Vehicle Weights and Dimensions Study

Volume 16

A Comparison of Various Computer Simulation Models for Predicting the Lateral Behaviour of Articulated Buses

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The Technical Steering Committee will be considering the findings of these research investigations in preparing its "Final Technical Report" (Volume 1 & 2), scheduled for completion in December 1986.

PREFACE

The report which follows constitutes one volume in a series of sixteen which have been produced by contract researchers involved in the Vehicle Weights and Dimensions Study. The research procedures and findings contained herein address one or more specific technical objectives in the context of the development of a consistent knowledge base necessary to achieve the overall goal of the Study; improved uniformity in interprovincial weight and dimension regulations.

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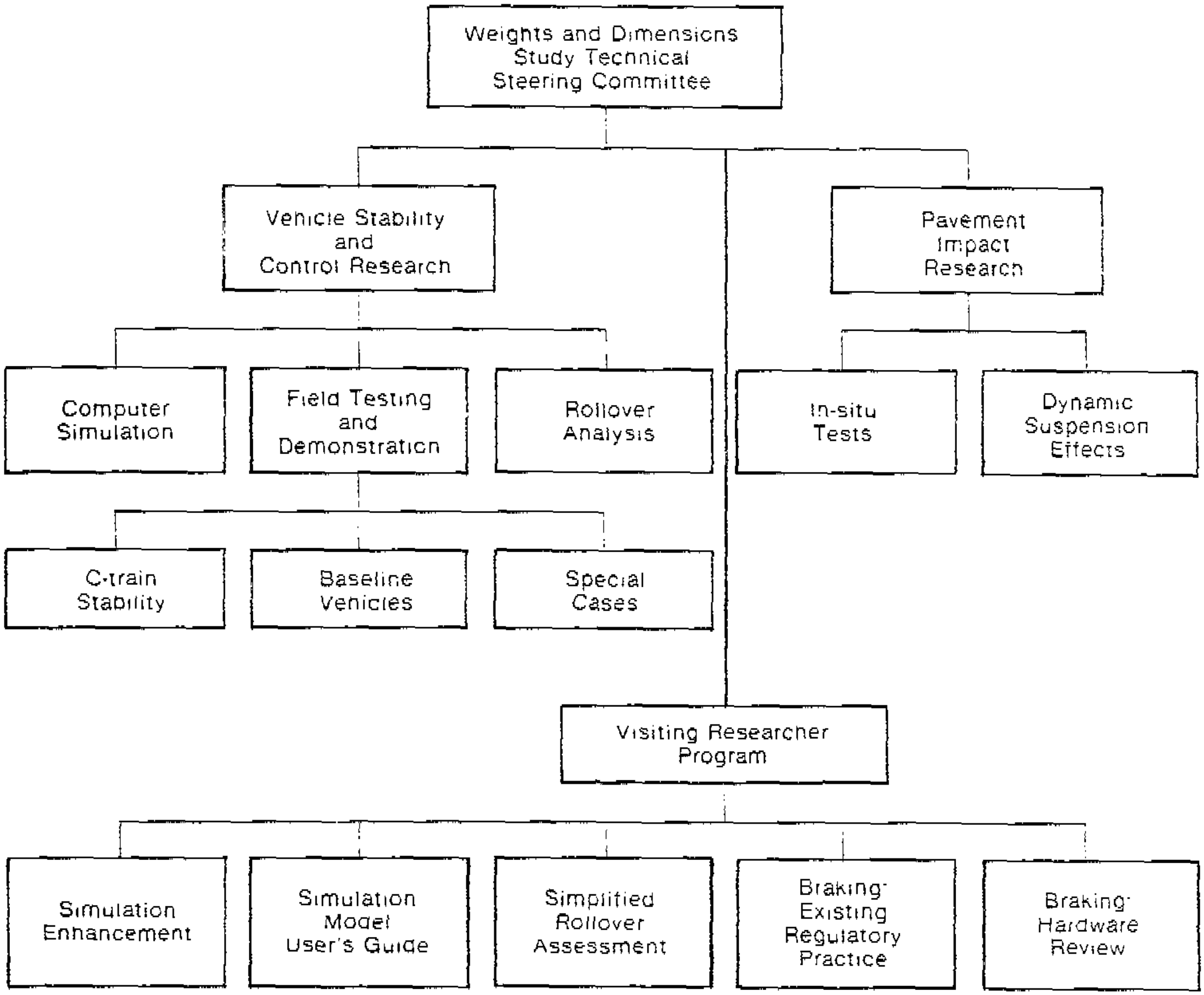

Volume 16

A Comparison of Various Computer Simulation Models for Predicting the Lateral Dynamic Behaviour of Articulated Vehicles

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FOREWORD

The work described in this report was performed under the Visiting Researcher Program (Computer Simulation Models) of the RTAC/CCMTA Vehicle Weights and Dimensions Study. This report, together with a previous report entitled "Computer Simulation of Heavy Vehicle Dynamic Behaviour - User's Guide to the UMTRI Models", by J.Y. Wong and M. El-Gindy, June 1985, forms the final Report to RTAC/CCMTA.

The study described in this report was performed by Dr. J.Y. Wong, Director, and Dr. M. El-Gindy, Senior Research Associate, Transport Technology Research Laboratory, Carleton University, Ottawa, Canada.

The guidance provided by the Project Manager and the Technical Steering Committee of the Vehicle Weights and Dimensions Study, and the assistance given by the staff members of the Engineering Research Division, University of Michigan Transportation Research Institute (UMTRI) during the course of the study are appreciated.

April 1986

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SUMMARY

The objective of this study is to compare the capabilities and limitations of various simulation models for the evaluation of the directional behaviour of commercial articulated vehicles. The steady-state steering response and the lateral dynamic behaviour in lane-change (obstacle avoidance) manoeuvres of six articulated vehicles with different design features have been predicted using the Phase 4 model, the yaw/roll model, the TBS model, and the linear yaw plane model, developed by the University of Michigan Transportation Research Institute (UMTRI). A comparison of the predictions made by these models has been performed. These predictions have also been compared with a limited amount of experimental data available. In addition, the static roll model developed by UMTRI has been examined, and a parametric sensitivity study has been performed.

It is believed that the results of this study provide additional quantitative information upon which the appropriate areas of application of various simulation models may be defined.

INTRODUCTION

With the increasing use of commercial articulated vehicles, such as tractor-semitrailers and truck-full trailers, in road transport, concerns for their safety in operation have been growing. This has stimulated intensive studies of the dynamic stability of this type of vehicle.

A variety of analytical (simulation) models for predicting the lateral dynamic behaviour of commercial articulated vehicles have been developed in recent years. These models vary greatly in capability, in complexity, in the number of degrees of freedom considered, and in the amount of input data required. For instance, the Phase 4 model developed by the University of Michigan Transportation Research Institute (UMTRI) incorporates up to 71 degrees of freedom and requires up to approximately 2300 lines of input data, dependent upon the vehicle configuration (1)(2). On the other hand, the linear yaw plane model developed also by UMTRI only includes the lateral and yaw motion of the tractor and articulation in the horizontal plane of the other sprung masses of the articulated vehicle, and only requires up to approximately 35 lines of input data. It should also be mentioned that not only a large amount of input data is required for a sophisticated model, but also special measuring equipment is needed to obtain a number of these input parameters. Quite often, even if the equipment is available, the cost of obtaining the required parameters will be considerable.

When a practising engineer wishes to evaluate the lateral dynamic behaviour of a vehicle, he will undoubtedly be faced with the problem of how to select an appropriate model for a given task. A recent survey has pointed out that while a wide range of simulation models are available, a systematic evaluation of these models, particularly with respect to their areas of application, has been lacking (3). To fill this gap and to provide guidance for the practising engineer to select an appropriate model for a particular task, a detailed comparison of some of the more widely known simulation models, including the linear yaw plane model, the TBS model, the yaw/roll model, and the Phase 4 model developed at UMTRI has been performed.

