SAFETY AND OPERATIONAL IMPACTS OF 53-FOOT TRUCK-TRAILERS IN MICHIGAN

Final Report

Robert D. Ervin
Thomas D. Gillespie

March 25, 1986

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16. Abstract

The interest in greater transport efficiency argues for permission to use longer trailers on the Michigan road system. The performance characteristics of 53' semitrailers were studied to determine whether penalties in cost or safety would accompany their introduction.

Operated with the tandem axles in the full-rearward position, the larger offtracking of the 53' semitrailers is incompatible with the geometry of many intersections in Michigan. On this basis a maximum wheelbase of 40.5' (measured from kingpin to center of the tandem axles) is recommended. At this wheelbase, dynamic behavior at high speeds is comparable to that of other trailers currently in use on the road system, although further decreases in the wheelbase can degrade dynamic performance. Thus 40.5' is also suggested as the minimum wheelbase. The use of 3 or more axles on the trailer is not recommended because of concerns about dynamic behavior of longer multi-axle trailers. Because the trailers would be operated with the rear axles in a forward position at all times, they represent a special case warranting use of rear underride guards.

When loaded to its full volume capacity the 53' semitrailer is expected to experience a slightly higher rollover frequency, but total rollover accidents would be unchanged due to the fewer number of trailers that would be required on the road. The ability to operate at greater weights is estimated to produce a 20 percent increase in pavement damage.

The study identified areas where further information and research is needed. A study of truck compatibility with road geometry at intersections is recommended in order to provide objective data for assessing the conflicts and risks of long trailers operating in these restricted areas. Studies to better establish the dynamic behavior of long trailers with multiple axles, and with slider bogeys in more forward positions are also recommended.

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Executive Summary

"Safety and Operational Impacts of 53-Foot Truck-Trailers in Michigan"

The performance characteristics of 53' semitrailers were studied in the context of their possible introduction into Michigan. The study addressed various properties of this vehicle configuration with a focus upon identifying constraints that may warrant inclusion in legislation which is currently pending in the State. The research effort entailed computer simulation of both low and high speed behavior of the vehicle as well as evaluation of certain costs that would be imposed by the use of 53' semitrailers in the State.

Listed below are each of the performance issues which were addressed, together with the prominent findings and recommendations on each subject.

Offtracking at Intersections

If the 53' semitrailer is operated with its tandem axles in the full-rearward position, with a wheelbase of 45.5' (measured from kingpin to center of the tandem axles), a gross intrusion will occur beyond the lane edges provided at many rural and urban intersections in Michigan. Based upon this observation, a recommendation is made that 53' semitrailers be allowed only if the maximum trailer wheelbase is constrained to 40.5' while on public roads -- basically equal to that currently found on 48' semitrailers. (The authors recognize that 50' semitrailers were legalized in Michigan in January of 1984 and that the wheelbase dimension is up to 42.5' on such units. Because of the substantial intrusion of such vehicles beyond the available space of intersections in Michigan, however, the current law allowing 50' semitrailers is not seen as a suitable precedent for guiding consideration of the 53' semitrailer. Further, it is recommended that Michigan law be revised to allow no more than a 40.5' wheelbase dimension with existing 50' semitrailers.)

Dynamic Response to Steering

If the 53' semitrailer is operated with a trailer wheelbase of 40.5', as recommended, it will exhibit dynamic properties which are virtually the same as those seen currently with 48' semi's. Because dynamic performance of the 53' unit is seen to degrade when wheelbase is shortened much beyond the 40.5' dimension, however, it is recommended that the pending legislation stipulate the 40.5' value as the minimum wheelbase, as well (with a tolerance of $\pm$ 0.5 feet to accommodate variations between

trailers). This provision essentially prevents wheelbase adjustments on public roads by means of so-called "slider bogies" which the trucking industry commonly uses to obtain short wheelbase lengths for maneuvering in tight areas.

Roll Stability Performance

On the one hand, longer semitrailers will carry a greater payload such that lower stability levels and an increased risk of vehicle rollover will result. This tendency is counterracted in an overall sense, however, since the larger trailers carry enough additional freight that fewer vehicle-trips are needed and the total number of anticipated rollovers is unchanged.

Multi-Axle Configurations

Since Michigan road-use laws allow greater gross weights to be carried when additional axles are fitted to the semitrailer, it may be that certain carriers in the state would opt for 53' semitrailers having as many as 8 trailer axles. Because of a number of concerns about the dynamic behavior of longer multi-axle trailers, however, it is recommended that the pending legislation specifically prohibit operation of 53' semitrailers having more than two axles.

Items of Cost to the Trucking Industry

Recognizing that the 53' semitrailer can be accommodated on Michigan roads only with the tandem bogie placed rather forward of the rear of the trailer bed, there is a risk that passenger cars impacting the rear of such semitrailers would underride the bed, at great hazard to the occupants . (Namely, the hood of the car passes rather freely beneath the bed overhang, such that the bed, itself, impacts the car directly in the windshield area.) Accordingly, a recommendation is made that 53' semitrailers be required to have a suitable rear underride guard installed. The cost of a suitable device has been estimated to be approximately $50.

An issue of the productivity of 53' semitrailers is posed by the placement of the bogie at a maximum wheelbase dimension of 40.5 feet. Namely, carriers of homogeneous commodities, with the payload center of gravity in the geometric center of the trailer, may be limited in gross vehicle weight to as low as 71,000 lbs, depending on the density of the freight. This situation occurs because the trailer tandem axles reach the 34,000-lb tandem load limit somewhat "prematurely" such that the total gross weight level becomes limited. While most truck shipments involve mixed-density commodities with which weight can be advantageously distributed, a certain sector of

the interested trucking community will look upon the 53' semitrailer as less than fully productive.

Another productivity matter is posed by the minimum wheelbase of 40.5' when operating on public roads. Namely, the inability to further reduce wheelbase so as to maneuver into areas having especially tight geometric constraints will curtail the utility of the unit to some degree.

Pavement Damage

The 53' semitrailer appeals to the industry for the haulage of increased freight per truckload. Compared to the common 48' semitrailers, 53' units provide for 10% more freight such that axle load levels are increased. It is estimated that pavement damage will accrue at a rate which is approximately 20% higher when freight is transported in 53' semitrailers as opposed to 48' semitrailers. A ballpark estimate of maintenance costs indicates that for each 1% of the fleet of 48' semitrailers which is replaced by 53' units, the cost of maintaining Michigan highways will increase by 0.3 to $1.3 million per year.

Matters for Additional Study

Additional research is recommended to provide a basis for assessing the conflict between future truck configurations and the Michigan road system -- especially relative to space at intersections. It would appear that the increases in truck length dimensions over the years have resulted in substantially greater space demands than were provided for in the design of many intersections in the State. A combined field test and analysis is suggested for obtaining an objective assessment of the current situation as well as a means for guiding future decisionmaking.

Additionally, the dynamic behavior of 53' semitrailers warrants further study with regard to the possible future admission of slider bogies and multi-axle configurations.

1.0 INTRODUCTION

The regulation of commercial trucking in the State of Michigan has undergone dramatic changes in recent years, and continues to do so as the governmental bodies try to facilitate changes that allow greater efficiency in the industry. Greater transport efficiency serves the interests of the populace, so long as it is not obtained at any sacrifice in safety, or the costs of constructing and maintaining the state road system. Certain of the Michigan industries center on the production of low density goods, such as cereals and containers. Transport of these products by road is seen as inefficient insofar as typical tractor-semitrailers do not fully utilize the legal weight allowance. Consequently, there is interest in allowing the use of semitrailers up to 53 feet in length on the roads. Semitrailers of this length are legal in 17 other states, including the adjacent states of Ohio, Indiana and Illinois.

To establish a basis for considering permit of these trailers, the Michigan Department of Transportation contracted for The University of Michigan Transportation Research Institute (UMTRI) to study the safety implications of longer semitrailers operating on the Michigan highway network. Two separate and independent studies were arranged. One entitled, "Truck Accident Trends," is being conducted by the Systems Analysis Division of UMTRI, and examines the truck accident statistics for trends that may be indicative of the safety impact of longer trailers. The second entitled, "Safety and Operational Impacts of 53 Foot Truck-Trailers in Michigan," was conducted by the Engineering Research Division of UMTRI, and looks more toward the operational impact of longer trailers. This document presents a report of the results from the latter study.

Due to the need for early results, the study was preliminary in nature and limited in scope to focus primarily on dynamic behavior of longer trailers, and the increased difficulty of maneuvering on the existing geometry of the highway system.

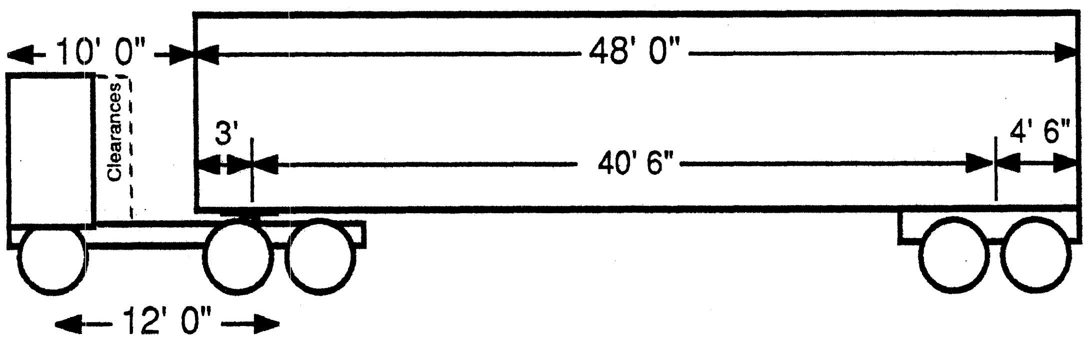
2.0 ANALYSIS OF PERFORMANCE ISSUES

An increase in semitrailer length impacts on performance of a tractor-semitrailer in two ways. First, the greater length changes the dynamic turning (yaw) behavior of the combination; and second, the length may affect the maneuverability (ability to make turns at intersections). The exact performance in each mode depends on a number of factors, not the least of which are tires, suspensions, load distribution, and geometric layout of the axles. However, for purposes of this study the interest is to determine the influence of factors related only to the longer semitrailer length. Thus, generic tractor and semitrailer properties have been assumed to be constant in the study, making adjustments only as needed to reflect the geometric changes in trailer length, and the associated changes in load distribution.

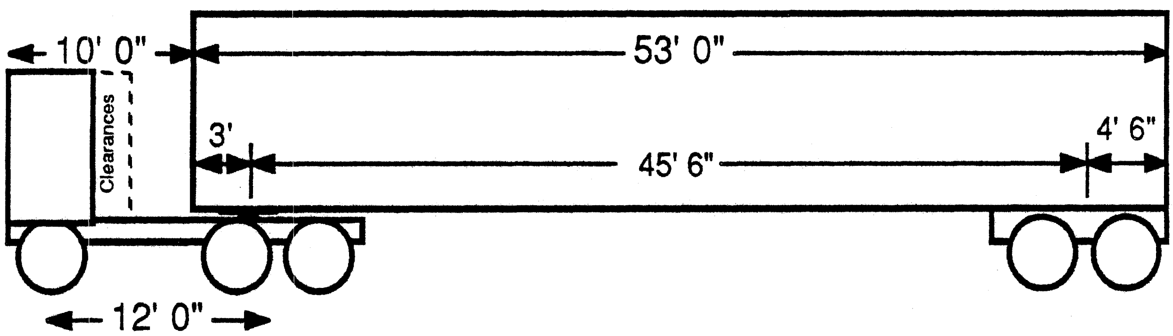
2.1 Vehicle Configurations Studied

The geometric design of 53' trailers for use in Michigan could evolve in a variety of ways generally bounded by two extremes. Figure 1 illustrates the possibilities. Using the 48' trailer for comparison (Figure 1a), the 53' unit could simply be constructed with a mid-body extension of the van length (Figure 1b) such that the trailer axles are located an additional 5' beyond the rear of the tractor (i.e., resulting in a 5' extension of the semitrailer wheelbase). The increased length has the tendency to make such a vehicle dynamically more stable in high-speed turns, but much more difficult to maneuver at low speeds through sharp intersections, due to the fact that the rear wheels of the trailer tend to cut across the corner. To obtain improved low-speed maneuverability, the longer semitrailer could be designed with a foreshortened wheelbase (Figure 1c) either by placing the kingpin coupling to the tractor further back on the body of the trailer, and/or by moving the trailer wheels forward of the rear of the van box. This design is illustrated in Figure 1c. Although this vehicle would maneuver like a much shorter trailer, its dynamic behavior in high-speed turns will not be as good as that of the configuration illustrated in Figure 1b.

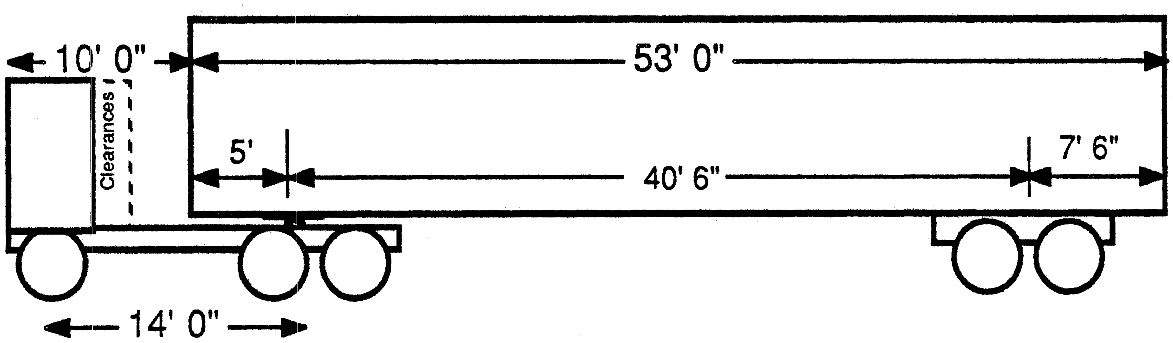
It may be noted that there is precedent for positioning the rear axles of the trailer in a more forward position. A major fraction of the trailers currently in use on the highways incorporate a "slider bogie" on the rear suspension of the trailer, so that it can be moved forward under the trailer when improved maneuverability is desired, and load conditions permit.



a) Geometry of tractor with 48 foot trailer



b) Geometry with trailer extended to 53 feet.



c) Geometry with alternate kingpin and bogey positions

Fig. 1 Geometric design possibilities with 53' trailers

In addition to these straightforward geometric issues, adjustments in length may also affect the distribution of load at the various axles on the combination, with influence on the high-speed dynamic behavior. While it is assumed that the maximum axle loads will be governed by prevailing Michigan road-use laws, the typical loads achieved in operation may be considerably below these limits, especially when hauling low-density materials. In the case of a trailer loaded uniformly with a low-density material, moving the trailer axles to a more forward position will cause them to carry a higher fraction of the total vehicle weight. To remain legal, the overall load of the vehicle combination may need to be reduced. Or, in the case where the axles are moved forward without a reduction in payload, the trailer axles would assume an overloaded condition.

Given these variables in geometric design and weight distribution, a number of possibilities were identified for study as example cases from which to deduce trends. While the emphasis was on 53' trailers, shorter vehicles in common use today were included for comparison purposes, as well as the longer 57' trailer that might be anticipated for the future. Table I lists the 17 trailer configurations studied in this project. Figure 2 shows the geometry of the vehicle combinations. The first four cases consider the 45' and 48' trailers commonly used today, with variations in the position of the trailer rear wheels that are employed. Note that the rear axle position is defined by the "bogie position," which is the distance from the rear of the van box to the centerline of the tandem axle set. The remainder of the cases represent the 50', 53' and 57' trailers that are alternate choices. Aside from length, different choices in kingpin position on the trailer and rear axle position are represented. The bogie positions ranging from 4.5 to 13.5 feet would be typical of that achievable with the available sliding mechanisms. Generally, seven to nine feet of slide is possible with current hardware. Cases 11, 14, and 17 represent peculiar extremes of forward axle placement. While they are not reasonable choices, they were examined to quantify the trends that are expected as axle positions are moved to forward extremes.

Although trailer loads may cover an infinite variety of conditions in practice, the special interest here is in loads of low-density materials that utilize the additional volume capacity available on the longer trailers. (When longer trailers are used to transport high-density cargo that does not utilize the additional interior volume, payload can be positioned along the trailer bed to give the desired distribution of axle loads. In such cases, the dynamic performance is rather similar to that obtained with shorter trailers.) Up to three load conditions are considered for study with each trailer configuration. The loads are selected to test the vehicle behavior at the maximum load condition, which generally yields the "worst case" performance. The load conditions are defined as follows:

TABLE I - Trailer and Load Configurations Studied

Case No.	Trailer Length	Kingpin Setting	Wheel-base	Bogey Position	Slider Length	Load Type*		
1	45 ft	3 ft	37.5 ft	4.5 ft		A		C
2	45	3	30.5	11.5	7 ft	A		
3	48	3	40.5	4.5		A		C
4	48	3	33.5	11.5	7	A		
5	50	3	42.5	4.5		A		C
6	50	3	33.5	13.5	9	A	B	
7	50	5	40.5	4.5		A		C
8	50	5	31.5	13.5	9	A	B	
9	53	3	45.5	4.5		A		C
10	53	3	37.5	12.5	8	A	B	
11	53	3	30.5	19.5	15	A	B	
12	53	5	43.5	4.5		A		C
13	53	5	37.5	10.5	6	A	B	
14	53	5	30.5	17.5	13	A	B	
15	57	5	47.5	4.5		A		
16	57	5	38.5	13.5	9	A	B	
17	57	5	30.5	21.5	17	A		

* A - Each trailer is loaded with a material of homogeneous density to produce a load c.g. that is at the midpoint of the trailer body. Load results in nominal axle loads of 12k/34k/34k in the "rearmost bogie" cases (No.'s 1, 3, 5, 9, and 15), with a c. g. load height that is 102 inches above the ground. When changes are made in bogie and kingpin location, relative to the "rearmost" cases, payload is reduced so that axle load limits are not exceeded.

*B - Trailer is loaded with homogeneous freight as in "A," but the gross weight is kept at 80,000 lb when the trailer axle is moved to a more forward position. Thus, the trailer axle load will be greater than 34k (even though illegal), and the tractor axles will be underloaded.

*C - Load is based on a material of constant density that just causes the 53' trailer to gross out. Thus the actual payload weight on any trailer equals (50,900 lb x Length) / 53.

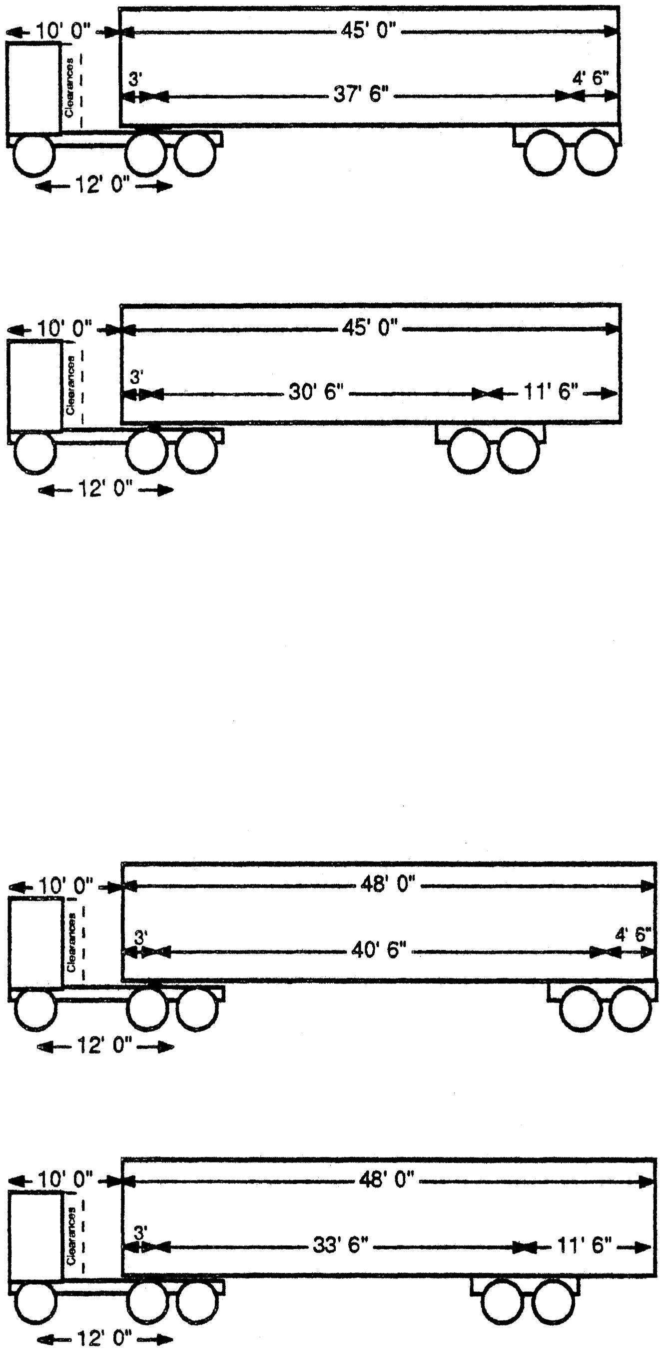


Fig. 2 Vehicle Geometries Included in the Analysis -- 45' and 48' Semitrailer Configurations

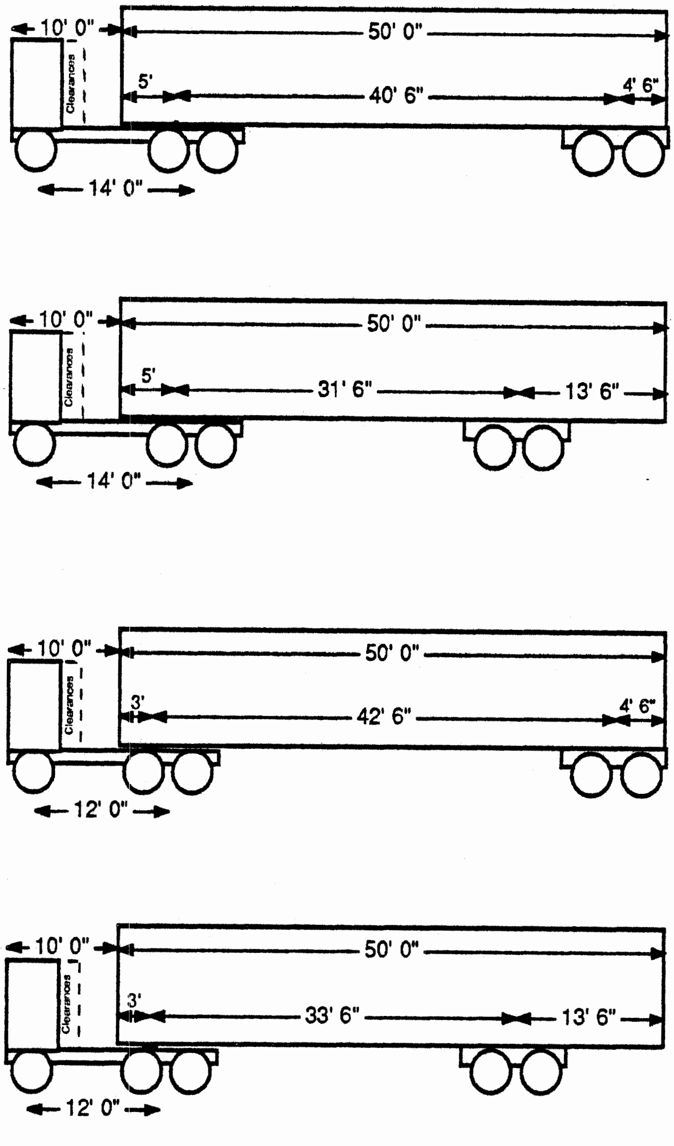


Fig. 2 (Cont.) -- 50' Semitrailer Configurations

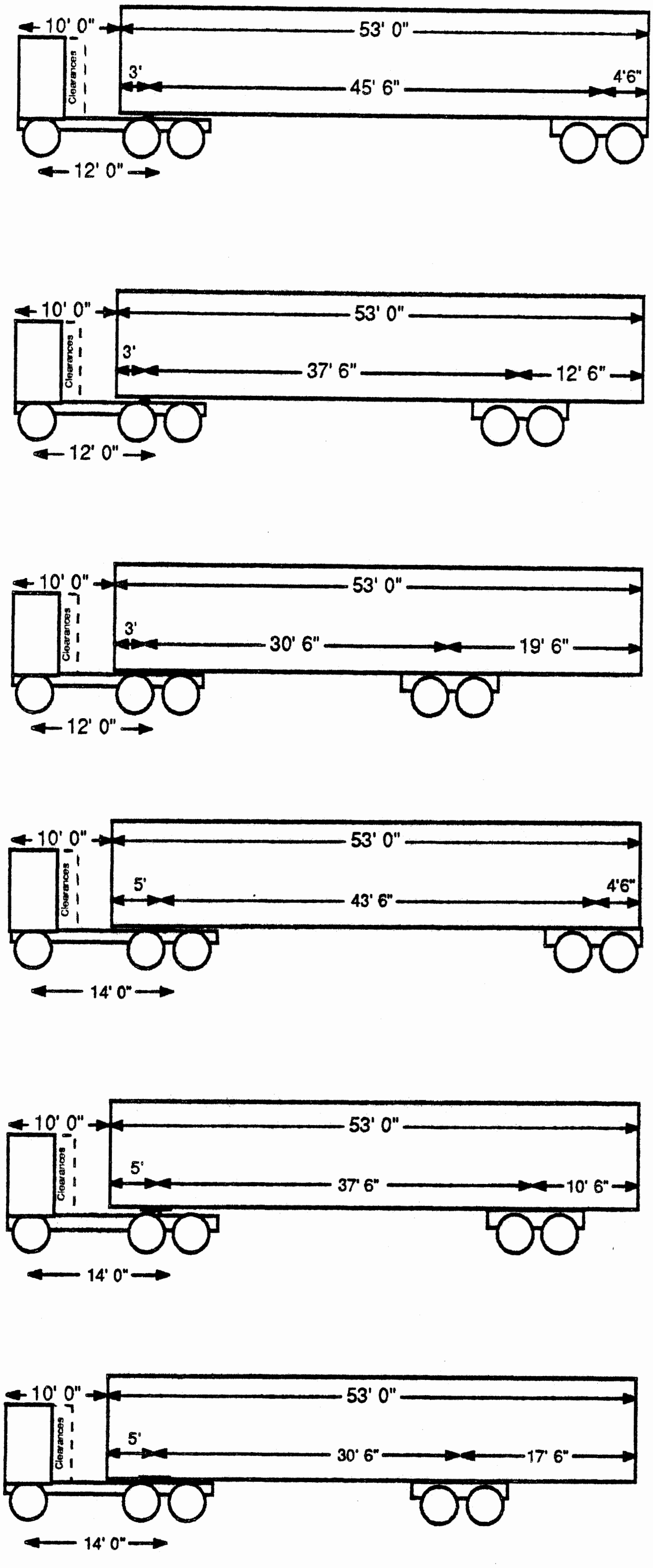


Fig. 2 (Cont.) -- 53' Semitrailer Configurations

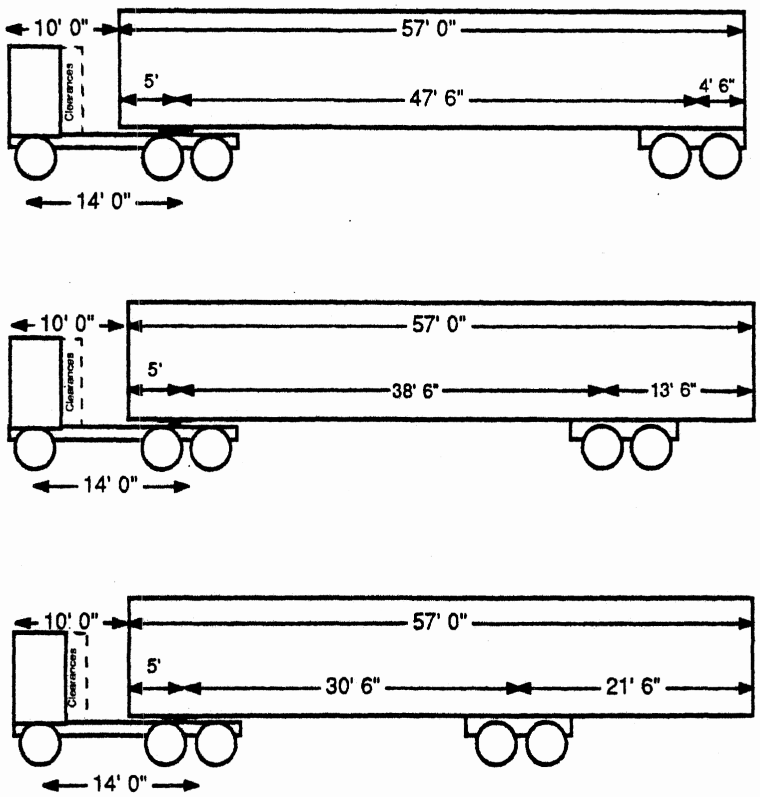


Fig. 2 (Cont.) -- 57' Semitrailer Configurations

A) Legal load of a homogeneous freight, with payload center at the mid-length of the trailer bed. With the trailer axles in their "rearmost" position (and with the kingpin set at 3' aft of the front edge of the trailer) this loading allows the tractor axles to reach a total of 46,000 lb load with 34,000 lb on the trailer axles (yielding the allowable gross combination weight (GCW) of 80,000 lbs). With a more forward bogie location, payload is reduced to keep the trailer tandem from exceeding a load of 34,000 lbs. For these cases, the load center of gravity (c.g.) height is assumed to be located 48 inches above the trailer floor (102 inches above the ground).

