Preliminary Analysis of the Dynamic Behavior of Recreational Doubles

Final Report

No. UMTRI - 89 - 29

by

Charles C. MacAdam
Zevi Bareket
Robert D. Ervin

October 20, 1989

UMTRI The University of Michigan Transportation Research Institute

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-89-29		

4. Title and Subtitle	5. Report Date
Preliminary Analysis of the Dynamic Behavior of Recreational Doubles	October 20, 1989
	6. Performing Organization Code
7. Author(s) C.C. MacAdam, Z. Bareket, R.D. Ervin	8. Performing Organization Report No. UMTRI-89-29
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road, Ann Arbor, Michigan 48109	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. MCD-89-012A
12. Sponsoring Agency Name and Address Office of Highway Safety Planning / State of Michigan 300 S. Washington Square Lansing, MI 48913	13. Type of Report and Period Covered Final 7/89 - 12/89
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A preliminary computer-based study was conducted to examine the dynamic response of a class of vehicles termed "recreational doubles." The nominal baseline vehicle configuration was comprised of three hitched units: a) a pick-up truck towing unit, b) a fifth-wheel recreational trailer, and c) a boat/trailer unit. Computer simulation was employed to evaluate the dynamic response of such vehicles using both step-steer and lane-change steering maneuvers. Articulation angle damping and lateral path overshoot by the rear boat trailer unit were used as performance measures for evaluating and comparing various configurations. Forward speed, trailer length, and hitching loads were identified as the principal parameters affecting the directional performance characteristics of this class of vehicles.

17. Key Words	18. Distribution Statement
vehicle, dynamics, doubles, recreational, highway, safety, simulation, directional, articulated, amplification, performance, boat, trailer, oscillation, speed, loading, hitch	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	52	

Table of Contents

1.0 Introduction

This document constitutes the final report on a study entitled, "Preliminary Analysis of the Dynamic Behavior of Recreational Doubles." The report presents the methods and findings of an *ad hoc* research project performed by the University of Michigan Transportation Research Institute (UMTRI) under sponsorship from the Michigan Office of Highway Safety Planning (OHSP).

This limited-scope project was prompted by House Bill No. 4357, pending in the 1989 session of the Michigan Legislature, which would allow the use of so-called, "recreational doubles" on Michigan highways. The purpose of the study was to provide a preliminary analysis of the recreational double in order to assess whether the vehicle might pose dynamic problems leading to loss of control.

The vehicle type in question is defined in the bill as "...a pickup truck ...equipped with a fifth wheel assembly...attached to a semitrailer designed for recreational living purposes...and towing an additional semitrailer." In other words, the "recreational double" is a combination vehicle in which both a "fifth-wheel" type trailer and an additional ball-hitched trailer are towed by a single pickup truck. Further, the vehicle combination is presumed to be driven by lay persons in a recreational, or vacation context. The bill is nominally intended to accommodate the desire of camping tourists to bring a boat along on their camping trip, although other types of "second trailer" could be envisioned as well.

The UMTRI study sought to address the hypothesis that a configuration of this type may exhibit lightly damped yaw motions and, perhaps, exaggerated demands on tire/road friction availability in response to steering inputs at highway speeds. Oscillatory motions, in particular, could conceivably present a distraction to other motorists and perhaps, in certain cases, pose a control problem that may result in an accident. Exaggerated demands for pavement frictional coupling would make loss of control under slippery conditions more likely.

Given that the study was to be completed in a period of only three months, no direct laboratory measurements of vehicle properties were possible and no dynamic tests of assembled vehicle combinations could be performed. On the other hand, measurement of trailer dimensions were conducted in the field and existing measurements of tire and suspension properties were found to be available in archival data. Because the computerized analysis used here has been highly refined through UMTRI research over a twenty-year time span, the study method is thought to provide a solid characterization of the qualitative behavior of recreational doubles. Nevertheless, precise quantitative evaluation would require direct measurement of inertial, suspension, and tire parameters from exemplar vehicles.

The purpose of the proposed study was thus to evaluate the dynamic control issues in a preliminary way so as to help guide the legislative process on behalf of public safety. In a preliminary meeting with the bill's sponsor, and other interested parties, it was established that the pending bill would address only recreational doubles fitting within an overall length of 59 feet and that neither a towed automobile nor a full trailer would be considered as the rearmost trailing unit (that is, the rear-most trailer would be a simple ball-hitched semitrailer, such as used in towing a recreational boat). In the course of the study, however, it was learned that the majority of fifth-wheel-type recreational trailers in service today are longer than would fit within a 59-foot constraint, with additional trailer attached. Thus, it is reasonable to expect that the constituency which seeks legal allowance of the recreational double would eventually strive to amend a 59-foot limit in order to accommodate the more popular, longer, fifth-wheel trailers. Accordingly, a modest addition to the study scope was undertaken in order to examine the behavior of one vehicle combination that typified the longer units that may later come under consideration.

Moreover, the study was to address the following objectives:

1) To determine the range of dynamic response to steer inputs likely to be exhibited by 59-foot recreational doubles combinations (with limited consideration of a characteristic unit over 59 feet in length)

2) To identify the parameters which are most influential in determining any undesirable dynamic behavior

3) To determine and recommend any simple dimensional or weight constraints that would serve as reasonable legal limits for avoiding undesirable dynamic behavior.

This report is organized into four additional sections, as follows:

Section 2.0 — discusses the computerized tools and the associated parameters through which the analysis of recreational doubles was performed,

Section 3.0 — outlines the matrix of cases which were covered in the computations,

Section 4.0 — presents the results of those computations and,

Section 5.0 — presents the principal conclusions

Appendix A — presents a computer printout of a sample baseline case, showing the numerical data which was input to describe vehicle parameters.

2.0 Analysis Methods and Parameters

2.1 Yaw/Roll Computer Model

The Yaw/Roll model is a time–domain mathematical simulation, capable of simulating the yaw/roll response of pneumatic-tired vehicles at constant speed. The model analyzes the combined directional and roll behavior of single and articulated vehicle combinations during dynamic maneuvers that can extend up to the rollover limit. In essence, the user inputs are the vehicle/driver parameters, a description of the required maneuver, and the desired length of simulation time.

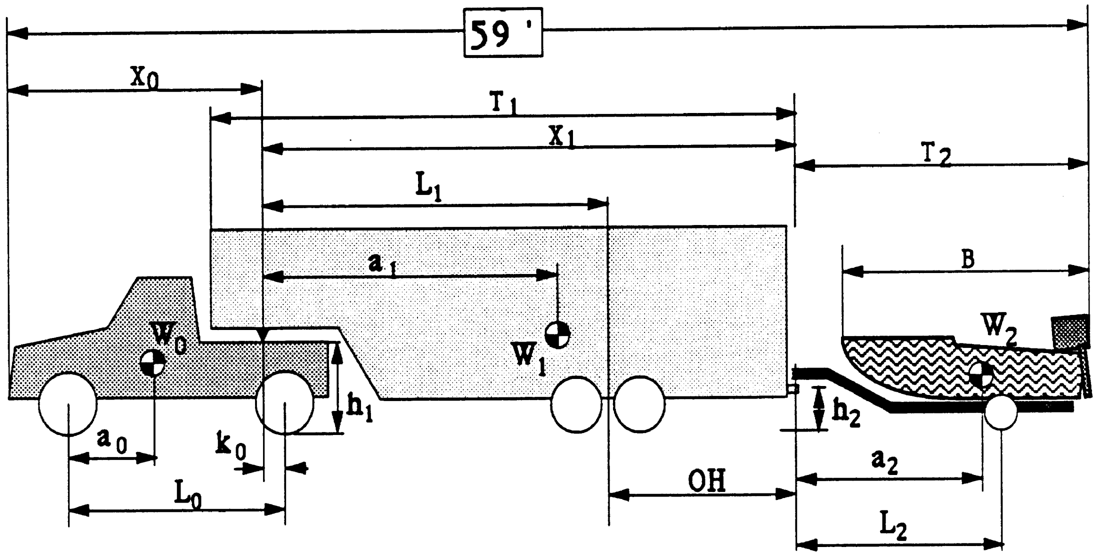
During the subject analysis, the model was employed to simulate both lane-change and step-steer maneuvers. The first is more of a "real-life" maneuver, with a simulated driver steering the vehicle through a full 12-foot lane change. The second maneuver is intended to reveal the inherent dynamic properties of the vehicle, employing a step steering input as a system disturbance. The response to this disturbance is then interpreted in terms of the general control qualities that will govern the vehicle's behavior in many practical steering maneuvers on the road. Both maneuvers, together with the procedure for characterizing the vehicle's response, are discussed further in section 4.0.

2.2 Vehicle Configuration

The configuration used in the simulation was a three-unit vehicle, namely, a pickup truck was the leading unit (tractor), followed by a recreational fifth-wheel trailer as the second unit (first semi-trailer), and a boat trailer was the third unit (second semi-trailer). In clinical terms, the hitching between the successive vehicle units is described as follows: A fifth wheel connection exists between the pickup truck and the second unit, affording two degrees of freedom, in pitch and yaw, while constraining the two units to roll together (thus transmitting roll moments between the two units). A ball hitch was used to connect the fifth-wheel trailer to the boat trailer, affording freedom in the pitch, roll, and yaw rotations and transmitting only the vertical and lateral force reactions between those units (note that longitudinal hitch forces are effectively zero since the yaw/roll model represents a constant-speed computation).

In order to identify a suitable baseline configuration, a field study was performed. During that survey, some of the most common pickup trucks and fifth wheel recreational trailers were identified. The figure and table on the following page summarizes the most common trailers, their geometries, and weights. The first eight trailers incorporated 2-axle suspensions, while the ninth unit had only a single axle. Below the name of each trailer model is also listed the tire size (e.g., H78-15).

Recreational Double



Recreational Trailers

#	Model / Notes	T_1	X_1	W_1	a_1	L_1	h_1	h_2	OH
1	Prowler Regal (32') (H78-15)	32.92	31.83	10000	15.92	20.42	3.75	1.71	11.42
2	Frolic (28') (H78-15)	28.9	26.9	7500	14.98	17.4	3.67	1.67	9.5
3	Coachman (26') (8.55-15)	27	25.8	7590	13.84	17.5	3.75	1.58	8.33
4	Prowler Lynx (18') (H78-13)	18.5	18.92	4200	11.05	12.7	3.25	1.25	6.25
5	Prowler Lynx (26') (F78-15)	26.5	26.92	6600	14.2	17.59	3.5	1.5	9.33
6	Taurus (27') (H78-15)	28	26.6	8200	13.17	17.08	3.75	1.6	9.5
7	Prowler Lynx (21') (F78-15)	21.5	21.92	4800	11.6	14.13	3.33	1.53	7.79
8	Road Ranger (36') (7 - 15)	36.58	34.75	11400	16.32	20.92	3.42	1.69	13.83
9	Nomad (17') (Single, E78-14)	17.42	17.42	3000	9.96	11.96	3.1	1.1	5.46

Note: - all length measurements in feet
- all weight measurements in pounds

The following table describes the baseline boat trailer that was selected for the simulation study. The symbols at the heading of the tables relate to the "Recreational Double" figure in the previous page:

Boat Trailer:

Model / Notes	B	T_2	W_2	a_2	L_2
"Sea Nymph (16', 40 HP)	18.75"	21.75"	1800	160"	15.2'

Throughout the study, the same pickup truck was used while different recreational and boat trailers were examined (see the following study matrix in section 3.0). The pickup, chosen for its popularity in towing fifth-wheel trailers, was a Ford F-250 with regular cab style, 133" wheelbase dimension, and single (not dual-rear) tire installations. The centerline of the fifth wheel coupling was located at a dimension of 2" ahead of the rear axle centerline on the pickup truck. In the simulations, the truck was equipped with a torsion (anti-roll) bar in the front suspension to represent common hardware. It should be noted that the bar is an option recommended by the manufacturer for such an application. The following table summarizes the the truck's geometry and weight parameters:

Truck:

Model / Notes	K_0	X_0	W_0	a_0	L_0	GVW
F–250 (St'd Cab)	2"	162"	4045	48.1"	133"	7700

Except for one case, all of the recreational trailers represented in the simulations incorporated two axles and leaf spring suspensions. Based on the field study, written specifications obtained for various units, and meetings with dealers of such trailers, no shock absorbers or torsion bars were employed in the trailer suspensions. The represented boat trailers employed similar leaf-spring suspension styles, but with only single supporting axles.

2.3 Simulation Parameters

A sample of the input file needed for running the Yaw/Roll simulation program is presented in Appendix A, together with the complete computed printout for the baseline vehicle combination. The complete input file lists the values and measurement units that were employed in representing the functional properties of the baseline vehicle combination, as they influence steering performance. The categories of input data, and the nominal sources used in quantifying each item for this study, are as follows:

- Operation Parameters:

These parameters are determined according to the desired operational conditions—vehicle speed, type of maneuver the vehicle will perform (given as a set of steer angle inputs, or a trajectory table), and the time duration of the simulated maneuver.

- Driver Parameters:

If so desired, a driver model can be employed to continuously control the vehicle throughout the maneuver, following a defined path along the ground. Parameters which are selected to operate the "driver model" include the reaction, or time delay, characteristic of the driver and the down-range distance, or preview length, which the driver employs in anticipating the needed adjustments in steering along the path.

- Vehicle Parameters:

This category describes the vehicle properties pertinent to the simulated configuration, and the types of joints between the units. Under this category fall:

Inertias, Sprung & Unsprung weights of each unit: These items (for the truck and recreational trailer) were taken from existing UMTRI data, employing direct measurements that had been conducted on a similar pickup truck and a recreational trailer. Since the available data represented earlier production models, the parametric values were scaled to reflect the known differences in geometric and weight parameters. Based on manufacturers' weights and measurements, the boat's inertial parameters were also calculated.

Geometry: The baseline geometry was taken from a combination of measurements performed during the field survey and data provided by the different trailers manufacturers. Variations in geometry were scaled from the baseline case in representing the off-baseline configurations that were simulated.

Suspension Stiffness: Suspension properties were also taken from existing data for the pickup and the recreational trailer and were interpolated to fit the specific configurations and axle loads. The same data were also proportioned for representing the boat trailer's suspension, according to the gross weight of the boat and trailer.

Tires: In accordance with the tire sizes and carcass construction type seen installed on exemplar pickup trucks, fifth wheel- and boat-type trailers, tire force and moment data were selected from previously-reported laboratory measurements. (An important item in this regard is the observation that virtually all tires for recreational trailers are of bias ply construction. This construction type is characterized by substantially lower levels of tire cornering stiffness—a property influencing the oscillatory tendencies of the vehicle combination—than with radial ply tires. Modern pickup trucks, on the other hand, are equipped with radials and were represented as such in the computations.)

3.0 Matrix of Simulation Runs

A matrix of simulation runs was conducted, covering the baseline vehicle configuration and a set of variations off of the baseline as a means to identify the more influential parameters. The baseline vehicle, described above and in detail in Appendix A, involved the Ford F-250 pickup truck towing a 26-foot fifth-wheel trailer followed by a ball-hitched trailer carrying a popular 16-foot boat configuration. The baseline speed was selected as 65 mph reflecting the current limit on the rural interstate system. The following variations were examined, covering values above and below that of the selected baseline:

Variable	Low	Baseline	High
Speed	55mph	65 mph	75 mph
Length of 5th-wh. trailer	24 ft	26 ft	28 ft
Payload wgt. on 5th-wh. trailer	0	1000 lbs	2000 lbs
Weight of boat & trailer	1200 lbs	1800 lbs	2400 lbs
Boat trailer hitch load (as % of total weight)	0%	12%	20%

In addition, five other special cases were examined, namely,

- the baseline vehicle with a substantially higher roll-steer coefficient in the boat trailer's suspension. This variation was simply to check the significance of the roll-steer issue, since little data was available for generalizing on the roll-steer component in recreational trailer design.

- a 14 ft-long, 1400 lb, snowmobile trailer replacing the boat trailer. The snowmobile trailer was seen as a likely wintertime option for people making use of a legal allowance on recreational doubles. The case was of possible technical interest primarily because it represents a very short trailer wheelbase, while still imposing a significant weight value.

- a 32 ft-long fifth-wheel trailer replacing the baseline 26-ft fifth-wheel trailer. This combination was examined at speeds of 55, 65, and 75 mph both as a pickup truck and fifth-wheel trailer alone (i.e., no boat trailer) and as a full recreational doubles combination, at 65 feet overall length, with boat trailer attached. As noted earlier, the 32-ft long combination was examined in order to explore potential problems that may be posed by longer units, recognizing that a future proposal is likely to come forward for extending any 59-foot allowance to permit doubles applications of the longer, and more popular, styles of fifth-wheel trailers.

- a case in which the baseline vehicle, with 26-ft fifth-wheel trailer was operated at full payload (2000 lbs) *and* heavy-weight (2400 lb) boat trailer *and* with boat trailer set up to have a 0% hitch load. This case was intended to address the likely possibility that some fraction of the recreational doubles operated in Michigan under any new law would employ a combination of unfavorable parameters, simply due to the specific assembly of trailers and load elements. Although one could not, at this point, estimate the probability of such combinations occurring, they were assumed to be inevitable.

- a case in which a very short (18-foot overall length) fifth-wheel trailer was employed together with the heavy-weight (2400 lb) boat trailer. Although it was understood that the very short fifth-wheel trailers are rare, this case was examined in order to explore whether some anomaly in behavior might prevail with short units.

4.0 Results of the Simulation Exercise

4.1 *Overview of Simulation Results*

Prior to discussing the simulation results in more detail, a short overview of the principal results is first presented.

1) Overall, the simulation calculations indicate that the baseline vehicle configuration (pickup truck / 26' trailer / 16' boat) behaves acceptably under most of the speed and loading conditions examined within this preliminary study. General trends that were observed show that increased trailer length, weight, and vehicle speed result in diminished dynamic performance (reduced damping and stability) of the baseline configuration. The most powerful factors influencing the dynamic performance were observed to be trailer length and forward speed.