The steady-state steering response and the lateral dynamic behaviour in lane-change (obstacle avoidance) type manoeuvres of six commercial articulated vehicles with different design features have been predicted using the four UMTRI computer simulation models. A comparison of the predictions made using these models and with a limited amount of experimental data available has been made. In addition, the static roll model developed by UMTRI has been examined, and a parametric sensitivity study has been performed.

The objective of this study is to compare the capabilities and limitations of various simulation models for the evaluation of the directional behaviour of commercial articulated vehicles. The results of the study will provide quantitative information upon which the appropriate areas of application of various models may be defined.

1. A BRIEF DESCRIPTION OF THE VARIOUS SIMULATION MODELS USED IN THE STUDY

A brief description of the basic features of the five simulation models used in the study, namely, the linear yaw plane model, the TBS model, the yaw/roll model, the Phase 4 model, and the static roll model developed at UMTRI, is given below (1)(2)(4).

1.1 The Linear Yaw Plane Model

The yaw plane model is a linear mathematical model for studying the directional behaviour of multiple articulated vehicles. The model was developed in 1978, originally for the purpose of analyzing the directional behaviour of double-bottom tankers.

Computer programs based on the model permit the evaluation of the following directional properties which are useful for studying a vehicle's directional stability and performance: (1) natural frequency and damping ratios of the natural modes of yaw motion (eigenvalues), (2) transient and steady-turning responses of each articulated unit of an articulated vehicle train, and (3) frequency response (by frequency response we mean the directional response of the vehicle to sinusoidal steer inputs).

At the present time, the computer programs permit the analysis of articulated vehicles which have up to three articulation points and a maximum of 11 axles. The computer codes can be easily expanded to the study of vehicles which have an even greater number of axles and articulation points.

In developing the equations of motion for the linear yaw plane model, the roll dynamics of the vehicle is neglected. Further, the vehicle is assumed to travel at a constant forward velocity. The degrees of freedom permitted in the model are therefore limited to lateral and yawing motion of the tractor and articulation in the horizontal plane of the other sprung masses of the multiple articulated vehicle.

The following are the assumptions made in the process of deriving the equations of motion:

A. The cornering forces and aligning moments generated at the tire-road interface are assumed to be linear functions of the sideslip angle of the tire.

B. Articulation angles made by the various elements of the vehicle train are small such that the following approximations hold: $\sin \Gamma_i \approx \Gamma_i$, $\cos \Gamma_i \approx 1$ (where Γ_i's are the articulation angles).

C. The motion of the vehicle takes place on a horizontal surface with uniform friction characteristics.

D. There are no significant tire forces present in the longitudinal direction (either tractive or braking).

E. Pitch and roll motions of the sprung masses are small and hence neglected.

F. All joints are frictionless and articulation takes place about vertical axes.

G. Steering system dynamics is not included in the model and the steering input is assumed to be given directly to the front wheels.

H. In the case of tanker trains, the tanker compartments are assumed to be either completely full or completely empty, thereby avoiding sloshing of the liquid.

I. Each element or unit of the articulated vehicle is assumed to be a rigid body (in the case of liquid filled tanks, all of the liquid is assumed to take part in the yawing motion, i.e., relative motion of the liquid with respect to the walls of the tank is neglected) and the unsprung masses are assumed to be rigidly attached to their respective sprung masses.

Due to the simple manner in which the vehicle is represented in the model, the input data required are moderate and computational costs are very low.

1.2 The TBS Model

This model is for predicting the directional response of commercial vehicles to steering inputs and/or braking (4). The simulation consists of two interactive computer programs, one for a straight truck and the other for a tractor-semitrailer. The model for the tractor-semitrailer has four degrees of freedom, namely, the longitudinal velocity, the lateral velocity, and the yaw velocity of the tractor, and the articulation angle of the semi-trailer relative to the tractor. There are no roll or pitch degrees of freedom. Load transfers, both longitudinal and lateral, are taken into consideration and are computed quasi-statically.

In this model, the hitch is assumed to transmit a yaw moment (but not a roll or pitch moment) through the friction in it. The hitch is modelled as a circular plate with a uniform pressure distribution, equal to the static load divided by the area of the plate. The coefficient of friction is assumed to be a constant. For "steel on steel", the value of the friction coefficient at the hitch is taken to be approximately 0.05.

The normal load on each wheel of the vehicle is equal to the sum of the static load and the load transfer (both longitudinal and lateral) taking place at any instant of time.

A simplified model for tandem axles is included. A quasi-static inter-axle load transfer is specified by entering an appropriate load transfer coefficient. The product of this coefficient and the braking force on one side of the tandem axles gives the inter-axle load transfer for that side.

For a free rolling tire, the model developed by Fiala is used to describe the relationship between lateral force and sideslip angle (4). For braking, two linear equations are used to describe the relationship between the braking effort coefficient and longitudinal slip, one for the range from zero to the peak value of the braking effort coefficient, and the other for the range from the peak value to the sliding value (100% skid) of the braking effort coefficient. For combined braking and cornering, an empirical equation is used to describe the functional relationships between the lateral and longitudinal forces and sideslip angle and longitudinal skid.

In the TBS model, antilock braking system can be accommodated. Dual tires are treated as two single tires, each sharing the vertical load on them equally and each yielding the same longitudinal and lateral forces.

Braking is handled in the model by specifying the time history of the attempted brake force for the brakes on either side of each axle. Since each side is considered separately, brake imbalance may be simulated. Steering inputs are entered in a tabular form. Each line of the table consists of the time followed by the average steer angle of the front wheels.

It should be mentioned that the model cannot handle the case when a wheel lifts off the ground. In other words, computations are stopped if this happens. Furthermore, if the articulation angle becomes larger than a user specified value, which may indicate "jackknifing" or "trailer swing", computations are also stopped.

1.3 The Yaw/Roll Model

The yaw/roll model was developed for the purpose of predicting the directional and roll response of single and multiple articulated vehicles engaged in steering manoeuvres which approach the rollover condition. It should be noted that the model does not permit the simulation of braking manoeuvres. The model is unique in the sense that it permits the analysis of unconventional vehicle layouts. The equations of motion are developed in such a fashion that it is possible to use the model for simulating vehicles with (1) any number of units and articulation points, (2) any number of placement of wheels and tires, and (3) any of the particular hitch mechanisms and constraints that are used in heavy-duty commercial vehicles.

In its present form, the computer code permits the simulation of vehicles with up to three articulation points (i.e., four sprung masses) and 11 axles. The computer program can be easily expanded to permit the analysis of vehicles with an even larger number of articulation points and axles.

In the model, the forward velocity of the lead unit is assumed to remain constant during the manoeuvre. Hence, each sprung mass is treated as a rigid body with five degrees of freedom: lateral, vertical, yaw, roll and pitch. The axles are treated as beam axles which are free to roll and bounce with respect to the sprung mass to which they are attached.

The following assumptions were made in the process of deriving the equations of motion:

A. Only steering manoeuvres (in which the input is an angular displacement of the front wheels on the lead unit) are modelled.

B. The vehicle moves over a horizontal surface possessing uniform frictional characteristics.

C. The pitch motions of the sprung masses are small such that $\sin \theta_s = \theta_s$ and $\cos \theta_s = 1$.

D. The relative roll displacements between the sprung masses and the axles remain small, such that $\sin(\phi_s - \phi_u) = \phi_s - \phi_u$ and $\cos(\phi_s - \phi_u) = 1$.

E. The relative roll motion between the unsprung and sprung masses takes place about roll centres, R, which are located at fixed distances beneath the sprung masses (see Fig. 1.1).

F. The line of action of the suspension springs remains parallel to the k_u axis (Fig. 1.1), with only compression and tensile forces being transmitted to the sprung mass. Figure 1.1 shows that the roll centre, R, is free to move in the k_u direction, such that any force on the axle in the j_u direction acts on the sprung mass at the roll centre, R. In the case of a suspension consisting of leaf springs, the springs are twisted (about a longitudinal axis) when the axle rolls relative to the sprung mass, with the resulting roll-resisting moment being treated as an auxiliary roll stiffness, KRS (see Fig. 1.1).