B) Illegal load to the nominal maximum gross combination weight rating - This corresponds to the case where the vehicle has been loaded to the legal GCW with the axles at the rear position (Case A); but then assumes the trailer axles have been moved to a forward position (perhaps to improve maneuverability on urban streets or in a terminal area) and are left in that position during road travel. With forward placement of the trailer axles, the load on the tractor falls below the 46,000 lb maximum and that on the trailer axles increases above 34,000 lb. This represents a worst case scenario for dynamic behavior. The same c.g. height is used as in case A.

C) Loaded in proportion to trailer length - In those cases where the trailers are used to transport a low density material, the total load will vary in accordance with the length (volume) available. The loads for this case are based on a material density that just achieves the 80,000 lb GCW value with the 53' trailer. Thus, the load used for all shorter trailers is reduced in proportion to trailer length.

In accordance with these cases, a loading algorithm was devised by which to estimate appropriate properties for the trailers and loads. The method was based on average weight properties for van-type semitrailers that have been developed in past work. The trailer is assumed to be comprised of a slider/axle assembly weighing 5225 lbs, and a van box weighing 179 lbs per foot of length. Thus the curb weight and inertial properties could be determined for each trailer separately. The payload weight was selected to obtain the axle load conditions desired for each case. Note that each of the loading scenarios reflects what can be achieved in practice (i.e., the axle load changes that occur as the trailer axle position is varied will be similar to that encountered by the fleet operator). For purposes of dynamic modeling of the vehicle, individual weights and moment of inertia values were determined for each trailer/load condition. The parameters describing each configuration are provided in Appendix A.

2.2 Low-Speed Offtracking

The maneuverability of a tractor-semitrailer is normally constrained by the tendency for the trailer to "cut" across corners. This property is known as inboard "offtracking" and is routinely taken as a significant consideration in determining vehicle size limits and in designing roads. Predicting such performance is readily accomplished using simple "offtracking" models [1]. The geometry of the tractor and trailer is described for the model along with the intended path of travel for the front axle of the tractor. The paths which are traced by various points on the tractor and trailer are then calculated by the model. Typically, the front axle of the tractor is taken through a right angle turn of a prescribed radius, and the inboard offtracking of the trailer wheels is computed.

An UMTRI offtracking model was prepared for this study using selected combinations of the tractor and semitrailer configurations described in the previous section. In accordance with the design policy of the American Association of State Highway and Transportation Officials (AASHTO), a 90-degree right turn intersection was examined, with the front outside tire of the tractor following a 45-foot radius arc. The program computes and plots the path of the tractor left front tire, the tractor rear inside tire, the trailer rear inside tire, and the left rear corner of the van box. The results of these computations are provided in Appendix B.

No single standard for intersection design is uniformly applied for all Michigan roads. It is understood that intersection design on Michigan rural roads generally follows the guidelines of the AASHTO WB-50 design vehicle, although several intersection design geometries exist for that vehicle. For purposes of this study, the Minimum Simple Curve with Taper was selected as representative of the WB-50 designs, and is considered appropriate for rural Michigan roads. This design consists of a 15:1 taper in the approach areas, generating a 4' offset at the point where the lane edge is tangent to a 60' corner radius.

In urban locations, curb design at right-angle intersections is commonly described by a simple 25-foot radius arc tangent to the outside edge of the lane. Insofar as the urban case represents a "sharper" turn radius, no tractor-semitrailers can make a right turn from the right lane at such intersections, but must enter and leave in the adjacent lane to the left. Compared on this basis, the WB-50 design for rural intersections is the more restrictive and was therefore used as a reference for judging offtracking performance of the subject combinations. The WB-50 lane edge dimensions are shown on the offtracking plots in Appendix B. The performance noted from the study can be summarized for the tested vehicle configurations as shown in Table II.

The offtracking intrusion values shown in Table II indicate the extent to which trailer wheels intrude beyond the edge of the WB-50-designed pavement, assuming that the tractor of the vehicle combination tracked the same reference path as in the design procedure. It should be noted that the AASHTO procedure for designing intersections assumes that the tractor negotiates the turn with its wheels clearing the lane edges by 1.5 to 2.0 feet. These clearances are intended to provide a margin, or tolerance, recognizing that drivers are not capable of precisely locating their vehicles in the provided lane. The "limiting vehicle" which can be fitted with essentially zero clearances within the WB-50 intersection design (that is, eliminating the design tolerances) is the current 48' semitrailer having a 40.5' wheelbase. (Thus, we might say that many intersections in Michigan are currently being pressed to their geometric limits by the existing 48' semitrailer. Indeed, the clamor raised by many state DOT's around the nation upon introduction of 48' semi's in 1982 suggests that Michigan is not alone in its marginal ability to accommodate 48' semitrailers.) Although not representing zero clearance to adjacent lanes, the offtracking results presented in Table II provide a picture of the relative difficulty of operating the alternative configurations in the Michigan road environment.

For the 53' trailer length (cases 9-14) the offtracking intrusion is quite sensitive to the trailer wheelbase, and hence the bogie position. Considering the 48' semitrailer as a reference (limit) case, comparable performance could be obtained with 53' trailers if the bogie is positioned to maintain a 40.5' wheelbase (9.5' forward of the rear of the trailer).

At the most forward bogie positions studied (cases 11 and 14), a negative aspect of the forward positioning is observed. Namely, in this type of intersection turn the rear projection of the trailer swings outboard by as much as two feet as the trailer pivots around the forward-positioned wheels. This may constitute a special hazard because the driver of the truck cannot see this area in his mirrors during a right-hand turn, and drivers of oncoming vehicles in adjacent lanes may not be expecting the trailer to swing outward into their lane.

TABLE II - Summary of Offtracking Performance

Case No.	Trailer Length	Kingpin Position	Wheel-base	Bogey Position	Offtracking Intrusion*
1	45 ft	3 ft	37.5 ft	4.5 ft	1 ft
3	48	3	40.5	4.5	2.5
5	50	3	42.5	4.5	3.5
7	50	5	40.5	4.5	2.5
9	53	3	45.5	4.5	5
10	53	3	37.5	12.5	1
11	53	3	30.5	19.5	-1
12	53	5	43.5	4.5	4
13	53	5	37.5	10.5	1
14	53	5	30.5	17.5	-1
15	57	5	47.5	4.5	6
16	57	5	38.5	13.5	2

*The clearance (-) or intrusion (+) of the path of the innermost edge of the trailer tires relative to the pavement edge at the WB-50-design rural intersection.

2.3 Dynamic Turning Response at High Speed

The yaw, or turning, behavior of truck combinations in high-speed maneuvers may be characterized by examining the ability of the trailer to accurately track any directional changes of the tractor. The behavior may be studied using computer simulations of the truck combination derived from any of several truck computer models in use at UMTRI [2,3]. For this study, the "Constant Velocity Yaw/Roll" model [2] was selected. The model has been used in numerous earlier studies, and has proven capable of reproducing the behavior of actual tractor-semitrailer combinations as measured in full-scale tests.

Data input files were assembled to represent the tractor and each of the trailers listed in Table I. Generic tractor properties were used, equivalent to typical 3-axle tractors in common use on the road. A 144-inch wheelbase tractor is used with trailers that have a 3' kingpin offset position. For the 5' offset, the tractor wheelbase was extended to 168 inches (to provide the additional clearance needed to accommodate the forward extension of the van box). The tractor tandem suspension is equivalent to the 4-spring type, and typical radial tire properties are used.

Each trailer in Table I is represented with a typical 4-spring suspension assembly and radial tires. A number of properties varied with each combination. These included:

- Weight of the trailer
- Weight of the load
- Load distribution at the kingpin and rear wheels
- Center of gravity height (trailer plus load)
- Roll, pitch and yaw moments of inertia (trailer plus load)
- Trailer wheelbase.

The properties of each truck combination are documented in the first pages of the simulation output, copies of which are provided in Appendix A.

The yaw behavior of the combinations was first examined in a "pulse" steer maneuver. In this maneuver, the vehicle is assumed to be traveling down a smooth and level road at 55 mph, at which time the steering wheel is "pulsed" to produce two degrees of steer on the front wheels for a period of 0.1 seconds, returning to zero thereafter. The pulse steer causes a quick change in the direction of travel of the tractor. This disturbance to the vehicle excites the dynamic yaw response mode of the trailer in a way that demonstrates its yaw damping. A low damping level indicates a vehicle that is prone to oscillation when disturbed by steering inputs, road bumps or crosswinds. The response is typically characterized by examining the lateral acceleration disturbances produced on the tractor and trailer, and may be compared to similar performance measures that have been calculated for other commercial vehicles in common use.

The results from the simulation for each case in this maneuver are shown as lateral acceleration plots in Appendix C. The amplitudes of the first and second peaks of trailer acceleration are examined, and their ratio is used to calculate a damping ratio for the combination. The observed damping ratios are summarized in Table III. As was expected, the longer trailers show damping ratios on the order of 0.5 (50% of critical damping) and higher for the cases where the trailer axles are placed at the rearmost position (at the rear of the van box); and the damping ratios generally increase with increasing trailer length. With reductions of load (load case C) the damping ratios are also improved, so that better performance is obtained. When the axles are moved forward, even with load reductions to keep within legal limits, the damping ratio always decreases. Although the 53' semitrailer maintains good damping at bogie positions up to 12.5', it deteriorates markedly at the 19.5' position. In the cases where the load on the trailer axles was increased as the bogie position was moved forward (load case B), the damping deteriorates to levels in the 0.26 to 0.46 range. Toward the low end of this range, the damping performance is seen as quite poor, falling well below that which is exhibited by the twin 28' doubles combinations operating on Michigan roads today.

Thus from the analysis of the pulse steer maneuvers, it is concluded that yaw damping will not pose a problem with any of the longer-wheelbase configurations studied. However, lacking a full understanding of the significance of the unusual damping levels falling in the vicinity of 0.3, there is a need for follow-up study of the dynamic behavior of the very-forward-bogie cases.

As a second level of evaluation, a "J-turn" maneuver was performed. The J-turn maneuver represents a steer onto a constant radius, as for example, when turning onto an exit ramp. This maneuver allows evaluation of the trailer's propensity to intrude outward beyond the path taken by the tractor. A turn of 1000 foot radius was used, negotiated at a speed of 55 mph, which exposes the combination to lateral accelerations just below 0.2 g's. For the high c.g. loading on the trailers this level of turn represents a challenging maneuver, just below the rollover point for the combination.

The J-turn performance of a selection of the trailer combinations from Table I is presented in Appendix D. The results are plotted in the form of the tracking paths of the

TABLE III - Damping Ratios in a Pulse Steer Maneuver

Case No.	Trailer Length	Kingpin Setting	Wheel-base	Bogey Position	Load Type	Damping Ratio
1A	45 ft	3 ft	37.5 ft	4.5 ft	A	.495
1C	45 ft	3 ft	37.5 ft	4.5	C	.536
2A	45	3	30.5	11.5	A	.420
3A	48	3	40.5	4.5	A	.522
3C	48	3	40.5	4.5	C	.561
4A	48	3	33.5	11.5	A	.456
5A	50	3	42.5	4.5	A	.552
5C	50	3	42.5	4.5	C	.556
6A	50	3	33.5	13.5	A	.432
6B	50	3	33.5	13.5	B	.398
7A	50	5	40.5	4.5	A	.517
7C	50	5	40.5	4.5	A	.409
8B	50	5	31.5	13.5	B	.376
9A	53	3	45.5	4.5	A	.587
9C	53	3	45.5	4.5	C	.587
10A	53	3	37.5	12.5	A	.496
10B	53	3	37.5	12.5	B	.462
11A	53	3	30.5	19.5	A	.325
11B	53	3	30.5	19.5	B	.262
12A	53	5	43.5	4.5	A	.548
12C	53	5	43.5	4.5	C	.548
13A	53	5	37.5	10.5	A	.491
13B	53	5	37.5	10.5	B	.456
14A	53	5	30.5	17.5	A	.360
14B	53	5	30.5	17.5	B	.307
15A	57	5	47.5	4.5	A	.583
16A	57	5	38.5	13.5	A	.491
16B	57	5	38.5	13.5	B	.450
17A	57	5	30.5	21.5	A	.298

tractor front axle, tractor leading trandem, trailer rear axle, and the rear extreme of the trailer van box. The first three plots cover the cases of 45-, 50- and 53-foot trailers when the trailer axles are in the rearmost positions. Although the trailer tracks approximately one foot outboard of the tractor, due to the lateral acceleration involved, there is no significant difference between the performance of the 45- and 53-foot trailers. Cases 10A and 10B are the 53' trailer with the axles at the 12.5' bogey position. At legal load (Case 10A) the rear of the van box tracks outboard to about 1.5 feet, while the overload condition (Case 10B) reaches nearly 2 feet. With the trailer axles in the extreme forward position of Case 11 (19.5 feet) the outboard excursions increase to 2-2.5 feet. It may be noted that excursions beyond 2 feet place the rear of the trailer outside of a 12' lane when the tractor-trailer is traveling in the center of the lane.

Although the J-turn involves a smooth transition into a turn, additional dynamic factors could come into play in quickly executed turns and evasive maneuvers. In a quick evasive maneuver, the trailer will go through a transient phase as it enters the turn which may involve some overshoot in its outward excursions. The overshoot magnitudes are specific to the turn maneuver selected, but will generally be aggravated by lack of damping in the system. For this reason, the more lightly damped combinations, typified by those with the most forward axle placements, will be most susceptible to dynamic overshoot. Step-steer maneuvers were simulated with some of the combinations to assess the significance of the overshoot problem. For trailers with their axles in the rearmost position, the transient peak in outboard offtracking was only about 12.5% greater then the steady state. With the axles moved forward to the 12.5' position, the overshoot increased to 19% for the 53' semitrailer. Thus transient offtracking should remain under 2' in the "worst case" turn with this vehicle. Moving the axle forward to the 19.5' position caused the transient offtracking to be 30% greater than the steady state. This, in combination with the high steady-state offtracking distance (2-2.5'), pinpoints a combination that is potentially difficult to keep in a traffic lane. Thus in high-speed turning, as in low-speed turning, an excessively forward trailer axle position may result in outboard offtracking that could pose a conflict condition with traffic in adjacent lanes.

3.0 DISCUSSION OF ISSUES

3.1 Conclusions from Performance Analysis

In the performance analyses of the preceding sections it was seen that 53' trailers with quite shortened wheelbase values may exhibit peculiar shortcomings with regard to their high-speed turning behavior and, with either very long or very short wheelbase values, may exhibit reduced maneuverability in low-speed turns. The most important factor influencing offtracking behavior in both high- and low-speed turns is clearly the trailer wheelbase (determined primarily by rear axle position).

With the maximum wheelbase (45.5'), the 53' trailers will behave comparably to the 45' and 48' trailers commonly used on Michigan roads in normal high-speed driving situations. In particular, any tendency toward lateral oscillations is damped as well as or better than that of the shorter trailers. However, in low-speed turns at intersections, the 53' semitrailer will exhibit reduced maneuverability. In negotiating a rural intersection designed to accommodate the AASHTO WB-50 vehicle, an offtracking intrusion of 5' will occur. Therefore, a right turn cannot be accomplished without either running the trailer tires well inboard of the pavement edge or intruding into adjacent lanes on entry and exit from the turn. On two-lane rural roads, the intrusion would be made into opposing traffic lanes. The expected impacts would include (a) greater impediment to traffic at intersections, (b) abuse of curbs, unprepared shoulders and roadside appurtenances, and (c) creation of traffic hazards during the turn.

The deficiencies in maneuverability can be overcome by regulating the allowable wheelbase on 53' trailers. The 48' trailers, which are becoming more common on the highways, have a 40.5' wheelbase and were seen to "use up" all of the margin which was designed into the typical intersection in Michigan. By constraining 53' trailers to use this wheelbase (by operating with the trailer axles centered 9.5' ahead of the rear of the box), low-speed maneuverability can be maintained at the level accepted with the 48' trailers, and without significant reductions in high-speed performance. The offtracking intrusion on AASHTO WB-50 turns with trailers of this wheelbase are on the order of 2.5 feet (see Appendix B). Several means are available for the driver to overcome this conflict. On the one hand, most tractors can achieve a turn of less than 45' radius with proper driving technique, allowing some reduction in the offtracking. Secondly, 2' of lane clearance on the outside are allowed in the calculations. By entering and exiting the turn at the lane edge, an additional 2.8' of clearance is theoretically possible. Thus from the perspective of turning performance, 53' trailers can be fitted within the available pavement space if restricted to operation with a wheelbase no greater than 40.5 feet.

On the other hand, when the wheelbase is decreased significantly beyond the 40.5' point, as may be desired for operations in certain areas of restricted geometry, an outboard offtracking problem arises in both low-speed and high-speed turns. Thus wheelbases significantly less 40.5' are also inadvisable on 53' trailers.

3.2 Rollover Considerations

With the transition to "larger" trailers it is natural to question whether increased safety risks will arise from an increased propensity for such vehicles to roll over on the highway. Rollover was not explicitly addressed in the performance analysis, but the available knowledge allows certain inferences to be drawn. A longer trailer does not have a lower rollover threshold as a consequence of its length, but rather due to its length is more difficult to get into a maneuver capable of rollover. Yet, the motivation for using these trailers is for transport of low-density goods, which implies that they may be used more extensively for transport of products that are "loaded to the ceiling." Consequently, they will be operated with greater payload weight and a higher composite c.g. than exists currently with shorter semitrailers hauling the same commodities. The higher center of gravity reduces their rollover threshold, and will result in a higher incidence of rollover accidents.

A rough estimate of the significance of the sensitivity can be obtained from other work that has been done on this subject [4]. All other things being equal, the rollover threshold of a combination vehicle is inversely proportional to its center of gravity height. The nominal thresholds for the vehicles of interest in this study can be estimated based on the load and its height, and assuming generic properties for the suspensions, tires, etc. The worst case rollover threshold occurs with the 53' trailer loaded to the 80,000 lbs GCW with a homogeneous product that also uses the full cube capacity of the van. Recognizing that, in practice, the typical tractor-semitrailer operates at an average 65,000-lb GCW, the rollover threshold of a cube-full 53' semi at this nominal load condition was also evaluated. For purposes of comparison, the roll stability of 48' and 45' trailers hauling freight of this same density were also examined. These represent the alternative means for transporting the same cargo in lieu of the 53' trailer, and provide a point of comparison for the longer trailer. Rollover thresholds for these four vehicle cases were estimated, yielding the results shown in Table IV.

The thresholds indicated are rather low and are typical of combination vehicles loaded to their volume capacity. A rough estimate of the impact on rollover accident frequency can be obtained by examining data that have been obtained from a number of sources. Figure 3 shows rollover experience as a function of rollover threshold gathered from BMCS accident data for semitrailers and tankers, and from several fleets. The figure shows that the average miles traveled per rollover increases dramatically with the rollover threshold. Because of the different types of vehicles represented and differences in operational conditions, drivers, etc., the data are scattered, but a nominal relationship can be inferred. The performance of the vehicles listed in Table IV are shown identified on the graph. Assuming that the graph is a valid basis for projecting the experience, rollovers may be expected every 2 to 7 million miles of use, depending on trailer and loading. While this contrasts with other semitrailer vehicles (e.g., every 25 million miles for 8800-gallon gasoline tankers), the risks should be judged on the basis of comparing alternatives. For transporting low-density products the alternative to the 53' trailer is currently the 48' unit. According to the graph, the 48' trailer at a weight of 60,900 lbs will go about 10% further between rollovers when compared to the 53' trailer loaded to 65,000 lbs with comparable freight. However, about 10% more 48' trailers would have to be on the road to haul the same tonnage of freight. Thus the total number of rollover accidents would be about the same with either choice.

3.3 Consideration of Multi-Axle Configurations of the 53' Semitrailer

Because of the peculiar nature of Michigan's road-use laws, it is common that trailers hauling relatively dense commodities in intra-Michigan transportation employ more than two trailer axles. Michigan law permits up to eight axles on a semitrailer, yielding a GCW in the vicinity of 154,000 lbs. There is concern that the longer 53' semitrailer being considered in this study might also become attractive for the shipment of certain dense commodities such that multi-axle (more than two-axle) trailer versions would develop if allowed under the law. It seems prudent, however, to recommend that the 53' semitrailer not be implemented in configurations having more than two trailer axles pending further examination of various dynamic performance issues.

TABLE IV - Estimated Rollover Thresholds for Selected Combinations

Gross Weight	Trailer Length	Sprung Mass CG Height	Rollover Threshold
80,000 lb	53 ft	87.98 in	.253 g's
65,000	53	84.21	.274
60,900	48	83.19	.280
58,400	45	82.49	.285

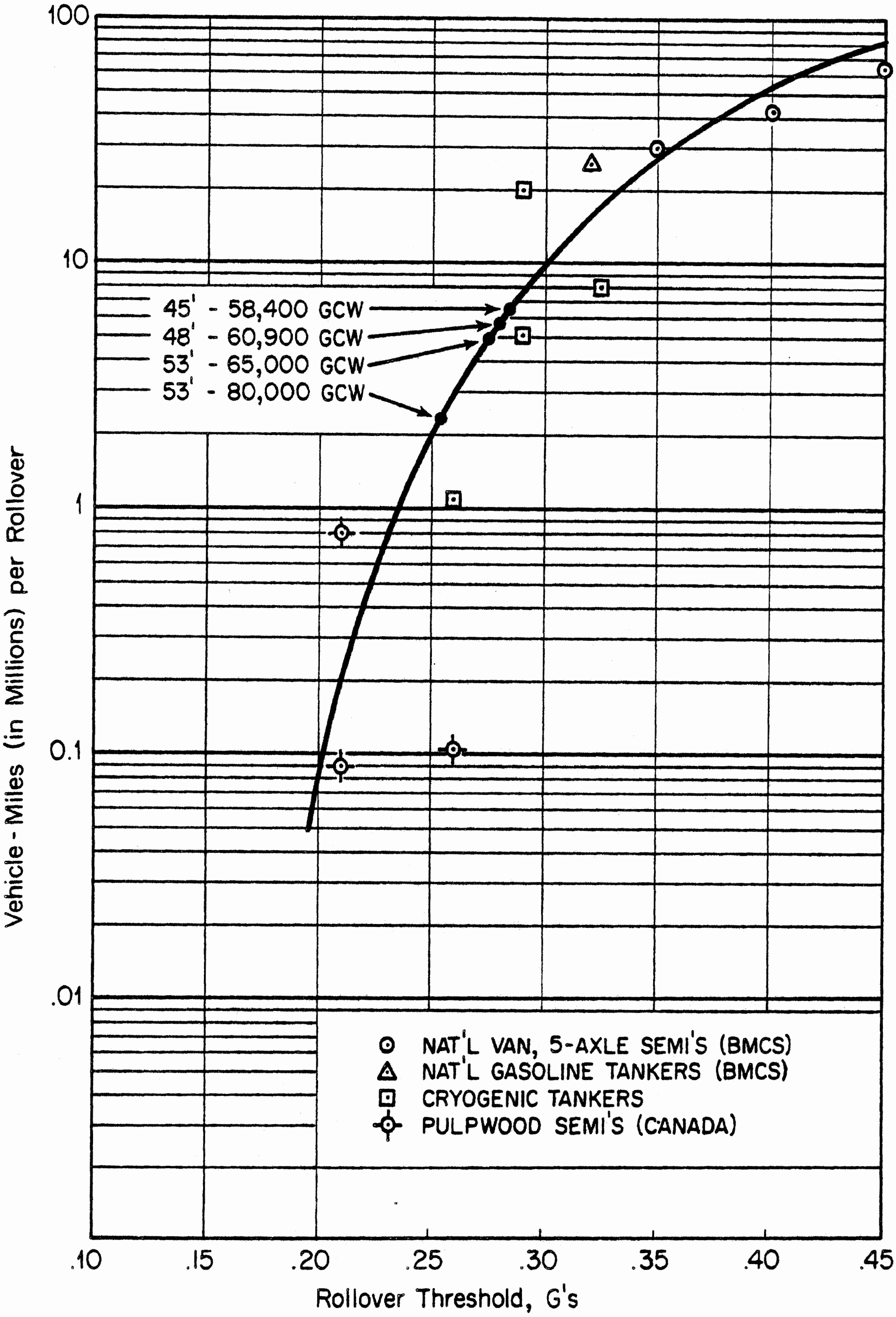


Fig. 3 Rollover Experience Expected with Different Trailers and Load Conditions

UMTRI studied some aspects of the dynamic behavior of multi-axle, 45' semitrailers in a prior study for the State of Michigan entitled, "Future Configuration of Tank Vehicles Hauling Flammable Liquids in Michigan" [5]. In this study, it was shown that with increased number of trailer axles, the tractor had increasing difficulty in negotiating a tight-radius turn when the pavement was slippery. While this same problem would also prevail with trailers of 53' layout, it is also apparent that additional dynamic problems might also arise. Namely, the spreading of a very large trailer load over the 53' dimension will impose a very large value of yaw moment of inertia, making rapid steering motions at the tractor increasingly tenuous. Analogous issues to this are being pursued currently at UMTRI in a study of Canadian truck configurations, some of which employ multi-axle trailers (up to 48' in length) [6]. Pending conclusion of this research and perhaps additional analysis of the 53' multi-axle case itself, it is suggested that the 53' semitrailer be permitted in only the two-axle version.

3.4 Considerations of Intersection Redesign

The analysis of turning behavior at intersections in this study has pointed out the incompatibility of current trailer lengths with intersection designs in the State of Michigan. Intersections designed per the AASHTO "Minimum Simple Curve with Taper" will be the site of significant offtracking intrusions when trailers of 40.5' wheelbase (48' trailers) and longer are driven through the turn along the design arc. Case 3 in Appendix B is the 40.5' wheelbase trailer and shows the location and extent of this intrusion. The only way the intersections can be negotiated without overrunning the curb is by positioning the tractor-semitrailer at the very edge of the lane at the entry and exit. In effect, the driver must use the 2' clearance margin at the lane edge that is assumed in the AASHTO design method.

Given that the 40.5' wheelbase trailer has come into popular service in the State, the clearances at intersections are now marginal for the prevailing traffic. The spacial conflicts can be readily seen when comparing offtracking trajectories to the typical curb designs. In Figure 4 the offtracking plots for the 40.5' wheelbase trailer have been overlaid with the AASHTO WB-50 "Minimum Simple Curve with Taper" and with the 25' simple radius typically employed at urban intersections in Michigan. The 25' radius curve cannot be negotiated from the curb lane with any tractor-trailer. Thus, it is assumed that the turn is made from and into the adjacent lane, and the curve has been located accordingly on the plot.

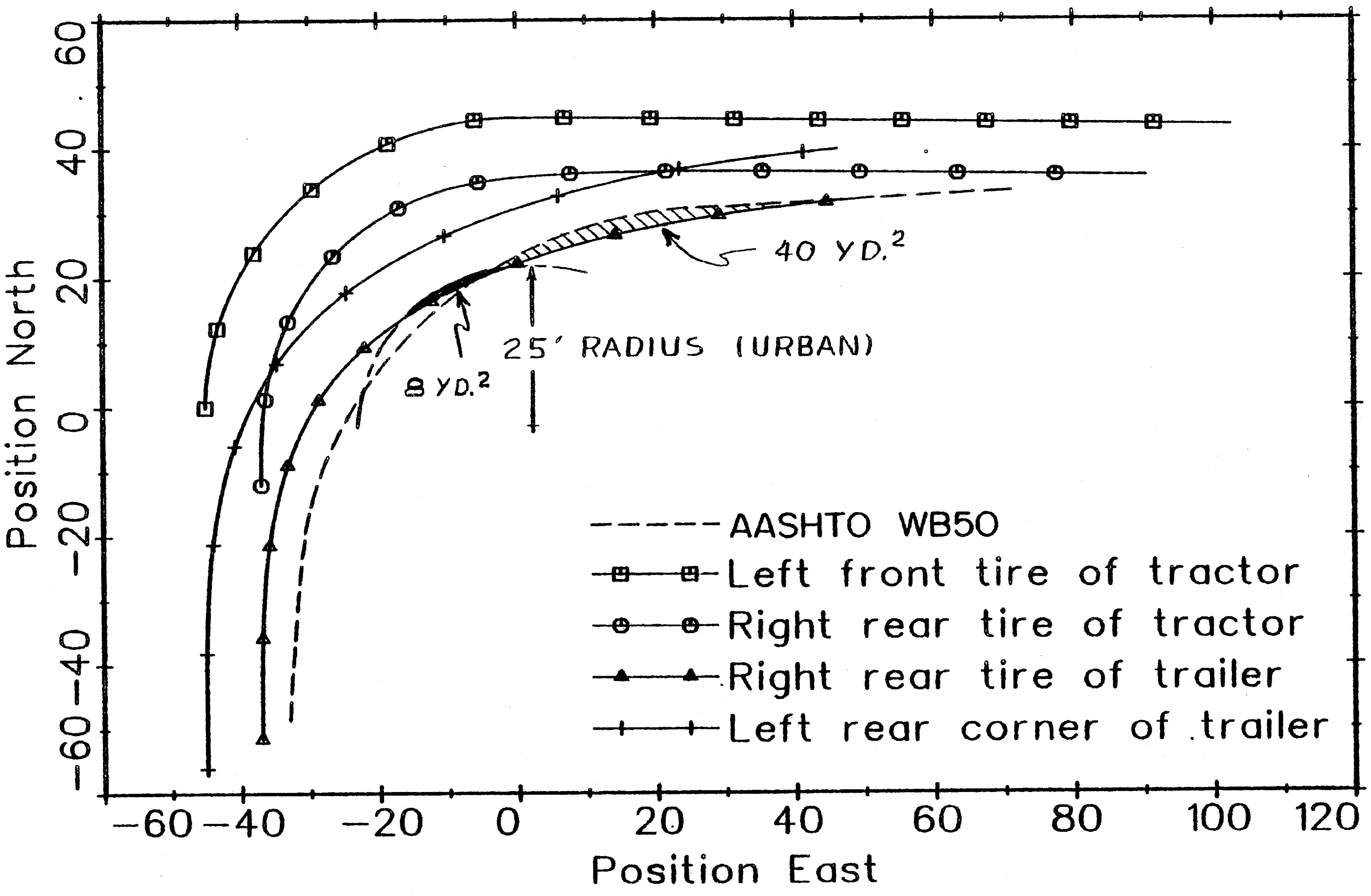


Fig. 4 Offtracking Intrusions at Intersections by Trailers with 40.5' Wheelbase

Redesigning and reconstructing the intersections to accommodate these trailers can be accomplished with selective modification of the curb profile in the locations where conflict is indicated. On the AASHTO WB-50 design an additional 2.5' of clearance is needed on the exit side of the curve. The total area of reconstruction in this case is approximately 40 square yards per corner, corresponding to 160 square yards per 4-way intersection. On the 25' radius urban design the intrusion area is approximately 8 square yards, corresponding to a total of 32 square yards of reconstruction at a 4-way intersection.