- *Increased trailer length* implies not only a greater weight but also a greater "rotational inertia" of the trailer unit. (The rotational inertia of a vehicle is a property which reflects roughly how the weight of the vehicle is distributed over its length.) As trailer length increases, its rotational inertia will not increase proportionately. Instead the rotational inertia increases at a considerably faster rate. This lengthening process ultimately will lead to a poor and unacceptable dynamic performance of the vehicle train due to the accompanying increases in trailer rotational inertia.

- *Increased vehicle speed* results in reduced dynamic performance of the vehicle train because of the normal reduction in tire damping forces that accompanies most ground vehicles operating at higher speeds. This effect of increased speed on an articulated recreational double will eventually lead to the loss of adequate damping at higher speeds where such forces are needed to attenuate the train oscillations that can develop in response to normal steering inputs.

2) In contrast to the 26-ft baseline configuration, simulation and analysis of a 32-ft trailer case indicated very poor and unacceptable dynamic performance properties. At 65 mph, the 32-ft trailer configuration exhibited relatively low to moderate levels of articulation damping. At the 75 mph condition, the same configuration became slowly

unstable with increasing amplitudes developing in the trailer and boat units. Removal of the boat trailer from the vehicle train resulted in a significantly improved, though still lightly damped, system response.

3) Various boat configurations (involving variations in weight and hitch load) and a short "snowmobile trailer" configuration were seen to have adequate damping and dynamic performance characteristics when coupled with the baseline vehicle configuration (26-ft fifth-wheel trailer). No major degradations were observed in the overall vehicle system performance due to the boat, as long as the trailer lengths were limited to approximately 26 feet.

4.2 *Presentation of Simulation Results*

The simulation study used two basic steering maneuvers to evaluate the dynamic response of each recreational vehicle configuration. The first maneuver was a simple fixed steering input of 25 degrees applied at the steering wheel ("step-steer" maneuver). (See Figure 4.1) The purpose of this "test" was to excite the vehicle train with a quickly applied steering input in order to evaluate the degree of damping present in the vehicle train. The small step-like application of steering input causes the train to initially oscillate back and forth. The oscillations will then die out over time if the steering is held fixed. The rate at which the articulation oscillations diminish is a measure of the damping and stability of the vehicle configuration.

The other steering maneuver used to evaluate each vehicle configuration was the "lane-change" maneuver. (See Figure 4.2) This maneuver was selected to provide a "test maneuver" similar to what could be experienced routinely on a normal highway outing. In this maneuver, a simulated driver is used to steer the vehicle in a normal lane-change manner, causing the vehicle to move laterally from its present lane to an adjacent lane. The simulated driver steers the vehicle 12 feet laterally (one lane width) over a forward travel distance of 150 feet. As each vehicle unit moves laterally from the initial lane to the adjacent lane in sequence, an oscillation will develop in the vehicle train. As the driver positions the lead unit (pickup truck) in the adjacent lane and ceases to provide any further steering, the train oscillations will ordinarily die out over time, much like the "step-steer" maneuver. Again, the rate at which the vehicle articulation oscillations become attenuated is a measure of the damping and stability of the vehicle configuration.

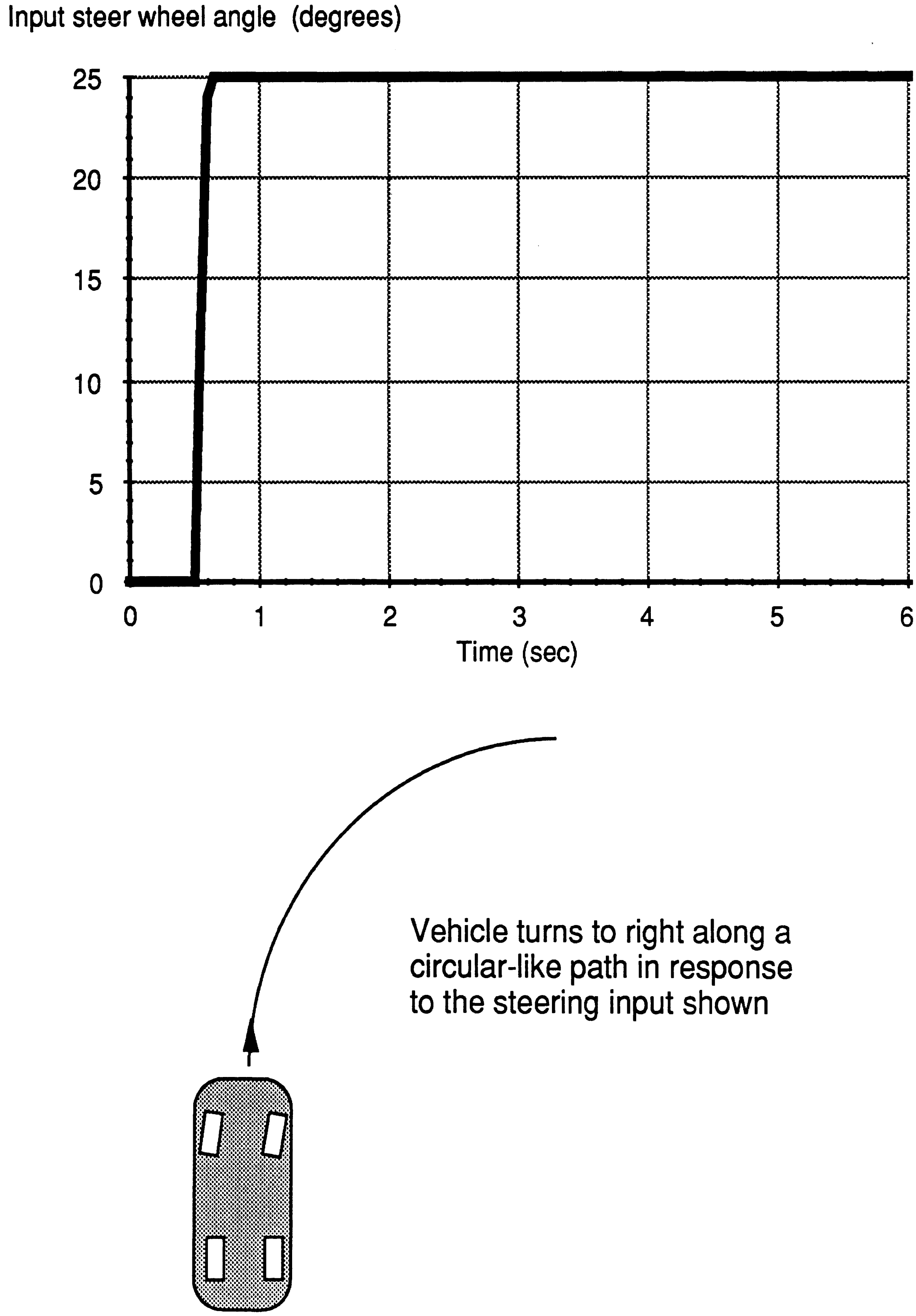


Figure 4.1 "Step-Steer" Maneuver; 25 degrees of Steering Wheel Angle.

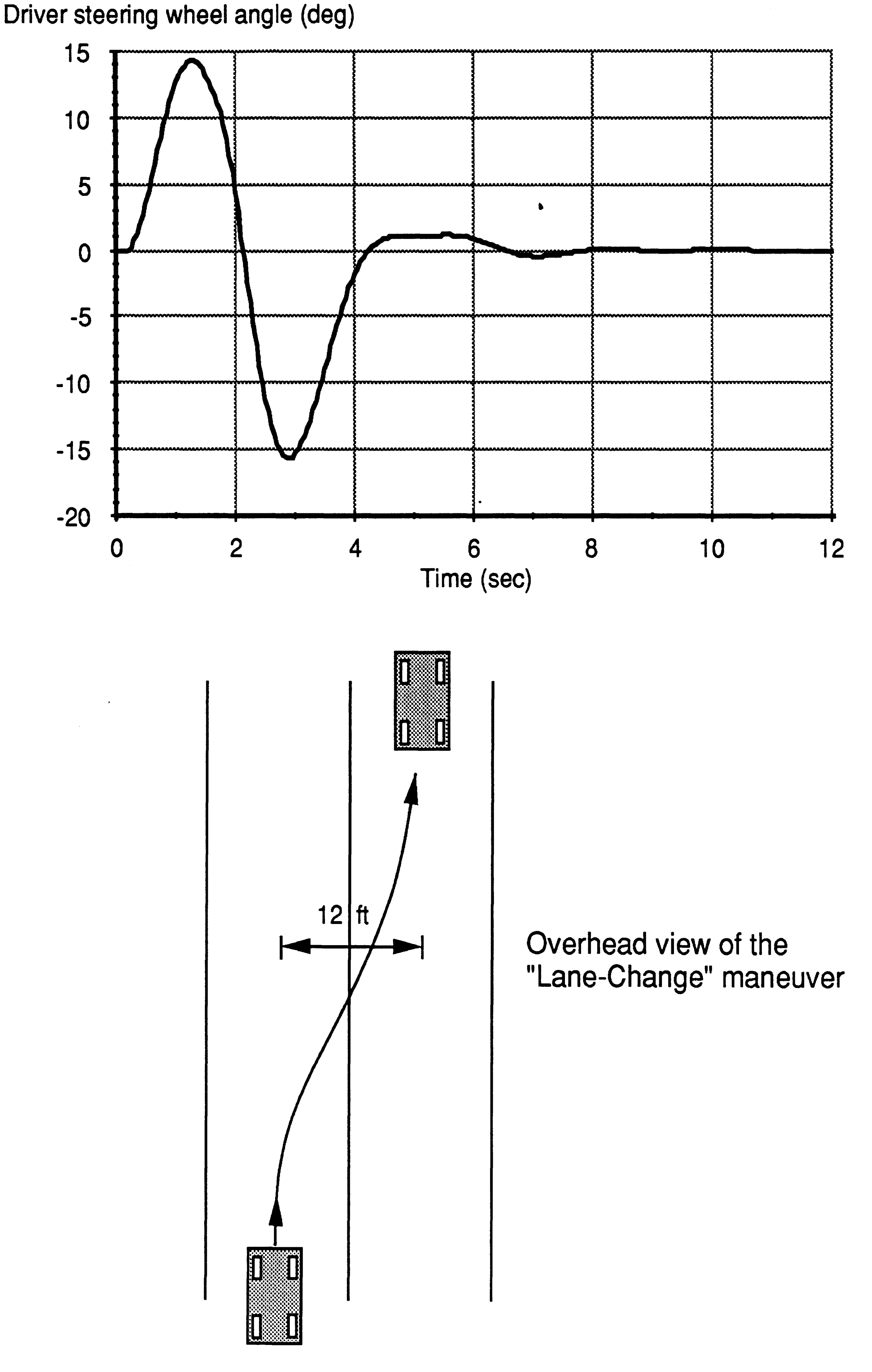


Figure 4.2 "Lane-Change" Maneuver. Vehicle Moves 12-ft Laterally from Present Highway Lane to Adjacent Lane.

Articulation Damping

One way of describing how much damping is present in a vehicle train is illustrated in Figure 4.3. Seen here is an example oscillatory response which diminishes over time. The rate at which such oscillations die out can be described in simple terms by a ratio of the two values seen on this graph, A and B. The parameter B represents the difference between the peak value achieved by the response in its first cycle and the final value prevailing after all oscillations die out. The other parameter A represents the difference between the peak values achieved in the first two oscillations. Consequently, a simple measure of the system damping can be obtained by the ratio A / B. For oscillations that do not damp out, A will be 0.0 and the ratio A / B will be 0.0. For very well damped systems in which no second oscillatory peak occurs, A will be equal to B and their ratio will be 1.0. Therefore, using this scheme to summarize the degree of damping present in a normally oscillatory system (such as an articulated vehicle), small values (less than 0.3 or so) for the damping ratio A / B would indicate poor damping, and large values (0.7 to 1.0) would indicate good damping qualities. This very scheme was used to summarize the level of damping present in each vehicle configuration and will be used in this section to discuss the basic results. However, prior to that discussion a set of example time history plots are first presented for the baseline vehicle configuration and two more lightly damped configurations in order to help focus the discussion that later follows.

Figure 4.4 contains the articulation angle responses of the pickup / trailer ("hitch 1-2") and of the trailer / boat ("hitch 2-3") for the baseline vehicle corresponding to the step-steer maneuver at 65 mph. As seen, the articulation oscillations diminish reasonably well from their initial peak values over several cycles. The damping ratio A / B for the baseline case of the trailer-boat articulation angle ("hitch 2-3") is seen to be approximately 0.6.

In contrast to this, the result seen in Figure 4.5 corresponds to the same 26-ft trailer baseline vehicle but at a higher speed of 75 mph. The level of damping seen here is considerably lower, with the damping ratio for the trailer/boat articulation angle at about 0.25. If we now substitute the 32-ft trailer into the vehicle train for the 26-ft trailer, the damping ratio reduces to nearly zero, as seen in Figure 4.6, indicating little or no damping for the longer vehicle train.

These three graphs help to illustrate the primary results observed in many of the computer runs performed during the study. Namely, that higher speeds and longer trailer

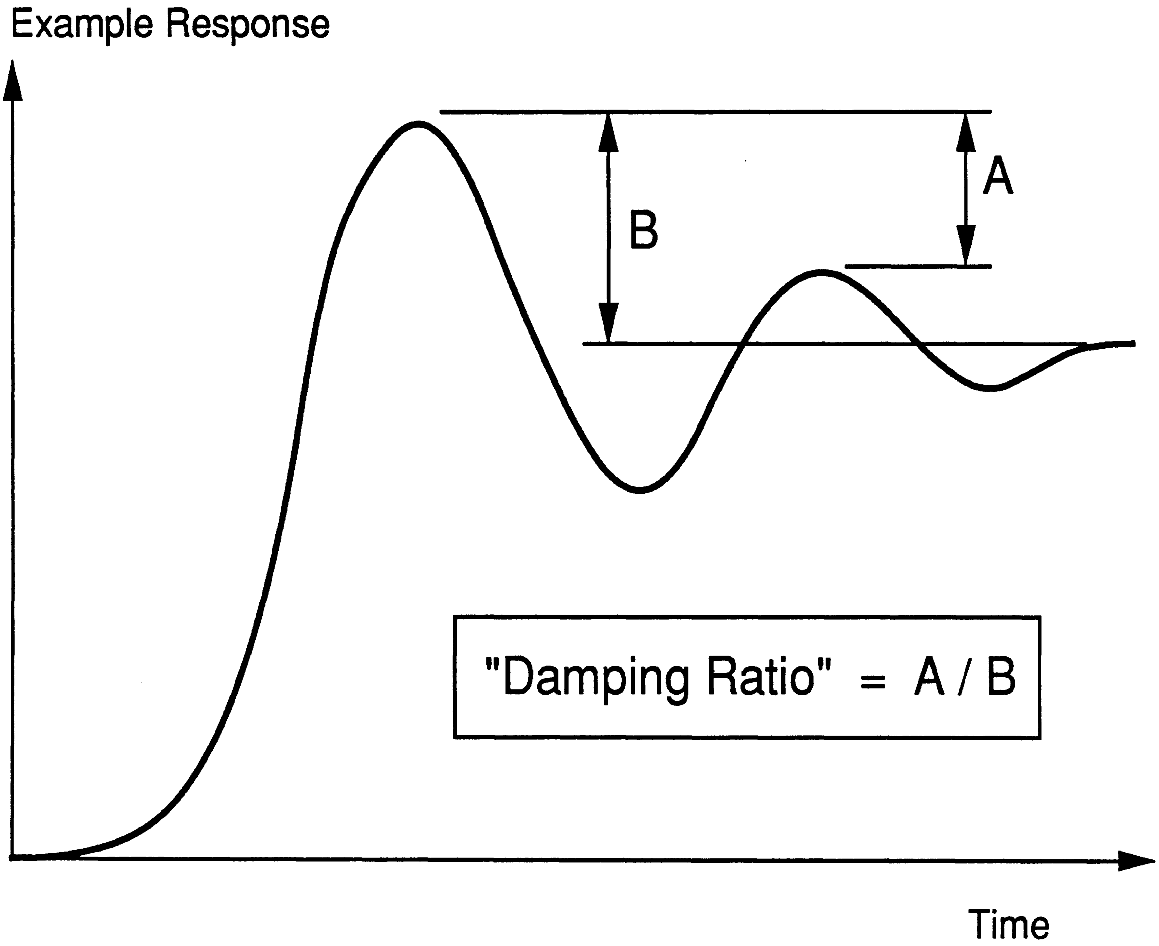
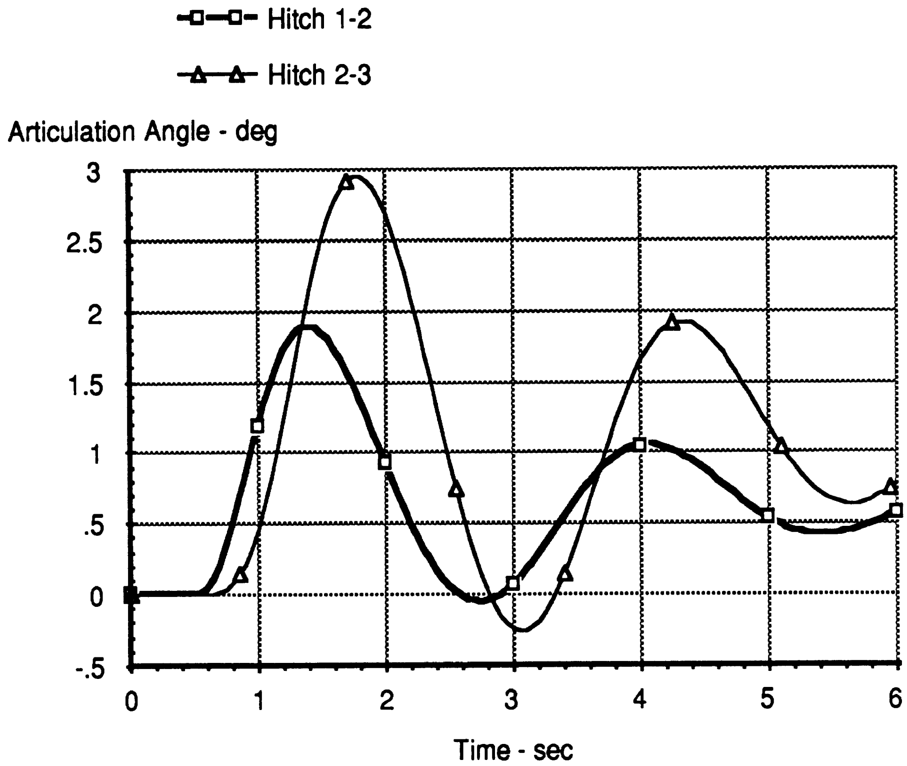
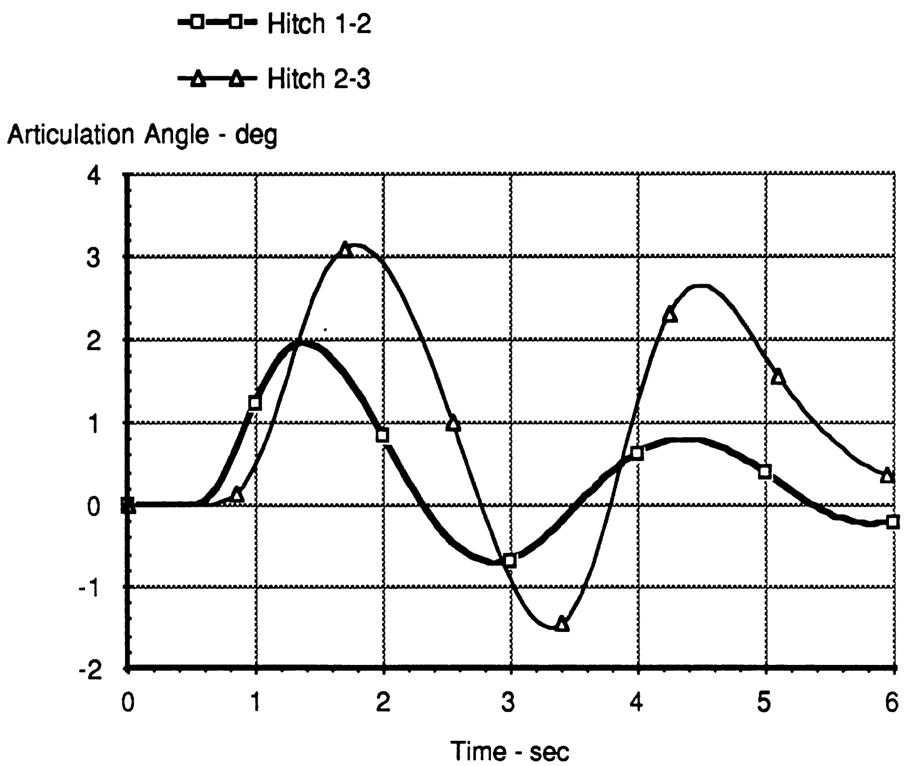