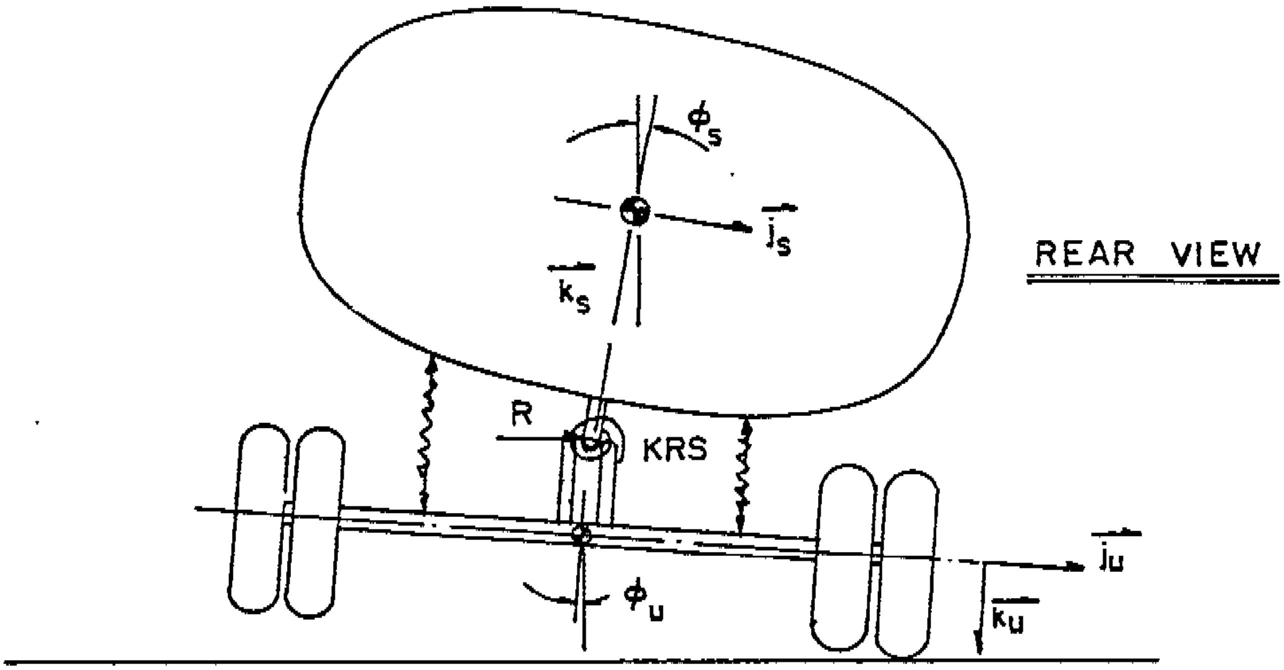


Figure 1.1 Idealized representation of axles and suspension springs

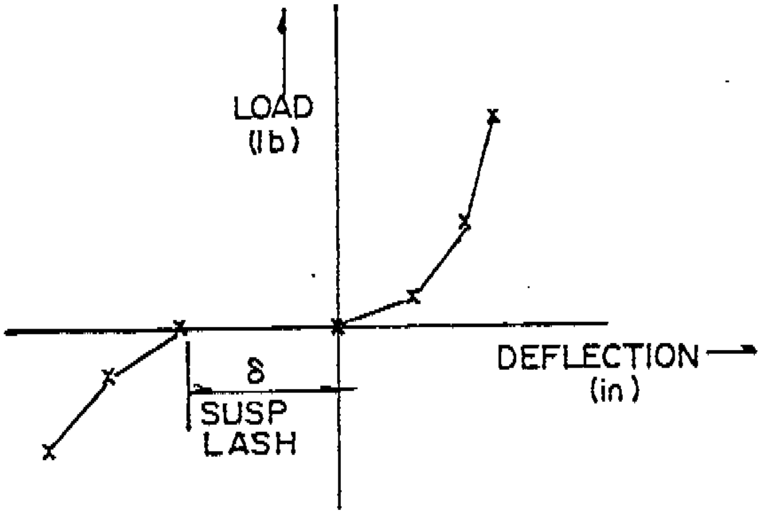


Figure 1.2 Idealized representation of suspension nonlinearities

G. Nonlinearities in the force-displacement behaviour of a suspension, such as suspension lash, are approximated as shown in Figure 1.2.

H. The forces acting on each axle are independent of the forces acting on adjacent axles, i.e., interaxle load transfers are neglected.

I. The cornering force and aligning moment produced by a given tire is a nonlinear function depending only on sideslip angle and vertical load. The influence of wheel inclination (or camber) on lateral force generation has been neglected on the grounds that inclination angles remain small prior to wheels being lifted off the ground in a severe manoeuvre.

J. The principal axes of inertia of the sprung and unsprung masses coincide with the respective body-fixed co-ordinate systems.

In its present form, the computer program permits the analysis of vehicles which are equipped with any of the four coupling mechanisms used in heavy-duty commercial vehicles, namely, the fifth wheel, inverted fifth wheel, kingpin, and pintle hook. Note that the "fifth wheel" and the "inverted fifth wheel" permit the lead and the trailing units to yaw and pitch with respect to one another, but are "stiff" in roll. On the other hand, the so-called "kingpin" connection permits only yaw motions between the lead and the trailing units. In the case of the "pintle hook", the trailing unit can roll, bounce, yaw, and pitch with respect to the lead unit.

1.4 The Phase 4 Model

This model was developed in 1980 for simulating the braking and steering dynamics of trucks, tractor-semitrailers, doubles, and triples combinations. The goal in developing this program was to consolidate principal features of all existing computer models into a single program. In short, the Phase 4 model represents UMTRI's latest thinking in computer modelling of the braking and steering response of commonly used commercial vehicles.

The Phase 4 program is a time-domain mathematical simulation of a truck/tractor, a semitrailer, and up to two full trailers. The motions of the vehicles are represented by differential equations derived from Newtonian mechanics, that are solved for successive time increments by digital integration.

The program is written in a generalized fashion to allow simulation of a large number of vehicle configurations. The first vehicle is the power unit and may be a truck or tractor, both of which may carry payload. As a single unit with no payload, it is equivalent to an empty truck or bobtail tractor. With payload, it is a truck, which, with a semitrailer simulates a car hauler, dromedary tractor, etc. The second unit is always a semitrailer (i.e., the current model does not include a truck with full trailer). The third and fourth units are full trailers consisting of semitrailers on either a fixed or converter dolly. Separate payload may be specified for each trailer.

The mathematical model incorporates up to 71 degrees of freedom. The number of degrees of freedom are dependent on the vehicle configuration and derive from the following:

- Six degrees of freedom (three translational and three rotational) for the truck/tractor sprung mass
- Three degrees of freedom for the semitrailer (the three other degrees of freedom of the semitrailer are effectively eliminated by dynamic constraints at the hitch)
- Five degrees of freedom for each of the two full trailers allowed
- Two degrees of freedom (vertical and roll) for each of the 13 axles allowed
- A wheel rotational degree of freedom for each of the 26 wheels allowed

The motion of each of the sprung masses is determined from the summation of forces and moments arising from the tires (acting through the unsprung mass and suspension), gravity, and the hitch point constraints. Small roll and pitch angle assumptions are made in deriving equations so that the simulation can be validly applied only up to a manoeuvre limit at which vehicle roll-over occurs.

The Phase 4 model can be used to simulate the following vehicle configurations:

Straight truck, empty and loaded
Bobtail tractor
Tractor-semitrailer (3 to 5 axles), empty and loaded
Tractor-Semitrailer-full trailer (5 to 9 axles), empty and loaded
Tractor-semitrailer-full trailer-full trailer (7 to 13 axles), empty and loaded.

For simulation of braking performance, the program incorporates state-or-the-art representation of truck air brake systems, antilock braking systems, and tire-road friction models. Typical examples of braking studies for which it can be, or has been used, are:

A. Stopping distance performance
B. Effects of brake timing
C. Dynamic behaviour in braking
D. Comparisons of antilock wheel control logic
E. Influence of tire-road friction coupling
F. Split friction surfaces
G. Brake proportioning
H. Tandem-axle effects on braking limits.