Additional factors may have to be considered in costing the rework. Clearances to utility poles, traffic signal and lighting standards, and sidewalks must be considered. In urban locations the affected curb areas frequently include ramps for handicapped that may require complete reconstruction because of the foreshortened ramp length.

3.5 Estimation of Industry Costs

The configuration of the 53' semitrailer which is recommended by this study involves a 2-axle trailer having a wheelbase of 40.5'. Speaking generally, no unusual components or assembly techniques will be required for the manufacture of such semitrailers to achieve this type of vehicle layout. There are four potential cost-related issues that would appear to follow from this recommendation, as discussed below.

1) The stipulation that the 53' semitrailer have a 40.5' wheelbase implies that the rear face of the tires on the rear axle will reside approximately 5.5' from the rear extremity of the trailer. In the event that a passenger car would impact the rear of such a trailer, there is risk of an underride penetration of the automobile since the trailer's wheelsets are not situated to prevent this type of response (in contrast to most other semitrailers having the trailer tandem placed in its normal, full-rearward, position). Underride is seen to be a major hazard to passenger cars in rear-end collisions with tractor-trailers. In a 1979 study of 194 car-into-truck accidents [7], it was found that, "By configuration, 85% of the fatal rear-end collisions involved underride, but only 43% of the non-fatal rear-ends involved underride..." Thus, the 53' semitrailer, with its rear bed extremity permanently overhung relative to the tandem, is in need of special attention with respect to a rear underride protection. It is recommended that Michigan law require all 53' semitrailers to be outfitted with a suitable rear underride guard structure. A suitable rear underride guard has been

estimated by the U.S. Department of Transportation to add \$50 to the cost of a semitrailer [8].

2) Manufacturer's of 53' semitrailers with the stipulated forward bogie position would naturally wish to consider whether any unusual stresses would develop in the overall trailer structure as a result of the distribution of beam loads along the length of the trailer. Although it is common for trailers to be built to handle the cantilever type of loads deriving when the tandem bogie is moved forward on a slider track, it may be that somewhat higher stress levels than normal might develop with the geometry of the 53' configuration. This consideration, while perhaps imposing some engineering costs to the manufacturer, is not expected to significantly influence trailer purchase cost.

3) Shippers who wish to transport homogeneous commodities in cube-full loads will find that a 53' semitrailer with wheelbase constrained to 40.5' cannot attain the full 80,000-lb gross weight allowance for certain values of freight density. That is, with the trailer's tandem bogie placed somewhat forward, a load of freight distributed uniformly over the entire length of the bed will cause the trailer axles to reach the 34,000-lb tandem load limit at a gross combination weight of approximately 71,000 lb. This condition will develop when the nominal density of the overall freight load is approximately 11 lb/ft^3. Thus, the fact that the 53' semitrailer must be constrained in wheelbase on behalf of offtracking considerations imposes a weight-capacity penalty, but only for certain shipments which involve a homogeneous freight load. The more common mixed-freight loadings will not generally encounter this problem since the denser commodities can be placed toward the front of the trailer, thus achieving full load utilization of all axles on the vehicle combination. Likewise, homogeneous freight having a density of approximately 16 lb/ft^3 and above can be loaded to the 80,000-lb GCW value by biasing the load forward in the trailer. Estimation of the industry costs deriving from a reduction in gross weight capacity with homogeneous freight in the density range from 11 to 16 lb/ft^3 was beyond the scope of this study.

4) The analysis of the 53' semitrailer with slider bogie in its forward-most position, presented in Section 2.3, showed certain unfavorable tendencies in dynamic behavior as well as a tendency to swing out the rearmost trailer extremity in a low-speed intersection turn. Pending a more in-depth examination of these matters, the authors have elected to recommend that the 53' semitrailer be allowed on Michigan

roads only with a specified wheelbase. To the trucking industry, this provision will mean that the vehicle cannot be rendered more maneuverable in highway areas where tighter space constraints exist. To the degree that such constraints in maneuverability tend to limit the versatility of the 53' semitrailer in different hauling missions, reduced productivity will result.

In summary, the industry is expected to bear a small additional cost in order to provide a suitable rear underride guard but otherwise will see no special cost items in the purchase of new 53' semitrailers in the recommended configuration. Productivity of the vehicle will be somewhat limited both by reduced gross weight capacity in transporting homogeneous freight loads and by limitations in maneuverability due to the fixed wheelbase requirements.

3.5 Consideration of the Increased Pavement Damage and Resulting Maintenance Costs Due to 53' Semitrailers

The industry's desire for a longer semitrailer derives from the perceived inefficiencies which accrue due to hauling low-density commodities in smaller trailers which currently "cube out" (that is, the trailer is filled to volumetric capacity) without the gross combination weight reaching the legal load limits. As an example, a certain operator transporting freight having, say, a density of 10 lb/ft^3 would carry only about 32,600 lbs of payload in a 48' semitrailer, for a gross combination weight of approximately 62,000 lbs (that is, well short of the legal maximum weight of 80,000 lbs allowed for 5-axle tractor semitrailers). If 53' semitrailers were permitted, this same freight could be hauled in trailer loads of more than 36,000 lbs, thereby increasing productivity by some 10%. At the same time, however, the larger trailer would impose higher axle loads and thus cause an accelerated rate of pavement wear. Even if one accounts for the fewer vehicle-trips needed to carry the same total amount of freight in the longer trailers, there will still be a net increase in the rate of pavement deterioration with the longer unit.

The destructive effect of truck axle loads on pavements is determined using the American Association of State Highway and Transportation Officials (AASHTO) Interim Guide for the Design of Pavement Structures [9]. This guide lays out a design policy by which the damage potential of single and tandem axle loadings is expressed in terms of equivalent 18,000-lb single axle loads (ESALS). The AASHTO design procedure indicates, approximately, that pavement damage accrues according to the fourth power of the axle load. Thus, relatively small numerical differences in axle load can imply large differences in the potential for pavement damage.

In order to illustrate the pavement damage implications of differing trailer lengths being considered in this study, two loading scenarios have been examined. Shown in Table V are the payload and gross weight values pertaining to scenarios in which payloads having average densities of 9.4 and 13.5 lb/ft^3, respectively, are considered to be cube-full-loaded in semitrailers having lengths of 45, 48, 50, and 53 feet. The 9.4 lb/ft^3 value represents a rather low-density commodity and yields a gross combination weight of 65,000 lbs in the 53' semitrailer. The 13.5 lb/ft^3 is that medium-density value which produces an 80,000-lb gross combination weight with the 53' semitrailer. The table illustrates the respective values of payload weight and gross combination weight which accrue when these two commodity density values are assumed. Clearly, the shorter trailer lengths involve smaller gross weight levels, considering the two constant-density scenarios.

In Tables VI and VII are shown the axle load values which reasonably represent the load distributions that would accompany the cited gross weight conditions. The indicated axle loads have been used in determining the differences in pavement damage which would derive from the various lengths of trailers. Equivalent 18,000-lb single axle loads (ESALS) have been evaluated from the AASHTO tables for both flexible and rigid pavements. For the flexible pavement determinations, values for the AASHTO constants of p_t=2.5 and SN=3 were assumed. With the rigid pavement evaluation, values of p_t=2.5 and D=9 were assumed.

Tables VI and VII show entries of ESAL values for the respective axle sets and for the total vehicles in the two scenarios. Recognizing, also, that the longer trailers carry more payload and would, thus, require fewer trips to carry the same quantity of freight, an adjustment factor has been derived which modifies the ESAL values in determining equivalent ESAL-miles. The adjustment factors simply represent the ratio of the payload weight for the 48' semitrailer to the payload weight for each of the other trailers. Thus, the 53' semitrailer, for example, shows an adjustment factor of 0.91 since the 48' trailer carries only 91% of the freight carried in a cube-full 53' trailer.

The bottom line of this analysis is shown in the far-right column of figures in Tables VI and VII. We see that:

TABLE V - Payload and Gross Weight Values (lb) for Two Loading Scenarios

1) 65,000 lb GCW for 53' Semitrailers (Uniform freight density = 9.4 lb/ft^3)

Trailer Length	45'	48'	50'	53'
Vehicle Tare Weight	29,755	30,295	30,655	31,195
Payload Weight	28,702	30,616	31,892	33,805
GCW	58,457	60,911	62,547	65,000

2) 80,000 lb GCS for 53' Semitrailers (Uniform freight density = 13.5 lb/ft^3)

Trailer Length	45'	48'	50'	53'
Vehicle Tare Weight	29,755	30,295	30,655	31,195
Payload Weight	41,438	44,200	46,042	48,805
GCW	71,193	74,495	76,697	80,000

TABLE VI - Axle Load Analysis - 65,000 lb Tractor-Semitrailer (Freight density = 9.4 lb/cu ft)

Trailer Length	Pvmt. Type	Axle 1 Load (lbs)	Axle 1 ESAL	Axles 2-3 Load (lbs)	Axles 2-3 ESAL	Axles 4-5 Load (lbs)	Axles 4-5 ESAL	Total ESALs	Adjustment Factor for No. of Trips	Adjusted ESALs	Percent change from 48'
45 ft		10,000		25,229		32,229					
	Flex		.12		.38		.28	0.78	1.07	.83	-9
	Rigid		.08		.55		.39	1.02	1.07	1.09	-11
48		10,000		26,456		24,456					
	Flex		.12		.45		.34	0.91	1.00	.91	0
	Rigid		.08		.67		.48	1.23	1.00	1.23	0
50		10,000		27,274		25,274					
	Flex		.12		.50		.38	1.00	.96	.96	+5
	Rigid		.08		.77		.55	1.40	.96	1.34	+9
53		10,000		28,500		26,500					
	Flex		.12		.59		.45	1.16	.91	1.06	+16
	Rigid		.08		.92		.68	1.68	.91	1.53	+24

TABLE VII - Axle Load Analysis - 80,000 lb Tractor-Semitrailer (Freight density = 13.5 lb/cu ft)

Trailer Length	Pvmt. Type	Axle 1 Load (lbs)	Axle 1 ESAL	Axles 2-3 Load (lbs)	Axles 2-3 ESAL	Axles 4-5 Load (lbs)	Axles 4-5 ESAL	Total ESALs	Adjustment Factor for No. of Trips	Adjusted ESALs	Percent change from 48'
45 ft		10,679		31,257		28,257					
	Flex		.16		.82		.57	1.55	1.07	1.66	-13
	Rigid		.11		1.36		.89	2.36	1.07	2.53	-16
48		11,174		32,460		30,860					
	Flex		.18		.94		.78	1.90	1.00	1.90	0
	Rigid		.14		1.59		1.29	3.02	1.00	3.02	0
50		11,505		33,096		32,096					
	Flex		.20		1.01		.90	2.11	.96	2.03	+7
	Rigid		.16		1.73		1.51	3.40	.96	3.26	+8
53		12,000		34,000		34,000					
	Flex		.23		1.11		1.11	2.45	.91	2.23	+17
	Rigid		.18		1.92		1.92	4.02	.91	3.66	+21

a) the 53' semitrailer would exceed the pavement damage potential of the 48' reference trailer by 16% and 24% on flexible and rigid pavements, respectively, if a freight density of 9.4 lb/ft^3 was considered

b) the 53' trailer exceeds the 48' unit by 17% and 21% on flexible and rigid pavements, respectively, in the heavier, 13.5 lb/ft^3 freight scenario

Example Cost Implications

When a certain fraction of the current population of combination trucks in Michigan converts from, say, the current standard of 48' semitrailers to 53' semitrailers, the typical ESAL-loading of pavements in Michigan would increase by approximately 20% per vehicle. In order to express the cost implications of such a conversion, in terms of the moneys spent to resurface, restore, and rehabilitate the State's roads, it is necessary to estimate both the total ESAL-miles of exposure involved and the typical maintenance costs in \$/ ESAL-miles. The net increase in maintenance costs would then be equal to the product of (the 20% increase in ESAL-miles) times (the total number of ESAL-miles being currently imposed by the vehicles which will convert to 53 footers) times (the maintenance cost, \$/ESAL-mile).

The total annual number of miles of combination truck traffic in the United States is estimated by the Federal Highway Cost Allocation Study of 1982 to be approximately 70 billion miles [10]. Apportioning Michigan's likely share of this total simply on the basis of population, this State would experience about 2.8 billion miles of combination vehicle traffic. Further, acknowledging that the average combination vehicle on the road has a gross combination weight of approximately 64,000 lbs [10], the average ESAL value per combination vehicle is approximately 1.35 (averaging between results for both flexible and rigid pavements). Thus, the State's total annual maintenance costs attributable to the ESAL-mile exposure is estimated by (the characteristic maintenance cost) times (1.35 ESAL-miles per vehicle-mile) times (2.8 billion vehicle-miles per year).

The cost of maintaining pavements, as a function of ESAL-mile exposures is estimated below, with vehicle-miles distributed by road type using 1977 base year data [9]:

Cost per ESAL-Mile (Cents)	Vehicle-Miles (Millions)	Road Type
5.0	14,127	Interstate Rural
15.0	8,954	Interstate Urban
13.0	10,914	Arterial Rural
41.0	9,806	Arterial Urban

Upon pro-rating the cost per ESAL-Mile according to the respective miles which are gathered nationally on each type of road system, we obtain a weighted average cost of 16.9 cents/ESAL-mile.

Accordingly, the total cost attributable to the pavement damage of 2.8 billion vehicle miles at 1.35 ESALS per vehicle and 16.9 cents per ESAL-miles is $638,000,000/ year. (Private communications with MDOT analysts reveal that, in 1985, Michigan may actually have spent only about 1/4 of this value as the portion of its highway costs allocable to combination trucks. Accordingly, in citing prospective annual increases in costs due to the longer semitrailers, below, we will show a cost range from a maximum value which is derived from the reference [10] data, down to 1/4 of that value. It may be, of course, that the lower value simply represents that portion of truck-related highway costs which Michigan could afford to cover in the 1985 construction and rehabilitation effort.) If we now consider differing fractions of the combination vehicle population that might switch from a nominal 48' semitrailer configuration to a 53' semitrailer, with a 20% increase in average ESAL loadings, the cost increases would be as shown below:

Assumed % of 48' Semis Replaced by 53' Semitrailers	Total Annual Increase in Pavement Damage Costs (Millions of Dollars)
1	0.3-1.3
2	0.6-2.6
3	1.0-3.8
4	1.3-5.1
5	1.6-6.4

Clearly, the above figures provide only a crude scaling of the pavement damage costs which may result from the envisioned switch to longer semitrailers. The reader should note that a number of simplifying assumptions have been made in attempting to reduce this complex economics issue to a direct cost figure.

3.7 Consideration of Field Tests and Analyses

The study reported here has exposed the need for three additional areas warranting examination. Namely, there is a need to further explore a) the problem of geometric intrusion beyond the space provided for vehicles at intersections in the State, b) the dynamic behavior of 53' semitrailers in the shorter wheelbase configurations obtained by the use of slider bogie hardware, and c) the dynamic behavior of multi-axle semitrailers which are 53' in overall length. Research efforts outlining these items are discussed below.

3.7.1 Field Study of Offtracking Intrusions at Intersections in Michigan

The objective of this study would be to evaluate the problems imposed by the operation of truck combinations at intersections whose geometric design provides less space than the vehicle requires. The study intends to provide a solid, objective basis upon which to project the burden which future increases in truck offtracking demands would impose on the State. "Burden" would be assessed on the basis of 1) geometric intrusion of the vehicle, 2) the apparent accident hazards imposed by such intrusions, and 3) the disruptions in traffic flow resulting from the slow movement of trucks through geometrically restrictive sites.

This study is rationalized upon the basis that the length of commercial trailers has steadily increased over the years, as shown in Figure 5 [11]. Although Michigan roads have been mostly built to accommodate the AASHTO WB-50 design vehicle, we recognize that the geometric requirements of this design were exceeded with the introduction of 45' semitrailers in the mid-1970's. As the 48' semi became the norm in new vehicles with the passage of the Surface Transportation Assistance Act in 1982, very substantial intrusions beyond the space requirements of the WB-50 designs were incurred. Indeed, the passage of the 1982 STAA legislation led to a broad clamor by the highway engineering community across the U.S. in reflection of the fact that highways, and especially intersections, had not been designed to handle such vehicles. Now with further advancements in trailer length being proposed, there is a clear need to establish, in an objective manner, the extent of the conflicts that longer vehicles impose and the cost of mitigating these conflicts. It seems necessary that a study be conducted which grips with the distribution of intersection designs actually prevailing in Michigan so that a statewide projection of the impacts of longer vehicles could be obtained. This study would provide the Michigan-specific findings to supplement the more general results of a current FHWA research project entitled, "Operation of Trucks on Roads and Streets with Restrictive Geometry" [12].

Task Statements

Task 1, Selection of Test Sites -- The various categories of design for intersections and other restrictive geometric elements prevailing in the State would be reviewed in order to identify the range of site geometries warranting inclusion in a field experiment. The nominal distribution of these categories of design across the State would be estimated to permit a later projection of statewide impacts. Individual sites for field testing would be selected on the basis of the immediate geometry of the site as well as traffic flow considerations.

Task 2, Preparation of a Field Test Methodology -- A field test exercise would be planned, entailing the operation of differing-length truck combinations over the selected sites. Differing-length semitrailers would be included in the study plan, as well as differing slider bogie placements on individual trailers. The field methodology would encompass the following:

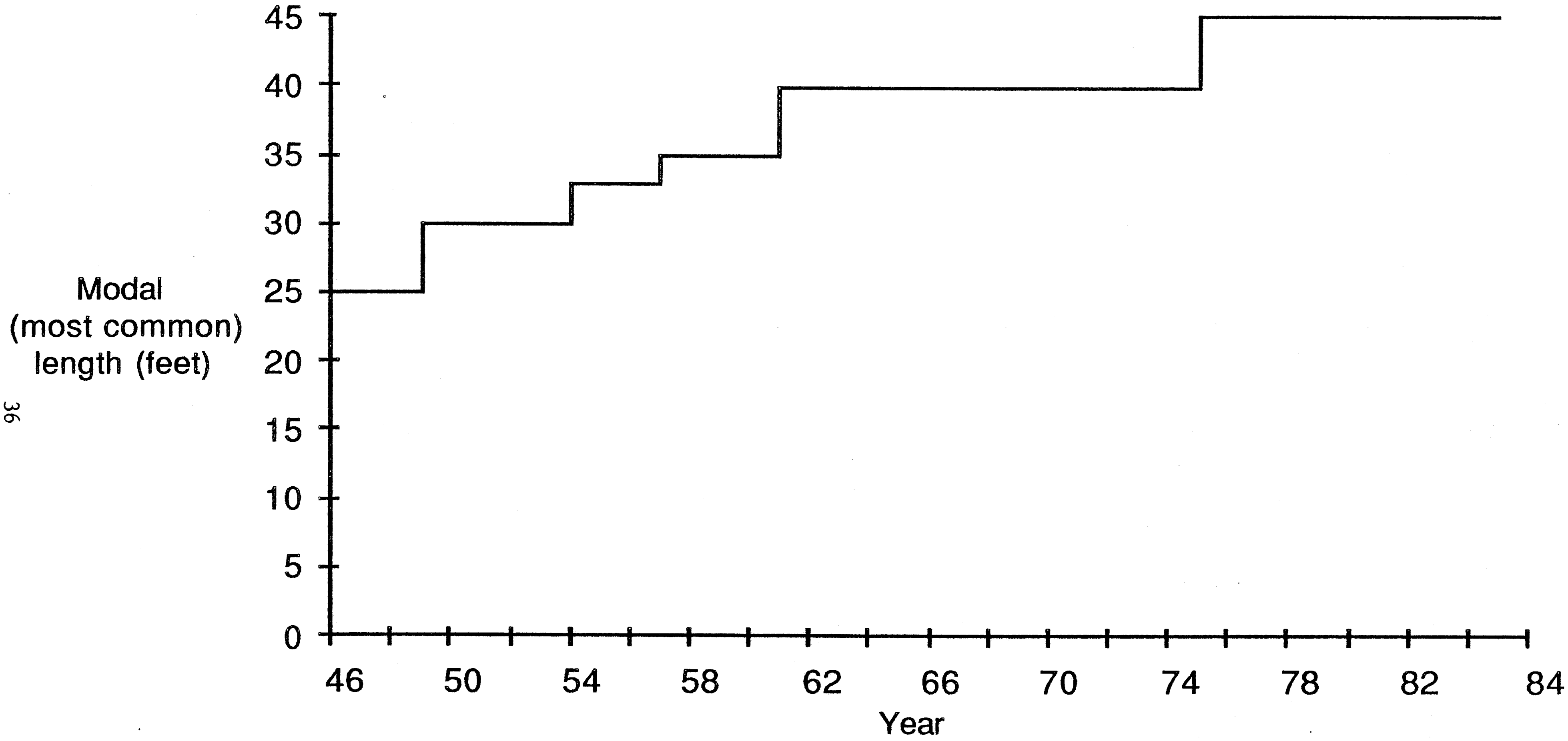


Fig. 5 Lengths of New Van Trailers Sold, 1946-1984

- vehicle selection
- selection of a set of professional drivers
- adaptation of the drivers to differing vehicles
- sequence of truck movements at each site
- method for measuring intrusions
- means for measuring changes in traffic flow due to truck operation
- means for characterizing the accident hazard introduced by truck intrusions

Task 3, Field Tests -- The selected trucks and drivers would be employed to operate over each of the chosen sites in a manner directed by the test procedure. Field data would be collected for analysis in Task 4. The scope of the field exercise is seen as involving some ten to twenty sites, six commercial vehicles, and perhaps six drivers who would be circulated through the differing vehicles.

Task 4, Data Analysis -- The gathered field data would be analyzed and a projection of the statewide impacts would be achieved by means of relating the results for individual sites to the distribution of site design categories across the State.

Task 5, Report -- The study would be documented in a report which serves to lay out the basis for reviewing the burdens imposed on the State by prospective future changes in truck dimensions.

A study of this scope is estimated to cost on the order of $150,000 and to require a time period of approximately 18 months.

3.7.2 A Study of 53' Semitrailers with Slider Bogies

The objective of this study would be to examine the dynamic behavior of 53' semitrailer combinations in which the trailer wheelbase is shorter than the 40.5' value recommended for allowance in the pending legislation. The study would address wheelbase values down to approximately 33' in order to explore the behavior of vehicles equipped with slider tandem bogies such as the industry may desire.

The rationale for this study is premised simply upon the limited analytical results presented earlier in this report. Namely, it was shown that 53' semitrailers with wheelbase values approaching 30' tend to exhibit degraded yaw response properties. Due to the limited scope of the current effort, it was not possible to suitably examine the degraded properties of the shorter wheelbase versions of 53' semitrailers. Recognizing that the trucking industry may find it hard to fully utilize 53' semis without being free to slide the bogie forward at tight intersections, the study is warranted as a step in making the vehicle maximally productive. The project would yield a definitive recommendation on the minimum trailer wheelbase that should be permitted with 53' semitrailers.

Task Statements

Task 1, In-Depth Analysis of 53' Semitrailers with Slider Bogies -- The dynamic properties of 53' semitrailers having wheelbase values from 33' to 40.5' would be examined by means of computer simulation in order to identify the major control issues which are at stake. The results of this analysis would be used to guide a full-scale test exercise in Task 2.

Task 2, Full-Scale Dynamic Tests -- A 53' semitrailer with slider tandem bogie would be obtained and instrumented for full-scale testing. The vehicle would be operated first in a proving grounds environment for exploration of dynamic response and driver sensation of any anomalous behavior. On the basis of both test and analytical results, judgements would be made as to the minimum value of trailer wheelbase which seems prudent to employ in general usage. The vehicle would be operated on the public road system at this minimum wheelbase value in order to obtain driver testimony and direct field observations with the vehicle.

Task 3, Final Report -- The results and methods of the study would be documented, together with a specific recommendation of that minimum value of trailer wheelbase which should be allowed in Michigan. The study results would also provide a careful delineation of the general issues posed by forward bogie placement on longer semitrailers. The generalized information would serve to guide the evaluation of any future trailer dimensional issues of this kind.

This research effort would cost approximately $75,000 and require a 1 year effort.

3.7.3 Study of the Dynamics of Multi-axle, 53' Semitrailers

The objective of this study would be to examine the dynamic behavior of 53' semitrailers having from 3 to 8 semitrailer axles.

The rationale for this study derives from the possible appeal which the multi-axle versions of the 53' semitrailer would have for the Michigan trucking industry. Multi-axle (more than two-axle) trailers are attractive among the shippers of dense commodities, thus allowing gross vehicle weights in the range between 80,000 lbs and approximately 154,000 lbs, depending upon the number of trailer axles. Prior UMTRI consideration of vehicles in this general class indicates that there are reasons for concern over certain response properties of such vehicles. The increase of bed length to 53' poses response mechanisms which have the potential for aggravating certain of these properties. The question addressed in this study is, "how serious are these aggravations and should constraints be placed upon the configuration of 53' semitrailers with more than two trailer axles?" The study would examine Michigan-specific vehicle cases by way of extension of the work which is currently underway at UMTRI on somewhat analogous Canadian vehicles.

<u>Task Statements</u>

Task 1, <u>Simulation of Multi-axle Units</u> -- Differing configurations of multi-axle, 53' semitrailers would be defined with variations in axle placement geometry and loading. The vehicle configurations would span the range from 3 to 8 semitrailer axles and from 80,000 to 154,000 lbs in gross combination weight. Simulated maneuvers would be selected to study the peculiar response features in which the multi-axle and high-load parameters of the vehicle are known to influence behavior.

Task 2, <u>Evaluation of Results</u> -- The results of the simulation study would be evaluated to determine specific constraints on vehicle configuration which may be warranted. The general implications of longer, multi-axle vehicle configurations would be outlined so as to guide future consideration of such vehicles in Michigan.

Task 3, <u>Final Report</u> -- The findings of the study would be documented, together with a specific legislative recommendation for allowance of multi-axle, 53' semitrailers in the State.

This study is estimated to cost approximately $100,000 and to require a term of 18 months.

4.0 CONCLUSIONS

1. The 53' trailer operated with its axles in the full rearward position (45.5' wheelbase from kingpin to center of the rear axles) will experience significant offtracking intrusion at intersection turns on Michigan highways. Making the reference AASHTO turn prescribed for the design of rural intersections, the intrusion is as much as 5 feet over the curb. To operate in such environments, the vehicle combination must transgress other traffic lanes thus creating impediments and hazards for other traffic.

2. The 53' trailer operated with the its axles centered 9.5' forward of the rear (40.5' wheelbase) performs equivalent to the currently permitted 48' trailer in offtracking at intersection turns. With this axle position, the dynamic turning behavior at high speed is also comparable to the 48' trailer.

3. To negotiate intersections designed according to the AASHTO WB-50 method, both the 48' trailer and the 53' trailer with 9.5' axle position will completely "use up" the 2' lane margins that have been provided for the design path of the tractor. If these vehicles are to negotiate the turns along the intended path leaving clearances between tire paths and the lane edges, reconstruction of the intersections would be required.

4. Operation of 53' trailers with the axles significantly more forward than the 9.5' position will degrade high- and low-speed turning performance in the form of significant outboard offtracking of the rear extremity of the trailer. Such axle positioning could arise on trailers with slider bogies installed forward of the 9.5' position to allow improved maneuverability in close quarters. The scope of this project did not allow identification of a maximum acceptable forward position of the bogie, although it is known that problems may arise with regard to a) increased tendency toward oscillatory behavior, b) lane intrusions of the rear trailer overhang in low- and high-speed turns, and c) propensity to jackknife on slippery surfaces.

5. Some additional costs may accrue to the fleet owner operating 53' trailers with the 9.5' axle position advisable from this study. Inasmuch as the trailer will operate permanently with approximately 5.5' of rear overhang, the application of a rear underride guard is advised. Increased costs on the order of $50 per unit have been estimated for this feature. The forward axle placement also impacts on the ability to utilize the trailer most efficiently when hauling homogeneous products in the range of density between 11 and 16 lb/ft^3. Under these special conditions, the distribution of load in the trailer does not permit

the tractor to be fully loaded, with the consequence that the unit will be limited to less than 80,000 lb gross combination weight.

6. The use of 53' trailers in lieu of 48' trailers will impose a 20 percent increase in pavement damage and costs. This estimate includes adjustment for the different number of each type of trailer required to transport a given amount of freight. The additional highway costs are estimated to fall between 0.3 and 1.3 million dollars per year for each one percent of 48' trailers replaced by 53' units.

7. The behavior of 53' trailers with multiple (3 or more) axles has not been studied sufficiently to predict safety performance at this time. Nevertheless, certain safety and control problems are known to be of concern, suggesting the need to further study their performance before permitting such vehicles in the state.

8. The impact of offtracking conflicts at intersections cannot be well quantified at this time with the limited knowledge available. A field study is warranted to provide information by which to make objective estimates of the true costs of operating longer truck combinations on Michigan roads. This study should include assessments of traffic delays, safety hazards, intersection reconstruction costs, and truck driver practices.

5.0 RECOMMENDATIONS

5.1 Recommended Provisions in the Law Permitting 53' Trailers in the State of Michigan

It is recommended that any legislative act which permits the operation of 53' trailers in the State of Michigan should include the following provisos:

- the semitrailers shall have a wheelbase of 40.5' plus or minus 0.5', measured from the kingpin coupling to the center of the rear axles (or to the center of the tandem axle assembly if equipped with two axles).