Figure 4.3 Example Oscillatory Response and the Definition of "Damping Ratio"



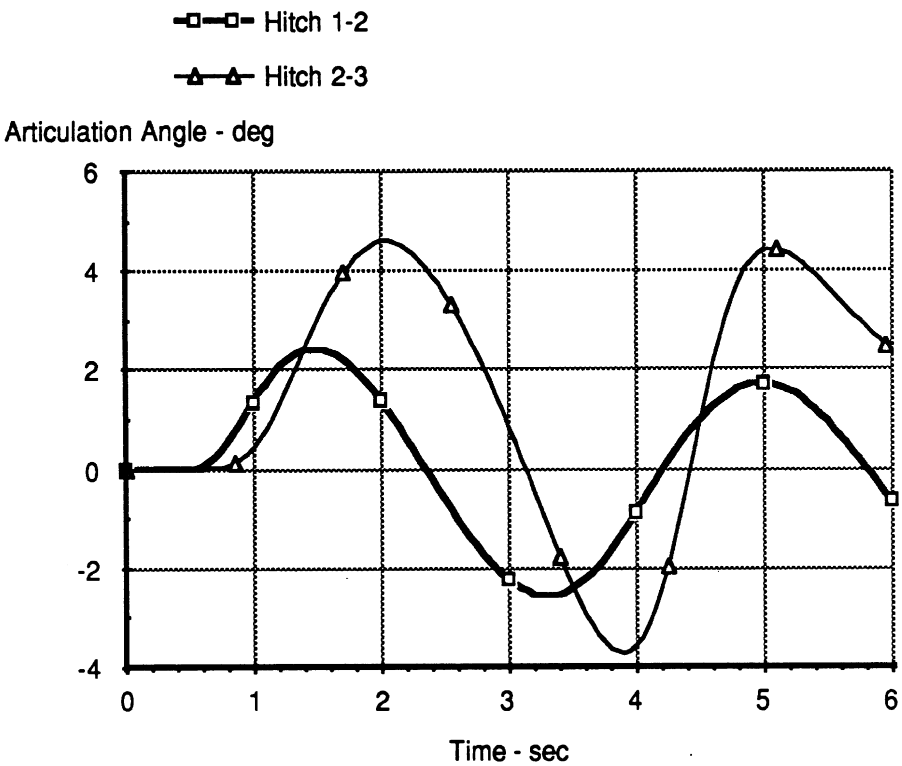
Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Step Steer.

Figure 4.4 Baseline Vehicle Response (65 mph).



Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 75 mph; Step Steer.

Figure 4.5 Baseline Vehicle at 75 mph.



Recreational Double (Pick-up/32'-Trailer/Boat) 75 mph;Step Steer.

Figure 4.6 32-ft Trailer at 75 mph.

lengths both contribute to reduced articulation damping and stability for this class of recreational vehicles.

A sequence of graphs are now presented which help to summarize the same damping ratios discussed above, but for all of the vehicle configurations studied. Each graph is a plot of the articulation angle damping ratios grouped according to a specific vehicle property (such as variations in trailer length, weight, speed, etc.) The first of these graphs (Figure 4.7) shows how the articulation angle damping ratios diminish for the baseline 26-ft trailer configuration when the vehicle speed is increased from 55 to 75 mph. Figure 4.8 shows a similar, though less severe, loss in articulation damping as trailer length is increased from 24 to 32 feet (all at vehicle speeds of 65 mph). In Figure 4.9, the effect on articulation damping of increased trailer payload is seen to be relatively small.

Variations in boat weight (boat & trailer) are seen in Figure 4.10, indicating that as boat weight increases, lower damping is observed in the baseline vehicle response (65 mph). Figure 4.11 shows how boat hitch load (as a percentage of boat weight) affects the damping ratios. For no boat hitch load on the trailer (0%), the trailer-boat articulation damping is relatively small at 0.36. As the hitch load is increased to values of 12% and 20% respectively, the same damping ratio improves to a levels in the vicinity of 0.55.

Finally, in Figure 4.12, the influence of vehicle speed on the damping of the 32-ft trailer configuration is seen. While the level of damping for the trailer-boat articulation response at 55 and 65 mph is about 0.5, an increase of 10 mph in speed causes this configuration to lose nearly all of its articulation damping. This rapid loss of damping as speeds increase above 65 mph with this configuration is worrisome. In fact, the corresponding results for the baseline 26-ft trailer configuration seen in Figure 4.7 exhibit a similar severe reduction in damping as speeds increase to 75 mph. However, the lowest damping level observed in Figure 4.7 for the baseline vehicle, while relatively small at 0.25, is well above the near zero value obtained with the 32-ft trailer configuration.

Lateral Boat Motion

Attention is now turned to the 12-ft lane-change maneuver (passing maneuver, etc.) as might be performed by a recreational vehicle driver on a normal highway outing. One additional issue that can arise for recreational doubles, in addition to the articulation damping/stability issue of the preceding section, is that of vehicle-to-vehicle

Figure 4.7. Baseline. Different Speeds

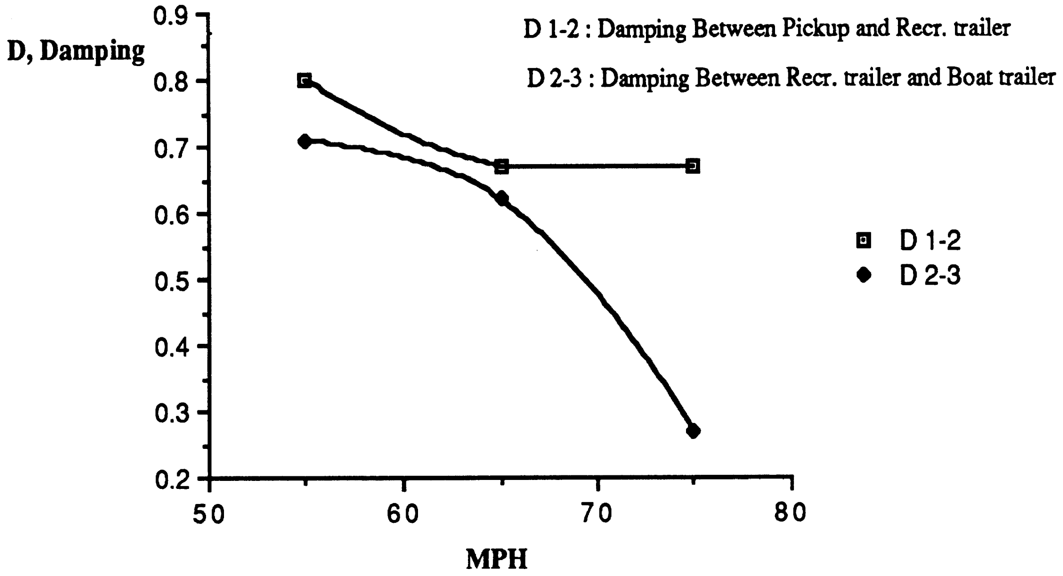


Figure 4.8. Different Recr. trailers Lengths

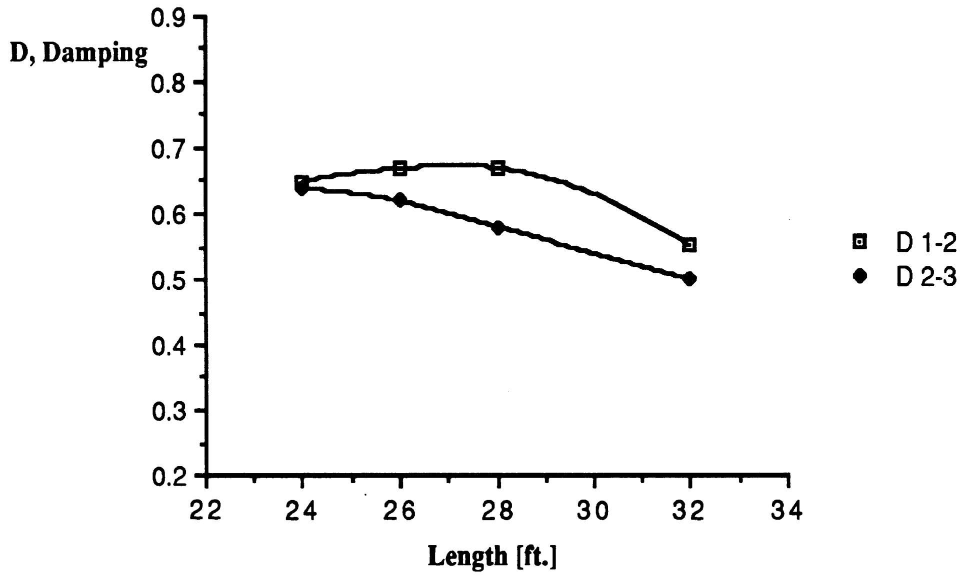


Figure 4.9. Different Recr. trailer Payloads

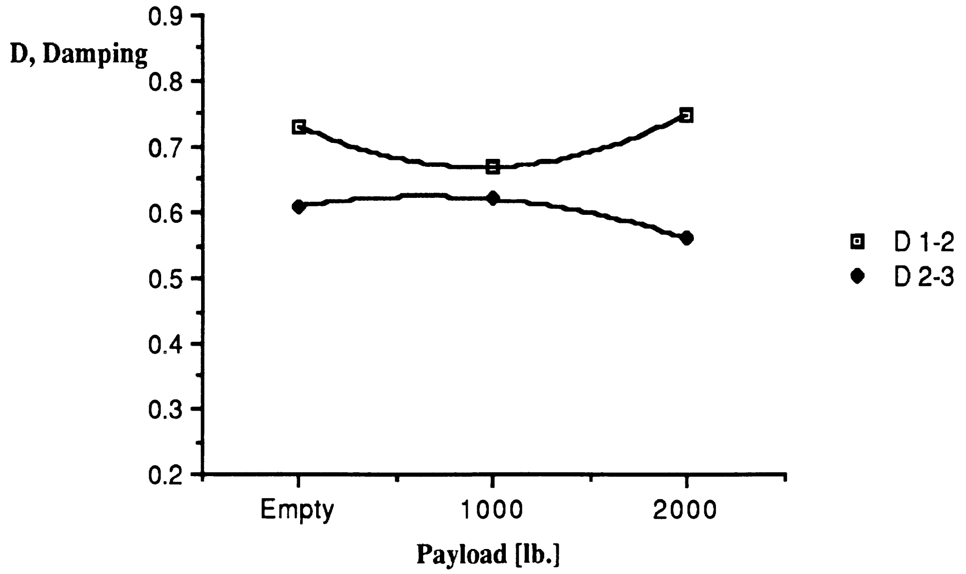


Figure 4.10. Different Boat Weights

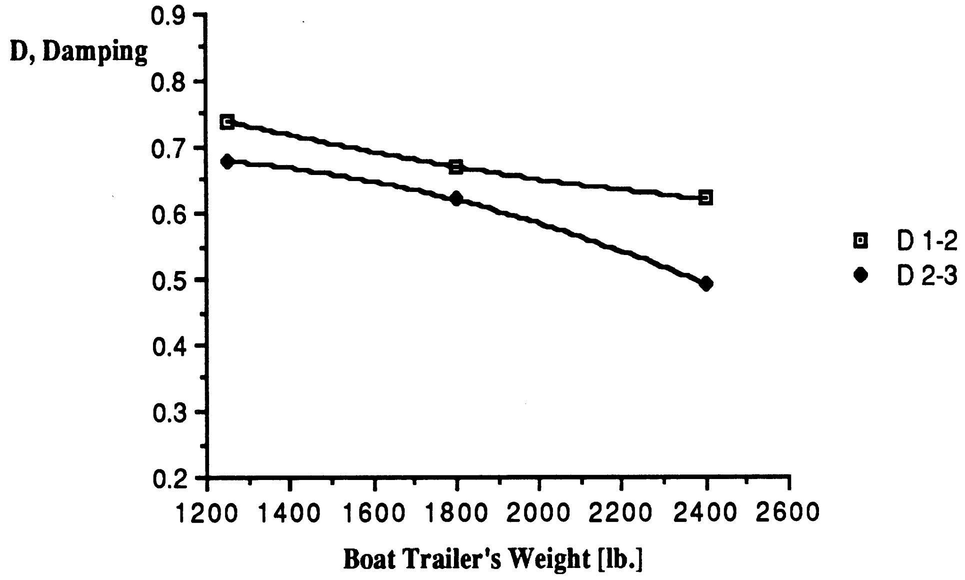


Figure 4.11. Different Boat Hitch-Loads

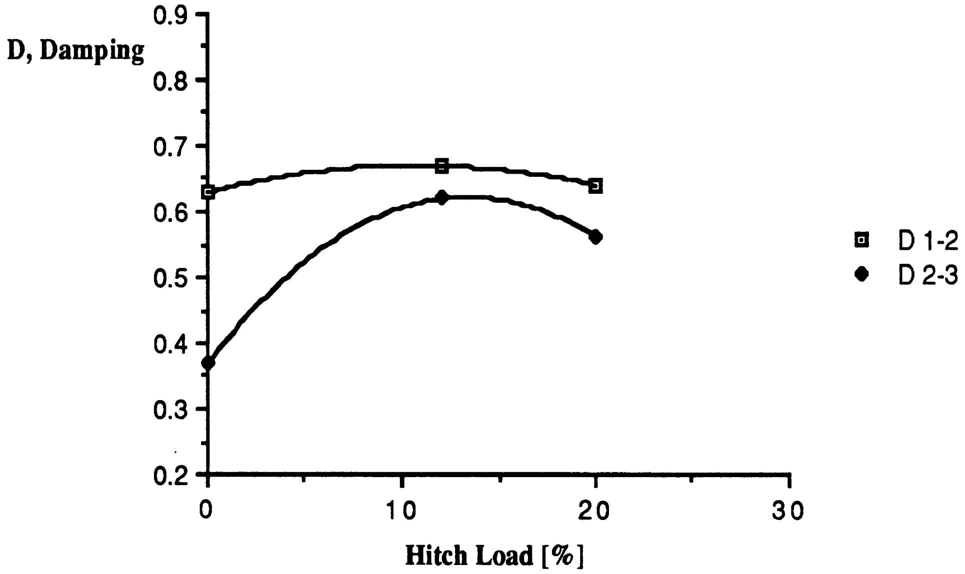
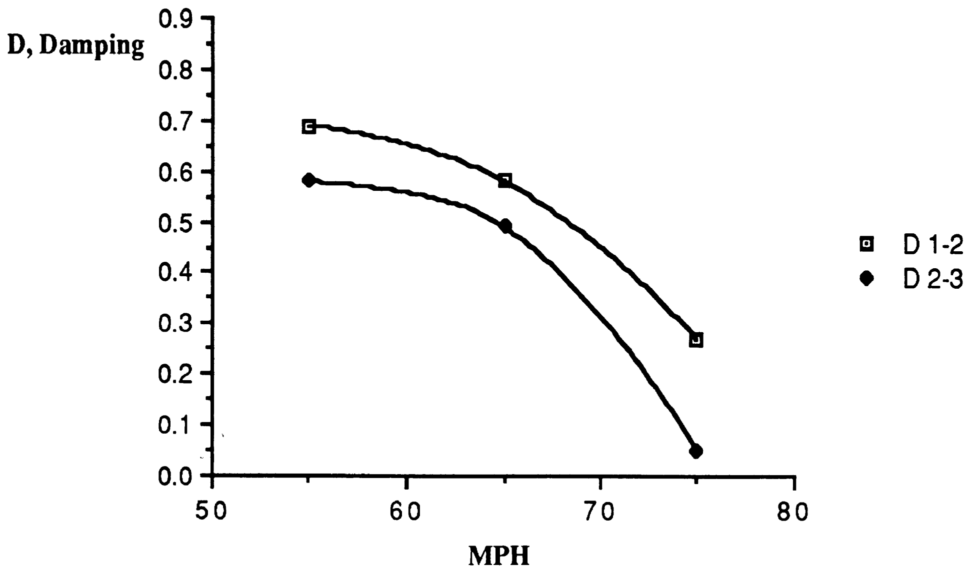


Figure 4.12. Speed Effect on a 32' trailer



clearances/interferences for such vehicles when maneuvering on highways in different traffic conditions. One simplified way to evaluate how much lateral "room," or lane width, may be needed by a vehicle, relates to how much lateral lane-overshoot occurs when a vehicle is steered through a conventional lane-change maneuver. Ideally, if a driver steers a vehicle from one 12-ft lane to another, only 12-ft of lateral highway width would be required. However, normal driver steering behavior and dynamic properties of vehicles ordinarily result in some overshooting by the vehicle into the adjacent lane during the steering maneuver, causing the vehicle to actually displace itself laterally a distance somewhat greater than the nominal 12-ft target distance. For articulated vehicles, this overshooting occurs with each unit in the vehicle train and usually becomes amplified along the vehicle with trailing units demanding greater lane width than preceding units. For a recreational double, this would imply that the most rearward unit (boat/trailer) would exhibit the largest lateral overshooting behavior. Thus, by observing the level of lateral path overshoot exhibited by the boat unit during a nominal lane-change maneuver, a simple performance measure for each recreational double configuration can be defined and used for comparison. The implicit assumption here is that the larger the overshoot value, the greater the likelihood that a particular recreational double will encounter maneuvering difficulties with adjacent vehicles during highway travel conditions.