For simulation of cornering performance behaviour, the program incorporated state-of-the-art representations of truck tire lateral force characteristics (with roll-off effects during combined braking), and vehicle suspension properties of significance to cornering behaviour. Typical examples of studies involving cornering are as follows:

A. Understeer/oversteer properties of commercial vehicles
B. Determining cornering limits
C. Assessing tandem-axle effects on cornering
D. Jackknife prediction
E. Effects of suspension properties on cornering and cornering limits
F. Accident simulation.

In addition to the above, the program can be operated open-loop (defined steer angle inputs) or closed-loop (defined path input), and on roads of specified grade or cross-slope.

The Phase 4 program is uniquely applicable in studies in which the influence of the following items are to be considered in detail:

A. Spring force/deflection characteristics (hysteresis and free-play)
B. Brake "fade" - brake temperature
C. Brake hysteresis
D. Load-leveler action in tandem suspensions
E. Brake proportioning algorithms
F. Steering system compliance (inputs at the steering wheel)
G. Frame torsional stiffness.

1.5 The Static Roll Model

The static roll model was developed for the purpose of calculating the rollover threshold of articulated vehicles during steady turning manoeuvres. The dynamics of roll motion are not included in the model. Instead, the roll response in a steady turn is computed by repeatedly solving, for small increments of roll angle, a set of equations which describe the static equilibrium of the vehicle in the roll plane.

Figure 1.3 shows the side view of an example tractor-semitrailer as presented in the roll plane model. As shown in the Figure, axles with similar suspension properties are grouped together in such a fashion that all the axles on the vehicle are represented by a set of three composite axles. The composite axles are:

1) tractor front axle
2) tractor rear axle (either a single or tandem axles are combined and represented by one axle)
3) trailer axle (all the axles on the trailer are combined and represented by one axle).

The torsional compliance that exists in the tractor frame is represented by a torsional spring element, KFR (Fig. 1.3). Similarly, the structural compliance in the body of the trailer and the fifth wheel arrangement are lumped together and represented by another torsional element, K5. The idealized representation of the friction (CFR) present in the tractor frame and the separation of the fifth wheel plates (LASH5) are shown in Figures 1.4 and 1.5 respectively.

In the model, the relative motion between the sprung mass and the axles is assumed to take place about roll centres which are at fixed distances beneath the sprung masses. As shown in Figure 1.6, the suspension springs are assumed to remain parallel to the $\vec{k}_{u_i}$ axes of the axles and transmit only compressive or tensile forces.

