800 LB, -30 DEG YAW)



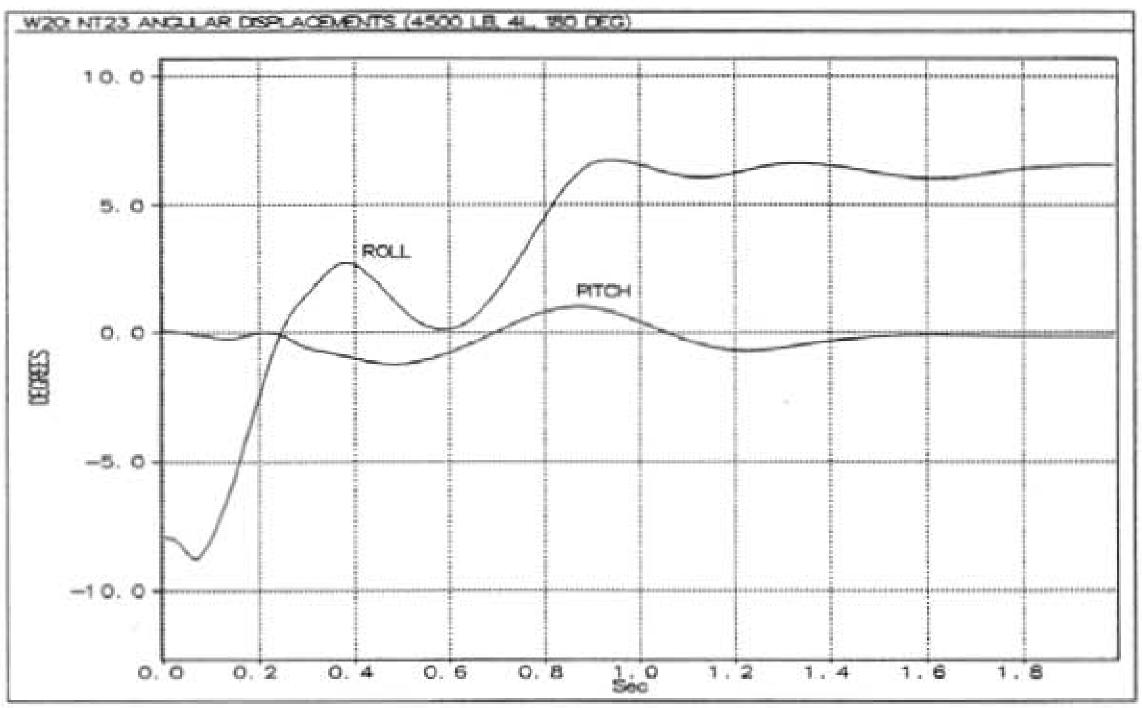
NT20 (6S, 1800 LB, 150 DEG YAW)



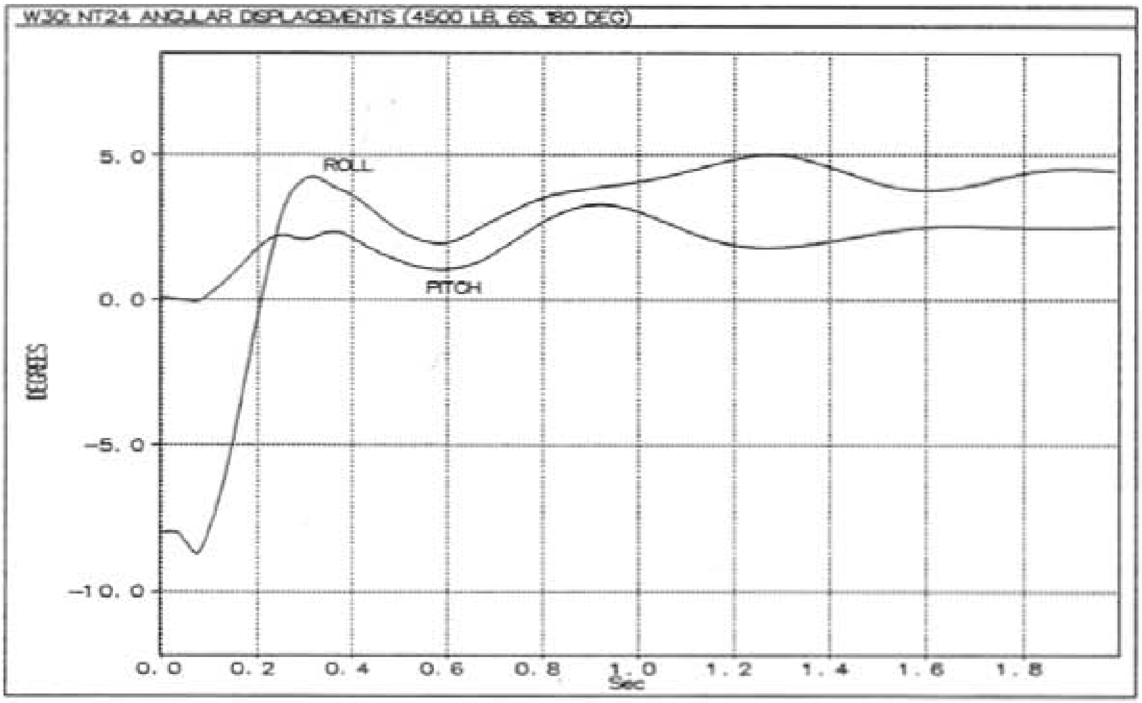
NT21 (6S, 1800 LB, -30 DEG YAW)