To clarify the discussion further as to what a "normal" set of lateral responses look like if plotted as a set of path trajectories, Figure 4.13 contains the set of trajectories for each unit of the baseline vehicle during a 12-ft lane-change maneuver. Seen here are plots of lateral distance versus forward travel distance of each unit's mass center as the vehicle moves 12 feet laterally, from its initial lane to an adjacent lane, while travelling forward at a speed of 65 mph. Figure 4.13 shows that the pickup truck and the trailer each overshoot the nominal 12-ft distance by about one foot (peak values of approximately 13 feet are seen). However, the boat unit exceeds the 12-ft target distance by nearly twice that amount or approximately two feet. Hence, for this particular configuration, a value of nearly 2 feet would be recorded as the amount of additional path overshoot required by this vehicle combination in the specified lane-change maneuver. If this same procedure is applied to each of the configurations studied, the results can be summarized on a set of graphs similar to those used for the damping ratio results.

Figure 4.14 shows the influence of travel speed on the amount of overshoot by the boat during the 12-ft lane-change maneuver. The amount of overshoot increases with speed ranging from just over 1 foot of overshoot at 55 mph to nearly 3 feet at 75 mph.

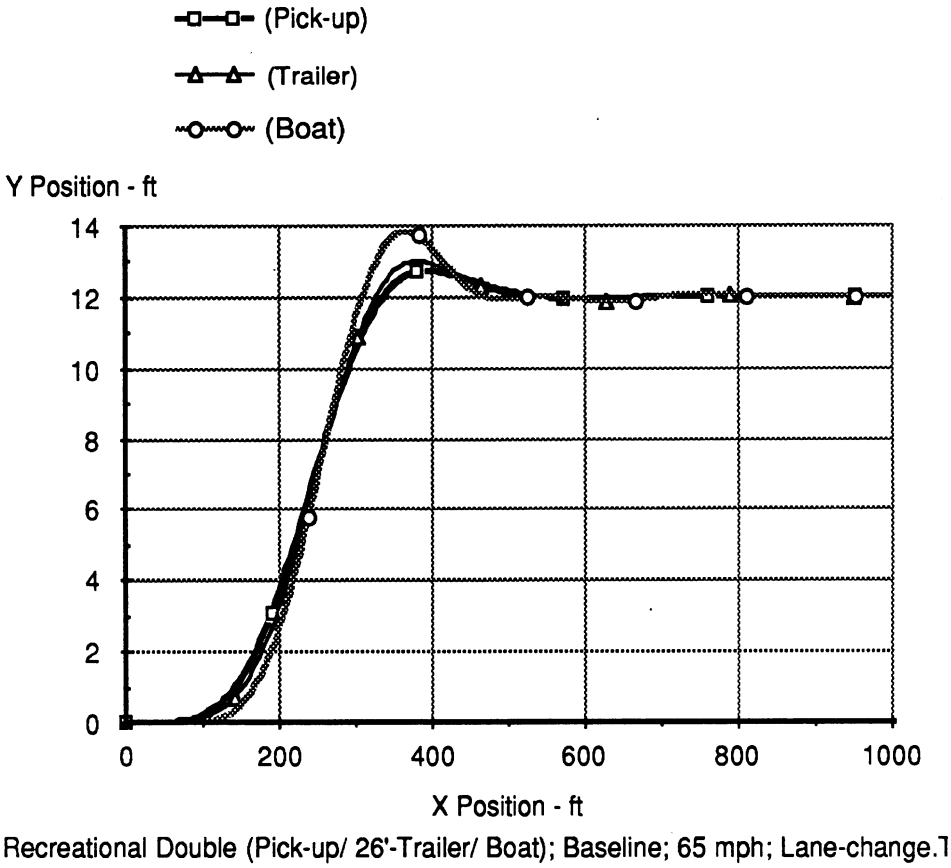
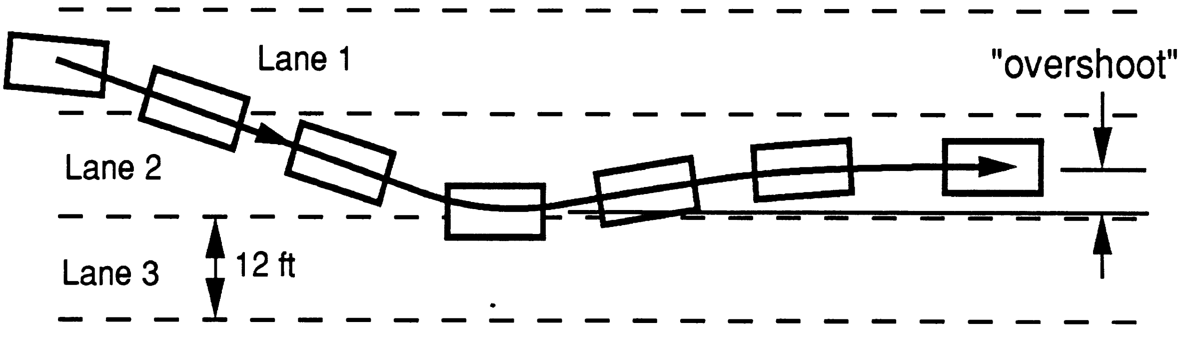


Figure 4.13 Lateral Path Overshoot Behavior of the Baseline Configuration.



Overhead view illustrating "overshoot" measure for the lane-change maneuver.

Figure 4.14. Baseline, Different Speeds

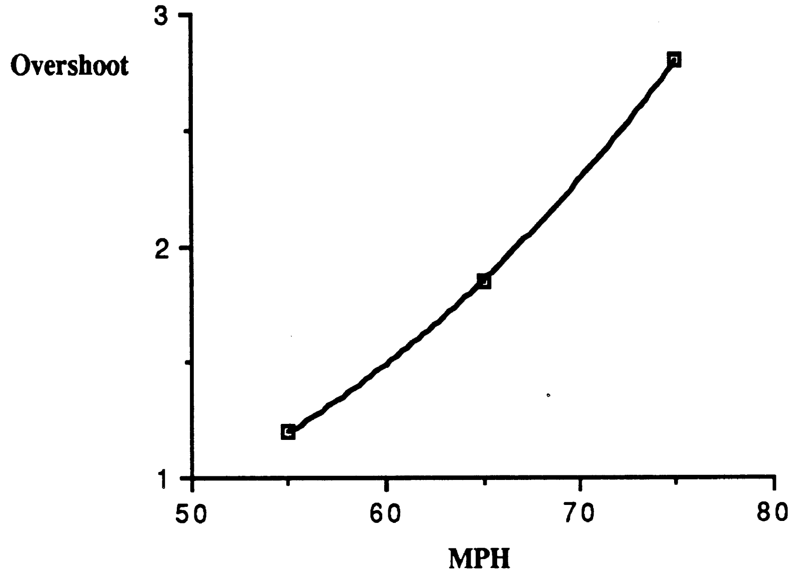


Figure 4.15. Different Recr. trailers Length

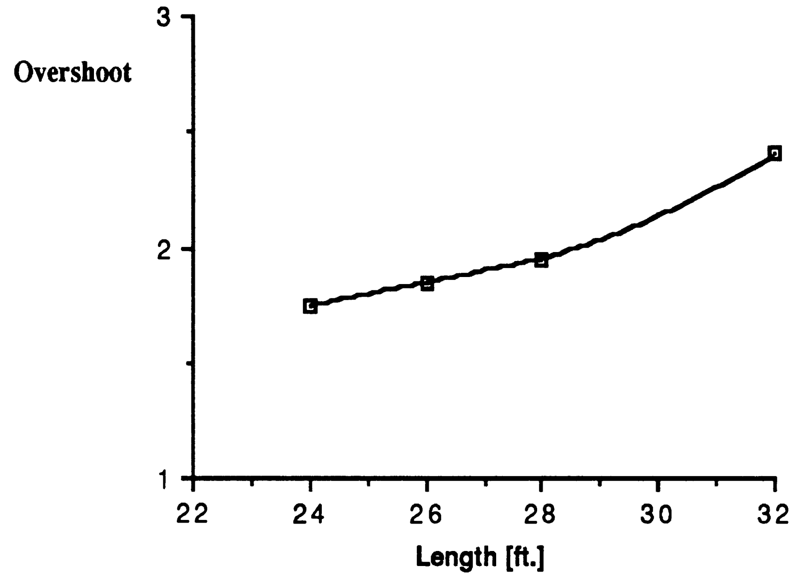


Figure 4.16. Different recr. Trailer Payloads

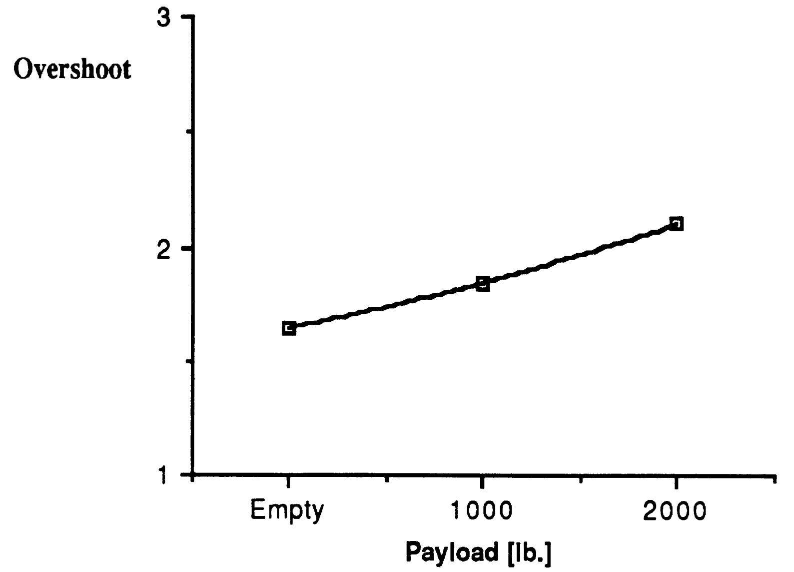


Figure 4.15 indicates that overshoot increases slightly for the baseline configuration as trailer length increases form 24 to 28 feet (at a speed of 65 mph). (The 32-ft trailer configuration is included in this figure for comparison.) In Figure 4.16, overshoot is seen increasing slightly as trailer payload weight is increased, again for a speed of 65 mph.

In Figures 4.17 and 4.18, the influences of boat weight and hitch load are seen. Larger boats and/or lighter boat hitch loads tend to produce more overshoot behavior by the boat.

Lastly, in Figure 4.19, the influence of forward speed on boat overshoot is shown for the 32-ft trailer configuration. As the speed increases to 75 mph, the 32-ft trailer configuration produces a very large overshoot response of more than 4 feet by the boat. Such behavior would undoubtedly result in likely interference problems with vehicles or traffic in adjacent lanes.

Special Cases

Four additional configurations were examined which considered a) a small trailer and large boat configuration, b) the influence of several simultaneous degrading variations on the baseline 26-ft trailer configuration, c) the response of a short "snowmobile" trailer with the baseline trailer, and d) "roll steer" effects of the boat trailer suspension. The first of these special cases examined an 18-ft (dual axle) trailer and larger 2400 lb boat configuration at a speed of 75 mph. The results of this simulation run indicated an acceptable level of damping as seen in the articulation angle responses of Figure 4.20 for the step-steer maneuver. The indicated level of damping for this configuration is approximately 0.6 at 75 mph.

Another configuration, which took the baseline 26-ft trailer vehicle, and then varied several other parameters *simultaneously* in an adverse manner, to illustrate a "worst case" scenario, was also studied. In this case, the trailer baseline payload was increased from 1000 lb to 2000 lb, the larger 2400 lb boat was used, a 0% hitch load for the boat was assumed, and the speed of travel was 75 mph. The results indicated that the resulting configuration loses nearly all of its articulation damping. Figure 4.21 shows the articulation angle response for this vehicle with a step steer maneuver having a damping ratio of nearly zero. The point of this computer run is not to comment on the likelihood of occurrence for this set of conditions, but rather to illustrate how, even for the reasonably

Figure 4.17. Different Boat Weights

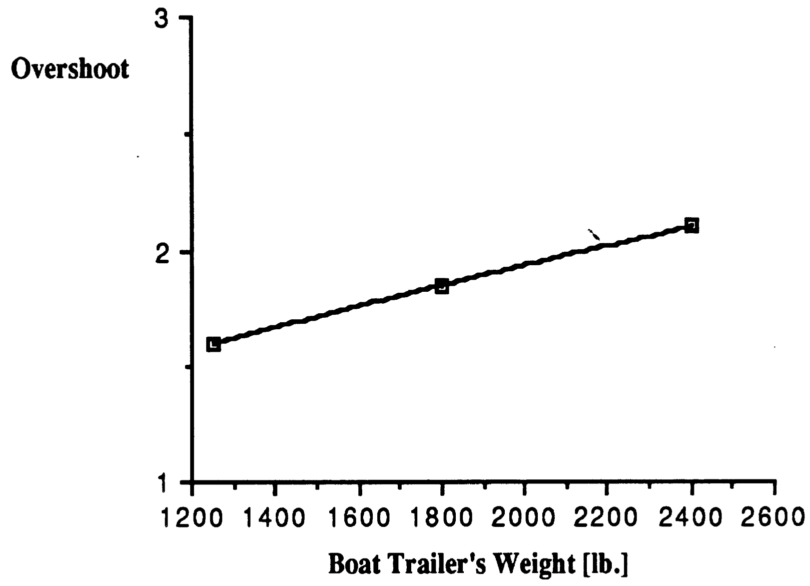


Figure 4.18. Different Boat Hitch-Loads

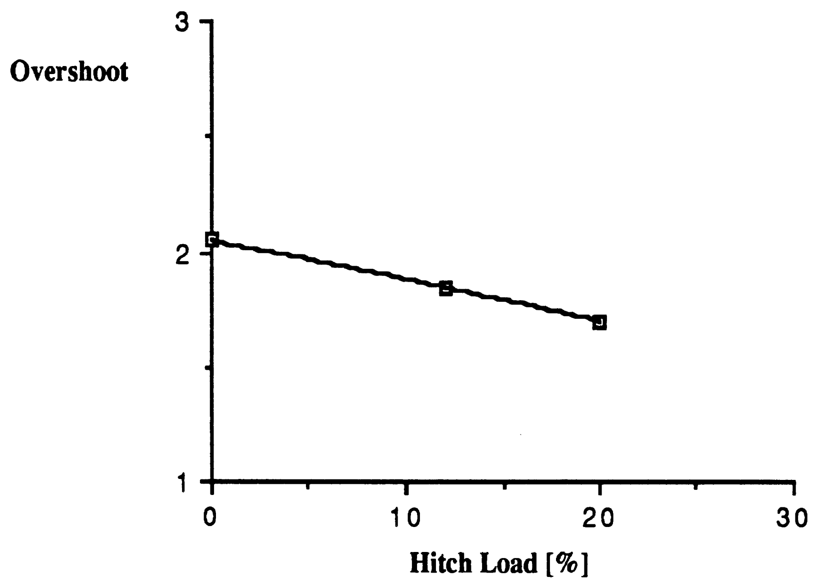
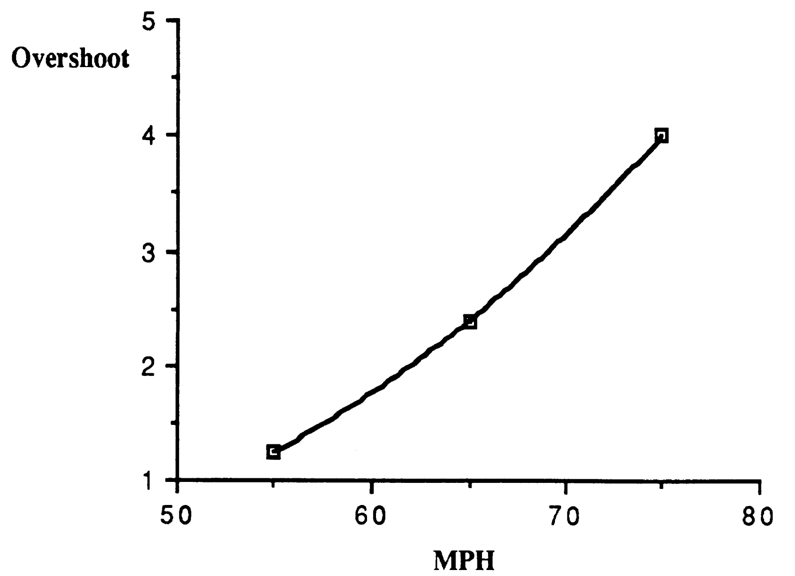