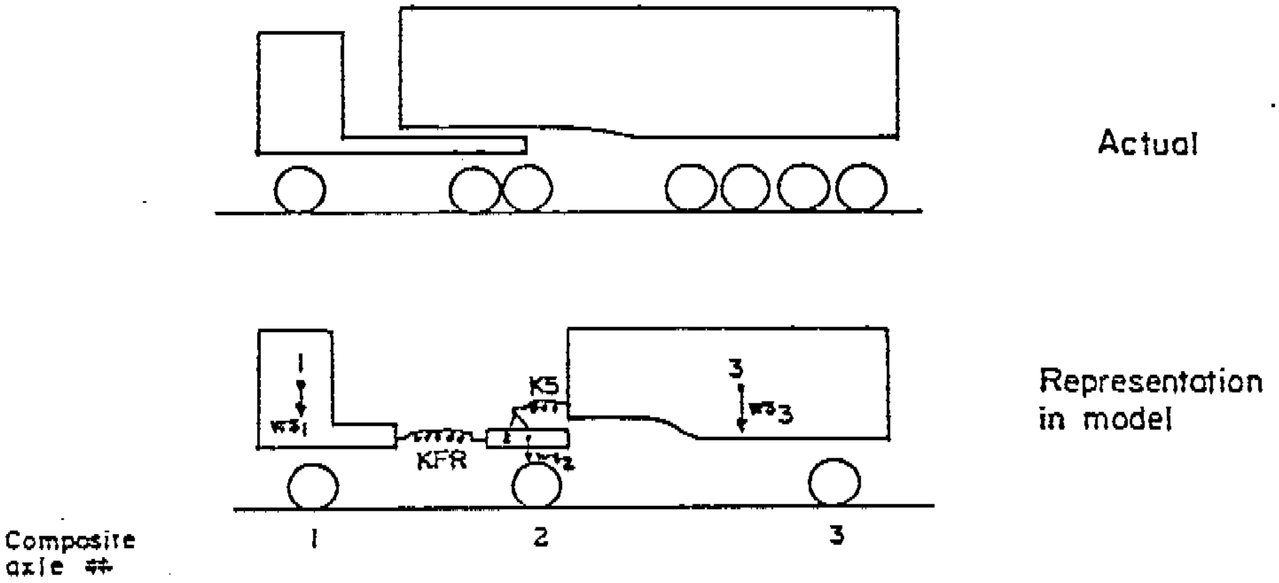


Figure 1.3 Side view of the representation of axles in the static roll model

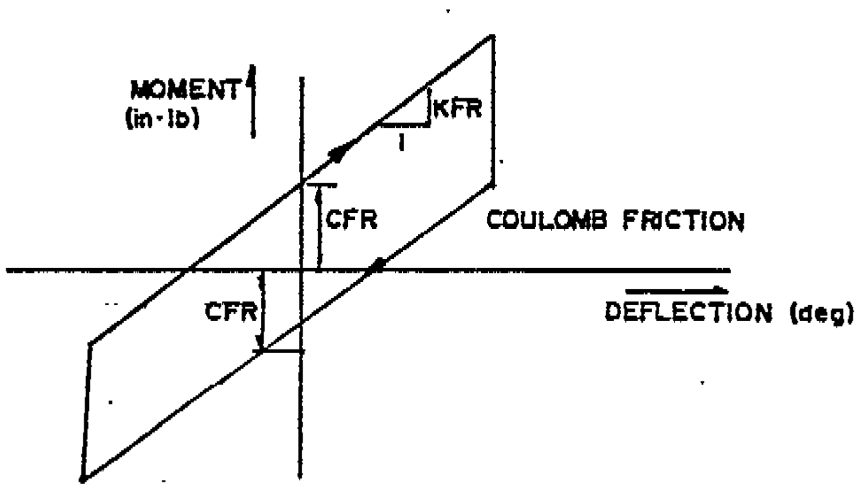


Figure 1.4 Idealized representation of tractor frame compliance

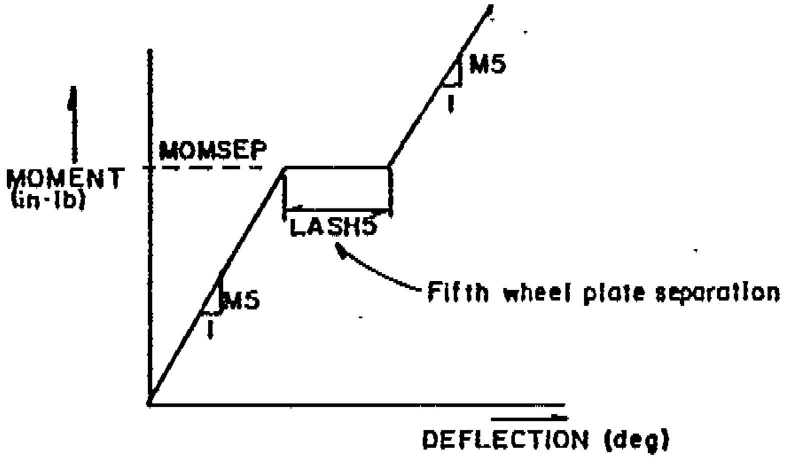
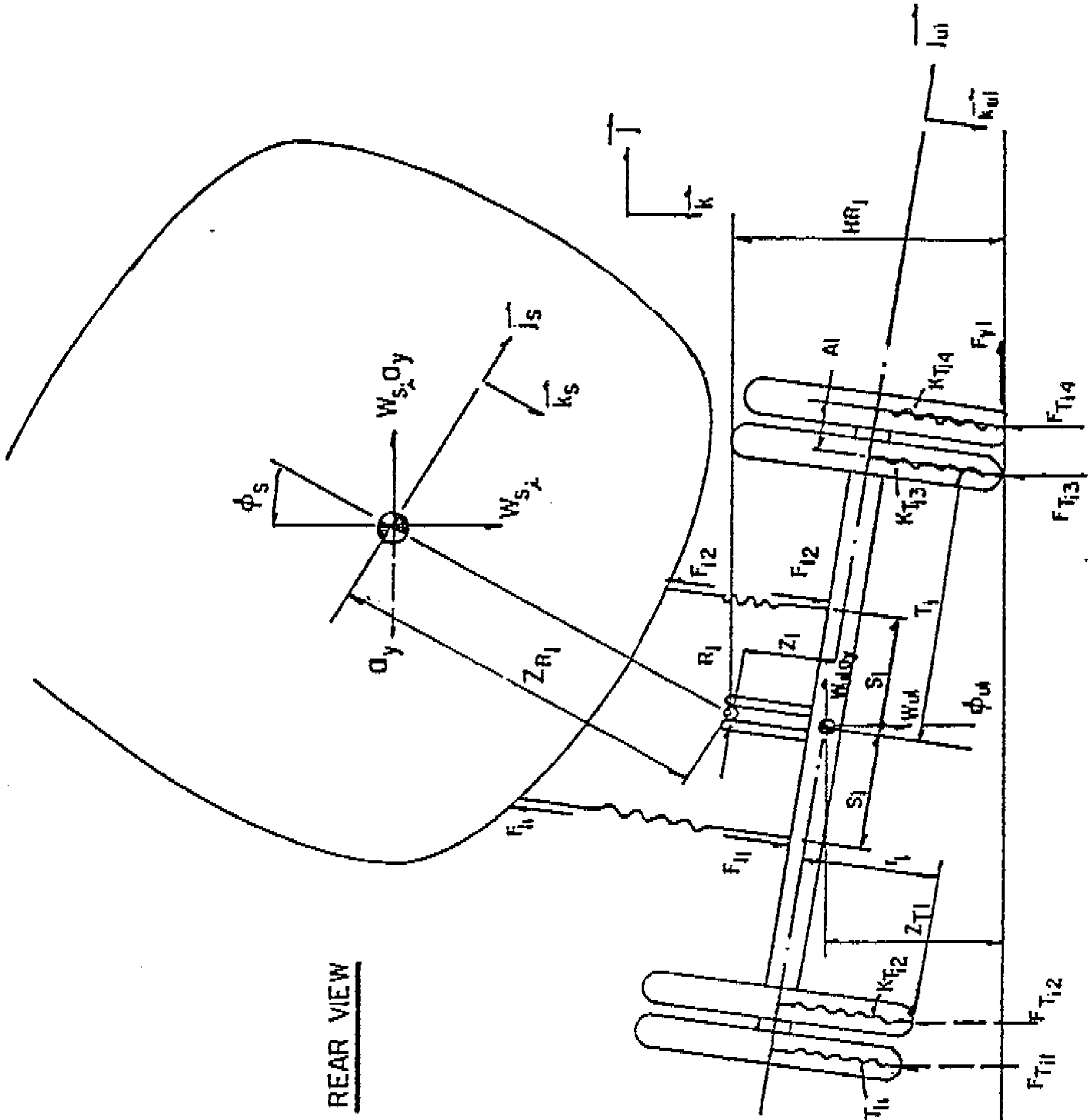


Figure 1.5 Idealized representation of fifth wheel compliance


REAR VIEW
ϕ_s
W_{s_i}
$W_{s_i} a_y$
$\vec{i}_s$
$\vec{k}_s$
a_y
Z_{R_i}
R_i
Z_i
F_{i2}
F_{i1}
S_i
T_i
$W_{ui} a_y$
W_{ui}
ϕ_{ui}
A_i
HR_i
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F_{yi}
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$F_{T_{i3}}$
$F_{T_{i2}}$
$F_{T_{i1}}$
$K_{T_{i4}}$
$K_{T_{i3}}$
$K_{T_{i2}}$
$K_{T_{i1}}$
Z_{T_i}

Figure 1.6

The roll centres are permitted to slide freely (with respect to the axles) along the $\vec{k}_{u_i}$ axes. All axle forces which act in a direction parallel to the $\vec{k}_{u_i}$ axles are taken up by the suspension springs, while all axle forces acting along the $\vec{j}_{u_i}$ axes are assumed to act through the roll centre, R_i.

Suspension nonlinearities such as backlash and progressively hardening suspension springs are presented by a tabular load-deflection input format. The suspension forces and local spring rates at any given deflection are then computed by linear interpolation. Figure 1.7 shows the representation of a suspension spring in the model.

The other simplifying assumptions implicit in the derivation of the equations are listed below.

A. The roll angles of the sprung mass and the axles are small, such that the small angle assumptions $\sin(\phi) = \phi$ and $\cos(\phi) = 1.0$ hold.

B. The articulation angles are small so that the influence of articulation angle on roll response can be neglected.

C. The total vertical load carried by each composite axle is assumed to remain constant during the rollover process. In order to accommodate any pitching motion that might take place during rollover, the sprung masses are permitted to take up different vertical deflections at each of the three axle locations.

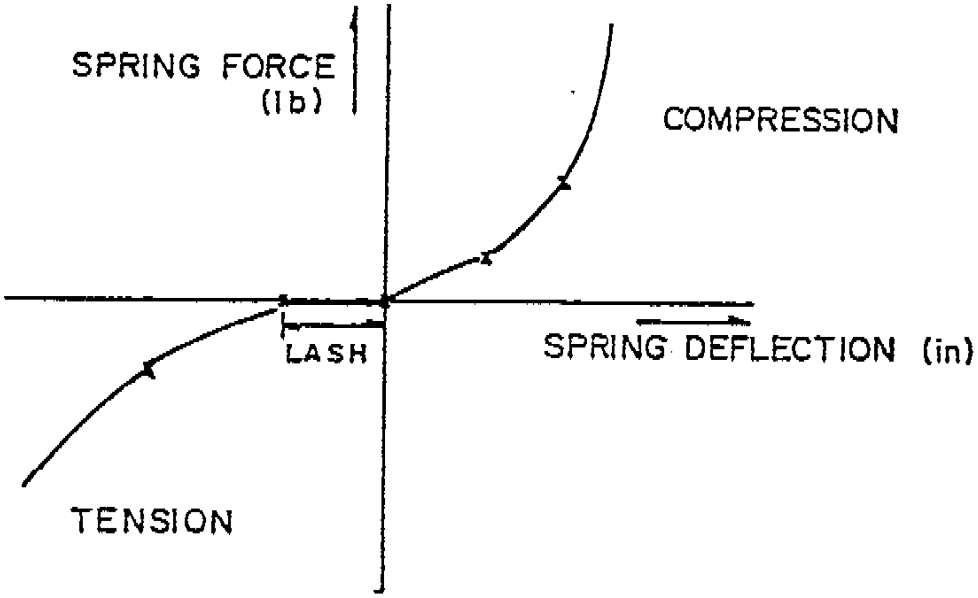


Figure 1.7 Idealized representation of suspension spring characteristics

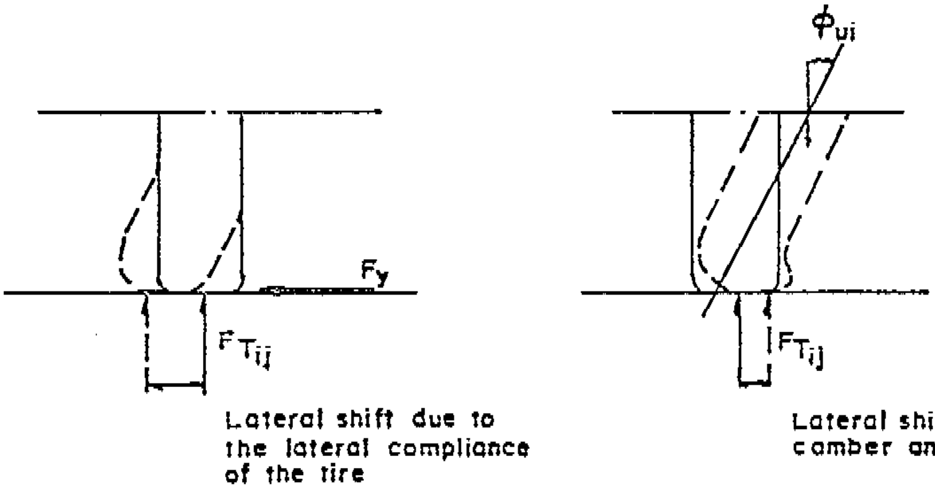


Figure 1.8 The effect of lateral compliance and camber angle on the centroid of the normal pressure distribution at the tire/road interface