- the semitrailer shall have no more than 2 axles.

- the semitrailer shall include a structure across its rear extremity sufficient to prevent underride of other vehicles.

5.2 Recommendations for Future Study

Research and/or field studies as described elsewhere in this report are warranted in the following areas:

1. Studies of intersection offtracking conflicts - to develop information and methods by which to evaluate the true costs of allowing operation of 48' and longer trailers in the State.

2. Studies of trailer dynamics with forward axle positions - to identify safety deficiencies incident to this mode of operation so that benefits in maneuverability can be balanced against safety in both low- and high-speed travel.

3. Studies of the dynamic behavior of 53' multiple-axle trailers - to provide information to guide future legislative actions in permitting such vehicles.

6.0 REFERENCES

1) M. W. Sayers, "Vehicle Off-Tracking Models," Presentation at the Symposium on Geometric Design for Large Trucks, TRB Meeting in Denver, Colorado, August 5-7, 1985.

2) T. D. Gillespie and C. C. MacAdam, "Constant Velocity Yaw/Roll Program," The University of Michigan Transportation Research Institute, Report No. UMTRI-82-39, October 1982.

3) C. C. MacAdam, et al, "A Computerized Model for Simulating the Braking and Steering Dynamics of Trucks, Tractor-Semitrailers, Doubles, and Triples Combinations - User's Manual - Phase 4," The University of Michigan Transportation Research Institute, Report No. UMTRI-80-58, September 1980.

4) R. D. Ervin, "Influence of Size and Weight Variables on the Roll Stability of Heavy Duty Trucks," SAE Paper No. 831163, 1983.

5) R. D. Ervin, et al., "Future Configurations of Tank Vehicles Hauling Flammable Liquids in Michigan," The University of Michigan Transportation Research Institute, Report No. UM-HSRI-80-73-1, December 1980.

6) "A Study of the Effects of Truck Weights and Dimensions on Stability and Control," Study underway for the Roads and Transportation Association of Canada, Completion scheduled for September 1986.

7) D. J. Minahan, and J. O'Day, "Comparison of Michigan Fatal and Non-fatal Car-into-Truck Accidents," The University of Michigan Transportation Research Institute, Report No. UM-HSRI-79-49, November 1979.

8) Notice of Proposed Rulemaking, FMVSS for Rear Underride Protection, Federal Register, Vol. 46, No. 5, Jan. 8, 1981.

9) Interim Guide for the Design of Pavement Structures, [Revised], American Association of State Highway and Transportation Officials, 1981.

10) Final Report on the Federal Highway Cost Allocation Study, Report of the Secretary of Transportation to the United States Congress, May 1982.

11) Truck Trailer Manufacturers Association, Trailer Length Survey, 1984.

12) Current research study entitled "Operation of Trucks on Roads and Streets with Restrictive Geometry," sponsored by the Federal Highway Administration and conducted by Goodell-Grivas, Inc., Southfield, Mich.

APPENDIX A

VEHICLE PARAMETER DATA FILES

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***********************************
*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 1A

\# OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 76632.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	242.30	48.37		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

\# OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 1A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11765.51	15436.27	15436.27					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 1A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57562.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 254681.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3848275.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3848275.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.37 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	16996.97	16996.97	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-183.70	-231.70	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

```
*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************

MDOT Tractor-Semitrailer - Case No. 1C

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   68598.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H

PEAK FRICTIONAL COEFFICIENT    = 0.79

                                         DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                         OF SPRUNG MASS   SPRUNG MASS    (IN.LB/DEG)       CONSTRAINT
                                         C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                  -105.10           -8.00    9999997.00           1
ARTICULATION PT # 1
                 ON UNIT # 2                   243.20           47.45

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)        =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)        =  11000.00

MECHANICAL TRAIL (IN)         =       1.00

# OF POINTS IN STEER TABLE    = 5

     TIME         STEERING WHEEL
     SEC             DEGREES
      0.0         0.0
      0.10        2.00
      0.19        2.00
      0.20        0.0
     10.00        0.0
```

MDOT Tractor-Semitrailer - Case No. 1C

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11448.25	13691.31	13691.31					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 1C

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 49528.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 221981.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3325431.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3325431.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.45 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	14883.57	14883.57	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-182.80	-230.80	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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********************************
*DIRECTIONAL RESPONSE SIMULATION*
********************************

MDOT Tractor-Semitrailer - Case No. 2A

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   66302.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H

PEAK FRICTIONAL COEFFICIENT   = 0.79

                                        DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                        OF SPRUNG MASS   SPRUNG MASS   (IN.LB/DEG)        CONSTRAINT
                                        C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                 -105.10          -8.00   9999997.00           1
ARTICULATION PT # 1
                 ON UNIT # 2                  240.20          47.14

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE   = 5

     TIME         STEERING WHEEL
     SEC              DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 2A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10904.37	10700.01	10700.01					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 2A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 47232.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 212586.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3015473.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3015473.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.14 INCHES

	AXLE # 4	AXLE.# 5	AXLE #	*********	*********	*********	*********	*********
	*********	*********	*********					
LOAD ON EACH AXLE (LB.)	16998.81	16998.81						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-101.80	-149.80						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************

MDOT Tractor-Semitrailer - Case No. 3A

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   76790.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                         DISTANCE AHEAD   HEIGHT BELOW    ROLL STIFFNESS    TYPE OF
                                         OF SPRUNG MASS   SPRUNG MASS    (IN.LB/DEG)        CONSTRAINT
                                         C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                 -105.10           -8.00      9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2                  261.00           48.18

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE    = 5

     TIME         STEERING WHEEL
     SEC              DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 3A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11778.36	15506.93	15506.93					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 3A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57720.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 255929.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4384242.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4384242.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.18 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	16998.89	16998.89						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-201.00	-249.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

****
DIRECTIONAL RESPONSE SIMULATION
****

MDOT Tractor-Semitrailer - Case No. 3C

OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 71752.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	261.90	47.62		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 3C

UNIT # 1

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11575.86	14393.20	14393.20					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 3C

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 52682.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 235419.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4012604.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4012604.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.62 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	15694.87	15694.87	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-200.10	-248.10	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 4A

OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 67198.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	258.90	47.02		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 4A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10979.18	11111.47	11111.47					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 4A

UNIT # 2

****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 48128.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 216792.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3499294.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3499294.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.02 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	16997.93	16997.93	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-119.10	-167.10	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

****
DIRECTIONAL RESPONSE SIMULATION
****

MDOT Tractor-Semitrailer - Case No. 5A

\# OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 76883.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	273.50	48.05		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

\# OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 5A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11785.62	15546.87	15546.87					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 5A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57813.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 256707.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4761386.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4761386.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.05 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	17001.82	17001.82						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-212.50	-260.50						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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**********************************
*DIRECTIONAL RESPONSE SIMULATION*
**********************************

MDOT Tractor-Semitrailer - Case No. 5C

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   73854.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT   = 0.79
```

	DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1 ON UNIT # 1	-105.10	-8.00	9999997.00	1
ARTICULATION PT # 1 ON UNIT # 2	274.00	47.72		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)      =  11000.00

MECHANICAL TRAIL (IN)       =      1.00

# OF POINTS IN STEER TABLE    = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 5C

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11664.09	14878.47	14878.47					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 5C

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 54784.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 244374.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4519470.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4519470.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.72 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	16216.49	16216.49						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-212.00	-260.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

****
DIRECTIONAL RESPONSE SIMULATION
****

MDOT Tractor-Semitrailer - Case No. 6A

OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 65111.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	270.70	46.53		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 6A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10804.65	10151.56	10151.56					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 6A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 46041.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 208559.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3593350.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3593350.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 94.53 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	17001.62	17001.62						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-107.30	-155.30						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************

MDOT Tractor-Semitrailer - Case No. 6B

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   76883.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                      DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                      OF SPRUNG MASS    SPRUNG MASS   (IN.LB/DEG)       CONSTRAINT
                                      C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1              -105.10          -8.00      9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2               269.30          48.05

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE    = 5

     TIME         STEERING WHEEL
     SEC             DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 6B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11141.84	12006.10	12006.10					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 6B

UNIT # 2

****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57813.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 256707.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4531770.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4531770.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.05 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	20864.48	20864.48	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-108.70	-156.70	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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**********************************
*DIRECTIONAL RESPONSE SIMULATION*
**********************************

MDOT Tractor-Semitrailer - Case No. 7A

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   80361.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H

PEAK FRICTIONAL COEFFICIENT    = 0.79

                                     DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                     OF SPRUNG MASS    SPRUNG MASS   (IN.LB/DEG)       CONSTRAINT
                                     C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1              -110.60          -8.00     9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2               249.00          48.32

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE    = 5

     TIME        STEERING WHEEL
     SEC            DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 7A

UNIT # 1

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3
LOAD ON EACH AXLE (LB.)	11383.43	17491.87	17491.87
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00
HALF SPRING SPACING (IN)	16.00	19.00	19.00
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50
DUAL TIRE SPACING (IN)	0.0	13.00	13.00
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00
ROLL STEER COEFFICIENT	0.0	0.0	0.0
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0
SPRING TABLE #	1	2	2
CORNERING FORCE TABLE #	1	1	1
ALIGNING TORQUE TABLE #	1	1	1

MDOT Tractor-Semitrailer - Case No. 7A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60494.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 267600.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4975486.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4975486.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.32 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	16996.92	16996.92						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-213.00	-261.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************


MDOT Tractor-Semitrailer - Case No. 7C

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   74651.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                      DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS   TYPE OF
                                      OF SPRUNG MASS   SPRUNG MASS    (IN.LB/DEG)      CONSTRAINT
                                      C.G. (INCHES)   C.G. (INCHES)

            ON UNIT # 1                   -110.60          -8.00     9999997.00          1
ARTICULATION PT # 1
            ON UNIT # 2                    250.00          47.72

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE    = 5

     TIME        STEERING WHEEL
     SEC            DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 7C

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11176.48	16146.72	16146.72					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 7C

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 54784.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 244374.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4519470.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4519470.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.72 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	15590.53	15590.53						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-212.00	-260.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 8A

```
# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   67413.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79
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		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-110.60	-8.00	9999997.00	1
	ON UNIT # 2	246.50	46.77		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE    = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 8A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10457.74	11474.87	11474.87					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 8A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 47546.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 214749.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3713289.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3713289.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 94.77 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	17002.76	17002.76						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-107.50	-155.50						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 8B

\# OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 80361.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-110.60	-8.00	9999997.00	1
	ON UNIT # 2	245.10	48.32		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

\# OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 8B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10795.48	13670.22	13670.22					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 8B

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60494.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 267600.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4745462.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4745462.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.32 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	21112.54	21112.54	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-108.90	-156.90	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 9A

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   77008.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                        DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                        OF SPRUNG MASS    SPRUNG MASS   (IN.LB/DEG)       CONSTRAINT
                                        C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                 -105.10          -8.00     9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2                  292.10          47.86

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)       =       1.00

# OF POINTS IN STEER TABLE    = 5

     TIME        STEERING WHEEL
     SEC             DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 9A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11796.69	15607.77	15607.77					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 9A

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57938.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 257803.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5356858.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5356858.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.86 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	16997.88	16997.88	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-229.90	-277.90	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 9C

\# OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 77008.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	292.10	47.86		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

\# OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 9C

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11796.69	15607.77	15607.77					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 9C

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57938.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 257801.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5356817.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5356817.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.86 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	16997.88	16997.88	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-229.90	-277.90	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************

MDOT Tractor-Semitrailer - Case No. 10A

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   67213.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H

PEAK FRICTIONAL COEFFICIENT   = 0.79
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	DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1 ON UNIT # 1	-105.10	-8.00	9999997.00	1
ARTICULATION PT # 1 ON UNIT # 2	289.80	46.61		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)      =  11000.00

MECHANICAL TRAIL (IN)      =      1.00

# OF POINTS IN STEER TABLE   = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 10A

UNIT # 1

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
LOAD ON EACH AXLE (LB.)	10979.75	11114.58	11114.58					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 10A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 48143.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 217714.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4251940.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4251940.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 94.61 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	17002.05	17002.05						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-136.20	-184.20						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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**********************************
*DIRECTIONAL RESPONSE SIMULATION*
**********************************

MDOT Tractor-Semitrailer - Case No. 10B

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   77008.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                         DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                         OF SPRUNG MASS   SPRUNG MASS    (IN.LB/DEG)       CONSTRAINT
                                         C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                 -105.10           -8.00    9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2                  288.50           47.86

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE    = 5

     TIME        STEERING WHEEL
     SEC            DEGREES
      0.0        0.0
      0.10       2.00
      0.19       2.00
      0.20       0.0
     10.00       0.0
```

MDOT Tractor-Semitrailer - Case No. 10B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11284.28	12789.51	12789.51					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 108

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57938.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 257803.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5127222.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5127222.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.86 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	20072.35	20072.35	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-137.50	-185.50	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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**********************************
*DIRECTIONAL RESPONSE SIMULATION*
**********************************

MDOT Tractor-Semitrailer - Case No. 11A

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   58641.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79
```

	DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1 ON UNIT # 1	-105.10	-8.00	9999997.00	1
ARTICULATION PT # 1 ON UNIT # 2	286.70	45.01		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE   = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 11A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10265.98	7188.87	7188.87					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 11A

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 39571.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 182168.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3370515.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3370515.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 93.01 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	16998.64	16998.64	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-55.30	-103.30	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************

MDOT Tractor-Semitrailer - Case No. 11B

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   77008.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT   = 0.79
```

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-105.10	-8.00	9999997.00	1
	ON UNIT # 2	285.20	47.86		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE   = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 11B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 10270.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 22400.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 73229.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10617.40	9121.64	9121.64					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	26.90	-92.10	-142.10					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 11B

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57938.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 257803.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5010011.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5010011.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.86 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	24073.66	24073.66	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-56.80	-104.80	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************


MDOT Tractor-Semitrailer - Case No. 12A

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   80311.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT   = 0.79


                                        DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                        OF SPRUNG MASS   SPRUNG MASS   (IN.LB/DEG)        CONSTRAINT
                                        C.G. (INCHES)   C.G. (INCHES)

                  ON UNIT # 1               -110.60          -8.00     9999997.00          1
ARTICULATION PT # 1
                  ON UNIT # 2                267.70          48.11

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)      =  11000.00

MECHANICAL TRAIL (IN)       =      1.00

# OF POINTS IN STEER TABLE    = 5

     TIME        STEERING WHEEL
     SEC            DEGREES
      0.0         0.0
      0.10        2.00
      0.19        2.00
      0.20        0.0
     10.00        0.0
```

MDOT Tractor-Semitrailer - Case No. 12A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11379.57	17466.81	17466.81					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 12A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60444.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 267999.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5581081.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5581081.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.11 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	16998.91	16998.91						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-230.30	-278.30						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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                  **********************************
                  *DIRECTIONAL RESPONSE SIMULATION*
                  **********************************

MDOT Tractor-Semitrailer - Case No. 12C

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   77805.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H

PEAK FRICTIONAL COEFFICIENT   = 0.79

                                          DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                          OF SPRUNG MASS   SPRUNG MASS    (IN.LB/DEG)       CONSTRAINT
                                          C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                  -110.60          -8.00      9999997.00            1
ARTICULATION PT # 1
                 ON UNIT # 2                   268.10          47.86

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)      =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE   = 5

     TIME         STEERING WHEEL
     SEC              DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 12C

UNIT # 1

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #
LOAD ON EACH AXLE (LB.)	11289.20	16879.38	16879.38	
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00	
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00	
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00	
HALF SPRING SPACING (IN)	16.00	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50	
DUAL TIRE SPACING (IN)	0.0	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.0	0.0	0.0	
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0	
SPRING TABLE #	1	2	2	
CORNERING FORCE TABLE #	1	1	1	
ALIGNING TORQUE TABLE #	1	1	1	

MDOT Tractor-Semitrailer - Case No. 12C

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 57938.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 257801.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5356817.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5356817.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.86 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	16378.52	16378.52						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-229.90	-277.90						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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**********************************
*DIRECTIONAL RESPONSE SIMULATION*
**********************************

MDOT Tractor-Semitrailer - Case No. 13A

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   72281.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                        DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                        OF SPRUNG MASS   SPRUNG MASS   (IN.LB/DEG)        CONSTRAINT
                                        C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1                 -110.60          -8.00    9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2                  266.20          47.21

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE    = 5

     TIME        STEERING WHEEL
     SEC            DEGREES
      0.0         0.0
      0.10        2.00
      0.19        2.00
      0.20        0.0
     10.00        0.0
```

MDOT Tractor-Semitrailer - Case No. 13A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10805.43	13734.89	13734.89					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 13A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 52414.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 235247.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 4681301.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 4681301.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.21 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	17002.90	17002.90	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-159.80	-207.80	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************


MDOT Tractor-Semitrailer - Case No. 13B

# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   80311.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79


                                        DISTANCE AHEAD  HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                        OF SPRUNG MASS  SPRUNG MASS   (IN.LB/DEG)        CONSTRAINT
                                        C.G. (INCHES)   C.G. (INCHES)

                  ON UNIT # 1                -110.60           -8.00   9999997.00          1
ARTICULATION PT # 1
                  ON UNIT # 2                 265.10           48.11

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE   = 5

     TIME        STEERING WHEEL
     SEC            DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 13B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11050.26	15326.25	15326.25					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 13B

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60444.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 267999.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5398985.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5398985.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.11 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	19304.12	19304.12	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-160.90	-208.90	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************

MDOT Tractor-Semitrailer - Case No. 14A

# OF SPRUNG MASSES      =  2

TOTAL # OF AXLES        =  5

GROSS VEHICLE WEIGHT    =   62912.00  LB.

FORWARD VELOCITY        =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT   = 0.79


                                       DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                       OF SPRUNG MASS   SPRUNG MASS    (IN.LB/DEG)       CONSTRAINT
                                       C.G. (INCHES)    C.G. (INCHES)

                  ON UNIT # 1              -110.60          -8.00      9999997.00            1
ARTICULATION PT # 1
                  ON UNIT # 2               263.60          45.74

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)      =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE    = 5

     TIME         STEERING WHEEL
     SEC              DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 14A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1 *********	AXLE # 2 *********	AXLE # 3 *********	AXLE # *********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10136.50	9386.84	9386.84					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 14A

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 43045.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 196646.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3705832.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3705832.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 93.74 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	17000.90	17000.90	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-78.40	-126.40	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

****
DIRECTIONAL RESPONSE SIMULATION
****

MDOT Tractor-Semitrailer - Case No. 14B

OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 80311.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-110.60	-8.00	9999997.00	1
	ON UNIT # 2	262.00	48.11		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 14B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10503.09	11769.63	11769.63					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 14B

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60444.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 267999.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5259218.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5259218.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 96.11 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	23134.33	23134.33						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-80.00	-128.00						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

****
DIRECTIONAL RESPONSE SIMULATION
****

MDOT Tractor-Semitrailer - Case No. 15A

OF SPRUNG MASSES = 2

TOTAL # OF AXLES = 5

GROSS VEHICLE WEIGHT = 80254.00 LB.

FORWARD VELOCITY = 55.00 M.P.H

PEAK FRICTIONAL COEFFICIENT = 0.79

		DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1	ON UNIT # 1	-110.60	-8.00	9999997.00	1
	ON UNIT # 2	292.60	47.85		

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

OPEN LOOP STEER INPUT
****

STEERING GEAR RATIO = 30.00

STEERING STIFFNESS (IN.LB/DEG) = 11000.00

TIE ROD STIFFNESS (IN.LB/DEG) = 11000.00

MECHANICAL TRAIL (IN) = 1.00

OF POINTS IN STEER TABLE = 5

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 15A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	11375.44	17439.95	17439.95					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 15A

UNIT # 2

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60387.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 268552.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 6444224.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 6444224.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.85 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
LOAD ON EACH AXLE (LB.)	16999.33	16999.33						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-253.40	-301.40						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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**********************************
*DIRECTIONAL RESPONSE SIMULATION*
**********************************

MDOT Tractor-Semitrailer - Case No. 16A

# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   69234.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT    = 0.79
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	DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1 ON UNIT # 1	-110.60	-8.00	9999997.00	1
ON UNIT # 2	290.10	46.48		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =     30.00

STEERING STIFFNESS (IN.LB/DEG)       =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE    = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 16A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = . 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10588.30	12323.53	12323.53					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 16A

UNIT # 2

\# OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 49367.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 223425.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 5028517.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 5028517.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 94.48 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	16999.31	16999.31	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-147.90	-195.90	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

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*********************************
*DIRECTIONAL RESPONSE SIMULATION*
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MDOT Tractor-Semitrailer - Case No. 16B

```
# OF SPRUNG MASSES        =  2

TOTAL # OF AXLES          =  5

GROSS VEHICLE WEIGHT      =   80254.00  LB.

FORWARD VELOCITY          =      55.00  M.P.H


PEAK FRICTIONAL COEFFICIENT   = 0.79


                                      DISTANCE AHEAD   HEIGHT BELOW   ROLL STIFFNESS    TYPE OF
                                      OF SPRUNG MASS   SPRUNG MASS   (IN.LB/DEG)        CONSTRAINT
                                      C.G. (INCHES)   C.G. (INCHES)

                 ON UNIT # 1               -110.60            -8.00    9999997.00          1
ARTICULATION PT # 1
                 ON UNIT # 2                288.60            47.85

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)       =  11000.00

MECHANICAL TRAIL (IN)        =      1.00

# OF POINTS IN STEER TABLE    = 5

     TIME         STEERING WHEEL
     SEC              DEGREES
      0.0          0.0
      0.10         2.00
      0.19         2.00
      0.20         0.0
     10.00         0.0
```

MDOT Tractor-Semitrailer - Case No. 16B

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	10895.18	14318.27	14318.27					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 16B

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 60387.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 268552.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 6163902.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 6163902.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 95.85 INCHES

	AXLE # 4	AXLE # 5	AXLE #
LOAD ON EACH AXLE (LB.)	20361.13	20361.13	
AXLE WEIGHT (LB.)	1500.00	1500.00	
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00	
X DIST FROM SP MASS CG (IN)	-149.40	-197.40	
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00	
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00	
HALF SPRING SPACING (IN)	19.00	19.00	
HALF TRACK - INNER TIRES (IN)	29.50	29.50	
DUAL TIRE SPACING (IN)	13.00	13.00	
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	
ROLL STEER COEFFICIENT	0.23	0.23	
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00	
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00	
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0	
SPRING TABLE #	3	3	
CORNERING FORCE TABLE #	1	1	
ALIGNING TORQUE TABLE #	1	1	

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

```
*********************************
*DIRECTIONAL RESPONSE SIMULATION*
*********************************
```

MDOT Tractor-Semitrailer - Case No. 17A

```
# OF SPRUNG MASSES       =  2

TOTAL # OF AXLES         =  5

GROSS VEHICLE WEIGHT     =   59438.00  LB.

FORWARD VELOCITY         =      55.00  M.P.H

PEAK FRICTIONAL COEFFICIENT   = 0.79
```

	DISTANCE AHEAD OF SPRUNG MASS C.G. (INCHES)	HEIGHT BELOW SPRUNG MASS C.G. (INCHES)	ROLL STIFFNESS (IN.LB/DEG)	TYPE OF CONSTRAINT
ARTICULATION PT # 1 ON UNIT # 1	-110.60	-8.00	9999997.00	1
ON UNIT # 2	286.70	44.61		

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

OPEN LOOP STEER INPUT
*********************

STEERING GEAR RATIO  =      30.00

STEERING STIFFNESS (IN.LB/DEG)      =  11000.00

TIE ROD STIFFNESS (IN.LB/DEG)      =  11000.00

MECHANICAL TRAIL (IN)        =       1.00

# OF POINTS IN STEER TABLE    = 5
```

TIME SEC	STEERING WHEEL DEGREES
0.0	0.0
0.10	2.00
0.19	2.00
0.20	0.0
10.00	0.0

MDOT Tractor-Semitrailer - Case No. 17A

UNIT # 1
****

OF AXLES ON THIS UNIT = 3

WEIGHT OF SPRUNG MASS = 11067.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 24100.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 111272.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 40.00 INCHES

	AXLE # 1	AXLE # 2	AXLE # 3	AXLE #				
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	9888.68	7776.02	7776.02					
AXLE WEIGHT (LB.)	1200.00	2300.00	2300.00					
AXLE ROLL M.I (LB.IN.SEC**2)	3700.00	4458.00	4458.00					
X DIST FROM SP MASS CG (IN)	45.40	-97.60	-147.60					
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	19.50	19.50					
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	18.25	29.00	29.00					
HALF SPRING SPACING (IN)	16.00	19.00	19.00					
HALF TRACK - INNER TIRES (IN)	40.00	29.50	29.50					
DUAL TIRE SPACING (IN)	0.0	13.00	13.00					
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00	4500.00					
ROLL STEER COEFFICIENT	0.0	0.0	0.0					
AUX ROLL STIFFNESS (IN.LB/DEG)	8700.00	8000.00	8000.00					
SPRING COULOMB FRICTION - PER SPRING (LB)	475.00	1000.00	1000.00					
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	28.00	0.0	0.0					
SPRING TABLE #	1	2	2					
CORNERING FORCE TABLE #	1	1	1					
ALIGNING TORQUE TABLE #	1	1	1					

MDOT Tractor-Semitrailer - Case No. 17A

UNIT # 2
****

OF AXLES ON THIS UNIT = 2

WEIGHT OF SPRUNG MASS = 39571.00 LB.

ROLL MOMENT OF INERTIA OF SPRUNG MASS = 182694.00 LB.IN.SEC**2

PITCH MOMENT OF INERTIA OF SPRUNG MASS = 3880837.00 LB.IN.SEC**2

YAW MOMENT OF INERTIA OF SPRUNG MASS = 3880837.00 LB.IN.SEC**2

HEIGHT OF SPRUNG MASS CG ABOVE GROUND = 92.61 INCHES

	AXLE # 4	AXLE # 5	AXLE #					
	*********	*********	*********	*********	*********	*********	*********	*********
LOAD ON EACH AXLE (LB.)	16998.64	16998.64						
AXLE WEIGHT (LB.)	1500.00	1500.00						
AXLE ROLL M.I (LB.IN.SEC**2)	4100.00	4100.00						
X DIST FROM SP MASS CG (IN)	-55.30	-103.30						
HEIGHT OF AXLE C.G. ABOVE GROUND (INCHES)	20.00	20.00						
HEIGHT OF ROLL CENTER ABOVE GROUND (INCHES)	27.00	27.00						
HALF SPRING SPACING (IN)	19.00	19.00						
HALF TRACK - INNER TIRES (IN)	29.50	29.50						
DUAL TIRE SPACING (IN)	13.00	13.00						
STIFFNESS OF EACH TIRE (LB/IN)	4500.00	4500.00						
ROLL STEER COEFFICIENT	0.23	0.23						
AUX ROLL STIFFNESS (IN.LB/DEG)	9000.00	9000.00						
SPRING COULOMB FRICTION - PER SPRING (LB)	750.00	750.00						
VISCOUS DAMPING PER SPRING (LB.SEC/IN)	0.0	0.0						
SPRING TABLE #	3	3						
CORNERING FORCE TABLE #	1	1						
ALIGNING TORQUE TABLE #	1	1						

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

FORCE LB	DEFLECTION INCHES
-20550.00	-15.00
-1170.00	-0.75
-150.00	0.0
1250.00	1.00
2550.00	2.00
3825.00	3.00
6925.00	6.50
9896.15	8.50
19176.75	15.50

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

FORCE LB	DEFLECTION INCHES
-11612.50	-10.00
-5362.50	-5.00
-50.00	-0.75
-50.00	0.0
1400.00	0.50
5550.00	1.50
8100.00	2.00
29188.50	6.50
36235.50	8.00

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

FORCE LB	DEFLECTION INCHES
-34112.50	-20.00
-350.00	-1.75
125.00	0.0
1300.00	0.50
3575.00	1.00
6500.00	1.50
28971.87	5.00

CORNERING FORCE TABLE # 1
********* ***** *********

LATERAL FORCE VS. SLIP ANGLL

0.0	1.00	2.00	4.00	8.00	12.00
1983.00	356.94	634.56	1070.82	1526.91	1804.53
5967.00	835.38	1611.09	2804.49	3938.22	4355.91
9441.00	944.10	1793.79	3398.76	5192.55	5759.01