Figure 4.19. Speed Effect, Behind a 32' trailer



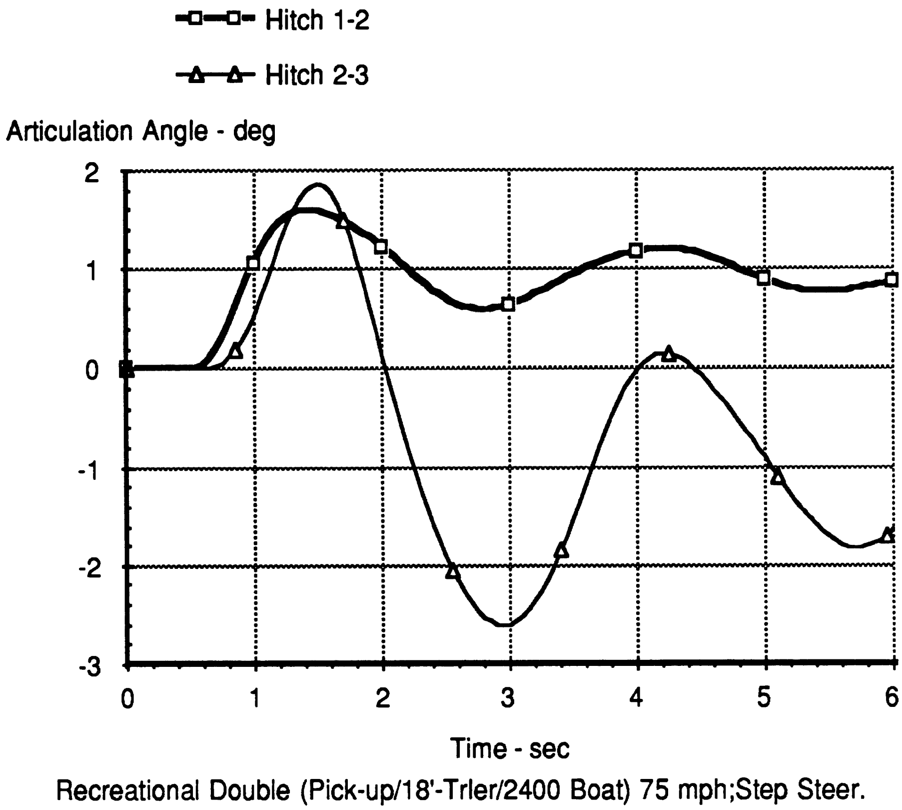
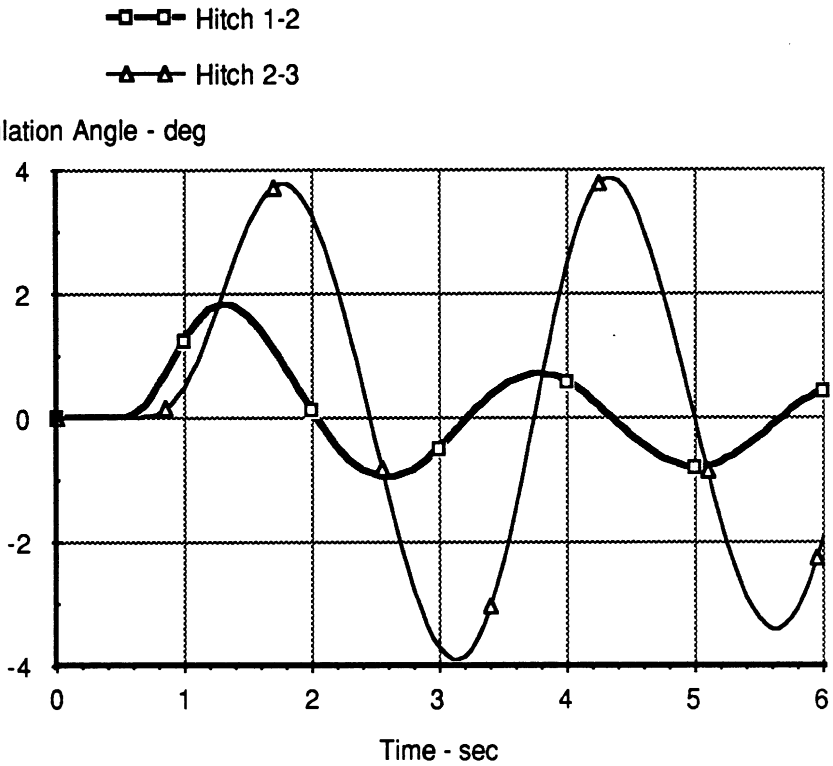


Figure 4.20 18-ft Trailer and 2400 lb Boat Configuration (75 mph).



Recreational Double (Pick-up/26'+2000/2400bt/0%HL);75 mph;Step Steer.

Figure 4.21 Special "Worst Case" Variation of the Baseline Vehicle (75 mph).

well-behaved baseline 26-ft trailer configuration, several modest "in-use" variations to the vehicle configuration could occur simultaneously to produce a significant deterioration in its baseline response.

Finally, computer analysis of a short (8-ft wheelbase) "snowmobile" trailer, substituted for the boat trailer in the baseline vehicle configuration, indicated good levels of damping at values of approximately 0.7 for a travel speed of 65 mph.

One additional case, examining "roll-steer" effects of the boat trailer suspension, was seen to have little effect on the baseline vehicle response, primarily because of the relatively small roll angle responses typically obtained from the boat trailer.

5.0 Conclusions

The computer simulations of vehicle behavior support certain conclusions which are listed here.

1) The baseline vehicle exhibits a relatively mild level of oscillatory motion in response to steering at 65 mph. That is, the behavior is not likely to cause objection by drivers or other motorists nor does it appear as a substantial degradation in maneuvering capability compared to that of the pickup truck and fifth-wheel trailer, taken alone.

2) Speed has a significant influence on the quality of response, with the vehicle becoming more oscillatory as speed rises. Speeds up to 75 mph were seen to cause substantial reductions in stability relative to the performance seen at 65 mph. (The higher speed cases were examined, of course, recognizing that normal travel on 65 mph-posted highways in Michigan frequently involves passing speeds and even steady speeding behavior approaching 75 mph.)

3) The length of the fifth-wheel trailer has a strong influence on response, with the longer vehicle being significantly less desirable than shorter versions. The reason for this influence is the combined destabilizing effect of increased yaw moment of inertia and increased overhang dimension, as measured rearward from the axle on the fifth wheel trailer to the ball hitch. The recreational double, having a first trailer which employs a relatively high ratio of overall length to wheelbase, is thus more or less unique among combination motor vehicles studied in the existing literature—in that its stability degrades, rather than improves, as trailer length is increased.

4) Increases in payload weight cause a moderate degradation in response quality, although even at the higher load, the behavior of the baseline vehicle was deemed to be within a reasonably acceptable range.

5) Increases in the weight of the boat trailer have a moderate influence on response quality, over the range examined. Although it is expected that dramatic increases in boat weight will cause patently unacceptable behavior, the recreational double is

relatively tolerant of the +/- 33% variations in boat weight studied with the baseline vehicle.

6) Movement of the boat aft on its trailer so as to reduce the %-load on the ball hitch tends to degrade the performance of the vehicle, although not to a major degree (even when going to 0% hitch load). This matter has importance because it is recognized that weight distribution on ball-hitched trailers varies widely.

7) The introduction of a substantial value of roll-steer coefficient in the suspension of the boat trailer had a negligible influence on response since the total rolling motions of this trailer are relatively small. Thus, this parameter which plays a substantial role in the behavior of heavy commercial trailers, is of minimal significance with the trailer units examined here.

8) The use of the rather small ball-hitched trailers, such as snowmobile trailers, seems to impart no adverse behavior to the combinations studied here.

9) The use of a 32-ft fifth-wheel trailer in place of the baseline 26-ft unit results in a system that, while reasonably well damped at 65 mph, becomes completely unstable at 75 mph. This result is the most dramatic finding of the study and suggests that the degradation of behavior with increases in the length of the fifth-wheel trailer, cited above in item #3, reaches a point of being totally unacceptable at least by the 32-ft long dimension.

10) A combination of unfavorable loadings and high speed in the baseline configuration was seen to result in a very poor, marginally stable, performance level. This result suggests that some fraction of the recreational doubles applications, even those fitting within the dimensions of the otherwise favorable "baseline" vehicle configuration, would be prone to control problems unless somehow restricted from use.

Discussion:

This project has addressed a rather complex dynamics problem in a small-scale study, using existing methods and data, plus techniques for estimating quantities that were not readily available. It is the authors' view that the presented results accurately represent the *qualitative* nature of the response that can be expected from recreational doubles. That is, one can be confident that recreational doubles will exhibit sensitivities to weight, length, and combinations of parameters that follow the basic trends illustrated here. Further, one can expect that such vehicles will, indeed, exhibit marginally stable behavior in the vicinity of highway speeds, under some combinations of parameters as shown here. However, it is reasonable to note that quantitative accuracy depends upon direct measurement of vehicle properties, thus going beyond the estimation techniques used here.

Clearly, this preliminary study has shown cases of both "favorable" and "unfavorable" performance characteristics over the range of possible configurations of recreational doubles combinations. Quite acceptable dynamic qualities were seen in the baseline vehicle which just fits within a 59-ft constraint on overall length. Even that vehicle, however, will exhibit marginal stability if a group of parameters are placed at unfavorable values at the same time. Thus, it appears that assurance of acceptable dynamic performance with such a vehicle requires that some constraints be placed upon, at least, the loading parameters involved. (Of course, the enforcement of an imagined set of loading constraints poses a separate problem of its own.)

The limited scope of this exploratory study was insufficient for determining a simple constraint on weights or dimensions, within the 59-ft overall length, for guiding the legislative language that would reasonably assure public safety. Thus, we cannot recommend a particular format for specifying the acceptable bounds for vehicle units in a 59-ft combination. Such bounds could be defined by means of additional analytical work, including laboratory measurements of representative tire properties and trailer yaw moments of inertia and by confirming dynamic tests on assembled vehicle combinations.

Because the dynamic quality of the vehicle combination degrades quickly as the length of the fifth wheel trailer increases beyond 26 feet, there may be only limited application of recreational doubles over the long term. We recognize, in particular, that the largest segment of the population of fifth-wheel trailers is greater than 26 feet in length, (thus requiring an overall length allowance greater than 59 feet in the recreational doubles configuration). Thus, there may be little attractiveness to an allowance which, due to stability problems with greater-length doubles, is not extendable in the future to embrace the longer fifth-wheel trailers.

APPENDIX A

SIMULATION INPUT

Echoed Input Data for the Baseline Configuration

****
RECREATIONAL DOUBLES STUDY
****
****
DIRECTIONAL RESPONSE SIMULATION
****

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

OF SPRUNG MASSES = 3

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 11846.00 LB.

FORWARD VELOCITY = 65.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = .89

	DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ON UNIT # 1	-90.00	-19.00	300000.00	1
ARTICULATION PT # 1				
ON UNIT # 2	163.50	-9.00		
ON UNIT # 2	-146.50	17.00	.00	4
ARTICULATION PT # 2				
ON UNIT # 3	160.00	5.00		

TYPE OF CONSTRAINT : 01 CONVENTIONAL 5TH WHEEL
02 INVERTED 5TH WHEEL
03 PINTLE HOOK
04 KING PIN(RIGID IN ROLL & PITCH)

CLOSED LOOP PATH FOLLOWER INPUT
****
DRIVER LAG = .20 SEC
PREVIEW INTERVAL = 1.50 SEC
CLOSED LOOP TIME = 99.00 SEC
RAMP-STEER RATE = .00 DEG/SEC

STEERING GEAR RATIO = 25.00

STEERING STIFFNESS (IN.LB/DEG) = 10000.00
TIE ROD STIFFNESS (IN.LB/DEG) = 15000.00
MECHANICAL TRAIL (IN) = 1.00

OF POINTS IN PATH TABLE = 4

X (FEET)	Y (FEET)
.00	.00
150.00	.00
300.00	12.00
9999.00	12.00

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

UNIT # 1
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 3336.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 8013.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 42384.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 42367.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 26.00 INCHES

	AXLE # 1	AXLE # 2	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	2602.00	2535.00						
AXLE WEIGHT (LB.)	245.00	465.00						
AXLE ROLL M.I (LB.IN.SEC**2)	1000.00	1000.00						
X DIST FROM SP MASS CG (IN)	41.00	-92.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	16.00	16.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	13.00	18.00						
HALF SPRING SPACING (IN)	26.00	26.00						
HALF TRACK - INNER TIRES (IN)	34.00	34.00						
DUAL TIRE SPACING (IN)	.00	.00						
STIFFNESS OF EACH TIRE (LB/IN)	1500.00	1500.00						
ROLL STEER COEFFICIENT	.00	.00						
AUX ROLL STIFFNESS (IN.LB/DEG)	3000.00	.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	20.00	100.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	20.00	20.00						
SPRING TABLE #	1	2						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 5400.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 21094.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 135190.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 135190.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 36.00 INCHES

	AXLE # 3	AXLE # 4	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	2563.00	2563.00						
AXLE WEIGHT (LB.)	300.00	300.00						
AXLE ROLL M.I (LB.IN.SEC**2)	1000.00	1000.00						
X DIST FROM SP MASS CG (IN)	-30.00	-63.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	14.00	14.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	17.00	17.00						
HALF SPRING SPACING (IN)	26.00	26.00						
HALF TRACK - INNER TIRES (IN)	34.00	34.00						
DUAL TIRE SPACING (IN)	.00	.00						
STIFFNESS OF EACH TIRE (LB/IN)	1500.00	1500.00						
ROLL STEER COEFFICIENT	.00	.00						
AUX ROLL STIFFNESS (IN.LB/DEG)	.00	.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	100.00	100.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	.00	.00						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	2	2						
ALIGNING TORQUE TABLE #	2	2						

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

UNIT # 3
****

OF AXLES ON THIS UNIT = 1

WEIGHT OF SPRUNG MASS = 1600.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 1500.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 8000.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 8000.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 24.00 INCHES

	AXLE # 5	AXLE #						
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	1582.00							
AXLE WEIGHT (LB.)	200.00							
AXLE ROLL M.I (LB.IN.SEC**2)	1000.00							
X DIST FROM SP MASS CG (IN)	-23.00							
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	12.00							
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	14.00							
HALF SPRING SPACING (IN)	23.00							
HALF TRACK - INNER TIRES (IN)	29.00							
DUAL TIRE SPACING (IN)	.00							
STIFFNESS OF EACH TIRE (LB/IN)	800.00							
ROLL STEER COEFFICIENT	.00							
AUX ROLL STIFFNESS (IN.LB/DEG)	.00							
SPRING COULOMB FRICTION - PER SPRING (LB)	40.00							
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	.00							
SPRING TABLE #	4							
CORNERING FORCE TABLE #	3							
ALIGNING TORQUE TABLE #	3							

SPRING TABLE # 1
****** *******

FORCE LB	DEFLECTION INCHES
-4000.00	-20.00
.00	.00
4000.00	20.00

SPRING TABLE # 2
****** *******

FORCE LB	DEFLECTION INCHES
-1800.00	-10.00
.00	.00
1300.00	7.00
3100.00	13.00

SPRING TABLE # 3
****** *******

FORCE LB	DEFLECTION INCHES
-7500.00	-10.00
.00	.00
7500.00	10.00

SPRING TABLE # 4
****** *******

FORCE LB	DEFLECTION INCHES
-5000.00	-10.00
.00	.00
5000.00	10.00

CORNERING FORCE TABLE # 1
********* ***** *********
LATERAL FORCE VS. SLIP ANGLL

.00	1.00	2.00	4.00	8.00	12.00
705.00	134.00	223.00	374.00	573.00	633.00
1530.00	258.00	503.00	861.00	1190.00	1209.00
2350.00	382.00	741.00	1270.00	1663.00	1673.00

CORNERING FORCE TABLE # 2
********* ***** *********
LATERAL FORCE VS. SLIP ANGLL

.00	1.00	2.00	5.00	10.00	15.00
751.00	159.00	310.00	577.00	792.00	833.00
1501.00	207.00	400.00	823.00	1310.00	1454.00
1877.00	194.00	370.00	859.00	1455.00	1717.00
2256.00	183.00	350.00	883.00	1496.00	1854.00

CORNERING FORCE TABLE # 3
********* ***** *********
LATERAL FORCE VS. SLIP ANGLL

.00	1.00	2.00	5.00	10.00	15.00
443.00	82.00	160.00	294.00	424.00	468.00
895.00	110.00	210.00	448.00	702.00	828.00
1117.00	108.00	205.00	475.00	763.00	924.00
1340.00	106.00	200.00	485.00	809.00	1010.00

ALIGNING TORQUE TABLE # 1
******** ****** *********
ALIGNING TORQUE VS. SLIP ANGLE

.00	1.00	2.00	4.00	8.00	12.00
705.00	72.00	96.00	108.00	48.00	-12.00
1530.00	228.00	732.00	444.00	264.00	120.00
2350.00	900.00	768.00	1008.00	552.00	300.00

ALIGNING TORQUE TABLE # 2
******** ****** *********
ALIGNING TORQUE VS. SLIP ANGLE

.00	1.00	2.00	5.00	10.00	15.00
751.00	312.00	600.00	240.00	-60.00	-144.00
1501.00	420.00	780.00	1356.00	672.00	264.00
1877.00	384.00	732.00	2124.00	1572.00	804.00
2256.00	360.00	720.00	2928.00	2820.00	1956.00

ALIGNING TORQUE TABLE # 3
******** ****** *********
ALIGNING TORQUE VS. SLIP ANGLE

.00	1.00	2.00	5.00	10.00	15.00
443.00	48.00	84.00	156.00	96.00	60.00
895.00	96.00	180.00	648.00	588.00	444.00
1117.00	252.00	480.00	948.00	996.00	852.00
1340.00	240.00	456.00	1260.00	1476.00	1356.00