D. The vertical load carried by each tire is assumed to act through the midpoint of its tread width. As shown in Figure 1.8, the effect of camber angle and the effect of the lateral compliance of the tire tend to have opposing effects on the lateral translation of the centroid of the normal pressure distribution at the tire-road interface. Both of these effects are small and tend to cancel out. In order to keep the analysis simple, the lateral translation of the normal load is neglected.

The model contains a fairly detailed description of suspension and tire properties, such that the accurate prediction of steady-turning rollover threshold is possible. Computational costs are low due to the fact that no roll dynamics is included in the model. Moreover, a single computer run is sufficient for computing the rollover threshold, as well as the roll response of the vehicle over the entire range of lateral acceleration levels up to the rollover threshold.

2. VEHICLE CONFIGURATIONS USED IN THE SIMULATION STUDY

To quantitatively compare their predictive ability, the computer simulation models described above were used to predict the responses of six different commercial articulated vehicles in two types of turning manoeuvres, namely steady-state turning and lane-change (obstacle avoidance) manoeuvres.

The six vehicle configurations selected include five tractor-semitrailers and one five-axle double with 27 ft. trailer (that is, a two-axle tractor with a single-axle semitrailer and a two-axle full trailer). The basic parameters of the vehicles are summarized in Table 2.1.

A. Vehicle Configuration 1 is a fully-loaded three-axle tractor with a two-axle semitrailer. The basic parameters are similar to those of an International Harvester three-axle tractor (COF 4000 D) with a Fruehauf 45 - foot van-type semitrailer (FG8-F2-45') described in reference (5). A complete set of input data for the four computer simulation models, namely the Phase 4 model, the yaw/roll model, the TBS model, and the linear yaw plane model, is given in Appendix A.

B. Vehicle Configuration 2 is similar to Vehicle Configuration 1, but with the following modifications:

a) The tractor frame has been stiffened, and its torsional stiffness has been increased from 20,000 to 120,000 in-lb/deg.

b) An auxiliary roll-stiffening device ("sway bar") has been installed on the tractor front suspension. The device provides an additional roll stiffness of 109,385 in-lb/deg.

Table 2.1

Basic Parameters of Various Vehicle Configurations

Vehicle Configuration	1	2	3	4	5	6
A. Tractor	3-axle	3-axle	3-axle	3-axle	3-axle	2-axle
Wheelbase (in)	142.0	142.0	144.0	144.0	144.0	120.0
Curb weight on front suspension (lb)	8,898	8,898	8,960	8,960	8,960	8,960
Curb weight on rear suspension (lb)	7,118	7,118	6,540	6,540	6,540	4,240
Sprung mass C.G. height (in)	39.7	39.7	44.0	44.0	44.0	44.0
Sprung mass roll moment of inertia (in-lb-sec^2)	18,166.6	18,166.6	15,000	15,000	15,000	15,000
Sprung mass pitch moment of inertia (in-lb-sec^2)	69,955.0	69,955.0	75,000	75,000	75,000	75,000
Sprung mass yaw moment of inertia (in-lb-sec^2)	69,955.0	69,955.0	75,000	75,000	75,000	75,000
Fifth wheel location, ahead of rear suspension centre (in)	0.0	0.0	14.35	14.35	0	8.73
Fifth wheel height (in)	48.5	48.5	48.0	48.0	48.0	48.0
Frame torsional stiffness (in-lb/deg)	20,000	120,000	50,000	50,000	50,000	50,000
Roll centre height of front suspension (in)	24.55	24.55	23.0	23.0	23.0	23.0
Auxiliary roll stiffness of front suspension (in-lb/deg)	0	109.385	1,500	0	0	1,500
Roll centre height of rear suspension (in)	22.0	22.0	29.0	29.0	29.0	29.0
Auxiliary roll stiffness of leading tandem axle (in-lb/deg)	0	0	6,000	0	0	
Auxiliary roll stiffness of trailing tandem axle (in-lb/deg)	78,000	78,000	6,000	78,000	78,000	8,000
Front tires	Type A	Type A	Type C	Type C	Type C	Type C
Rear tires	Type A	Type A	Type C	Type C	Type C	Type C

Table 2.1

Basic Parameters of Various Vehicle Configurations

Vehicle Configuration		1	2	3	4	5	6
B. Semitrailer		Tandem Axle	Tandem Axle	Tandem Axle	Tandem Axle	Tandem Axle	Single Axle
Wheelbase	(in)	410.0	410.0	432.0	432.0	432.0	252.0
Kingpin static load	(lb)	6,252.3	6,252.3	4,500	4,500	4,500	2,250
Curb weight on rear suspension	(lb)	11,068.7	11.068.7	7,500	7,500	7,500	3,750
Sprung mass C. G. height	(in)	69.0	69.0	60.0	60.0	60.0	60.0
Sprung mass roll moment of inertia (in-lb-sec^2)		73,000	73,000	60,000	60,000	60,000	30,000
Sprung mass pitch moment of inertia (in-lb-sec^2)		789,869	789,860	750,000	750,000	750,000	93,750
Sprung mass yaw moment of inertia (in-lb-sec^2)		789,869	789,869	750,000	750,000	750,000	93,750
Payload weight	(lb)	40,600	40,600	52,500	52,500	52,500	25,800
Payload C.G. ahead of rear suspension centre	(in)	182.0	182.0	213.9	213.9	213.9	117.7
Payload C.G. height	(in)	64.5	64.5	85.0	85.0	85.0	85.0
Payload roll moment of inertia (in-lb-sec^2)		37,500	37,500	132,000	132,000	132,000	65,000
Payload pitch moment of inertia (in-lb-sec^2)		1,727,000	1,727,000	3,050,000	3,050,000	3,050,000	375,000
Payload yaw moment of inertia (in-lb-sec^2)		1,727,000	1,727,000	3,100,000	3,100,000	3,100,000	375,000
Roll stiffness of fifth wheel (in-lb/deg)		9,999,999	9,999,999	1,000,000	1,000,000	1,000,000	1,000,000
Roll centre height		25.6	25.6	29.0	29.0	29.0	29.0
Auxiliary roll stiffness of leading tandem axle (in-lb/deg)		0	0	10,000	0	0	10,000
Auxiliary roll stiffness of trailing tandem axle (in-lb/deg)		0	0	10,000	0	0	
Tires		Type B	Type B	Type C	Type C	Type C	Type C

Table 2.1

Basic Parameters of Various Vehicle Configurations

Vehicle Configuration	1	2	3	4	5	6
C. Trailer						2-axle
Distance from dolly suspension to pintle hook (in)						80.0
Turntable location ahead of dolly suspension centre (in)						0
Turntable height (in)						48.0
Wheelbase (in)						252.0
Curb weight on front suspension (lb)						4,250
Curb weight on rear suspension (lb)						4,250
Sprung mass C.G. height (in)						60.0
Sprung mass roll moment of inertia (in-lb-sec^2)						36,000
Sprung mass pitch moment of inertia(in-lb-sec^2)						115,000
Sprung mass yaw moment of inertia (in-lb-sec^2)						115,000
Payload weight (lb)						26,500
Payload C.G. ahead of rear suspension centre (in)						126.0
Payload C.G. height (in)						85.0
Payload roll moment of inertia (in-lb-sec^2)						65,000
Payload pitch moment of inertia (in-lb-sec^2)						375,000
Payload yaw moment of inertia (in-lb-sec^2)						375,000
Centre height of front suspension (in)						29.0
Auxiliary roll stiffness of front suspension (in-lb-deg)						10,000
Roll centre height of rear suspension (in)						29.0
Auxiliary roll stiffness of rear suspension (in-lb/deg)						10,000
Tires						Type C

The stiffening of the tractor frame and the increasing of the roll stiffness of the front suspension of the tractor modify the roll moment distribution between the tractor front and rear suspensions in a turning manoeuvre. High percentage of the roll moment will be supported by the front suspension, which causes more lateral load transfer from the inside tire to the outside tire on the tractor front axle. This produces an understeer effect for the tractor. Therefore, the increasing of the frame torsional stiffness and the roll stiffness of the front suspension of the tractor will result in a significant change in the handling behaviour of the vehicle.