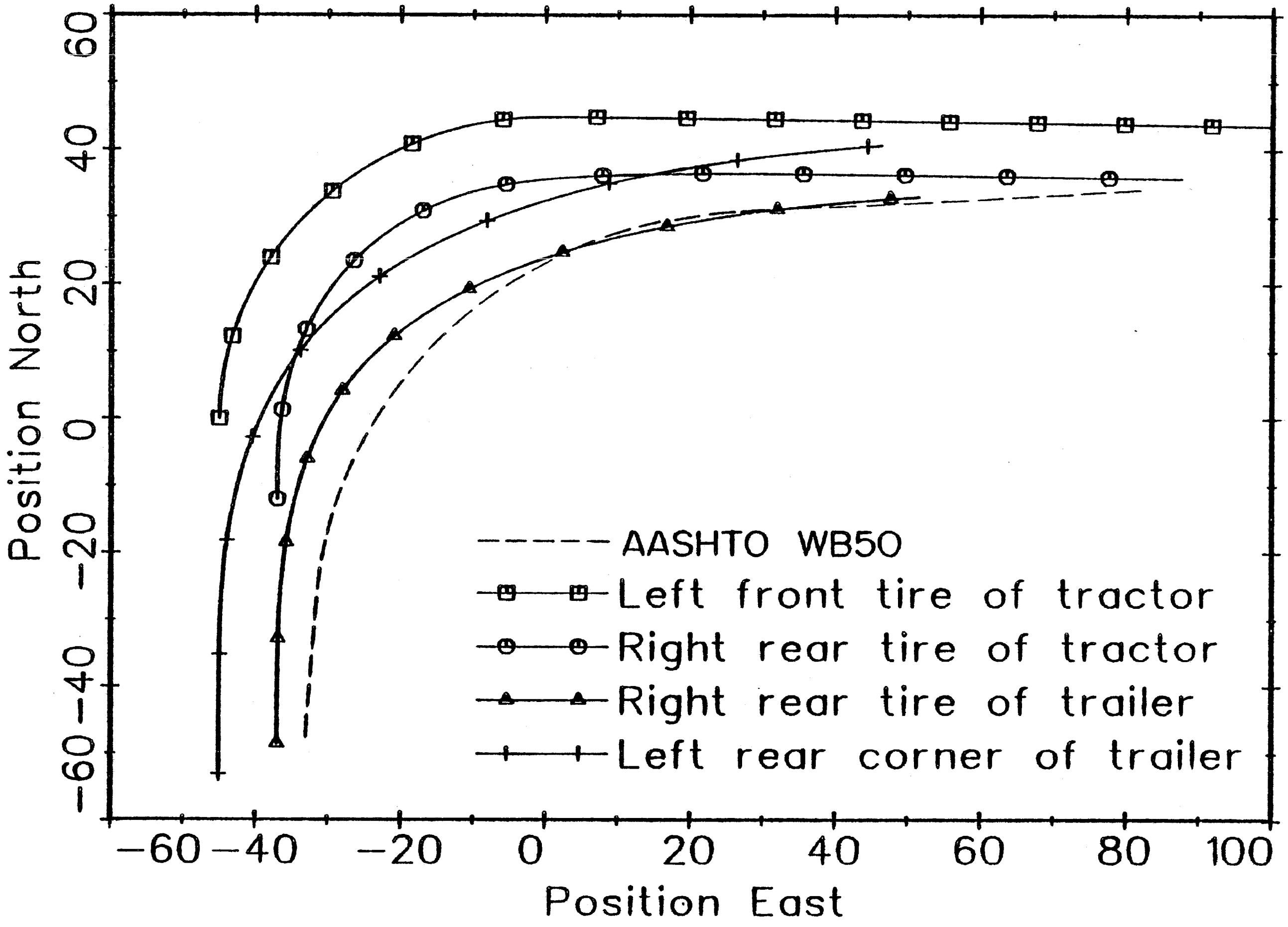
ALIGNING TORQUE TABLE # 1
******** ****** *********

ALIGNING TORQUE VS. SLIP ANGLE

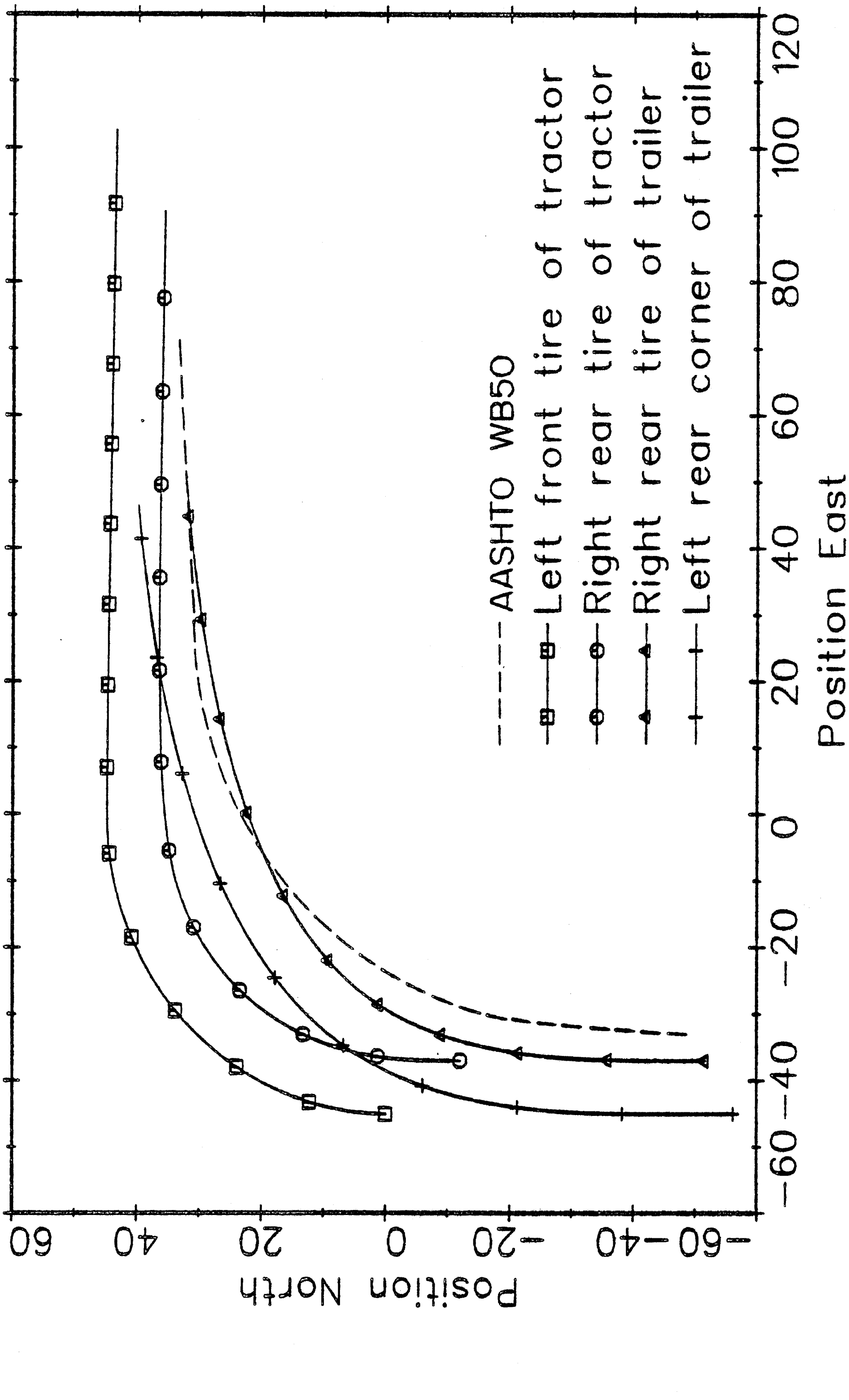
0.0	1.00	2.00	4.00	8.00	12.00
2000.00	336.00	528.00	660.00	444.00	252.00
3980.00	1020.00	1716.00	2256.00	1728.00	1092.00
5970.00	1764.00	3156.00	4344.00	3240.00	2184.00
7950.00	2484.00	4608.00	6720.00	5304.00	3576.00
9440.00	3000.00	5616.00	8604.00	7104.00	4620.00

APPENDIX B

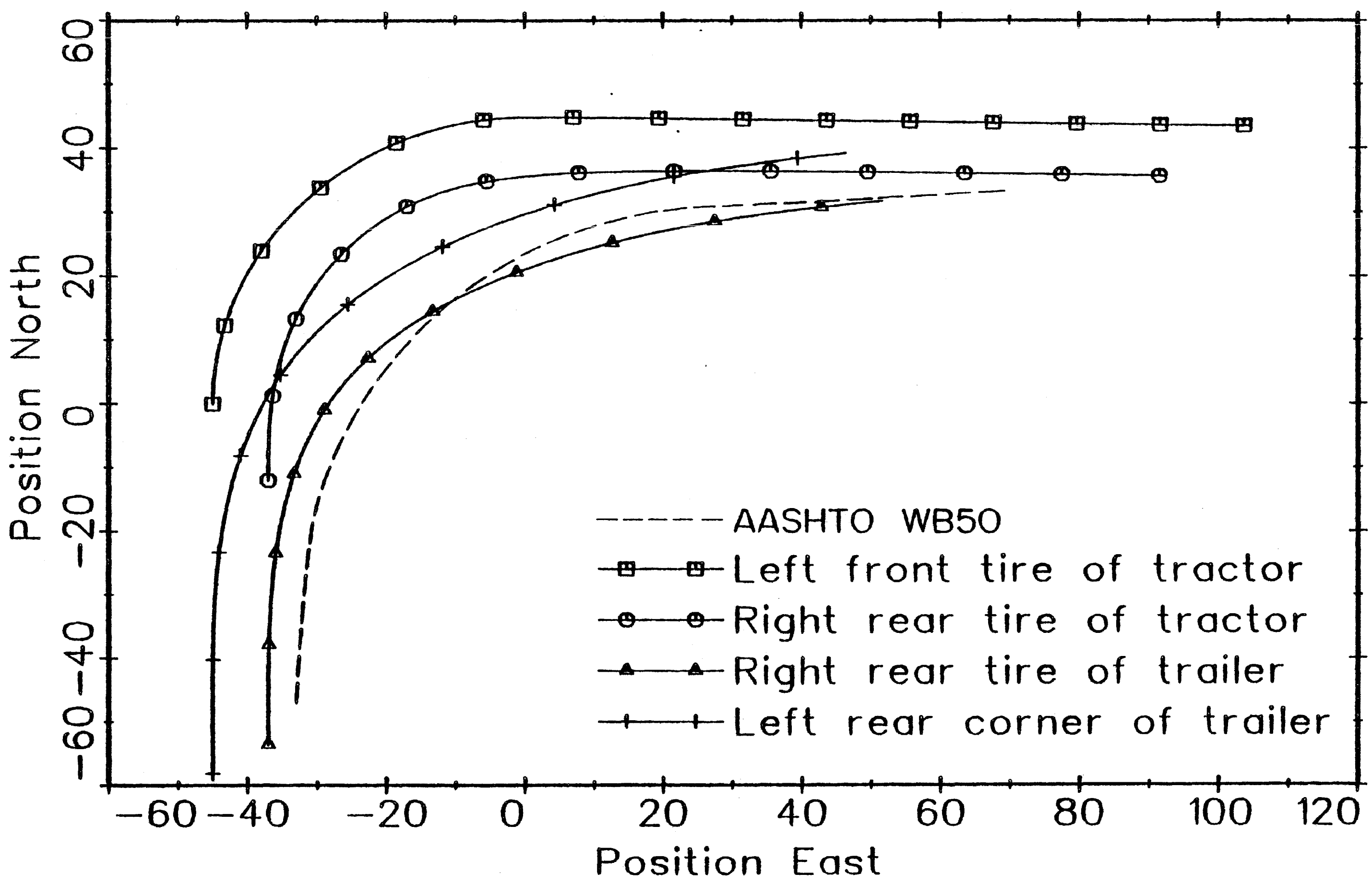
LOW-SPEED OFFTRACKING IN AN AASHTO WB50 INTERSECTION



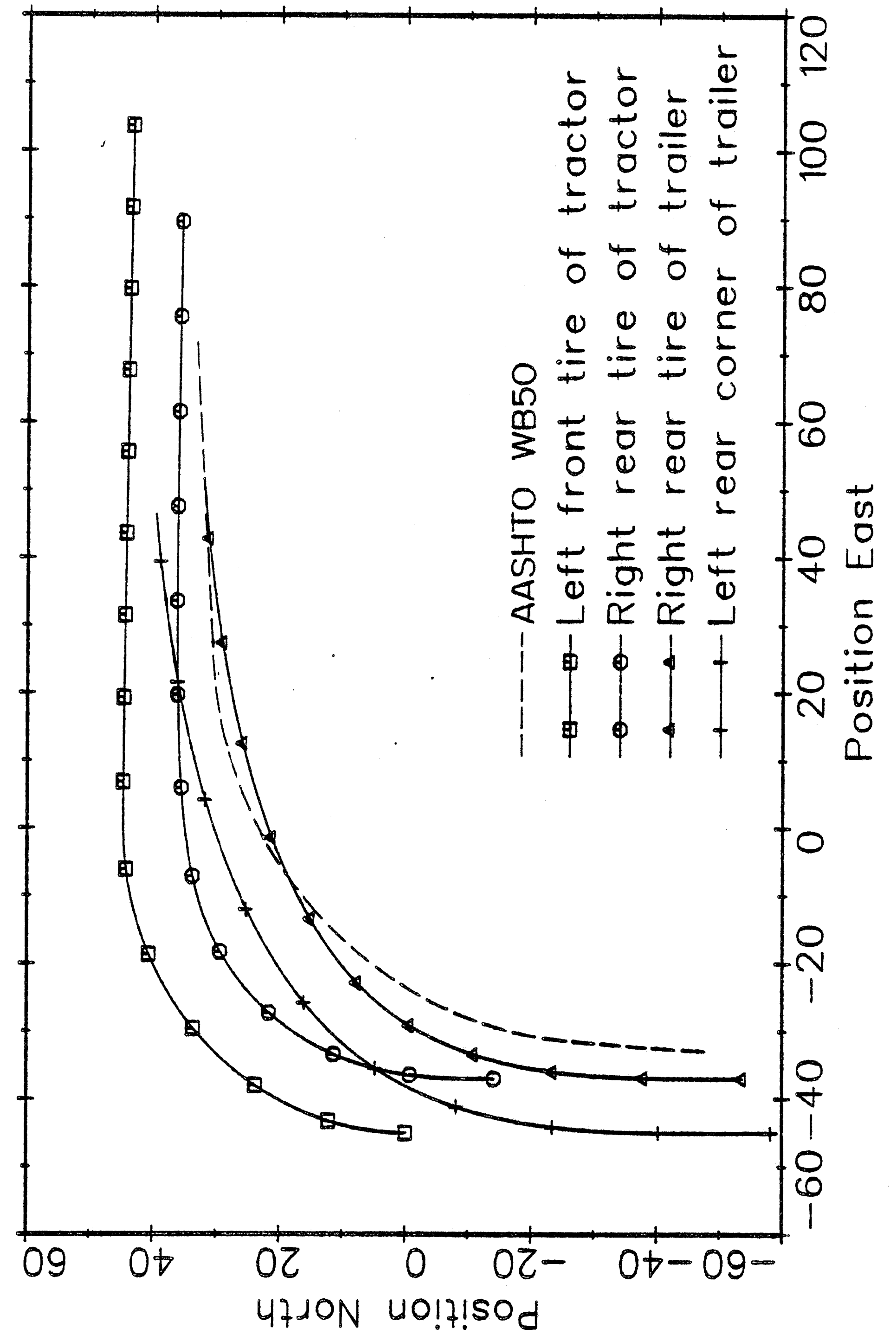
Impact of 53 ft Truck/Trailers in Michigan – Case No. 1



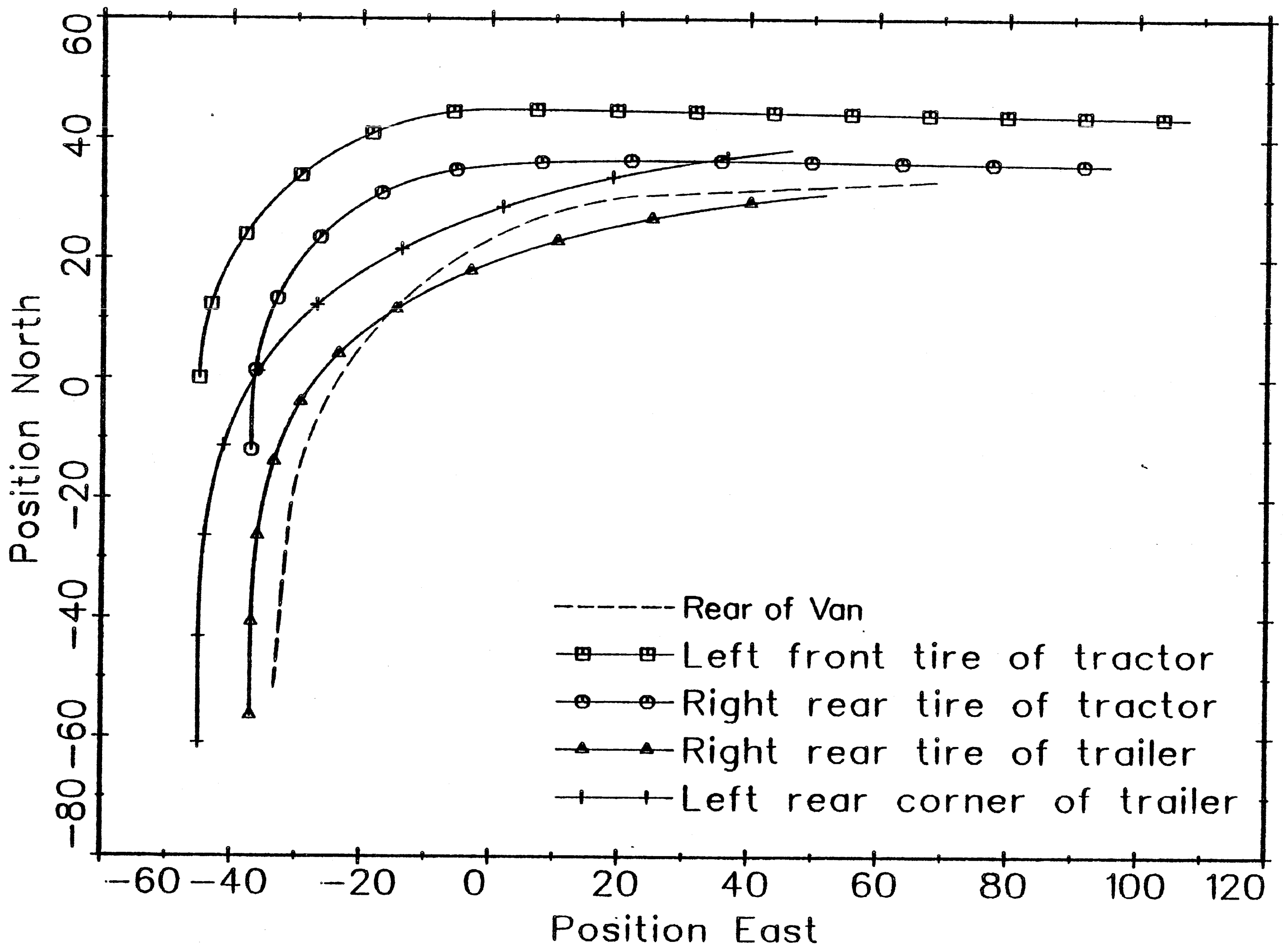
Impact of 53 ft Truck/Trailers in Michigan — Case No. 3



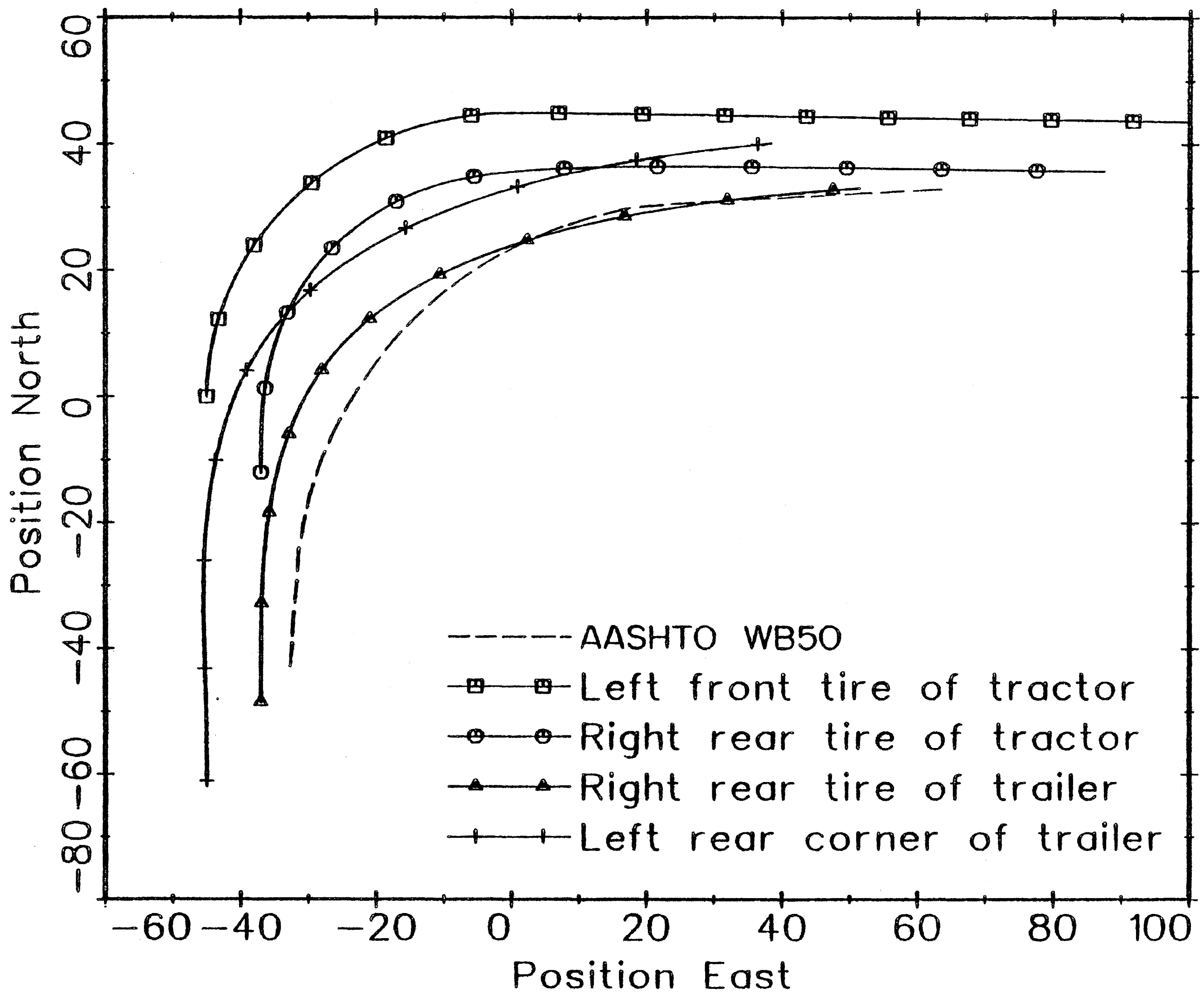
Impact of 53 ft Truck/Trailers in Michigan – Case No. 5



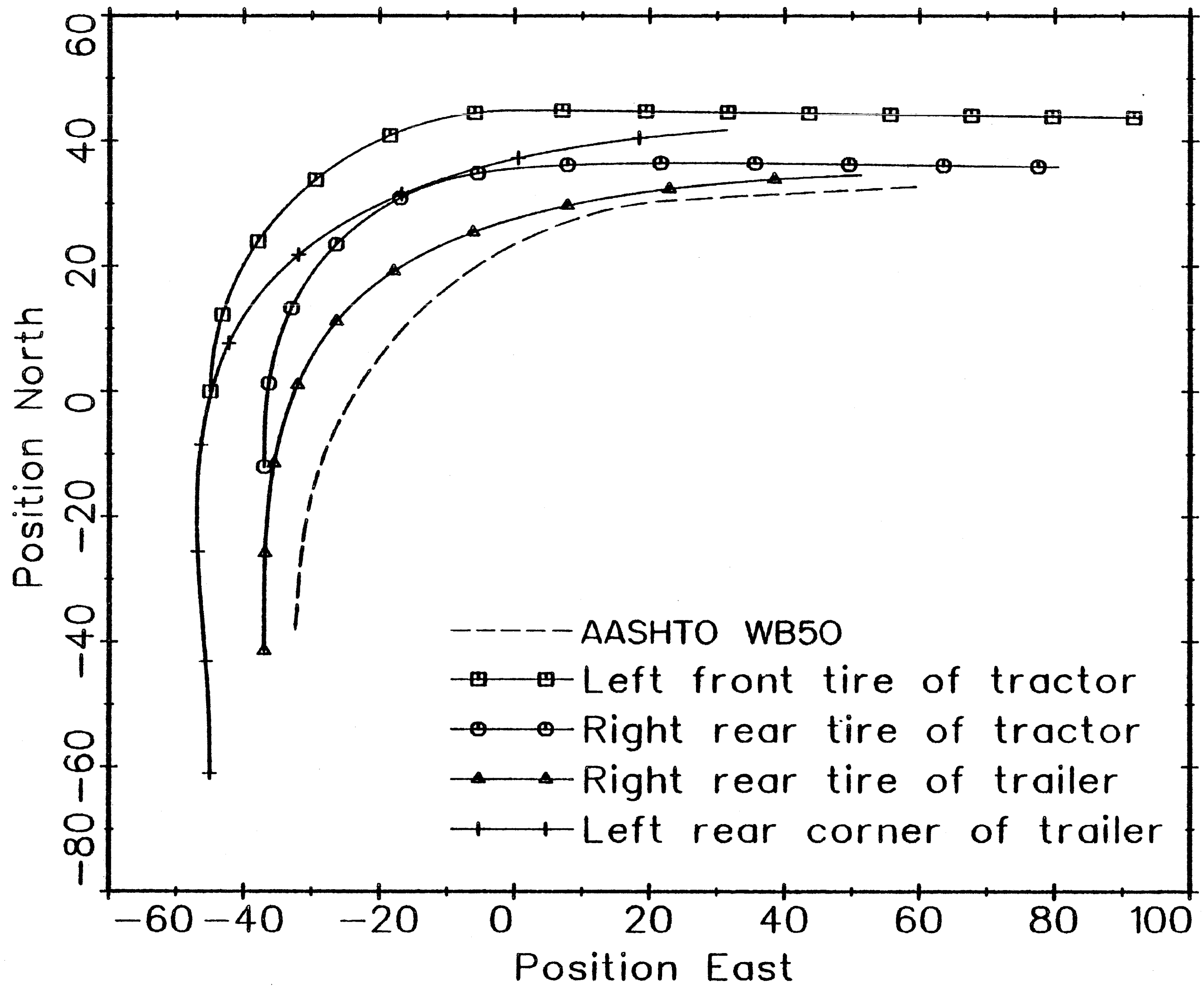
Impact of 53 ft Truck/Trailers in Michigan — Case No. 7



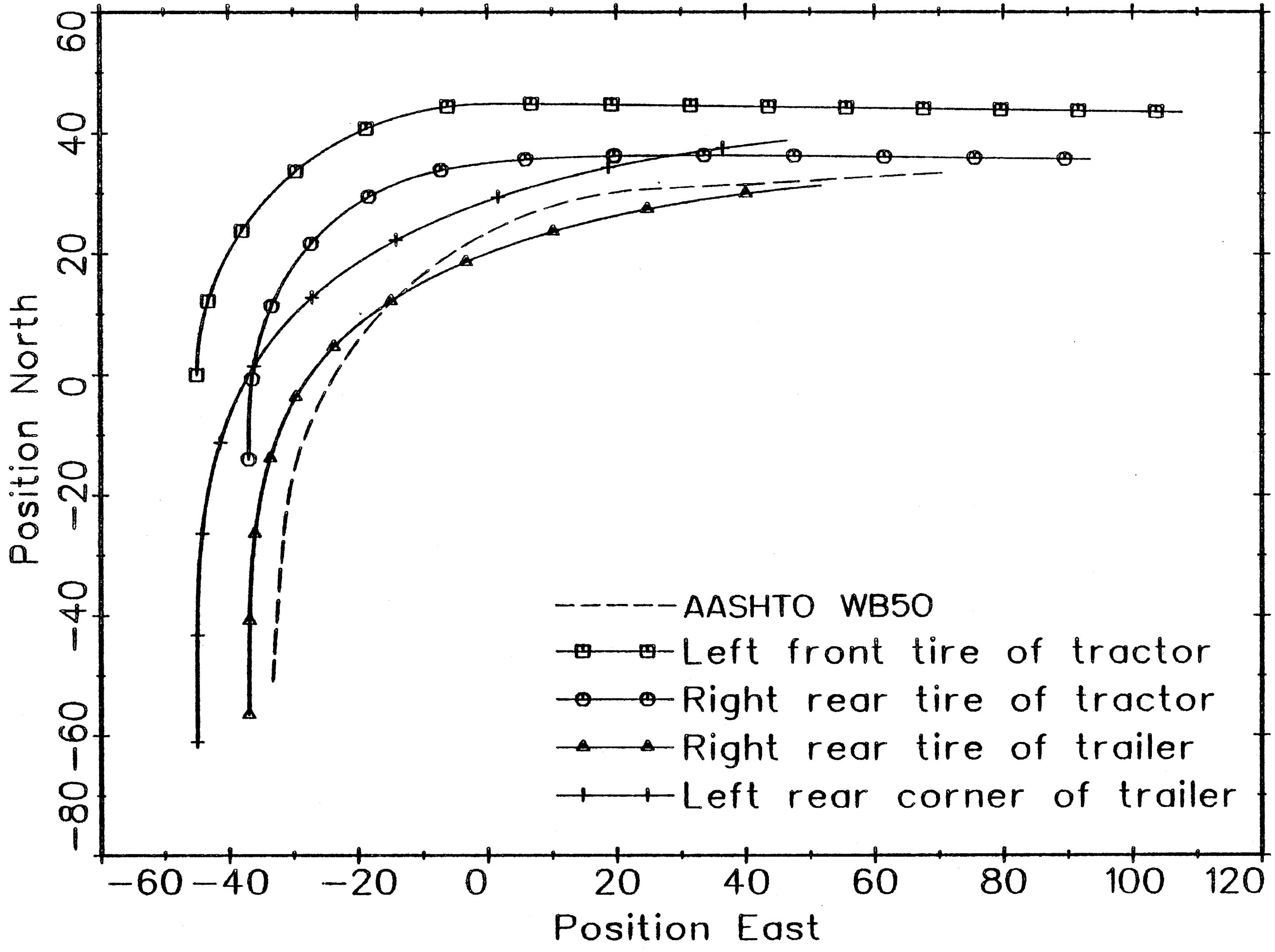
Impact of 53 ft Truck/Trailers in Michigan — Case No. 9