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

SPRUNG MASS # 1
****

TIME (SEC)	FORWARD POSITION (IN)	LATERAL POSITION (IN)	VERTICAL POSITION (IN)	ROLL ANGLE (DEG)	YAW ANGLE (DEG)	PITCH ANGLE (DEG)	FORWARD VEL IN/SEC	LATERAL VEL IN/SEC	ROLL RATE DEG/SEC	YAW RATE DEG/SEC	PITCH RATE DEG/SEC	LATERAL ACCN. IN/SEC**2	STEER ANGLE DEG
.00	0.00	.00	.000	.00	.00	.000	1143.96	.00	.00	.00	.00	.00	.00
.10	109.82	.00	-.006	.00	.00	.016	1143.96	.00	.00	.00	.27	.00	.00
.20	228.79	.00	-.019	.00	.00	.043	1143.96	.00	.00	.00	.22	.00	.00
.30	343.19	0.00	-.029	0.00	0.00	.059	1143.96	.03	-.02	.02	.11	1.04	.72
.40	453.01	.01	-.034	0.00	.01	.068	1143.96	.08	-.04	.10	.08	2.66	1.83
.50	567.40	.05	-.034	-.01	.02	.074	1143.96	.10	-.09	.29	.06	5.29	3.53
.60	681.80	.14	-.034	-.02	.07	.079	1143.96	-.04	-.15	.57	.04	8.71	5.43
.70	796.20	.32	-.033	-.04	.14	.082	1143.96	-.45	-.22	.95	.03	13.38	7.57
.80	910.59	.64	-.032	-.07	.26	.085	1143.96	-1.19	-.31	1.40	.02	18.65	9.48
.90	1024.99	1.14	-.031	-.10	.42	.086	1143.96	-2.30	-.41	1.89	.01	24.67	11.15
1.00	1139.38	1.89	-.031	-.15	.64	.088	1143.96	-3.76	-.52	2.38	.01	31.48	12.63
1.10	1253.77	2.96	-.030	-.20	.90	.089	1143.96	-5.51	-.63	2.85	0.00	38.36	13.60
1.20	1372.74	4.49	-.030	-.27	1.22	.090	1143.96	-7.53	-.74	3.28	-.01	45.50	14.19
1.30	1487.12	6.41	-.029	-.35	1.56	.090	1143.96	-9.55	-.83	3.61	-.02	51.92	14.29
1.40	1601.49	8.86	-.029	-.44	1.94	.091	1143.96	-11.53	-.89	3.84	-.02	57.60	13.98
1.50	1715.85	11.88	-.029	-.53	2.33	.092	1143.96	-13.32	-.91	3.95	-.03	62.08	13.22
1.60	1830.20	15.53	-.029	-.62	2.72	.092	1143.96	-14.84	-.88	3.95	-.04	65.34	12.26
1.70	1944.52	19.83	-.029	-.70	3.11	.092	1143.96	-16.00	-.80	3.84	-.05	67.14	11.06
1.80	2058.82	24.79	-.029	-.77	3.49	.092	1143.96	-16.74	-.66	3.63	-.05	67.24	9.51
1.90	2173.09	30.43	-.029	-.83	3.83	.092	1143.96	-17.05	-.46	3.30	-.05	64.82	7.14
2.00	2287.32	36.71	-.029	-.86	4.14	.092	1143.96	-16.90	-.22	2.81	-.04	60.41	4.39
2.10	2401.52	43.59	-.029	-.87	4.39	.092	1143.96	-16.20	.02	2.16	-.03	53.08	.88
2.20	2515.69	51.00	-.029	-.86	4.57	.092	1143.96	-14.87	.29	1.37	-.02	43.93	-2.49
2.30	2629.82	58.84	-.028	-.81	4.66	.092	1143.96	-12.88	.58	.50	-.01	33.10	-5.63
2.40	2743.93	67.01	-.028	-.74	4.67	.092	1143.96	-10.28	.87	-.43	.01	20.23	-8.79
2.50	2858.02	75.37	-.027	-.64	4.58	.092	1143.96	-7.14	1.17	-1.34	.02	6.78	-11.26
2.60	2972.11	83.80	-.027	-.51	4.40	.092	1143.96	-3.60	1.46	-2.21	.02	-7.11	-13.18
2.70	3086.20	92.16	-.027	-.35	4.14	.093	1143.96	.16	1.72	-2.97	.02	-21.09	-14.64
2.80	3200.30	100.30	-.027	-.17	3.81	.093	1143.96	3.97	1.91	-3.60	.01	-34.23	-15.42
2.90	3314.43	108.10	-.027	.03	3.42	.093	1143.96	7.63	2.00	-4.08	0.00	-46.17	-15.65
3.00	3428.60	115.44	-.028	.23	3.00	.093	1143.96	10.97	1.99	-4.38	-.02	-56.28	-15.30
3.10	3542.80	122.21	-.028	.42	2.55	.093	1143.96	13.83	1.88	-4.52	-.03	-64.32	-14.55
3.20	3657.04	128.34	-.029	.60	2.10	.094	1143.96	16.13	1.67	-4.50	-.05	-69.83	-13.56
3.30	3771.32	133.78	-.029	.75	1.66	.094	1143.96	17.80	1.40	-4.33	-.06	-72.94	-12.09
3.40	3885.63	138.49	-.029	.88	1.24	.093	1143.96	18.79	1.06	-4.03	-.06	-74.18	-10.61
3.50	3999.97	142.45	-.029	.96	.86	.093	1143.96	19.08	.72	-3.65	-.06	-73.37	-9.03
3.60	4114.33	145.69	-.029	1.02	.51	.093	1143.96	18.73	.41	-3.20	-.06	-70.37	-7.22
3.70	4228.72	148.23	-.029	1.05	.22	.093	1143.96	17.80	.11	-2.70	-.05	-65.81	-5.69
3.80	4343.11	150.10	-.029	1.04	-.03	.093	1143.96	16.39	-.18	-2.17	-.04	-59.80	-4.27
3.90	4457.51	151.39	-.029	1.01	-.22	.092	1143.96	14.58	-.47	-1.64	-.03	-52.30	-2.86
4.00	4571.91	152.15	-.028	.95	-.36	.092	1143.96	12.52	-.74	-1.15	-.02	-44.45	-1.79

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

SPRUNG MASS # 2
****

TIME (SEC)	FORWARD POSITION (IN)	LATERAL POSITION (IN)	VERTICAL POSITION (IN)	ROLL ANGLE (DEG)	YAW ANGLE (DEG)	PITCH ANGLE (DEG)	FORWARD VEL IN/SEC	LATERAL VEL IN/SEC	ROLL RATE DEG/SEC	YAW RATE DEG/SEC	PITCH RATE DEG/SEC	LATERAL ACCN. IN/SEC**2	ARTIC ANGLE DEG
.00	-253.50	.00	.000	.00	.00	.000	1143.96	.00	.00	.00	.00	.00	.00
.10	-143.68	.00	-.001	.00	.00	-.007	1143.96	.00	.00	.00	-.12	.00	.00
.20	-24.71	.00	-.001	.00	.00	-.018	1143.96	.00	.00	.00	-.07	.00	.00
.30	89.69	0.00	.002	0.00	0.00	-.021	1143.96	0.00	-.01	0.00	-.02	.02	0.00
.40	199.51	0.00	.007	0.00	0.00	-.023	1143.96	0.00	-.03	.01	-.02	.09	.01
.50	313.90	0.00	.010	-.01	0.00	-.025	1143.96	-.01	-.08	.03	-.03	.40	.02
.60	428.30	.01	.011	-.02	.01	-.028	1143.96	-.06	-.13	.09	-.02	1.10	.06
.70	542.70	.04	.012	-.03	.02	-.030	1143.96	-.17	-.20	.20	-.01	2.36	.12
.80	657.09	.09	.013	-.06	.05	-.031	1143.97	-.42	-.28	.39	-.01	4.40	.21
.90	771.49	.18	.014	-.09	.10	-.032	1143.97	-.89	-.38	.67	-.01	7.42	.32
1.00	885.89	.36	.015	-.13	.19	-.032	1143.99	-1.65	-.49	1.05	-.01	11.55	.45
1.10	1000.29	.65	.015	-.19	.32	-.033	1144.00	-2.78	-.60	1.51	-.01	16.86	.58
1.20	1119.26	1.14	.016	-.26	.50	-.034	1144.03	-4.38	-.72	2.06	-.01	23.58	.72
1.30	1233.67	1.86	.016	-.33	.74	-.034	1144.06	-6.35	-.81	2.63	-.02	31.01	.83
1.40	1348.07	2.89	.016	-.42	1.03	-.034	1144.10	-8.67	-.88	3.20	-.03	39.09	.91
1.50	1462.47	4.31	.016	-.51	1.37	-.035	1144.13	-11.27	-.90	3.73	-.03	47.44	.95
1.60	1576.88	6.20	.017	-.60	1.77	-.035	1144.16	-14.02	-.88	4.16	-.04	55.52	.95
1.70	1691.28	8.65	.017	-.68	2.20	-.035	1144.17	-16.74	-.80	4.48	-.05	62.83	.91
1.80	1805.66	11.73	.017	-.76	2.66	-.035	1144.17	-19.29	-.66	4.65	-.06	68.65	.83
1.90	1920.04	15.49	.017	-.82	3.13	-.035	1144.15	-21.54	-.47	4.68	-.07	72.98	.71
2.00	2034.38	19.97	.017	-.85	3.59	-.035	1144.11	-23.35	-.25	4.56	-.07	75.65	.55
2.10	2148.69	25.20	.017	-.87	4.03	-.035	1144.06	-24.56	-.01	4.26	-.06	76.31	.36
2.20	2262.97	31.18	.017	-.85	4.44	-.035	1144.00	-25.04	.26	3.77	-.06	74.47	.13
2.30	2377.19	37.90	.017	-.81	4.78	-.035	1143.93	-24.66	.54	3.08	-.04	70.04	-.12
2.40	2491.36	45.30	.017	-.75	5.05	-.035	1143.87	-23.29	.83	2.20	-.03	62.86	-.38
2.50	2605.49	53.33	.017	-.65	5.22	-.035	1143.84	-20.87	1.13	1.17	-.01	52.61	-.64
2.60	2719.57	61.86	.017	-.52	5.28	-.036	1143.83	-17.45	1.42	.03	0.00	39.40	-.88
2.70	2833.61	70.78	.017	-.36	5.22	-.036	1143.86	-13.16	1.69	-1.15	.01	23.76	-1.08
2.80	2947.64	79.93	.017	-.18	5.05	-.036	1143.91	-8.18	1.89	-2.30	.01	6.71	-1.24
2.90	3061.66	89.15	.017	.01	4.76	-.036	1143.99	-2.71	1.99	-3.37	0.00	-10.97	-1.34
3.00	3175.70	98.25	.017	.21	4.38	-.036	1144.07	3.02	1.98	-4.32	-.02	-28.51	-1.38
3.10	3289.77	107.06	.017	.41	3.91	-.036	1144.15	8.74	1.88	-5.08	-.04	-45.08	-1.35
3.20	3403.88	115.44	.017	.58	3.37	-.035	1144.21	14.21	1.67	-5.62	-.06	-59.88	-1.27
3.30	3518.05	123.22	.017	.74	2.79	-.035	1144.23	19.17	1.39	-5.93	-.08	-71.71	-1.13
3.40	3632.27	130.29	.017	.86	2.19	-.035	1144.22	23.49	1.06	-6.02	-.09	-80.61	-.95
3.50	3746.54	136.57	.017	.95	1.59	-.035	1144.19	27.03	.73	-5.90	-.10	-86.95	-.74
3.60	3860.86	141.98	.017	1.01	1.02	-.035	1144.13	29.61	.42	-5.57	-.10	-90.58	-.50
3.70	3975.22	146.50	.017	1.04	.48	-.035	1144.05	31.13	.12	-5.06	-.09	-91.48	-.27
3.80	4089.61	150.12	.017	1.03	.01	-.035	1143.97	31.51	-.17	-4.39	-.08	-89.64	-.04
3.90	4204.01	152.84	.017	1.00	-.39	-.035	1143.90	30.75	-.46	-3.60	-.06	-85.00	.17
4.00	4318.42	154.73	.017	.94	-.71	-.035	1143.85	28.90	-.73	-2.72	-.05	-77.95	.35

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

SPRUNG MASS # 3
****

TIME (SEC)	FORWARD POSITION (IN)	LATERAL POSITION (IN)	VERTICAL POSITION (IN)	ROLL ANGLE (DEG)	YAW ANGLE (DEG)	PITCH ANGLE (DEG)	FORWARD VEL IN/SEC	LATERAL VEL IN/SEC	ROLL RATE DEG/SEC	YAW RATE DEG/SEC	PITCH RATE DEG/SEC	LATERAL ACCN. IN/SEC**2	ARTIC ANGLE DEG
.00	-560.00	.00	.000	.00	.00	.000	1143.96	.00	.00	.00	.00	.00	.00
.10	-450.18	.00	.013	.00	.00	.011	1143.96	.00	.00	.00	.19	.00	.00
.20	-331.21	.00	.027	.00	.00	.026	1143.96	.00	.00	.00	.07	.00	.00
.30	-216.81	0.00	.021	0.00	0.00	.026	1143.96	0.00	0.00	0.00	-.04	0.00	0.00
.40	-106.99	0.00	.014	0.00	0.00	.023	1143.96	0.00	0.00	0.00	-.01	-.01	0.00
.50	7.40	0.00	.015	0.00	0.00	.025	1143.96	.01	0.00	-.01	.03	-.06	0.00
.60	121.80	0.00	.018	0.00	0.00	.028	1143.96	.03	.01	-.03	.02	-.18	.01
.70	236.20	0.00	.017	0.00	-.01	.029	1143.96	.08	.02	-.05	0.00	-.38	.03
.80	350.59	-.01	.015	0.00	-.01	.029	1143.97	.17	.02	-.08	0.00	-.64	.06
.90	464.99	-.02	.015	.01	-.02	.029	1143.97	.27	.02	-.09	.01	-.88	.13
1.00	579.39	-.04	.016	.01	-.03	.030	1143.99	.33	.01	-.05	.01	-.92	.22
1.10	693.79	-.07	.016	.01	-.03	.031	1144.02	.26	-.03	.07	0.00	-.49	.35
1.20	812.77	-.10	.015	0.00	-.01	.031	1144.07	-.10	-.10	.31	0.00	.87	.51
1.30	927.18	-.13	.015	-.01	.04	.031	1144.14	-.88	-.21	.70	0.00	3.45	.70
1.40	1041.59	-.11	.015	-.04	.13	.031	1144.22	-2.25	-.36	1.24	0.00	7.67	.89
1.50	1156.02	-.02	.015	-.09	.29	.031	1144.32	-4.34	-.53	1.93	0.00	13.80	1.08
1.60	1270.46	.22	.015	-.15	.52	.031	1144.42	-7.21	-.72	2.73	-.01	21.94	1.25
1.70	1384.90	.68	.015	-.23	.84	.032	1144.51	-10.85	-.89	3.60	-.01	31.94	1.36
1.80	1499.36	1.46	.015	-.32	1.24	.032	1144.58	-15.12	-1.03	4.43	-.02	43.35	1.42
1.90	1613.83	2.68	.014	-.43	1.72	.032	1144.62	-19.78	-1.09	5.15	-.04	55.27	1.41
2.00	1728.29	4.46	.014	-.54	2.27	.032	1144.61	-24.59	-.98	5.74	-.05	66.42	1.32
2.10	1842.76	6.90	.014	-.63	2.86	.032	1144.55	-29.31	-.91	6.15	-.07	76.90	1.17
2.20	1957.20	10.10	.014	-.72	3.49	.032	1144.41	-33.67	-.84	6.35	-.08	86.25	.95
2.30	2071.61	14.17	.014	-.79	4.13	.031	1144.23	-37.34	-.68	6.32	-.09	93.85	.66
2.40	2185.98	19.18	.013	-.85	4.75	.031	1144.01	-40.11	-.38	6.05	-.09	98.09	.30
2.50	2300.29	25.16	.013	-.87	5.33	.031	1143.79	-41.77	-.13	5.49	-.08	99.92	-.11
2.60	2414.52	32.13	.013	-.88	5.83	.031	1143.60	-41.93	.04	4.60	-.07	98.96	-.56
2.70	2528.67	40.08	.013	-.86	6.23	.031	1143.49	-40.18	.34	3.31	-.05	94.62	-1.01
2.80	2642.73	48.97	.013	-.80	6.48	.031	1143.48	-36.16	.78	1.67	-.02	85.11	-1.44
2.90	2756.71	58.70	.014	-.69	6.56	.031	1143.60	-29.87	1.40	-.20	0.00	69.78	-1.80
3.00	2870.63	69.12	.014	-.53	6.44	.031	1143.82	-21.49	1.83	-2.18	.02	49.46	-2.06
3.10	2984.52	80.01	.015	-.33	6.13	.032	1144.11	-11.53	2.31	-4.09	.03	23.38	-2.22
3.20	3098.41	91.13	.015	-.08	5.63	.032	1144.42	-.70	2.63	-5.78	.01	-5.11	-2.26
3.30	3212.33	102.20	.015	.18	4.98	.032	1144.69	10.33	2.56	-7.14	-.02	-33.68	-2.19
3.40	3326.31	112.93	.015	.43	4.22	.032	1144.87	20.89	2.35	-8.08	-.06	-59.80	-2.03
3.50	3440.38	123.07	.014	.64	3.38	.032	1144.94	30.56	1.85	-8.64	-.10	-81.37	-1.78
3.60	3554.54	132.41	.013	.81	2.50	.032	1144.87	39.05	1.49	-8.86	-.13	-98.41	-1.48
3.70	3668.79	140.77	.013	.93	1.61	.032	1144.70	46.33	.95	-8.85	-.15	-110.15	-1.13
3.80	3783.12	148.03	.013	1.01	.74	.031	1144.42	52.29	.73	-8.57	-.15	-119.14	-.73
3.90	3897.51	154.10	.012	1.08	-.09	.031	1144.10	56.66	.59	-8.02	-.15	-125.36	-.30
4.00	4011.95	158.93	.012	1.12	-.86	.031	1143.75	59.16	.29	-7.18	-.14	-128.41	.15