It should be pointed out that although the frame stiffener and the auxiliary roll-stiffening device on the front suspension employed to achieve significant changes in roll moment distribution would never be used in practice, they do provide changes in vehicle handling characteristics suitable for studying the influence of altering the roll moment distribution and for evaluating the ability of various simulation models to predict these influences.

A complete set of input data for the four computer models for simulating this vehicle configuration is given in Appendix B.

C. In comparison with Vehicle Configuration 1 and 2, Vehicle Configuration 3 has different loading conditions, and is equipped with a different type of tire. Furthermore, the fifth wheel is located 14.35 in. ahead of the rear suspension centre of the tractor. These factors combined will make the handling behaviour of this vehicle configuration different from that of Vehicle Configurations 1 and 2.

D. Vehicle Configuration 4 is similar to Vehicle Configuration 3, but with the following modifications:

a) Auxiliary roll-stiffening devices on the tractor front suspension and on its leading tandem axle suspension have been removed. Consequently, the auxiliary roll stiffness of the two suspensions are reduced to zero.

b) A different auxiliary roll-stiffening device is installed on the trailing tandem axle of the tractor and its roll stiffness is increased to 78,000 in-lb/deg.

These two factors combined produce an oversteer effect for the tractor.

A complete set of input data for the four computer models for simulating this vehicle configuration is given in Appendix D.

E. Vehicle Configuration 5 is similar to Vehicle Configuration 4, with the exception that the fifth wheel centre is located at the centre of the rear suspension of the tractor. The rearward shift of the fifth wheel centre, as compared with that in Vehicle Configuration 4, tends to produce an oversteer effect for the tractor.

A complete set of input data for the computer models for simulating this vehicle configuration is given in Appendix E.

F. Vehicle Configuration 6 is a five-axle double with 27 ft trailers. It consists of a two-axle tractor, a single axle semitrailer and a two-axle full trailer. This vehicle configuration is included in the study to provide an additional case for evaluating the predictive ability of the various computer simulation models. It should be mentioned that only the linear yaw plane model, the yaw/roll model, and the Phase 4 model were used in the simulation of this vehicle configuration, as the TBS model was designed solely for simulating the tractor-semitrailer.

Three sets of input data for the three computer models for simulating this vehicle configuration are given in Appendix F.

As can be seen from Table 2.1, three types of tire, referred to as Type A (Firestone Rib 10.00 x 22F), Type B (Freuhauf Rib 10.00 x 20F), and Type C, are used in the study. The variations of the cornering (lateral) force and aligning torque with sideslip angle for the three types of tire are shown in Figs. 2.1, 2.2, and 2.3, respectively. It can be seen that Types A and B have lower concerning stiffness (or the equivalent) than Type C. The aligning torque of Type A is higher than those of Types B and C at sideslip angles less than approximately 8° with normal load of 9,000 lb, and at sideslip angles less than approximately 10° with normal load of 6,000 lb. Types B and C have similar aligning torque-sideslip angle characteristics at normal loads of 6,000 and 9,000 lb.