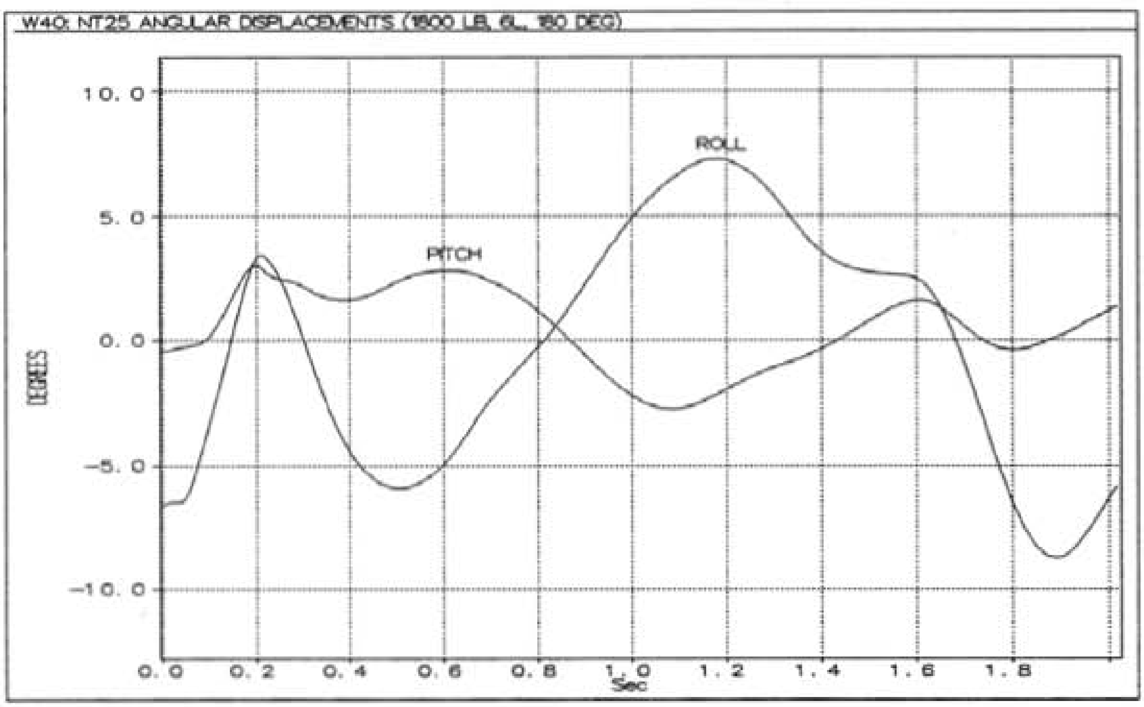
NT22 (6L, 4500 LB, 180 DEG YAW)