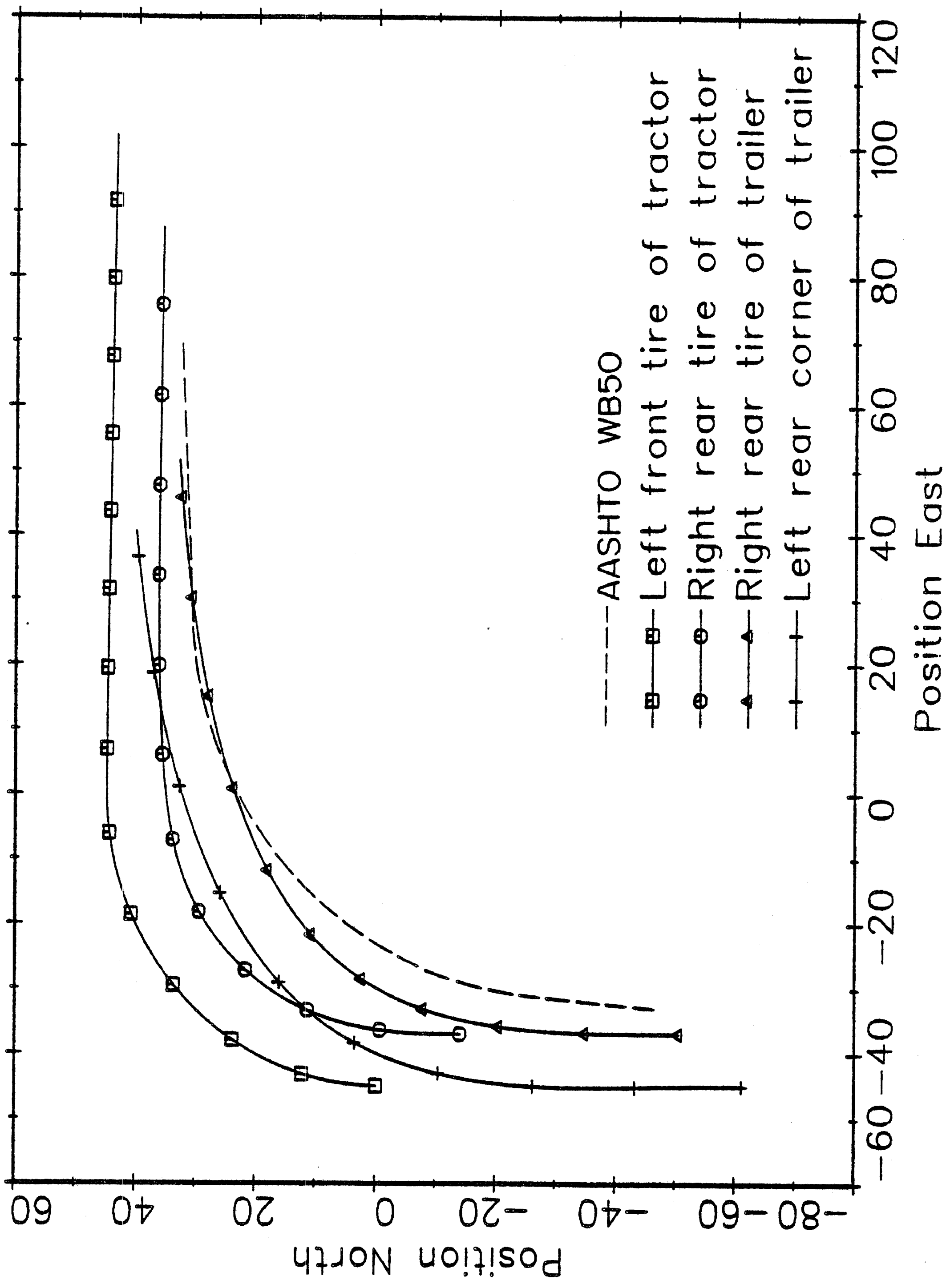
Impact of 53 ft Truck/Trailers in Michigan – Case No. 10



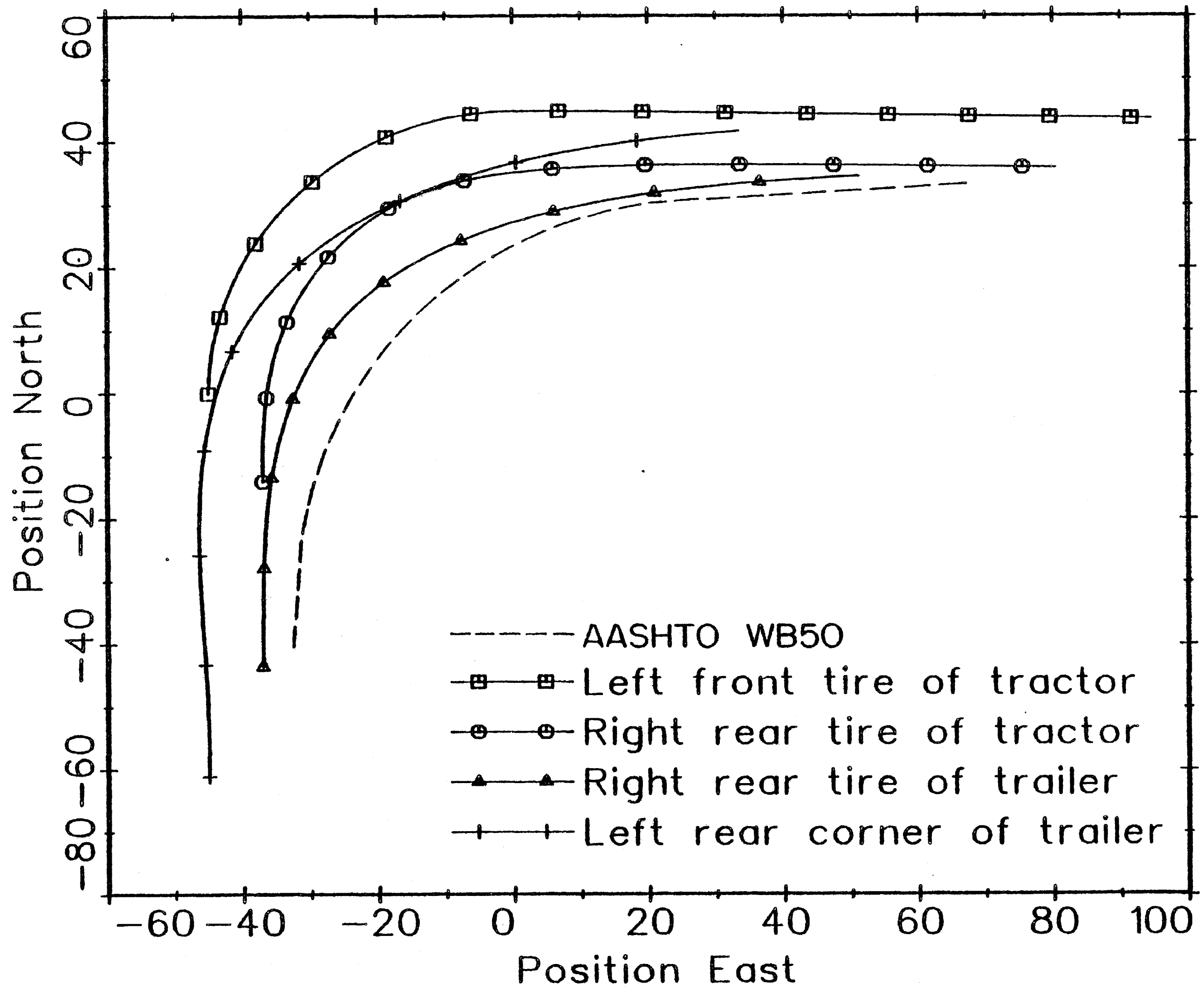
Impact of 53 ft Truck/Trailers in Michigan – Case No. 11



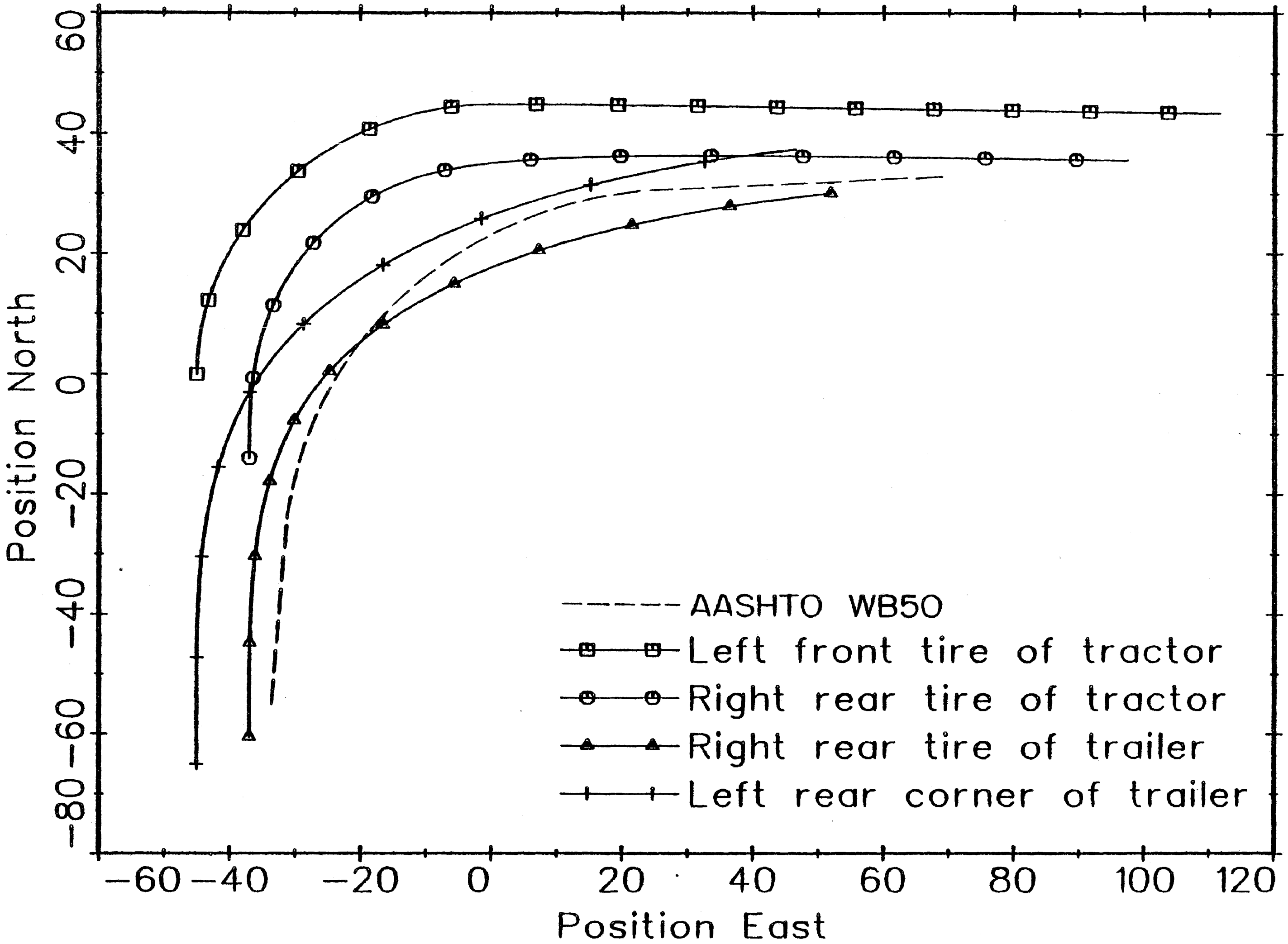
Impact of 53 ft Truck/Trailers in Michigan – Case No. 12



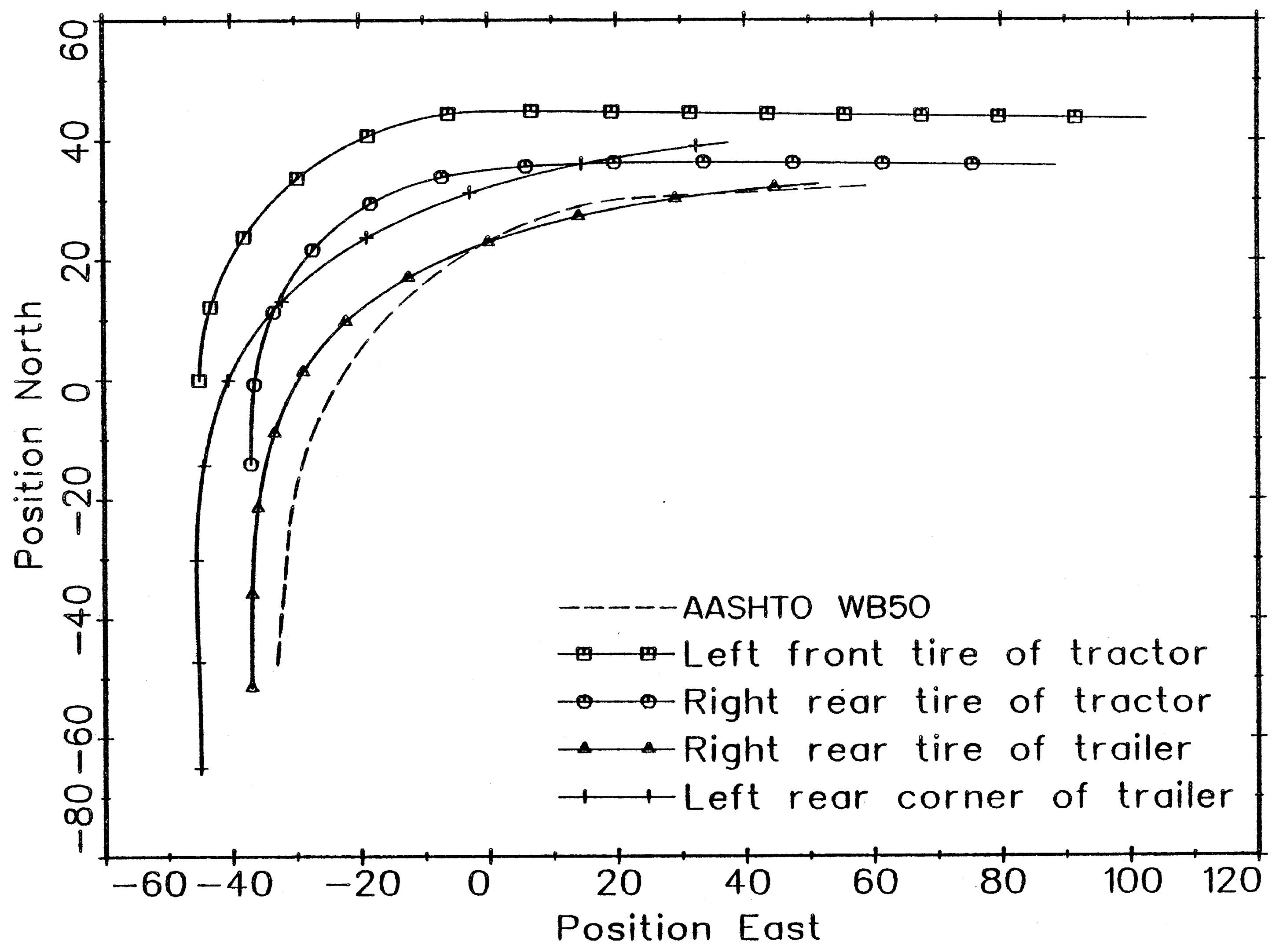
Impact of 53 ft Truck/Trailers in Michigan — Case No. 13



Impact of 53 ft Truck/Trailers in Michigan – Case No. 14



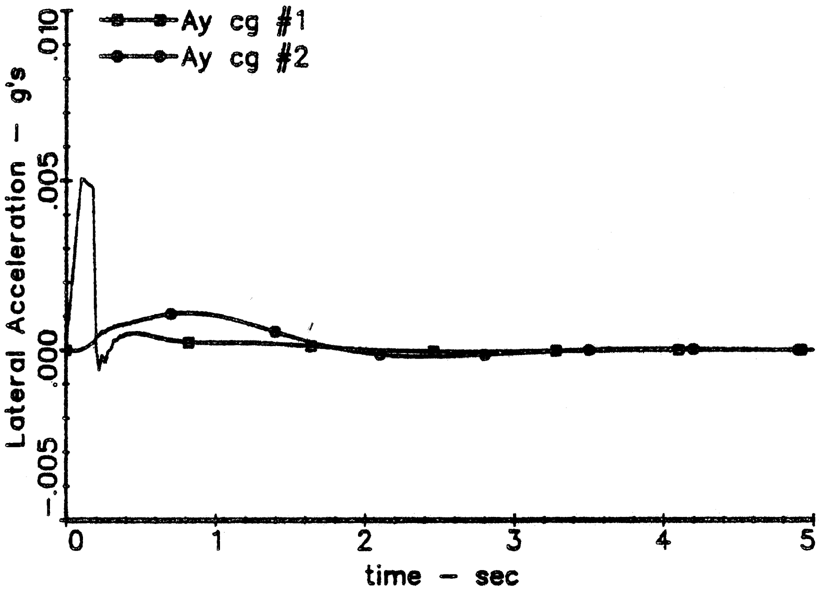
Impact of 53 ft Truck/Trailers in Michigan – Case No. 15



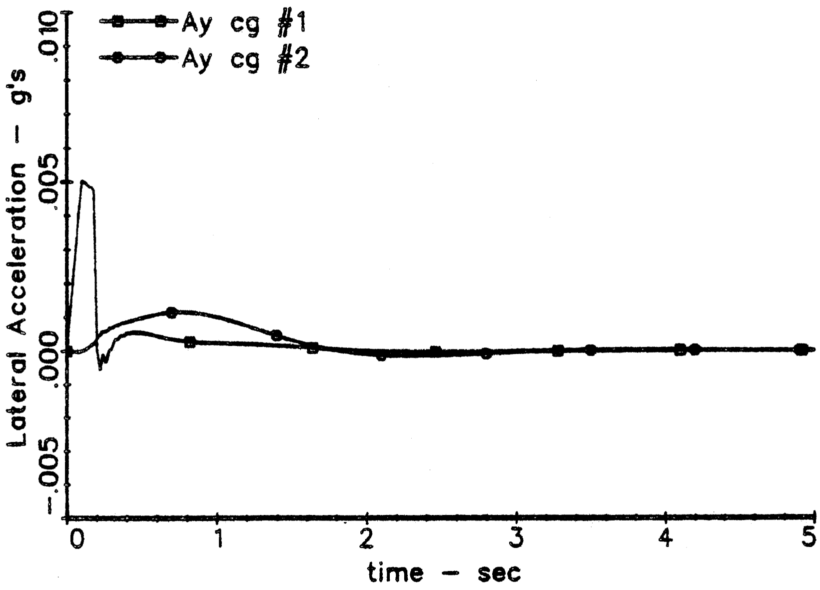
Impact of 53 ft Truck/Trailers in Michigan — Case No. 16