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

CONSTRAINT FORCES
****

NOTE: LATERAL FORCE ALONE IS PRINTED FOR PINTLE HOOK TYPE CONSTRAINT.
LOCATE FORCES & MOMENTS BASED ON CONSTRAINT TYPE

TIME	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
.00	.0	1078.3	.0	.0	.0	201.5	.0	.0		
.10	.0	1095.7	.0	.0	.0	201.3	.0	.0		
.20	.0	1106.8	.0	.0	.0	201.0	.0	.0		
.30	-.5	1100.4	125.8	.0	0.0	200.9	.0	.0		
.40	-1.6	1098.3	206.9	.0	0.0	201.0	.0	.0		
.50	-5.8	1099.6	528.0	.0	.2	201.1	.0	.0		
.60	-13.6	1099.5	986.5	.0	.3	201.1	.0	.0		
.70	-25.5	1099.0	1486.7	.0	.6	201.1	.0	.0		
.80	-42.3	1098.9	2138.2	.0	.7	201.0	.0	.0		
.90	-63.6	1098.8	2861.7	.0	.7	201.1	.0	.0		
1.00	-88.5	1098.6	3570.9	.0	.3	201.1	.0	.0		
1.10	-115.8	1098.4	4262.1	.0	-.7	201.1	.0	.0		
1.20	-144.9	1098.2	4867.2	.0	-2.4	201.1	.0	.0		
1.30	-171.7	1097.8	5278.1	.0	-5.0	201.1	.0	.0		
1.40	-195.8	1097.4	5507.9	.0	-8.6	201.0	.0	.0		
1.50	-215.6	1096.9	5555.6	.0	-13.1	201.0	.0	.0		
1.60	-228.9	1096.4	5365.0	.0	-18.4	200.9	.0	.0		
1.70	-236.5	1096.0	5070.1	.0	-24.3	200.8	.0	.0		
1.80	-238.4	1095.6	4724.8	.0	-30.2	200.7	.0	.0		
1.90	-233.3	1095.5	4095.3	.0	-36.0	200.6	.0	.0		
2.00	-221.5	1095.4	3401.3	.0	-41.3	200.5	.0	.0		
2.10	-201.4	1095.6	2517.0	.0	-46.0	200.4	.0	.0		
2.20	-170.4	1096.1	1285.5	.0	-49.9	200.4	.0	.0		
2.30	-131.5	1096.8	40.3	.0	-52.5	200.4	.0	.0		
2.40	-86.0	1097.5	-1203.2	.0	-53.4	200.4	-.0	.0		
2.50	-35.7	1098.2	-2375.6	.0	-52.1	200.6	-.0	.0		
2.60	17.0	1098.8	-3334.5	.0	-48.8	200.7	-.0	.0		
2.70	69.6	1099.1	-4039.3	.0	-43.3	200.9	-.0	.0		
2.80	119.8	1099.0	-4571.5	.0	-35.6	201.0	-.0	.0		
2.90	165.1	1098.6	-4962.3	.0	-25.5	201.1	-.0	.0		
3.00	203.4	1097.9	-5126.0	.0	-13.6	201.2	-.0	.0		
3.10	232.5	1097.0	-5056.3	.0	-.2	201.1	-.0	.0		
3.20	250.6	1096.1	-4705.6	.0	14.0	200.9	-.0	.0		
3.30	260.3	1095.3	-4391.5	.0	27.3	200.7	-.0	.0		
3.40	261.9	1094.8	-4068.5	.0	39.0	200.5	-.0	.0		
3.50	255.6	1094.5	-3667.8	.0	49.0	200.3	-.0	.0		
3.60	242.4	1094.5	-3163.0	.0	56.8	200.1	-.0	.0		
3.70	223.4	1094.7	-2560.1	.0	62.2	200.0	-.0	.0		
3.80	199.7	1095.1	-1959.6	.0	65.5	200.0	-.0	.0		
3.90	170.4	1095.7	-1331.5	.0	67.1	200.0	.0	.0		
4.00	139.6	1096.4	-883.0	.0	66.7	200.1	.0	.0		

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

AXLE # 1
****

			LEFT SIDE					RIGHT SIDE					
TIME (SEC)	ROLL (DEG)	BOUNCE (IN)	SLIP ANGLE (DEG)	VERTICAL LOAD (LB.)	LATERAL FORCE (LB.)	ALIGNING TORQUE (FT.LB)	SPRING FORCE (LB.)	SLIP ANGLE (DEG)	VERTICAL LOAD (LB.)	LATERAL FORCE (LB.)	ALIGNING TORQUE (FT.LB)	SPRING FORCE (LB.)	SPECIAL STEER (DEG)
.00	.000	.000	.00	1301.0	.0	.00	1178.5	.00	1301.0	.0	.00	1178.5	
.10	.000	.009	.00	1288.7	.0	.00	1166.5	.00	1288.7	.0	.00	1166.5	
.20	.000	.036	.00	1280.3	.0	.00	1157.9	.00	1280.3	.0	.00	1157.9	
.30	-.002	.058	-.02	1282.2	5.4	-.37	1157.7	-.02	1279.3	5.2	-.36	1158.9	
.40	-.005	.070	-.06	1287.1	13.2	-.91	1160.0	-.06	1278.3	12.8	-.87	1160.4	
.50	-.011	.076	-.12	1293.8	25.6	-1.76	1161.5	-.11	1273.7	24.6	-1.68	1161.0	
.60	-.019	.079	-.18	1301.2	40.6	-2.80	1163.0	-.18	1267.0	38.7	-2.63	1160.2	
.70	-.029	.081	-.27	1310.2	60.0	-4.14	1165.4	-.26	1258.5	56.4	-3.83	1158.1	
.80	-.041	.082	-.36	1321.1	80.6	-5.59	1168.2	-.35	1247.8	74.7	-5.04	1155.6	
.90	-.055	.082	-.45	1333.4	103.2	-7.18	1171.9	-.44	1235.6	94.1	-6.32	1151.9	
1.00	-.070	.082	-.56	1347.3	128.2	-8.96	1176.9	-.54	1221.8	114.8	-7.67	1146.9	
1.10	-.088	.083	-.66	1362.5	152.7	-10.73	1182.7	-.64	1206.6	134.1	-8.90	1140.9	
1.20	-.106	.083	-.76	1379.0	177.9	-12.56	1189.8	-.74	1190.1	152.8	-10.08	1133.7	
1.30	-.124	.083	-.84	1395.0	200.0	-14.20	1197.3	-.82	1174.1	168.2	-11.02	1126.0	
1.40	-.141	.084	-.91	1410.3	219.2	-15.63	1205.1	-.89	1158.8	180.7	-11.75	1118.0	
1.50	-.157	.084	-.96	1424.1	233.5	-16.72	1212.5	-.94	1144.9	189.0	-12.21	1110.4	
1.60	-.170	.085	-1.00	1435.7	243.7	-17.51	1219.3	-.98	1133.3	194.2	-12.48	1103.4	
1.70	-.180	.085	-1.01	1444.5	248.2	-18.16	1225.0	-.99	1124.5	195.7	-12.52	1097.7	
1.80	-.186	.085	-1.00	1449.7	245.8	-17.72	1228.8	-.98	1119.3	192.2	-12.27	1093.8	
1.90	-.184	.085	-.94	1448.6	231.1	-16.66	1231.4	-.92	1120.3	181.0	-11.56	1091.3	
2.00	-.178	.086	-.85	1442.5	208.4	-15.00	1231.4	-.83	1126.4	164.5	-10.54	1091.5	
2.10	-.164	.085	-.71	1430.5	173.4	-12.43	1229.0	-.70	1138.4	139.1	-8.96	1094.1	
2.20	-.145	.085	-.56	1413.2	133.8	-9.55	1224.9	-.54	1155.7	109.9	-7.14	1098.6	
2.30	-.120	.084	-.38	1391.4	90.5	-6.42	1217.9	-.37	1177.6	76.4	-5.01	1105.9	
2.40	-.090	.084	-.18	1365.0	41.5	-2.92	1208.2	-.17	1204.0	36.3	-2.40	1115.8	
2.50	-.057	.083	.02	1334.9	-5.7	.40	1196.5	.02	1234.1	-5.3	.36	1127.7	
2.60	-.020	.083	.23	1302.0	-51.0	3.51	1182.1	.22	1267.1	-48.7	3.31	1142.2	
2.70	.020	.083	.43	1266.7	-93.7	6.37	1165.4	.42	1302.4	-93.5	6.44	1158.7	
2.80	.060	.083	.61	1231.5	-130.5	8.75	1148.6	.60	1337.6	-136.4	9.51	1175.3	
2.90	.096	.083	.77	1198.8	-161.3	10.67	1133.1	.75	1370.4	-176.0	12.40	1190.6	
3.00	.131	.084	.91	1168.1	-184.6	12.06	1117.6	.88	1401.0	-209.8	14.92	1205.6	
3.10	.161	.085	1.01	1141.0	-201.2	13.09	1103.0	.98	1427.9	-237.2	17.00	1219.7	
3.20	.186	.086	1.08	1119.1	-209.9	14.33	1090.4	1.05	1449.7	-256.5	19.49	1231.8	
3.30	.203	.086	1.11	1104.0	-212.7	14.71	1082.2	1.08	1464.6	-265.8	20.92	1239.8	
3.40	.212	.087	1.12	1095.9	-212.0	14.64	1078.2	1.08	1473.0	-268.2	21.25	1244.1	
3.50	.215	.087	1.09	1093.2	-207.2	14.02	1076.8	1.05	1475.8	-262.6	20.29	1245.6	
3.60	.212	.087	1.03	1095.5	-197.2	12.74	1077.4	.99	1473.5	-248.1	18.00	1245.0	
3.70	.204	.086	.95	1102.7	-183.8	11.63	1080.0	.92	1466.2	-228.0	16.51	1242.7	
3.80	.191	.086	.85	1114.5	-166.4	10.59	1084.9	.82	1454.4	-203.2	14.67	1238.0	
3.90	.173	.086	.74	1130.3	-145.6	9.34	1092.2	.71	1438.6	-174.1	12.52	1231.0	
4.00	.152	.085	.62	1149.2	-124.4	8.06	1101.4	.60	1419.7	-145.1	10.37	1222.1	

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

AXLE # 2
****

			LEFT SIDE					RIGHT SIDE					
TIME (SEC)	ROLL (DEG)	BOUNCE (IN)	SLIP ANGLE (DEG)	VERTICAL LOAD (LB.)	LATERAL FORCE (LB.)	ALIGNING TORQUE (FT.LB)	SPRING FORCE (LB.)	SLIP ANGLE (DEG)	VERTICAL LOAD (LB.)	LATERAL FORCE (LB.)	ALIGNING TORQUE (FT.LB)	SPRING FORCE (LB.)	SPECIAL STEER (DEG)
.00	.000	.000	.00	1267.5	.0	.00	1035.0	.00	1267.5	.0	.00	1035.0	.000
.10	.000	-.008	.00	1285.1	.0	.00	1051.9	.00	1285.1	.0	.00	1051.9	.000
.20	.000	-.032	.00	1296.0	.0	.00	1062.7	.00	1296.0	.0	.00	1062.7	.000
.30	0.000	-.051	0.00	1289.3	0.0	0.00	1057.3	0.00	1288.8	0.0	0.00	1056.6	.000
.40	-.001	-.062	0.00	1288.6	.8	-.05	1056.1	0.00	1286.3	.8	-.05	1054.0	.000
.50	-.004	-.071	-.02	1292.6	3.8	-.26	1058.7	-.02	1285.1	3.7	-.26	1053.8	.000
.60	-.010	-.079	-.05	1297.2	10.3	-.70	1060.3	-.05	1279.9	10.1	-.69	1051.7	.000
.70	-.018	-.085	-.10	1304.3	21.4	-1.48	1062.2	-.10	1271.8	21.0	-1.43	1049.0	.000
.80	-.030	-.090	-.17	1315.2	37.8	-2.62	1065.3	-.17	1261.0	36.5	-2.48	1045.8	.000
.90	-.046	-.094	-.26	1329.4	59.5	-4.14	1069.5	-.26	1246.7	56.4	-3.80	1041.5	.000
1.00	-.066	-.097	-.37	1346.5	85.9	-6.00	1074.7	-.37	1229.3	79.5	-5.33	1035.9	.000
1.10	-.088	-.099	-.50	1366.3	115.9	-8.15	1081.3	-.50	1209.6	104.5	-6.95	1029.2	.000
1.20	-.113	-.101	-.63	1388.3	149.4	-10.58	1089.2	-.63	1187.5	130.8	-8.61	1021.1	.000
1.30	-.137	-.102	-.76	1409.7	181.9	-12.97	1097.5	-.76	1166.1	154.7	-10.09	1012.6	.000
1.40	-.160	-.103	-.87	1430.0	212.5	-15.24	1105.9	-.88	1145.8	175.8	-11.37	1003.9	.000
1.50	-.180	-.104	-.97	1447.9	239.2	-17.24	1113.8	-.98	1127.9	193.2	-12.38	995.7	.000
1.60	-.195	-.104	-1.05	1461.7	259.4	-19.87	1120.8	-1.05	1114.0	204.6	-13.64	988.5	.000
1.70	-.206	-.105	-1.10	1470.9	272.7	-22.02	1125.7	-1.11	1104.7	211.4	-14.55	983.4	.000
1.80	-.211	-.105	-1.12	1475.1	278.6	-22.98	1128.3	-1.13	1100.4	214.3	-14.93	980.7	.000
1.90	-.209	-.105	-1.11	1473.6	276.4	-22.62	1127.5	-1.12	1101.9	213.1	-14.77	981.5	.000
2.00	-.201	-.105	-1.07	1466.4	265.0	-20.77	1124.4	-1.07	1108.9	207.0	-13.97	984.8	.000
2.10	-.186	-.105	-.99	1453.4	243.2	-17.56	1119.3	-.99	1121.8	194.5	-12.43	990.1	.000
2.20	-.163	-.105	-.86	1432.9	209.4	-15.03	1112.4	-.86	1142.3	172.1	-11.11	997.4	.000
2.30	-.133	-.106	-.69	1405.6	166.1	-11.83	1102.6	-.69	1169.6	141.6	-9.25	1007.5	.000
2.40	-.095	-.106	-.49	1372.4	115.5	-8.14	1090.4	-.49	1202.8	102.9	-6.82	1020.1	.000
2.50	-.052	-.107	-.27	1334.3	60.6	-4.22	1075.7	-.26	1241.1	56.8	-3.82	1035.2	-.000
2.60	-.005	-.107	-.02	1292.2	4.7	-.32	1058.3	-.02	1283.3	4.6	-.32	1052.8	-.000
2.70	.045	-.108	.23	1248.0	-49.0	3.31	1038.7	.23	1327.7	-51.6	3.58	1072.3	-.000
2.80	.094	-.108	.47	1204.4	-98.0	6.50	1018.6	.47	1371.3	-109.3	7.70	1092.1	-.000
2.90	.139	-.109	.69	1164.1	-140.3	9.14	999.9	.69	1411.7	-165.3	11.79	1110.3	-.000
3.00	.178	-.108	.88	1129.1	-174.9	11.22	983.6	.88	1446.6	-216.1	15.57	1126.1	.000
3.10	.210	-.108	1.04	1101.1	-200.3	13.12	970.4	1.04	1474.5	-258.2	19.55	1138.7	.000
3.20	.231	-.107	1.16	1082.4	-216.0	15.15	961.6	1.15	1493.2	-288.7	24.55	1147.1	.000
3.30	.243	-.107	1.23	1071.4	-225.6	16.34	957.3	1.23	1504.0	-308.2	27.78	1151.2	.000
3.40	.246	-.106	1.26	1068.6	-229.8	16.85	957.5	1.26	1506.7	-316.0	29.07	1150.9	.000
3.50	.242	-.106	1.25	1072.4	-228.5	16.70	960.7	1.24	1502.8	-312.2	28.46	1147.7	.000
3.60	.231	-.105	1.20	1081.6	-222.1	15.91	965.7	1.19	1493.6	-298.4	26.17	1142.9	.000
3.70	.216	-.105	1.11	1095.5	-211.0	14.51	972.6	1.11	1479.6	-276.2	22.53	1136.4	.000
3.80	.195	-.105	1.00	1114.0	-195.7	12.47	981.5	1.00	1461.1	-247.4	17.90	1127.8	.000
3.90	.169	-.105	.87	1137.2	-173.3	11.16	992.0	.87	1437.9	-212.3	15.26	1117.7	.000
4.00	.139	-.106	.73	1163.6	-148.1	9.66	1004.8	.73	1411.5	-175.1	12.49	1105.2	.000