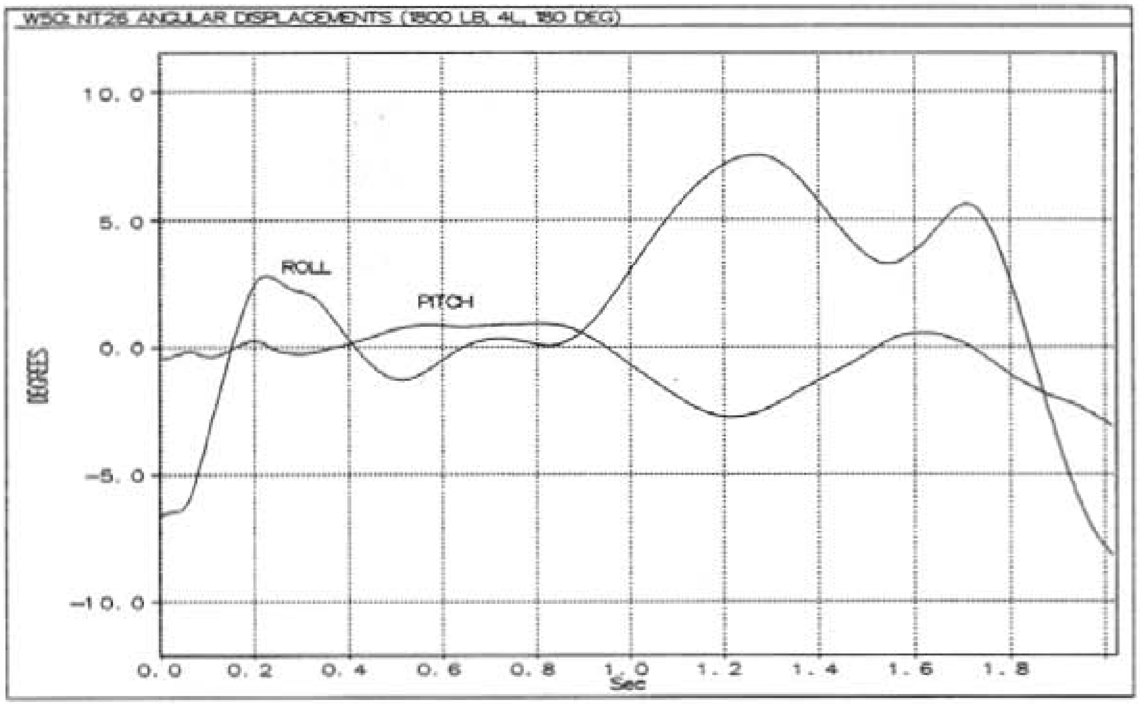
NT23 (4L, 4500 LB, 180 DEG YAW)



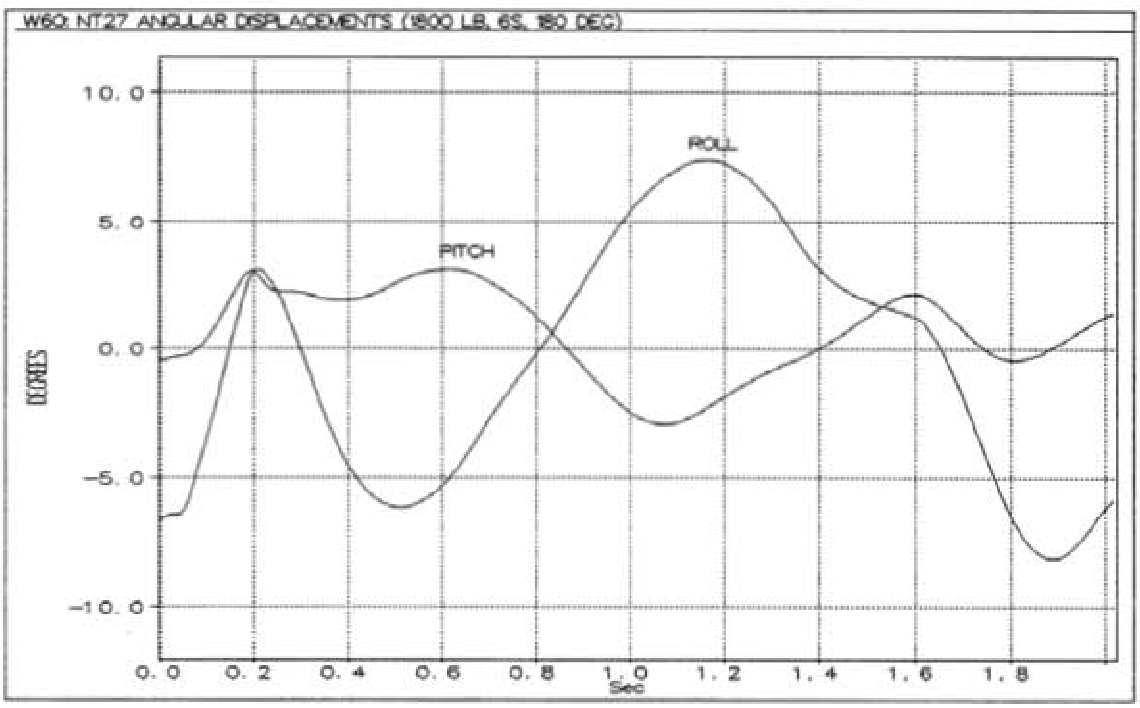
NT24 (6S, 4500 LB, 180 DEG YAW)



NT25 (6L, 1800 LB, 180 DEG YAW)



NT26 (4L, 1800 LB, 180 DEG YAW)



NT27 (6S, 1800 LB, 180 DEG YAW)