APPENDIX C

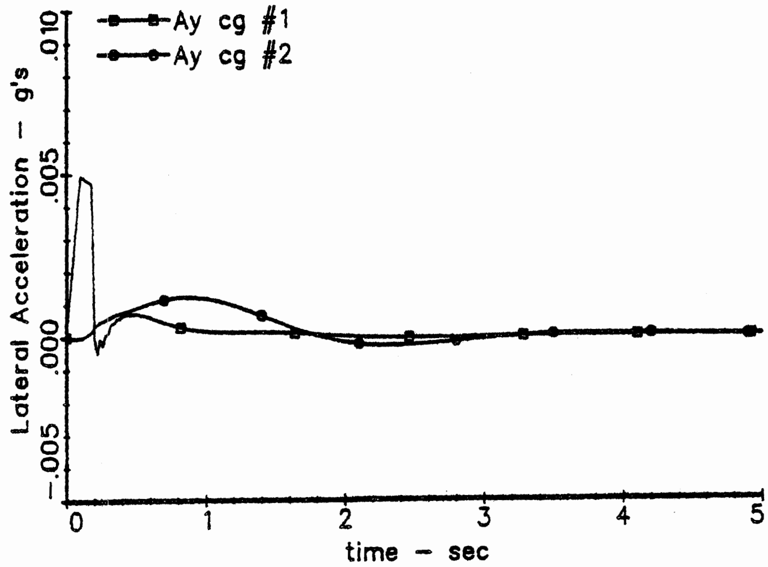
"PULSE" STEER OSCILLATION PLOTS



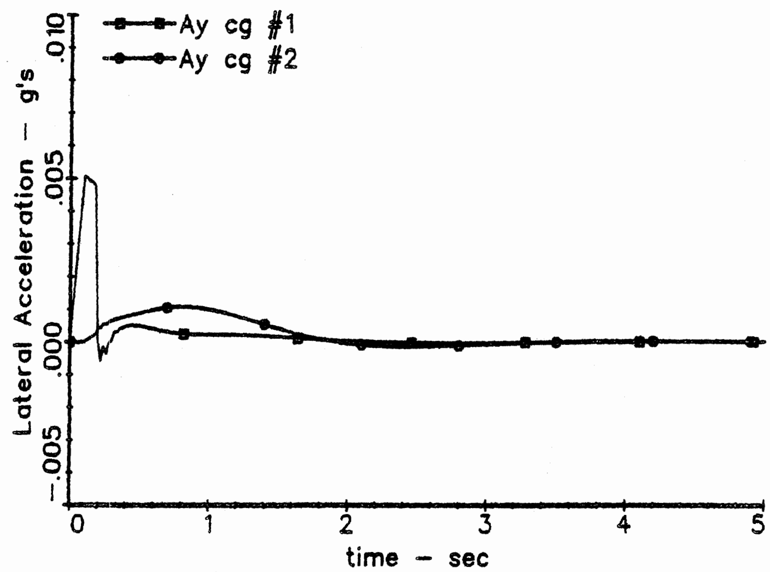
MDOT Tractor—Semitrailer — Case No. 1A



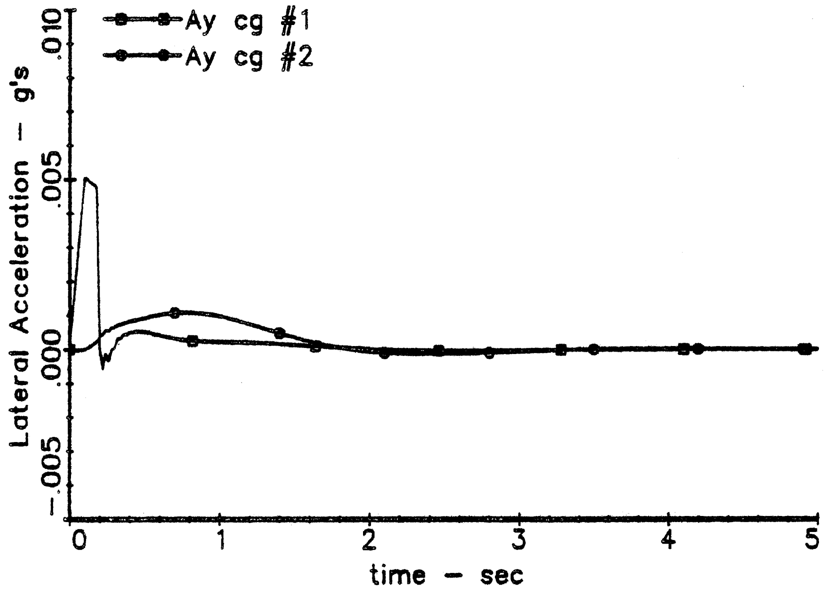
MDOT Tractor—Semitrailer — Case No. 1C



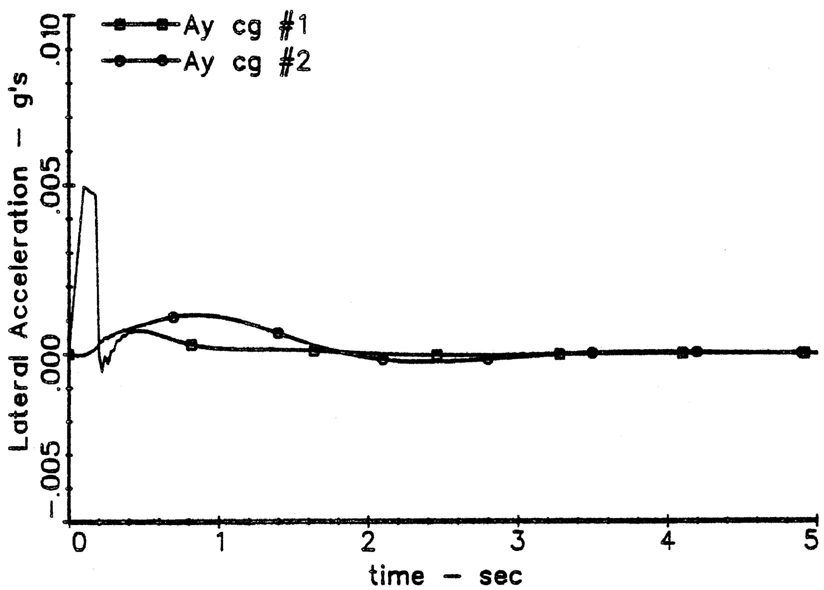
MDOT Tractor–Semitrailer – Case No. 2A



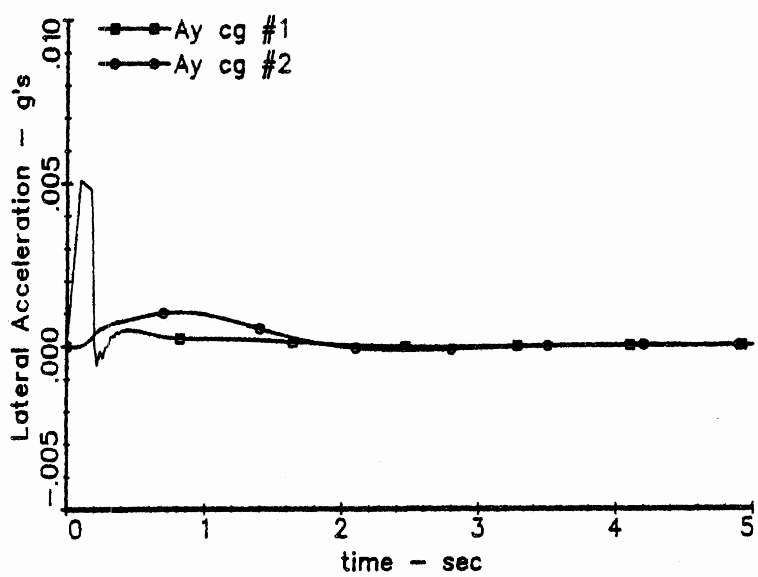
MDOT Tractor–Semitrailer – Case No. 3A



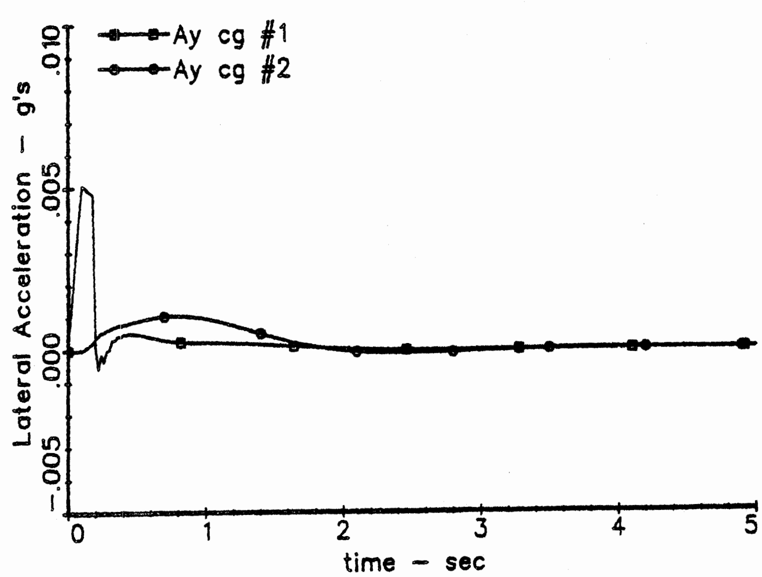
MDOT Tractor–Semitrailer – Case No. 3C



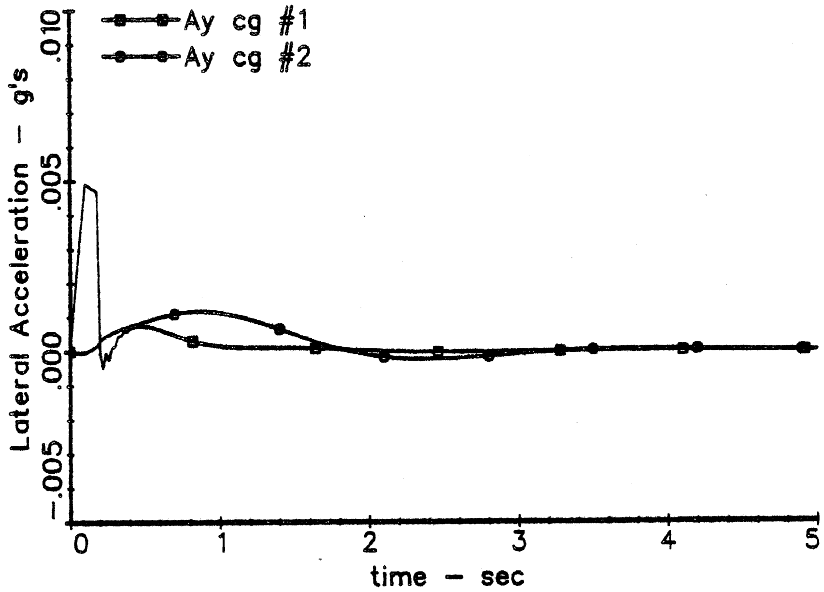
MDOT Tractor–Semitrailer – Case No. 4A



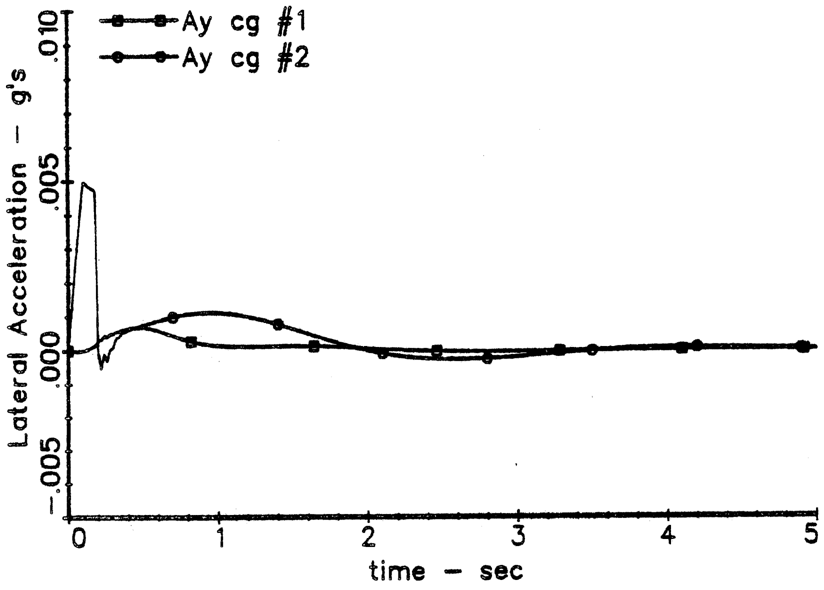
MDOT Tractor-Semitrailer - Case No. 5A



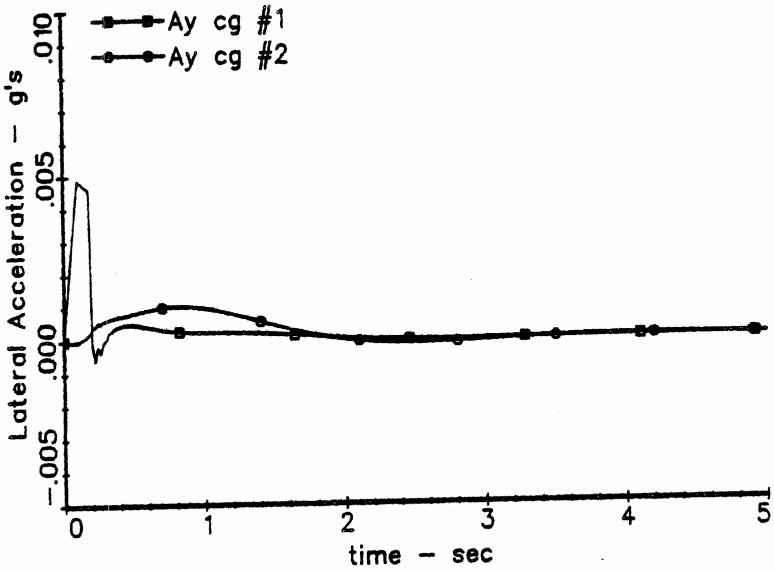
MDOT Tractor-Semitrailer - Case No. 5C



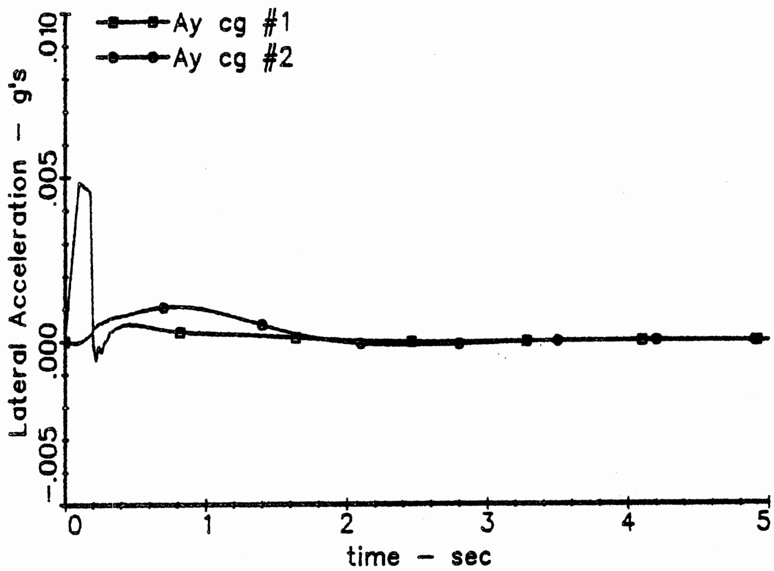
MDOT Tractor-Semitrailer - Case No. 6A



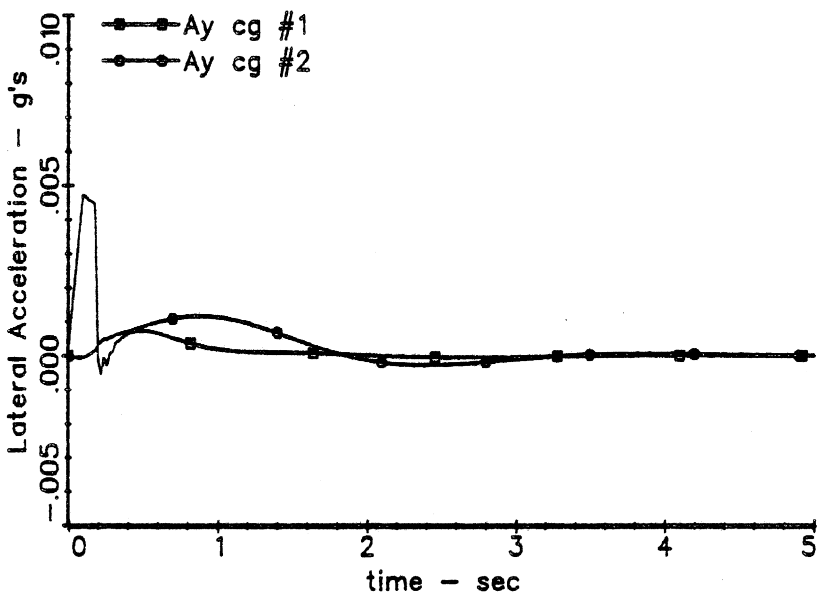
MDOT Tractor-Semitrailer - Case No. 6B



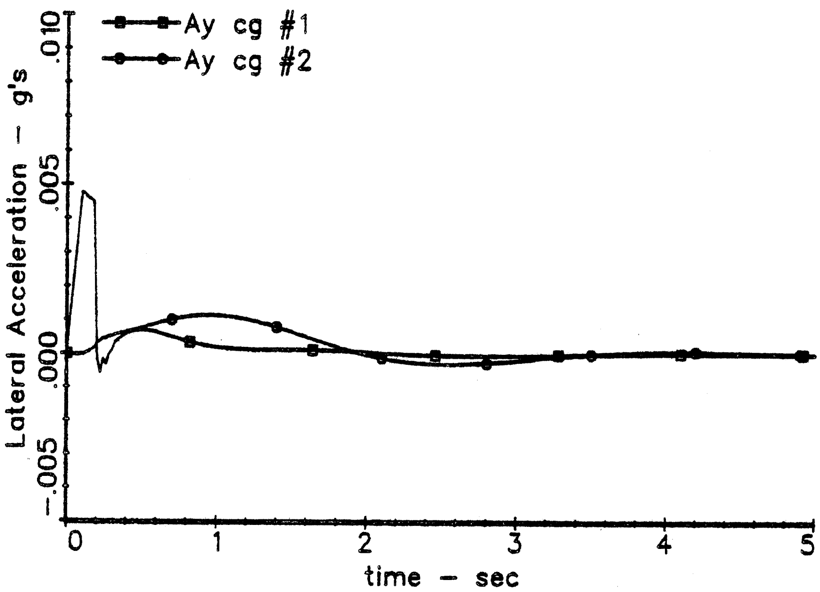
MDOT Tractor–Semitrailer – Case No. 7A



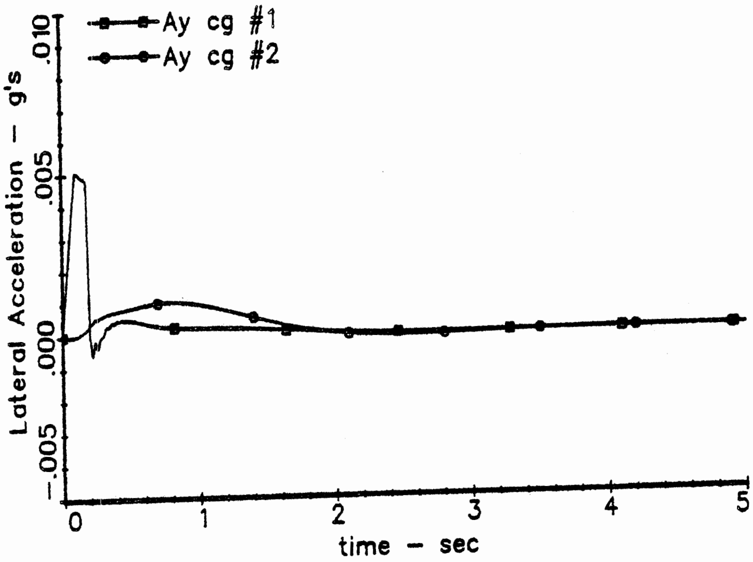
MDOT Tractor–Semitrailer – Case No. 7C



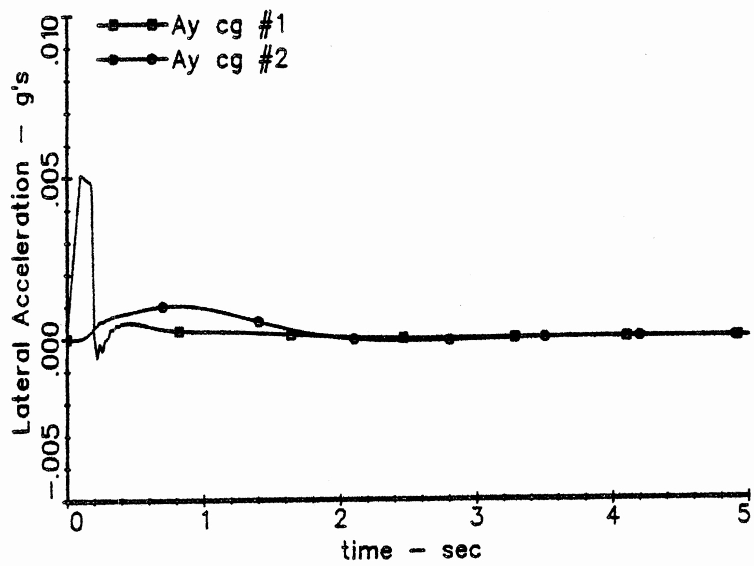
MDOT Tractor-Semitrailer - Case No. 8A



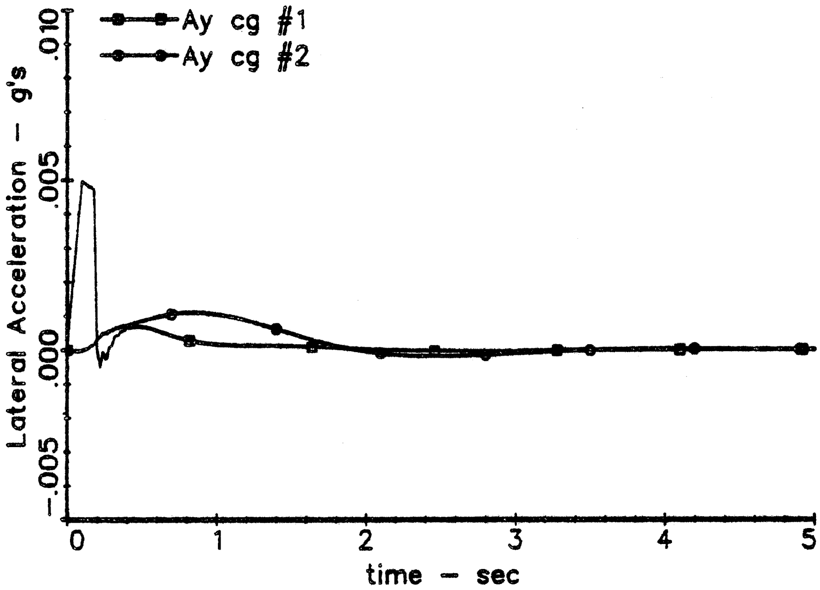
MDOT Tractor-Semitrailer - Case No. 8B



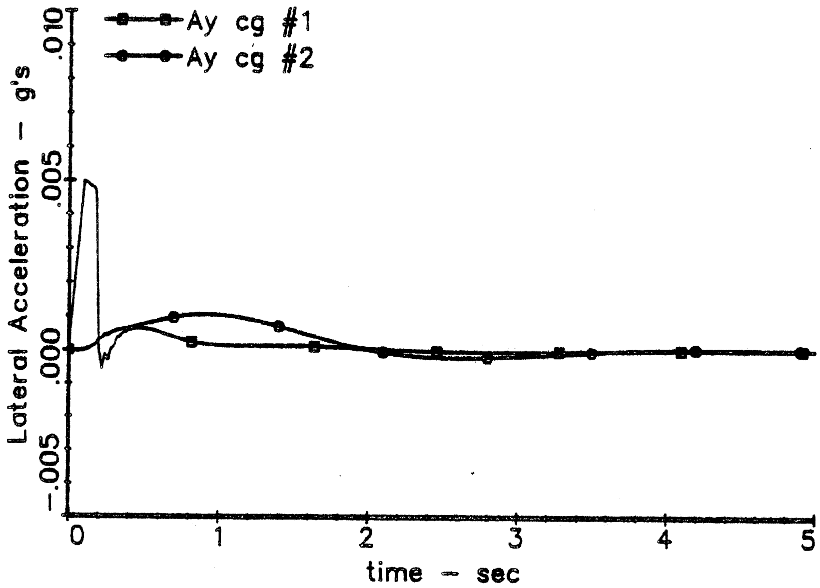
MDOT Tractor–Semitrailer – Case No. 9A



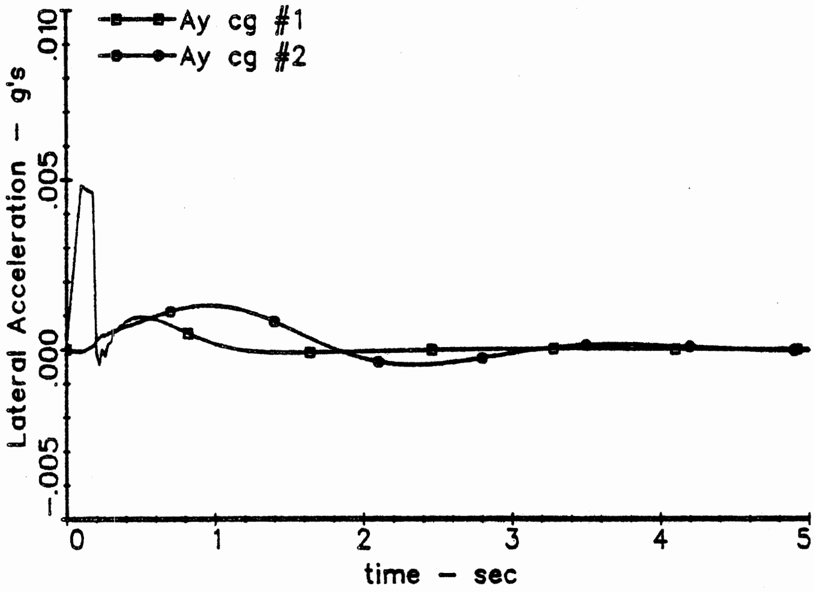
MDOT Tractor–Semitrailer – Case No. 9C



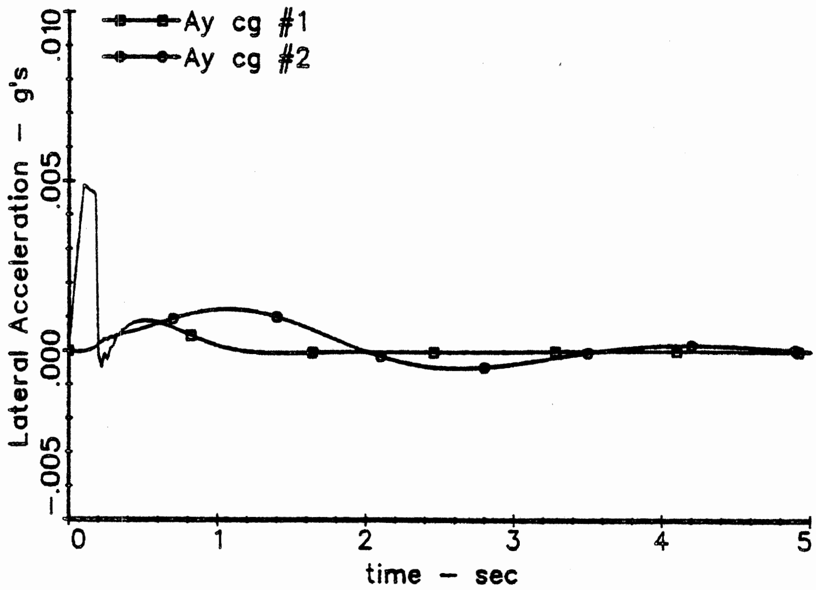
MDOT Tractor–Semitrailer – Case No. 10A



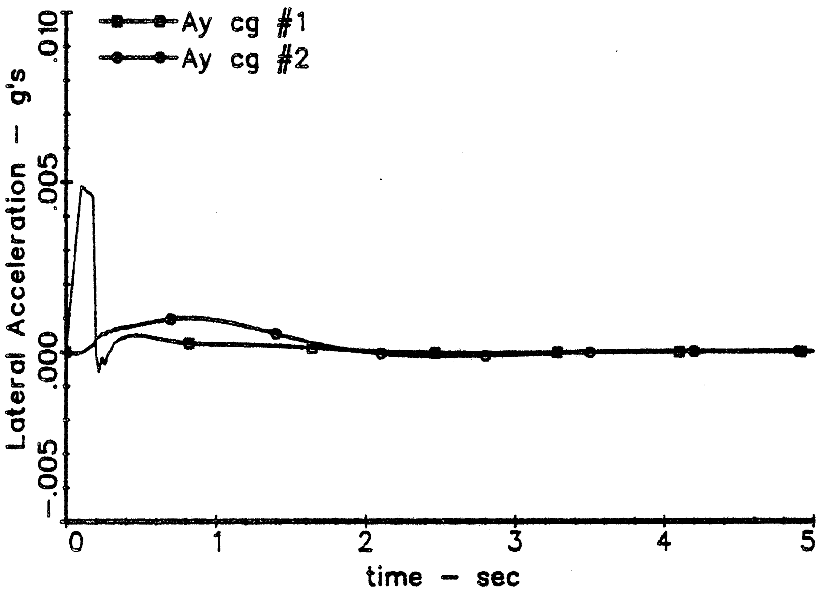
MDOT Tractor–Semitrailer – Case No. 10B



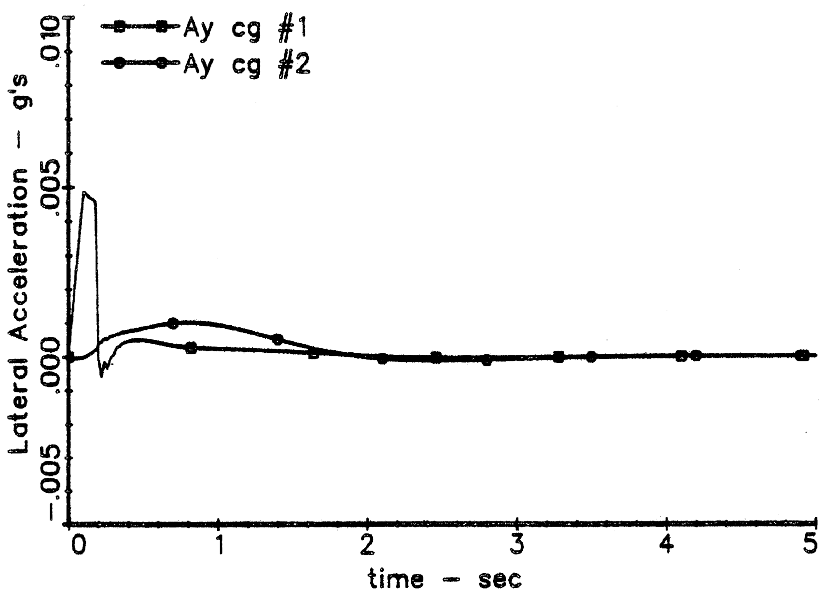
MDOT Tractor–Semitrailer – Case No. 11A