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

AXLE # 3
****

TIME (SEC)	ROLL (DEG)	BOUNCE (IN)	LEFT SIDE SLIP ANGLE (DEG)	LEFT SIDE VERTICAL LOAD (LB.)	LEFT SIDE LATERAL FORCE (LB.)	LEFT SIDE ALIGNING TORQUE (FT.LB)	LEFT SIDE SPRING FORCE (LB.)	RIGHT SIDE SLIP ANGLE (DEG)	RIGHT SIDE VERTICAL LOAD (LB.)	RIGHT SIDE LATERAL FORCE (LB.)	RIGHT SIDE ALIGNING TORQUE (FT.LB)	RIGHT SIDE SPRING FORCE (LB.)	SPECIAL STEER (DEG)
.00	.000	.000	.00	1281.5	.0	.00	1131.5	.00	1281.5	.0	.00	1131.5	.000
.10	.000	.002	.00	1277.8	.0	.00	1127.8	.00	1277.8	.0	.00	1127.8	.000
.20	.000	.006	.00	1275.3	.0	.00	1125.4	.00	1275.3	.0	.00	1125.4	.000
.30	0.000	.006	0.00	1277.7	0.0	0.00	1127.8	0.00	1277.6	0.0	0.00	1127.5	.000
.40	-.001	.004	0.00	1280.8	-.1	.01	1131.0	0.00	1279.3	-.1	.01	1128.9	.000
.50	-.003	.002	0.00	1282.5	0.0	.01	1133.2	0.00	1277.8	0.0	.01	1127.0	.000
.60	-.006	.002	0.00	1284.6	.5	-.08	1136.0	0.00	1274.2	.5	-.08	1122.9	.000
.70	-.011	.003	-.01	1289.4	1.9	-.31	1141.3	-.01	1269.9	1.9	-.31	1118.1	.000
.80	-.019	.002	-.03	1296.8	4.9	-.82	1148.7	-.03	1263.6	4.9	-.81	1111.7	.000
.90	-.030	.002	-.05	1306.6	10.5	-1.76	1157.9	-.05	1254.1	10.3	-1.72	1102.8	.000
1.00	-.044	.002	-.10	1319.8	19.4	-3.26	1169.4	-.10	1240.8	18.9	-3.17	1091.3	.000
1.10	-.064	.002	-.17	1336.9	32.5	-5.46	1183.3	-.17	1223.9	31.3	-5.24	1077.4	.000
1.20	-.088	.002	-.26	1358.9	51.0	-8.57	1200.2	-.26	1202.1	48.5	-8.11	1060.5	.000
1.30	-.116	.002	-.37	1383.6	73.5	-12.38	1218.3	-.37	1177.4	68.8	-11.50	1042.3	.000
1.40	-.147	.002	-.50	1411.0	100.2	-16.90	1237.6	-.50	1150.0	92.2	-15.39	1022.9	.000
1.50	-.179	.002	-.64	1440.1	130.2	-21.97	1257.2	-.64	1121.0	117.6	-19.59	1003.0	.000
1.60	-.212	.002	-.79	1469.1	161.9	-27.35	1276.1	-.79	1091.9	143.5	-23.87	983.8	.000
1.70	-.243	.002	-.94	1496.4	193.4	-32.70	1293.0	-.94	1064.6	168.3	-27.98	966.5	.000
1.80	-.269	.002	-1.07	1519.7	219.9	-36.97	1307.3	-1.08	1041.4	190.3	-31.48	951.9	.000
1.90	-.288	.003	-1.19	1537.3	241.8	-40.34	1316.8	-1.19	1023.8	208.7	-34.36	942.1	.000
2.00	-.301	.003	-1.28	1548.5	258.8	-42.99	1321.1	-1.29	1012.6	223.1	-36.60	937.7	.000
2.10	-.306	.003	-1.34	1552.6	269.7	-44.69	1319.8	-1.34	1008.5	232.4	-38.06	938.9	.000
2.20	-.302	.003	-1.36	1549.0	273.3	-45.25	1312.9	-1.36	1012.2	235.6	-38.56	946.0	.000
2.30	-.287	.003	-1.33	1536.5	268.1	-44.45	1299.7	-1.33	1024.9	231.4	-37.92	959.5	.000
2.40	-.263	.002	-1.24	1514.5	252.9	-42.12	1280.2	-1.24	1046.9	218.8	-35.98	979.4	.000
2.50	-.227	.002	-1.10	1482.5	225.1	-37.78	1254.8	-1.10	1078.9	197.2	-32.65	1005.3	-.000
2.60	-.179	.002	-.91	1439.9	184.1	-31.06	1223.3	-.91	1121.5	165.6	-27.60	1037.4	-.000
2.70	-.120	.001	-.67	1387.6	133.2	-22.44	1185.6	-.67	1173.9	124.0	-20.70	1075.5	-.000
2.80	-.054	.001	-.39	1328.6	76.7	-12.89	1143.7	-.39	1232.9	74.1	-12.41	1117.8	-.000
2.90	.017	.001	-.09	1265.7	17.5	-2.93	1099.6	-.09	1295.8	17.6	-2.95	1161.9	-.000
3.00	.089	.001	.22	1201.9	-41.6	6.95	1055.7	.22	1359.5	-43.6	7.34	1205.5	.000
3.10	.157	.001	.53	1140.5	-97.7	16.30	1014.4	.53	1420.9	-106.7	17.99	1246.2	.000
3.20	.220	.002	.82	1084.5	-148.7	24.74	978.0	.82	1476.8	-168.4	28.46	1282.0	.000
3.30	.274	.002	1.09	1036.8	-192.1	31.75	947.4	1.08	1524.4	-221.9	37.26	1311.8	.000
3.40	.315	.003	1.32	1000.6	-227.0	37.19	924.7	1.31	1560.6	-263.4	43.69	1333.8	.000
3.50	.344	.003	1.50	974.1	-254.5	41.48	909.7	1.49	1587.0	-296.2	48.83	1348.3	.000
3.60	.363	.003	1.62	957.4	-273.7	44.50	901.5	1.62	1603.7	-319.3	52.47	1356.1	.000
3.70	.371	.004	1.69	950.3	-284.2	46.14	899.7	1.68	1610.9	-331.9	54.46	1357.8	.000
3.80	.368	.004	1.70	952.9	-285.7	46.38	904.3	1.69	1608.3	-333.7	54.74	1353.4	.000
3.90	.354	.003	1.65	965.2	-278.3	45.23	915.2	1.64	1596.0	-324.8	53.33	1342.9	.000
4.00	.330	.003	1.54	986.8	-262.3	42.74	932.0	1.53	1574.5	-305.5	50.30	1326.6	.000

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

AXLE # 4
****

TIME (SEC)	ROLL (DEG)	BOUNCE (IN)	LEFT SIDE SLIP ANGLE (DEG)	LEFT SIDE VERTICAL LOAD (LB.)	LEFT SIDE LATERAL FORCE (LB.)	LEFT SIDE ALIGNING TORQUE (FT.LB)	LEFT SIDE SPRING FORCE (LB.)	RIGHT SIDE SLIP ANGLE (DEG)	RIGHT SIDE VERTICAL LOAD (LB.)	RIGHT SIDE LATERAL FORCE (LB.)	RIGHT SIDE ALIGNING TORQUE (FT.LB)	RIGHT SIDE SPRING FORCE (LB.)	SPECIAL STEER (DEG)
.00	.000	.000	.00	1281.5	.0	.00	1131.5	.00	1281.5	.0	.00	1131.5	.000
.10	.000	.004	.00	1274.4	.0	.00	1124.5	.00	1274.4	.0	.00	1124.5	.000
.20	.000	.012	.00	1268.9	.0	.00	1119.1	.00	1268.9	.0	.00	1119.1	.000
.30	0.000	.014	0.00	1271.1	0.0	0.00	1121.2	0.00	1271.1	0.0	0.00	1121.0	.000
.40	-.001	.013	0.00	1274.0	0.0	.01	1124.1	0.00	1272.4	0.0	.01	1122.1	.000
.50	-.003	.012	0.00	1274.8	.1	-.02	1125.5	0.00	1270.0	.1	-.02	1119.3	.000
.60	-.006	.013	0.00	1276.4	.9	-.16	1127.5	0.00	1265.7	.9	-.16	1114.7	.000
.70	-.011	.014	-.02	1281.1	3.0	-.50	1132.2	-.02	1260.8	3.0	-.50	1109.6	.000
.80	-.019	.014	-.04	1288.5	7.1	-1.19	1139.2	-.04	1253.8	7.0	-1.17	1103.1	.000
.90	-.031	.014	-.07	1298.7	14.2	-2.38	1147.9	-.07	1243.5	13.9	-2.33	1094.3	.000
1.00	-.047	.014	-.13	1312.4	25.2	-4.23	1158.7	-.13	1229.3	24.6	-4.11	1083.0	.000
1.10	-.067	.014	-.21	1330.3	40.9	-6.87	1172.1	-.21	1211.2	39.4	-6.59	1069.4	.000
1.20	-.093	.014	-.32	1353.3	62.6	-10.53	1188.3	-.32	1188.2	59.4	-9.92	1052.9	.000
1.30	-.122	.015	-.44	1379.1	88.5	-14.89	1205.9	-.45	1162.2	82.5	-13.78	1035.1	.000
1.40	-.154	.015	-.59	1407.7	118.6	-19.99	1224.6	-.59	1133.5	108.6	-18.11	1016.0	.000
1.50	-.188	.015	-.75	1437.8	151.8	-25.62	1243.8	-.75	1103.4	136.4	-22.70	996.4	.000
1.60	-.222	.015	-.91	1467.8	186.4	-31.47	1262.3	-.91	1073.4	164.1	-27.29	977.5	.000
1.70	-.253	.016	-1.06	1495.6	219.1	-36.87	1279.3	-1.07	1045.6	189.5	-31.37	960.0	.000
1.80	-.279	.016	-1.20	1518.7	245.7	-40.99	1293.5	-1.21	1022.4	211.3	-34.76	945.5	.000
1.90	-.299	.016	-1.32	1536.3	267.6	-44.38	1303.1	-1.33	1004.8	229.7	-37.62	935.6	.000
2.00	-.311	.016	-1.41	1547.3	283.9	-46.92	1307.6	-1.42	993.8	243.3	-39.76	930.9	.000
2.10	-.315	.016	-1.46	1550.9	293.2	-48.37	1306.7	-1.47	990.3	251.2	-40.98	931.7	.000
2.20	-.310	.016	-1.46	1546.3	294.1	-48.52	1300.2	-1.47	994.8	252.0	-41.13	938.3	.000
2.30	-.294	.016	-1.41	1532.5	285.3	-47.14	1287.7	-1.42	1008.6	244.8	-40.01	951.1	.000
2.40	-.268	.016	-1.30	1508.9	265.4	-44.08	1269.0	-1.31	1032.2	228.3	-37.45	970.2	.000
2.50	-.229	.016	-1.13	1474.7	231.1	-38.69	1244.6	-1.14	1066.3	202.1	-33.39	995.1	-.000
2.60	-.179	.015	-.91	1430.0	183.8	-31.00	1213.9	-.91	1111.0	165.2	-27.52	1026.3	-.000
2.70	-.118	.015	-.63	1375.2	126.2	-21.24	1177.3	-.63	1165.7	117.6	-19.63	1063.3	-.000
2.80	-.049	.015	-.33	1313.8	63.5	-10.66	1136.3	-.32	1227.1	61.5	-10.30	1104.7	-.000
2.90	.025	.015	.01	1248.7	-1.2	.20	1093.0	.01	1292.3	-1.2	.20	1147.9	-.000
3.00	.098	.015	.35	1182.9	-64.5	10.78	1049.8	.34	1358.0	-68.1	11.46	1190.8	.000
3.10	.169	.015	.68	1119.9	-123.8	20.63	1009.0	.67	1421.1	-136.2	22.96	1231.1	.000
3.20	.233	.015	.99	1062.8	-176.7	29.36	972.9	.98	1478.3	-201.7	34.08	1266.6	.000
3.30	.287	.016	1.26	1015.4	-219.0	35.96	941.8	1.25	1525.7	-254.5	42.35	1296.8	.000
3.40	.327	.016	1.49	979.1	-253.8	41.38	919.0	1.48	1562.0	-296.3	48.84	1318.9	.000
3.50	.357	.017	1.67	952.9	-280.2	45.52	903.7	1.66	1588.1	-328.2	53.87	1333.7	.000
3.60	.375	.017	1.79	936.8	-297.7	48.26	895.1	1.78	1604.2	-349.5	57.23	1342.0	.000
3.70	.382	.017	1.84	930.6	-305.8	49.52	892.9	1.83	1610.4	-359.4	58.80	1344.2	.000
3.80	.378	.017	1.83	934.5	-304.3	49.29	896.9	1.82	1606.6	-357.7	58.52	1340.4	.000
3.90	.362	.017	1.75	948.1	-293.5	47.60	907.1	1.75	1592.9	-344.6	56.45	1330.5	.000
4.00	.336	.017	1.62	971.3	-273.7	44.51	923.2	1.61	1569.8	-320.7	52.69	1315.0	.000

Recreational Double (Pick-up/ 26'-Trailer/ Boat); Baseline; 65 mph; Lane-change.

AXLE # 5
****

TIME (SEC)	ROLL (DEG)	BOUNCE (IN)	LEFT SIDE SLIP ANGLE (DEG)	LEFT SIDE VERTICAL LOAD (LB.)	LEFT SIDE LATERAL FORCE (LB.)	LEFT SIDE ALIGNING TORQUE (FT.LB)	LEFT SIDE SPRING FORCE (LB.)	RIGHT SIDE SLIP ANGLE (DEG)	RIGHT SIDE VERTICAL LOAD (LB.)	RIGHT SIDE LATERAL FORCE (LB.)	RIGHT SIDE ALIGNING TORQUE (FT.LB)	RIGHT SIDE SPRING FORCE (LB.)	SPECIAL STEER (DEG)
.00	.000	.000	.00	791.0	.0	.00	691.0	.00	791.0	.0	.00	691.0	.000
.10	.000	-.007	.00	799.8	.0	.00	699.5	.00	799.8	.0	.00	699.5	.000
.20	.000	-.021	.00	804.8	.0	.00	704.4	.00	804.8	.0	.00	704.4	.000
.30	0.000	-.021	0.00	799.4	0.0	0.00	699.5	0.00	799.4	0.0	0.00	699.5	.000
.40	0.000	-.015	0.00	797.0	0.0	0.00	697.1	0.00	797.0	0.0	0.00	697.2	.000
.50	0.000	-.015	0.00	799.2	0.0	0.00	699.1	0.00	799.2	0.0	0.00	699.2	.000
.60	0.000	-.017	0.00	800.4	-.2	.01	700.4	0.00	800.7	-.2	.01	700.6	.000
.70	.001	-.018	0.00	799.2	-.5	.04	699.4	0.00	800.1	-.5	.04	699.9	.000
.80	.002	-.017	.01	798.1	-1.0	.07	698.5	.01	799.8	-1.0	.07	699.4	.000
.90	.003	-.016	.02	798.0	-1.6	.11	698.6	.02	800.7	-1.6	.11	700.1	.000
1.00	.004	-.017	.02	798.0	-1.8	.13	698.7	.02	801.4	-1.8	.13	700.6	.000
1.10	.003	-.017	.01	798.2	-1.3	.09	698.7	.01	800.9	-1.3	.09	700.3	.000
1.20	-.001	-.017	-.01	799.8	1.0	-.07	699.5	-.01	799.0	1.0	-.07	699.3	.000
1.30	-.010	-.017	-.05	803.6	5.7	-.39	701.4	-.05	795.2	5.7	-.39	697.4	.000
1.40	-.027	-.017	-.13	810.3	13.8	-.96	704.9	-.13	788.7	13.7	-.93	694.0	.000
1.50	-.051	-.017	-.25	820.3	26.1	-1.82	710.1	-.25	778.7	25.5	-1.73	688.8	.000
1.60	-.085	-.017	-.40	833.9	43.0	-3.02	717.2	-.41	765.0	41.3	-2.78	681.6	.000
1.70	-.127	-.017	-.60	851.0	64.5	-4.57	726.1	-.60	747.9	60.8	-4.04	672.5	.000
1.80	-.177	-.017	-.83	871.1	90.0	-6.46	736.5	-.83	727.9	82.9	-5.43	661.9	.000
1.90	-.230	-.016	-1.08	892.7	117.3	-8.50	747.7	-1.08	706.3	105.6	-6.76	650.3	.000
2.00	-.279	-.016	-1.33	912.5	142.6	-11.63	758.2	-1.34	686.4	127.2	-7.88	639.5	.000
2.10	-.323	-.016	-1.57	930.4	166.7	-15.18	766.9	-1.58	668.5	147.8	-8.90	630.2	.000
2.20	-.365	-.015	-1.80	947.3	188.5	-18.89	775.6	-1.81	651.5	166.0	-9.75	621.1	.000
2.30	-.400	-.015	-1.98	961.4	206.7	-22.28	782.8	-1.99	637.4	180.9	-10.41	613.5	.000
2.40	-.421	-.014	-2.12	970.0	218.3	-25.00	787.6	-2.13	628.8	188.3	-11.15	608.5	.000
2.50	-.428	-.014	-2.20	972.9	224.5	-26.31	788.4	-2.21	625.9	192.3	-11.57	607.6	-.000
2.60	-.428	-.014	-2.19	972.7	224.0	-26.22	788.3	-2.20	626.0	191.9	-11.52	607.8	-.000
2.70	-.414	-.014	-2.08	967.1	215.2	-24.19	785.6	-2.09	631.7	186.1	-10.92	610.7	-.000
2.80	-.381	-.015	-1.86	953.5	194.4	-20.13	779.3	-1.86	645.3	170.0	-9.91	617.6	-.000
2.90	-.315	-.015	-1.51	927.0	160.9	-14.36	765.8	-1.51	671.8	142.0	-8.61	631.7	-.000
3.00	-.227	-.016	-1.06	891.5	115.9	-8.40	747.2	-1.06	707.3	103.8	-6.66	651.2	-.000
3.10	-.118	-.017	-.53	847.4	56.9	-4.03	725.2	-.53	751.6	53.5	-3.56	673.8	-.000
3.20	.011	-.017	.04	795.2	-4.4	.30	697.1	.04	803.8	-4.4	.30	702.0	-.000
3.30	.137	-.017	.63	744.1	-62.9	4.17	669.8	.62	855.0	-66.8	4.75	729.0	.000
3.40	.254	-.016	1.18	696.7	-113.8	7.18	644.5	1.17	902.3	-126.9	9.68	753.4	.000
3.50	.348	-.016	1.68	658.7	-155.8	9.26	623.8	1.67	940.2	-176.2	16.98	773.1	.000
3.60	.422	-.015	2.12	628.5	-187.6	11.06	608.2	2.10	970.4	-216.8	24.83	787.8	.000
3.70	.471	-.014	2.49	608.5	-206.6	12.90	597.1	2.47	990.3	-247.6	31.89	798.1	.000
3.80	.507	-.013	2.79	594.3	-221.2	14.16	590.6	2.77	1004.5	-272.6	37.33	804.1	.000
3.90	.537	-.013	3.00	581.9	-230.7	14.84	583.8	2.98	1016.8	-290.7	41.45	810.5	.000
4.00	.553	-.012	3.11	575.3	-235.7	15.16	580.1	3.09	1023.4	-300.7	43.68	814.0	.000