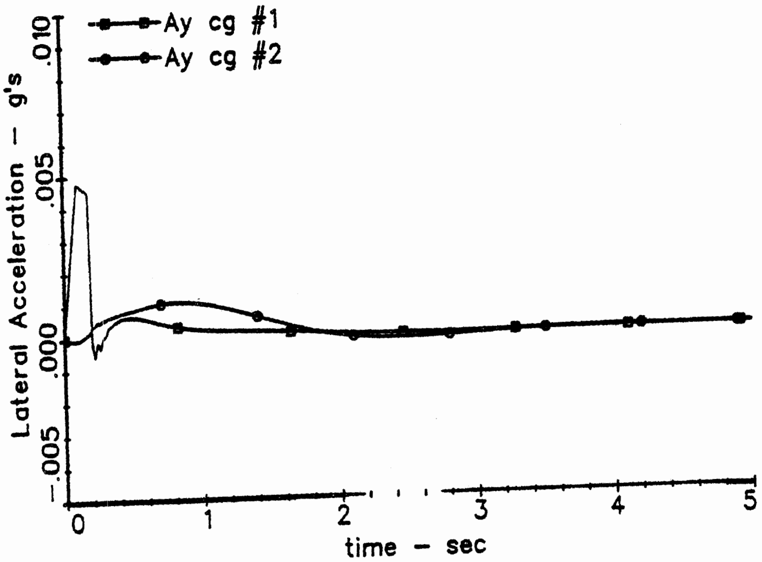
MDOT Tractor–Semitrailer – Case No. 11B



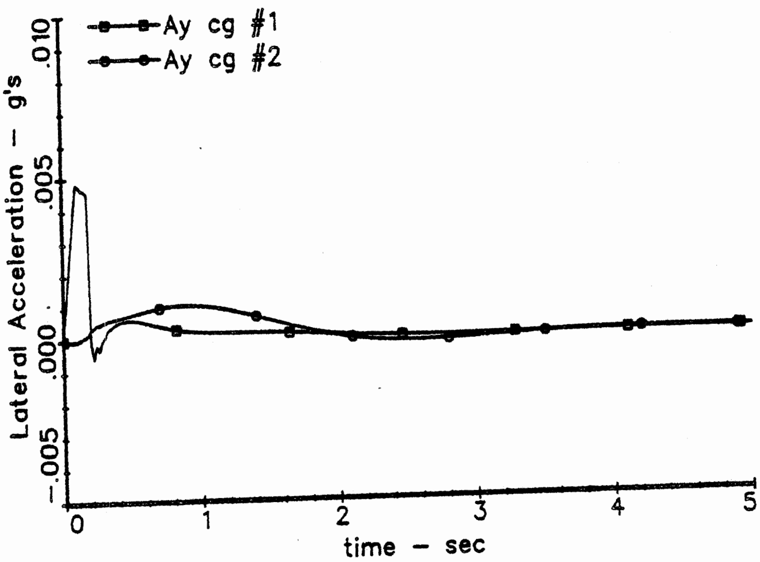
MDOT Tractor–Semitrailer – Case No. 12A



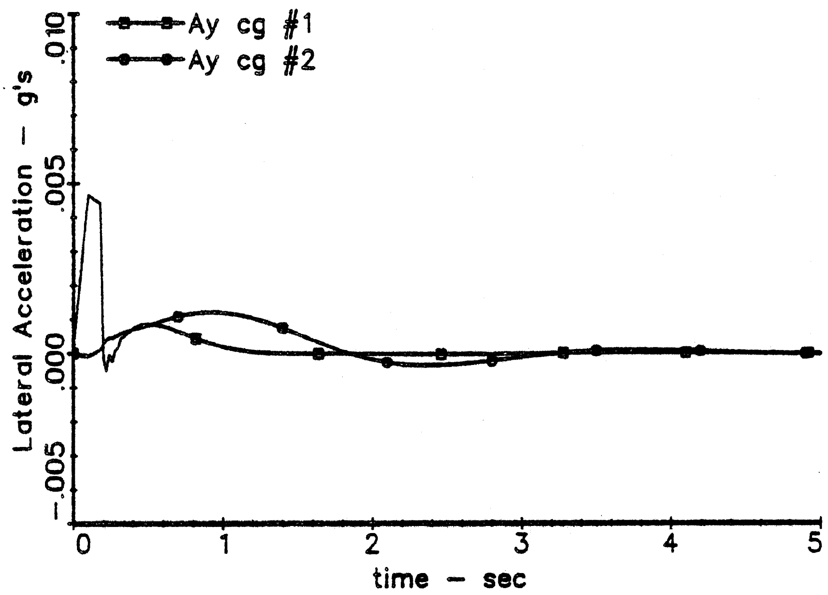
MDOT Tractor–Semitrailer – Case No. 12C



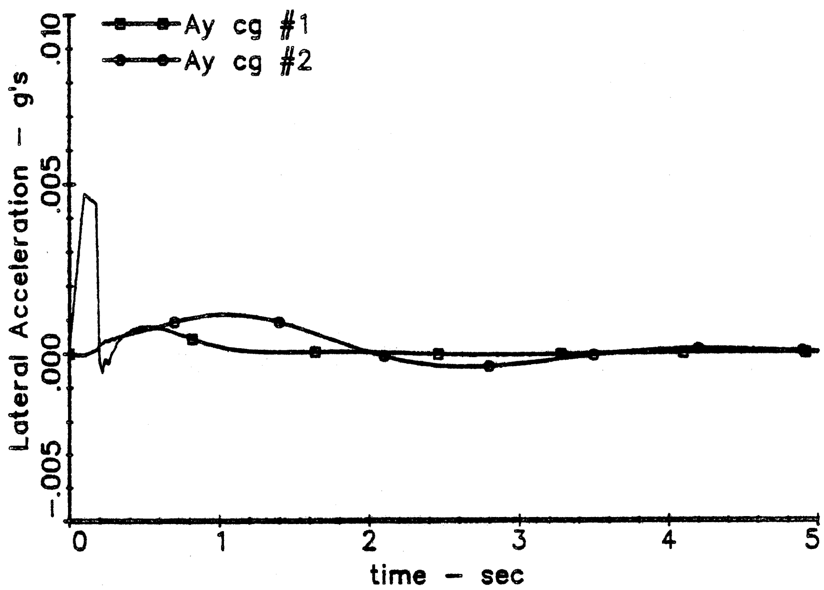
MDOT Tractor-Semitrailer - Case No. 13A



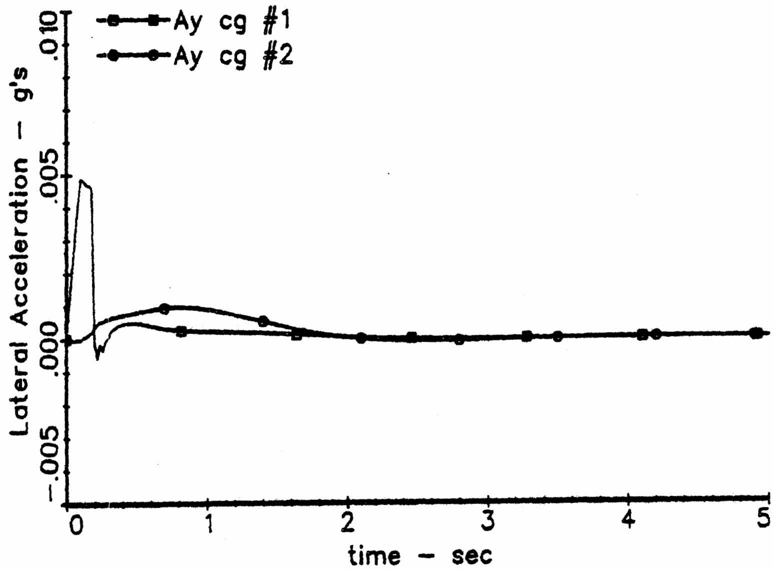
MDOT Tractor-Semitrailer - Case No. 13B



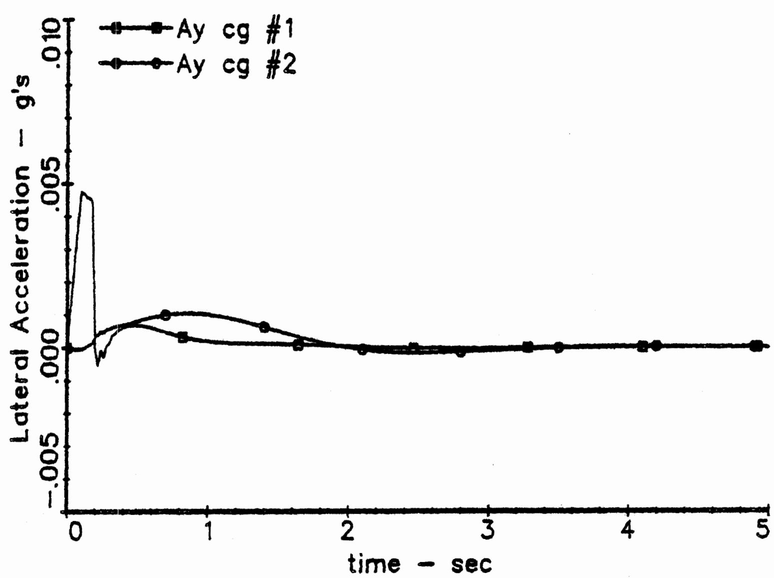
MDOT Tractor–Semitrailer – Case No. 14A



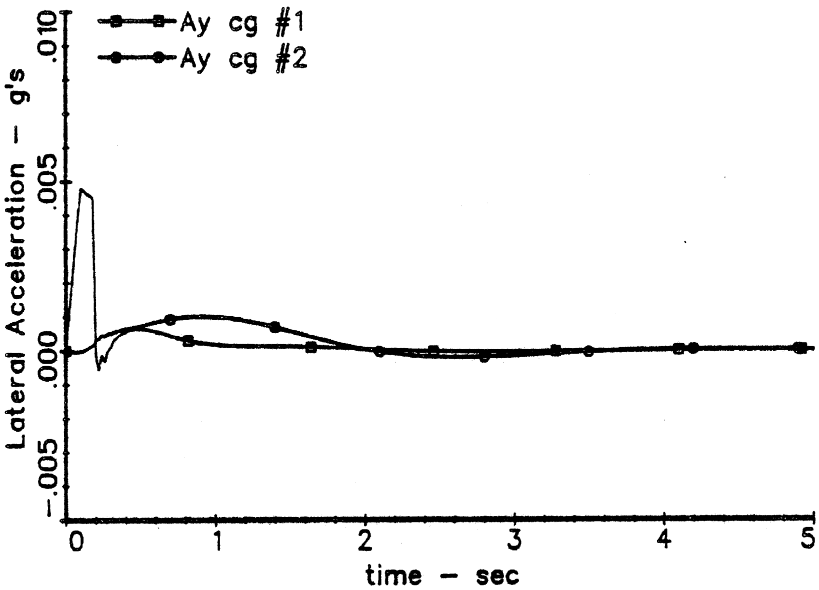
MDOT Tractor–Semitrailer – Case No. 14B



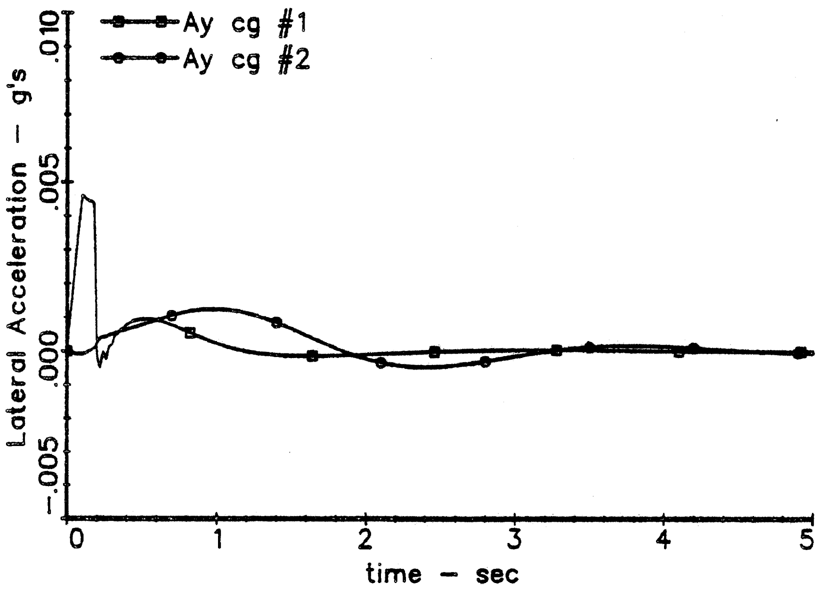
MDOT Tractor–Semitrailer – Case No. 15A



MDOT Tractor–Semitrailer – Case No. 16A



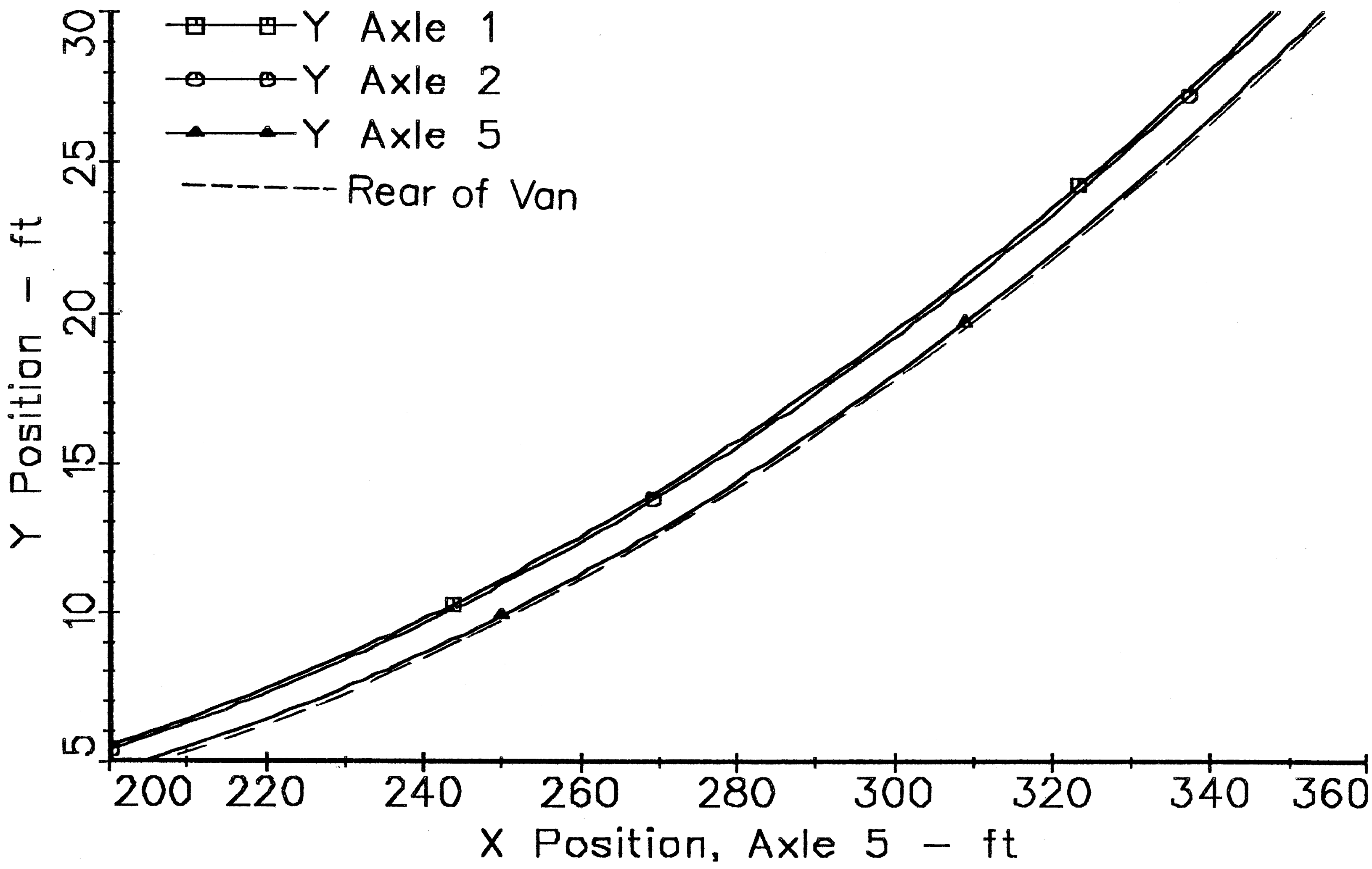
MDOT Tractor–Semitrailer – Case No. 16B



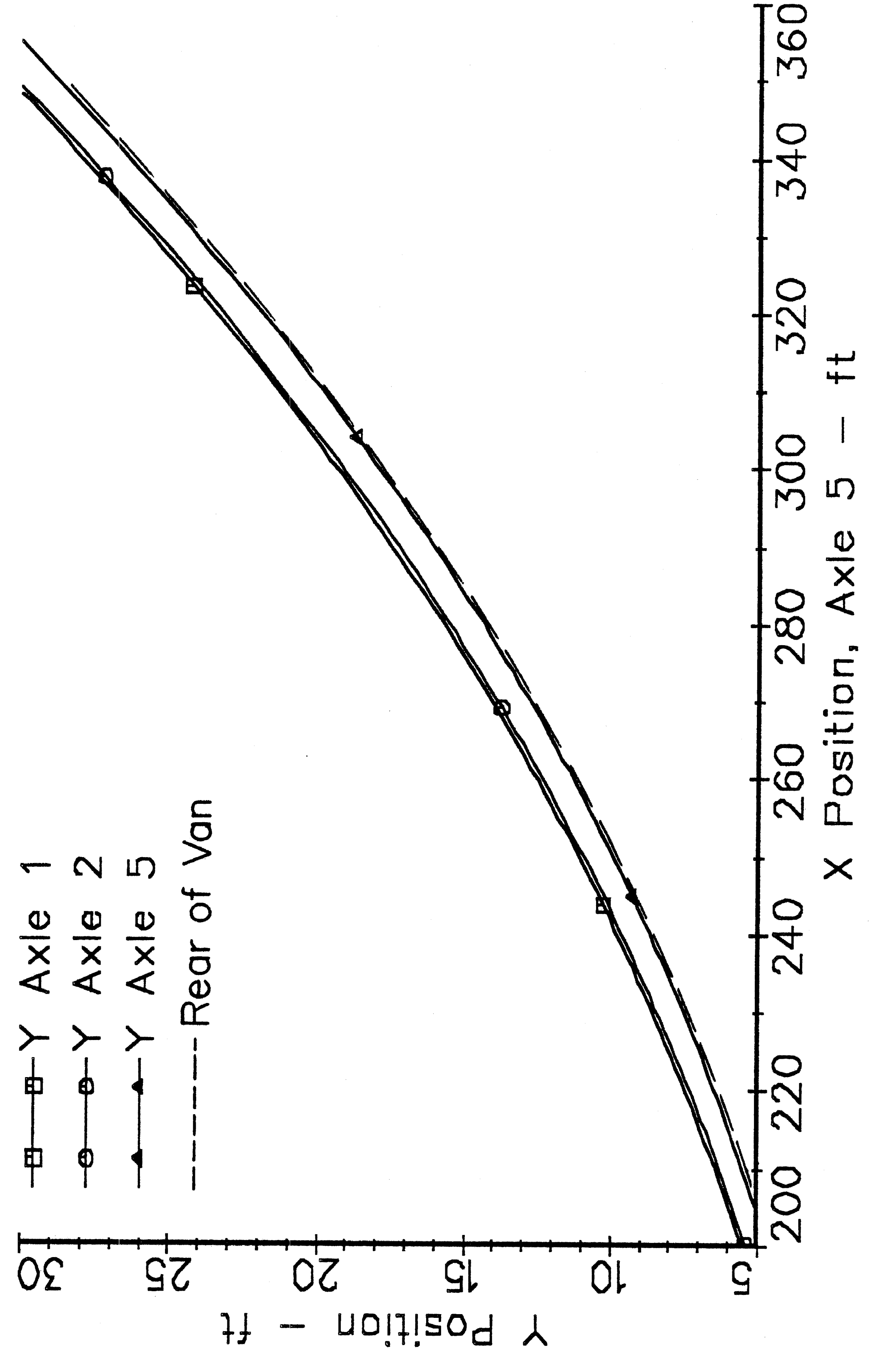
MDOT Tractor–Semitrailer – Case No. 17A

APPENDIX D

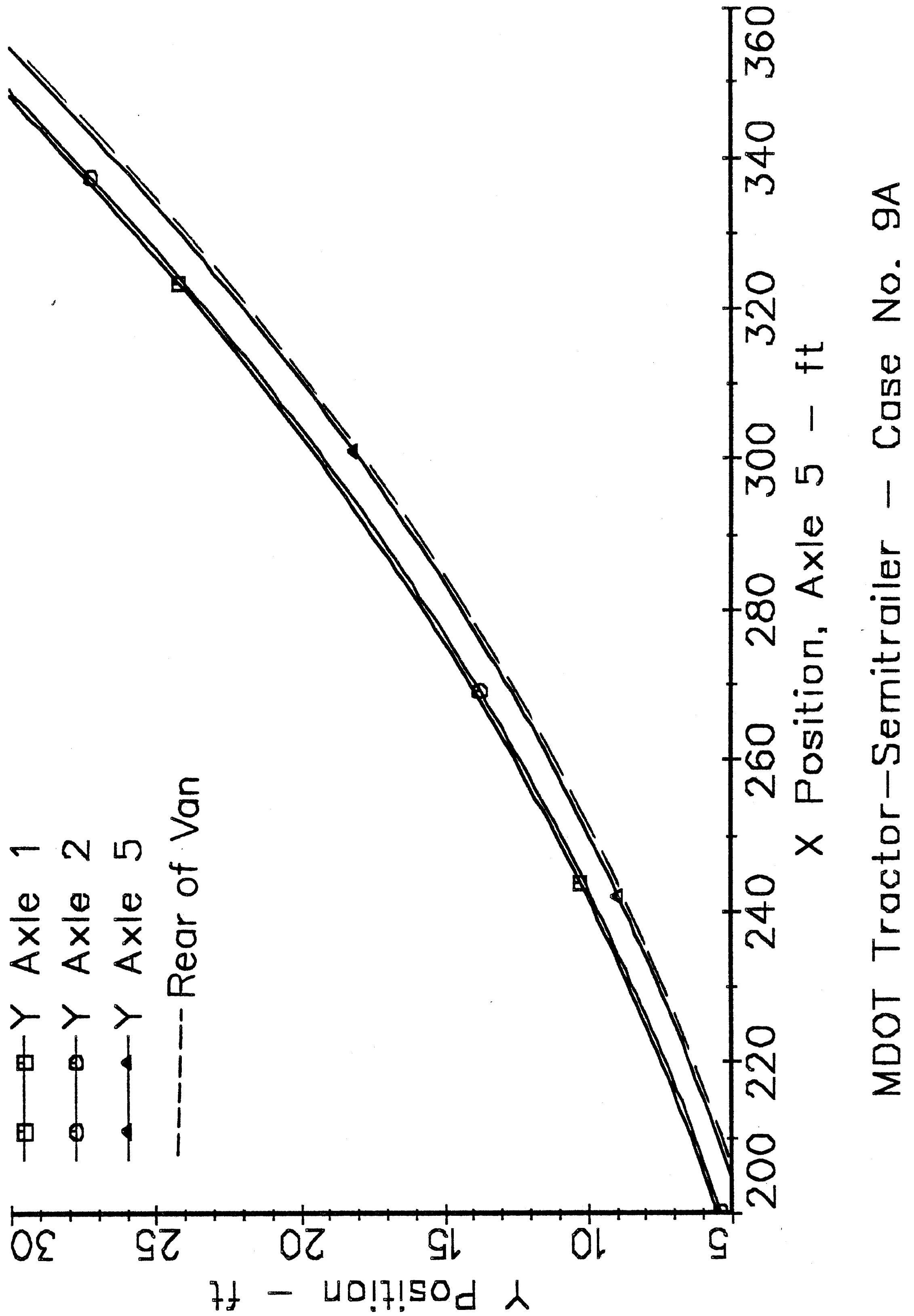
J-TURN OFFTRACKING PLOTS

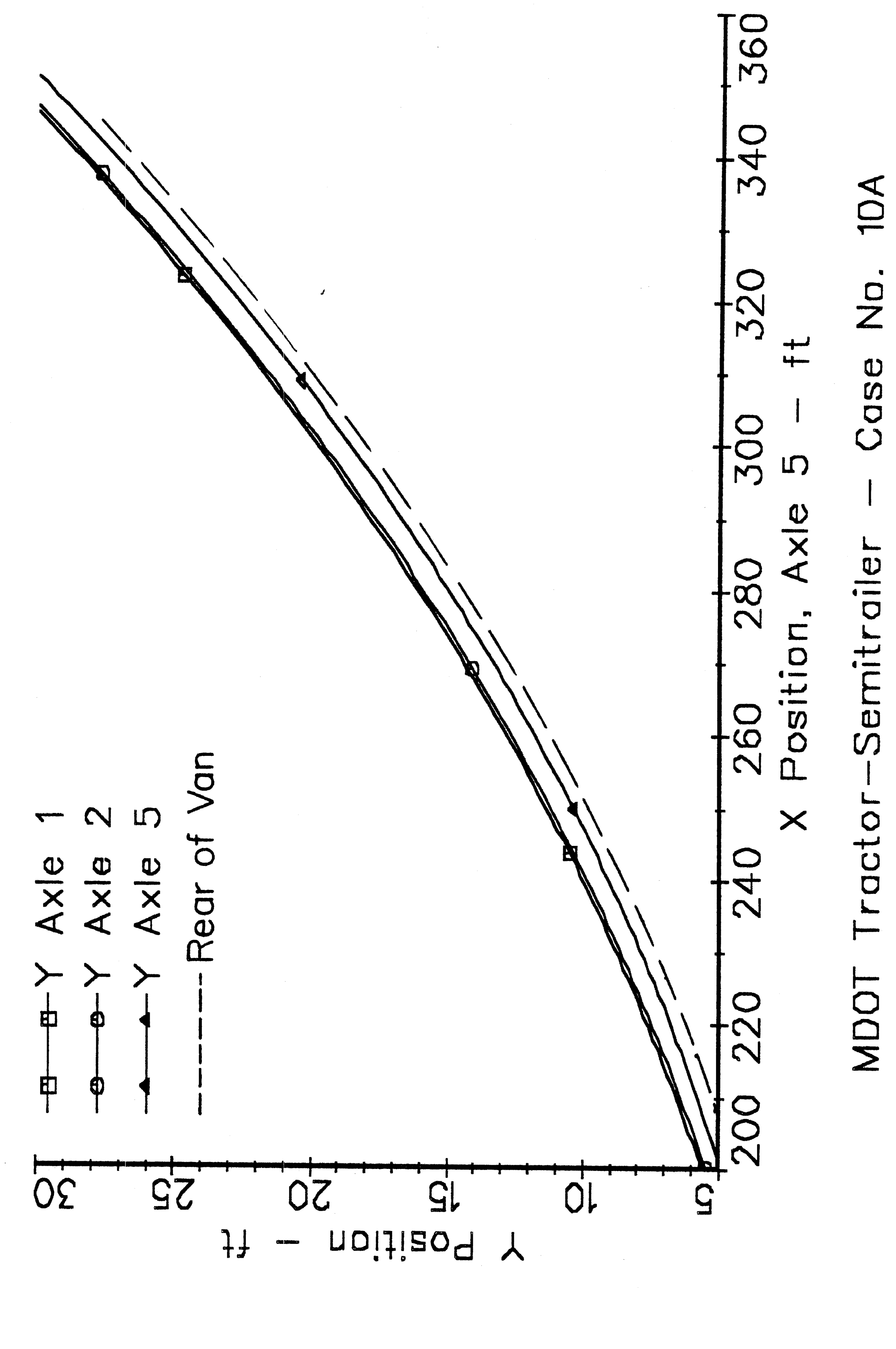


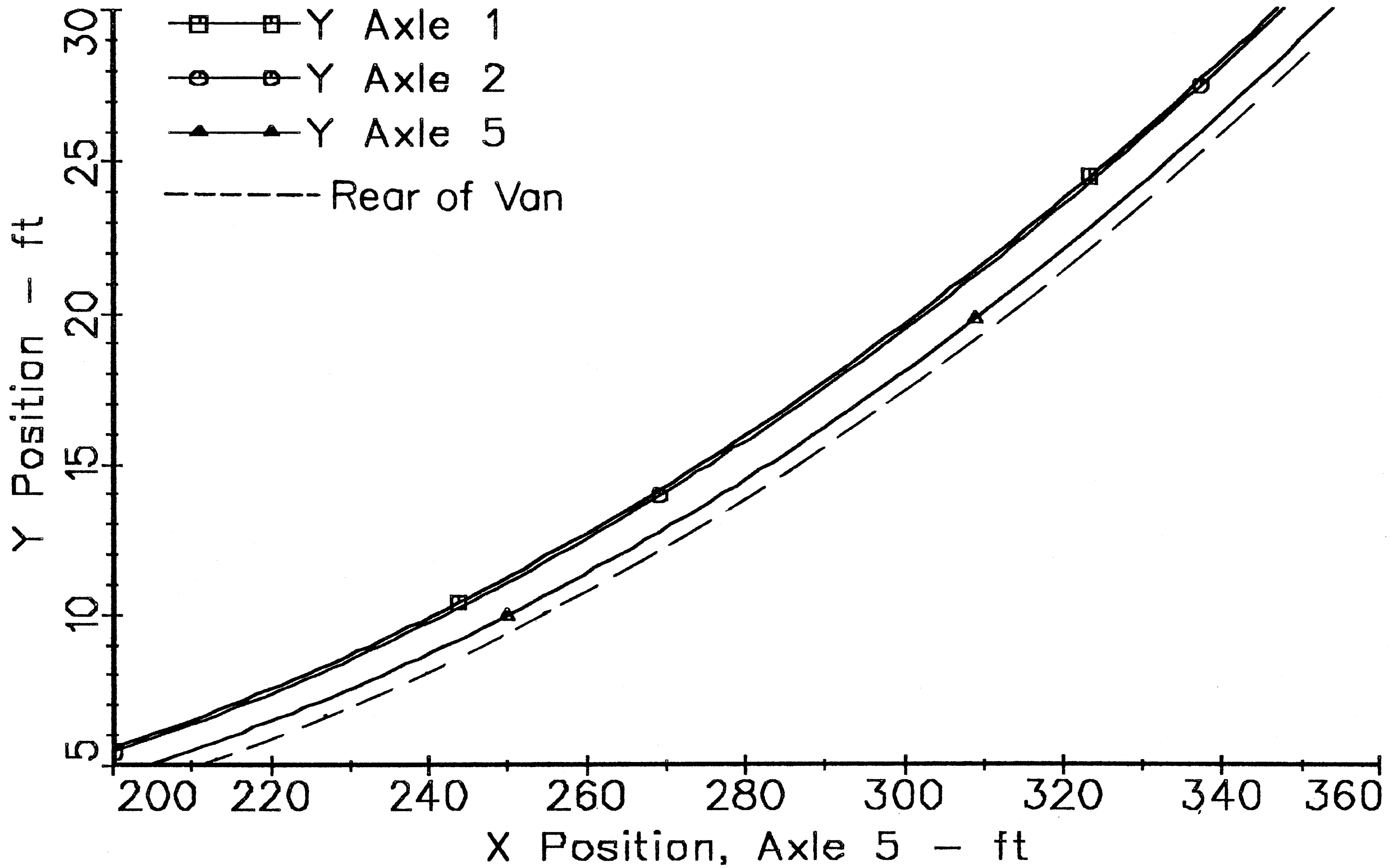
MDOT Tractor—Semitrailer — Case No. 1A



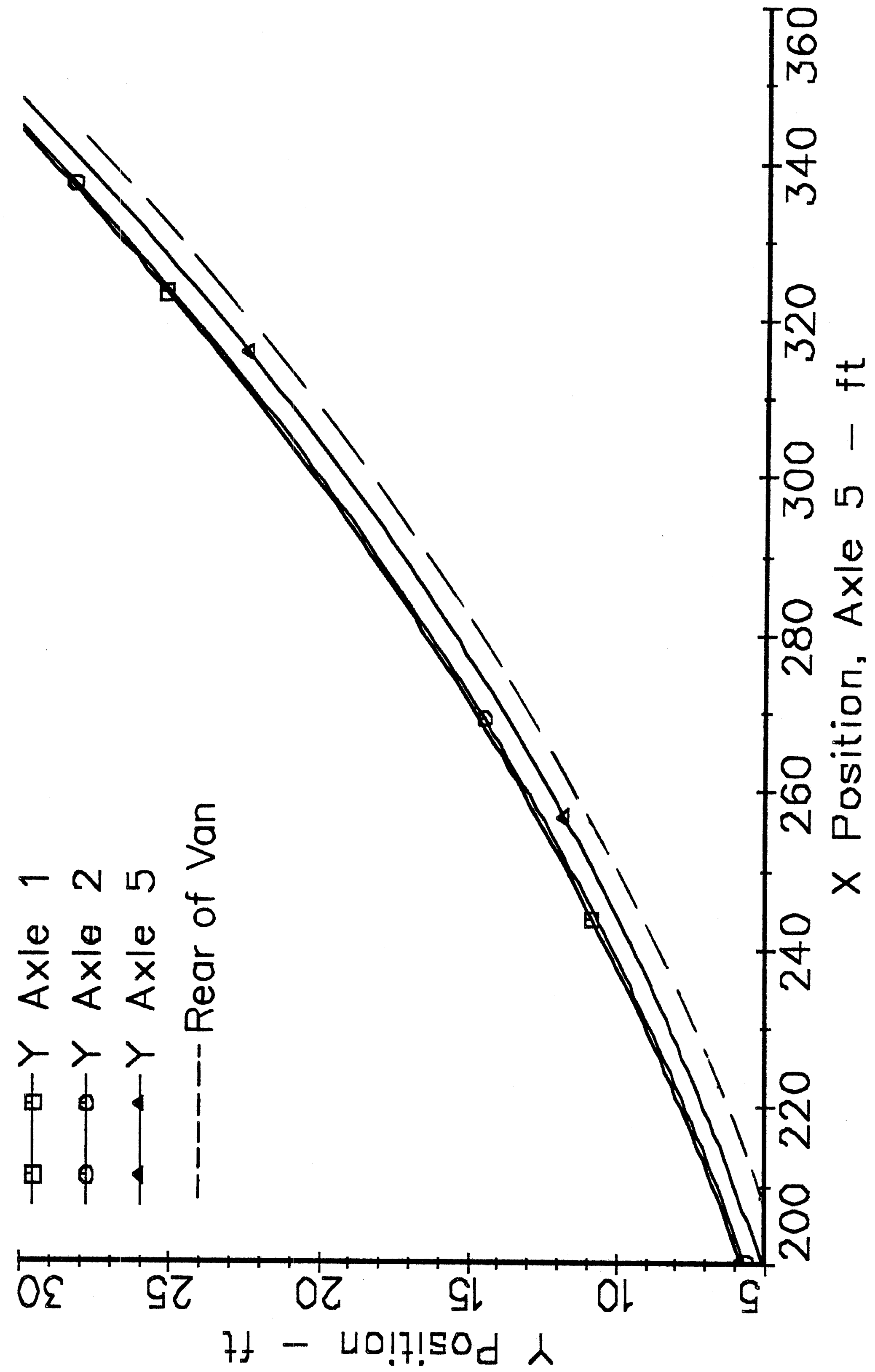
MDOT Tractor—Semitrailer — Case No. 5A


Y Axle 1
Y Axle 2
Y Axle 5
Rear of Van
Y Position — ft
X Position, Axle 5 — ft
MDOT Tractor—Semitrailer — Case No. 9A
5
10
15
20
25
30
200
220
240
260
280
300
320
340
360

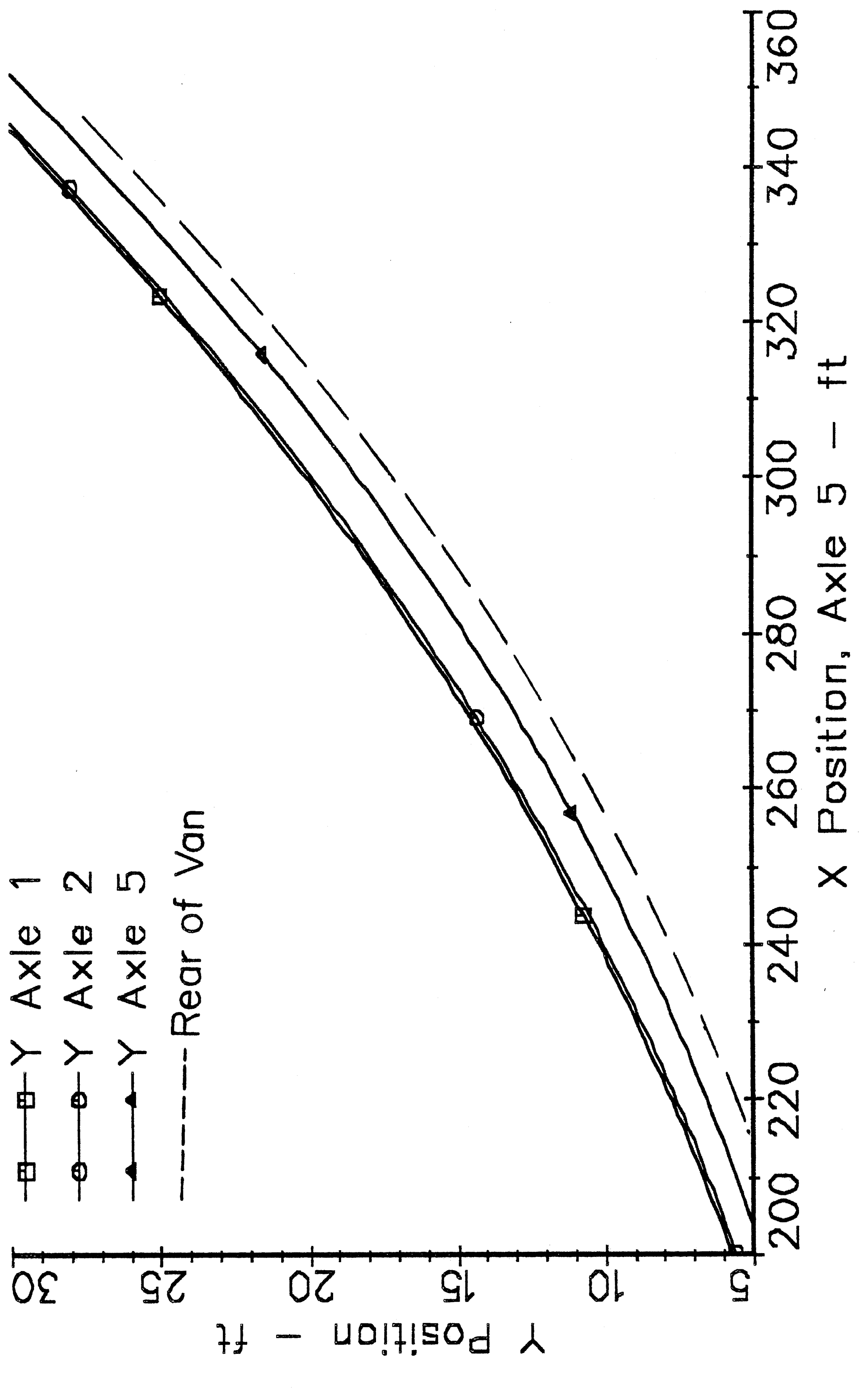

Y Axle 1
Y Axle 2
Y Axle 5
Rear of Van
Y Position - ft
5
10
15
20
25
30
200
220
240
260
280
300
320
340
360
X Position, Axle 5 - ft
MDOT Tractor-Semitrailer - Case No. 10A



MDOT Tractor—Semitrailer — Case No. 10B



MDOT Tractor–Semitrailer – Case No. 11A



MDOT Tractor—Semitrailer — Case No. 11B