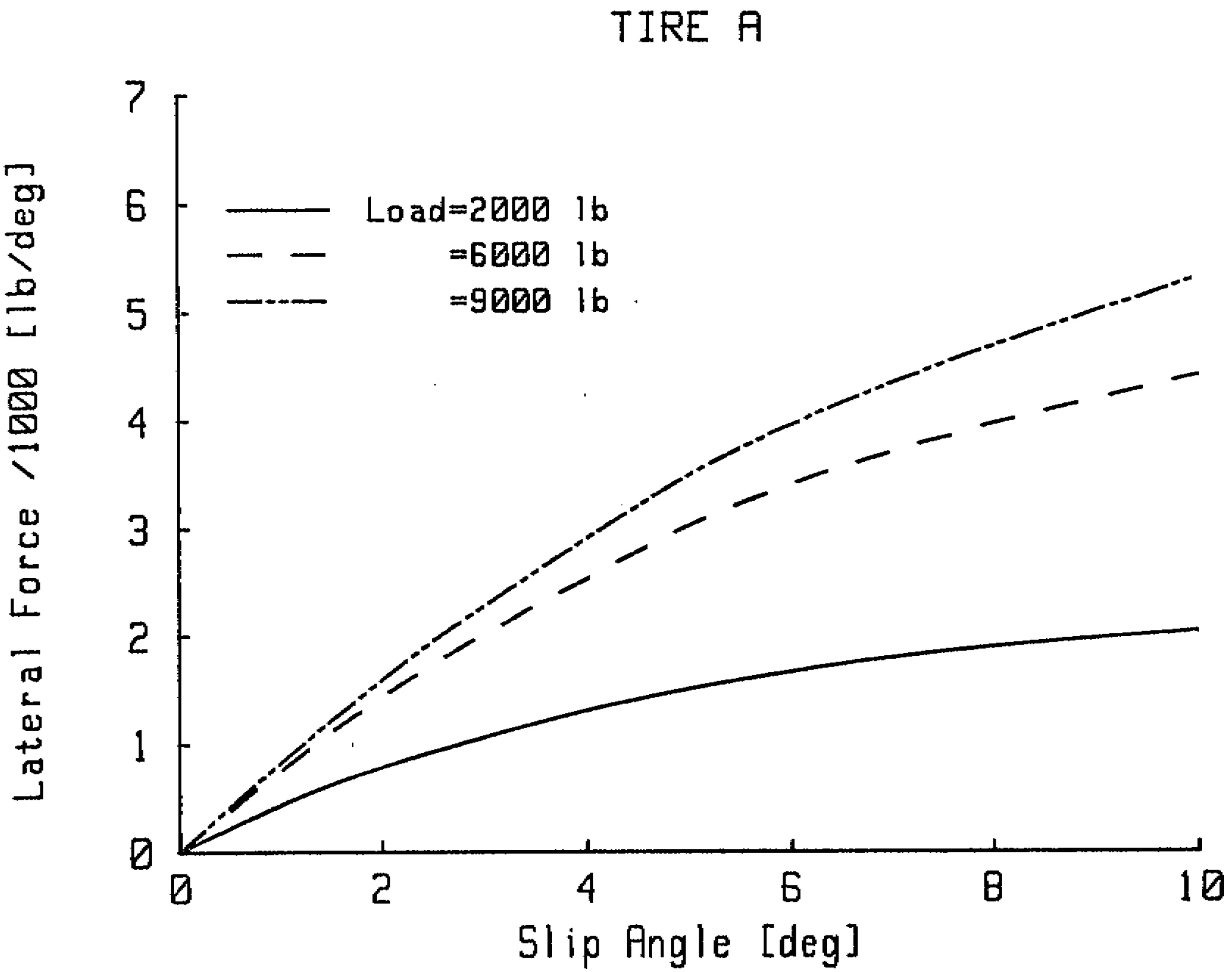


Fig. 2.1 (a) Firestone 10.00 x 22F

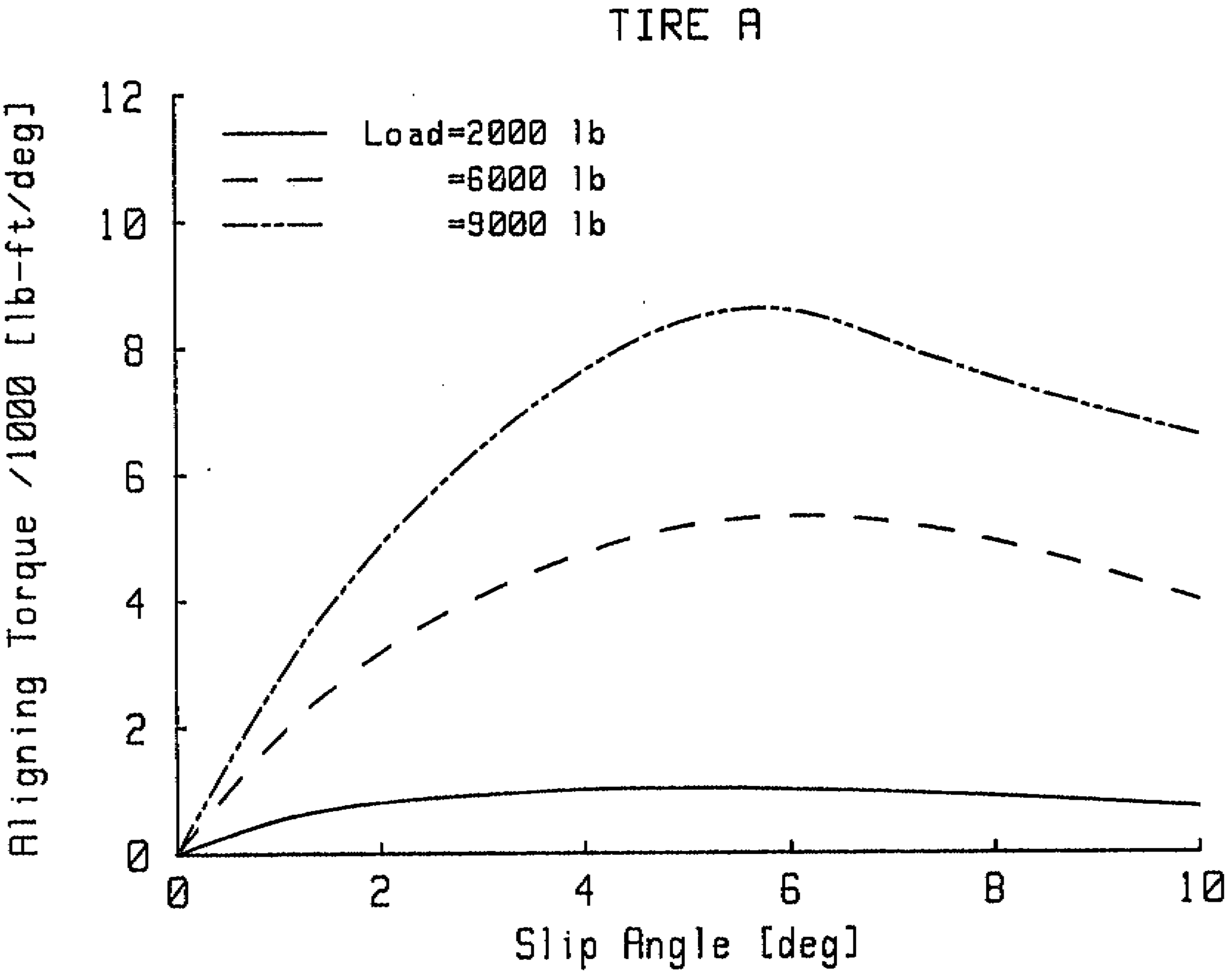

TIRE A
Load=2000 lb
=6000 lb
=9000 lb
Aligning Torque /1000 [lb-ft/deg]
12
10
8
6
4
2
0
0
2
4
6
8
10
Slip Angle [deg]

Fig. 2.1 (b)

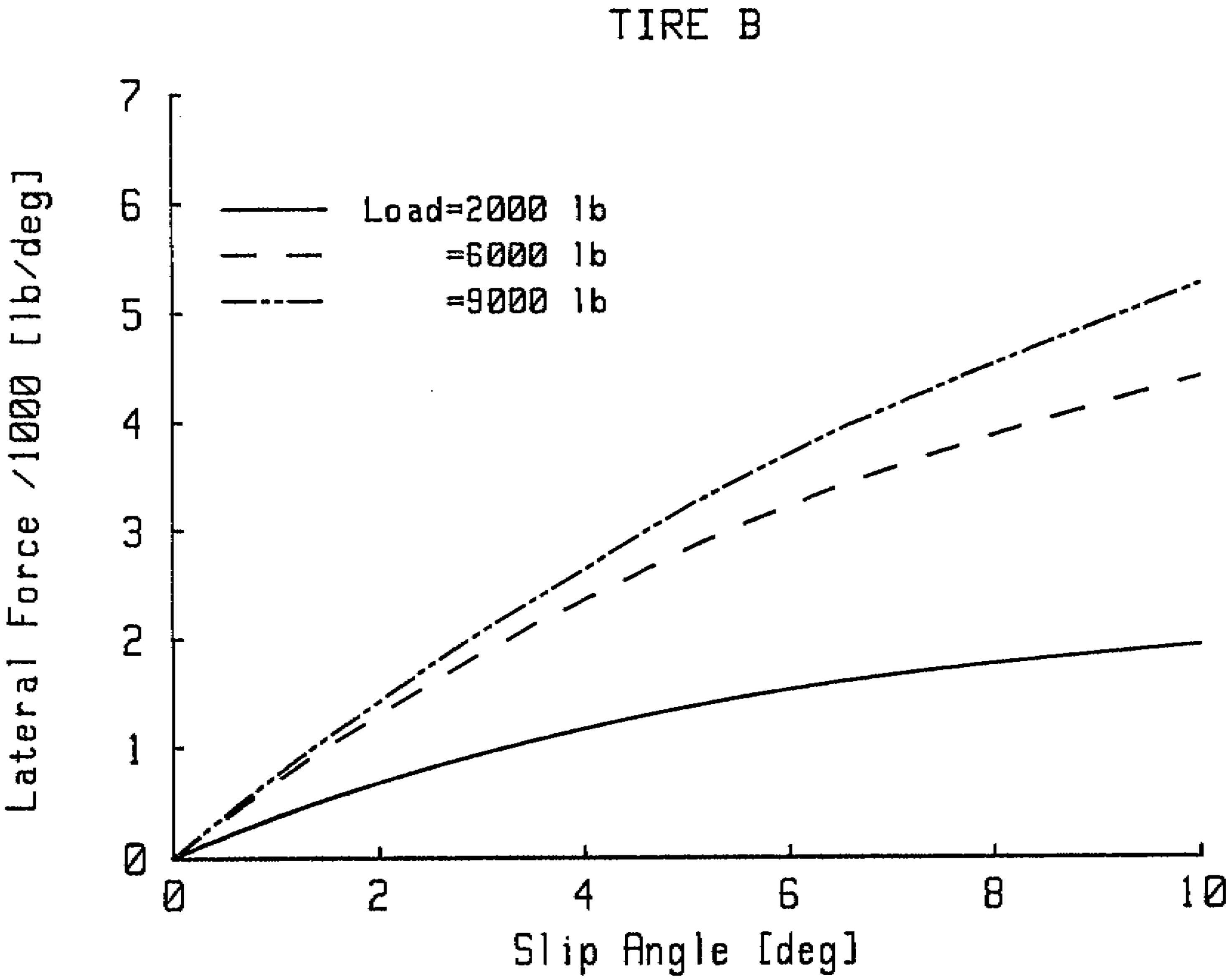


Fig. 2.2 (a) Freuhauf 10.00 x 20F

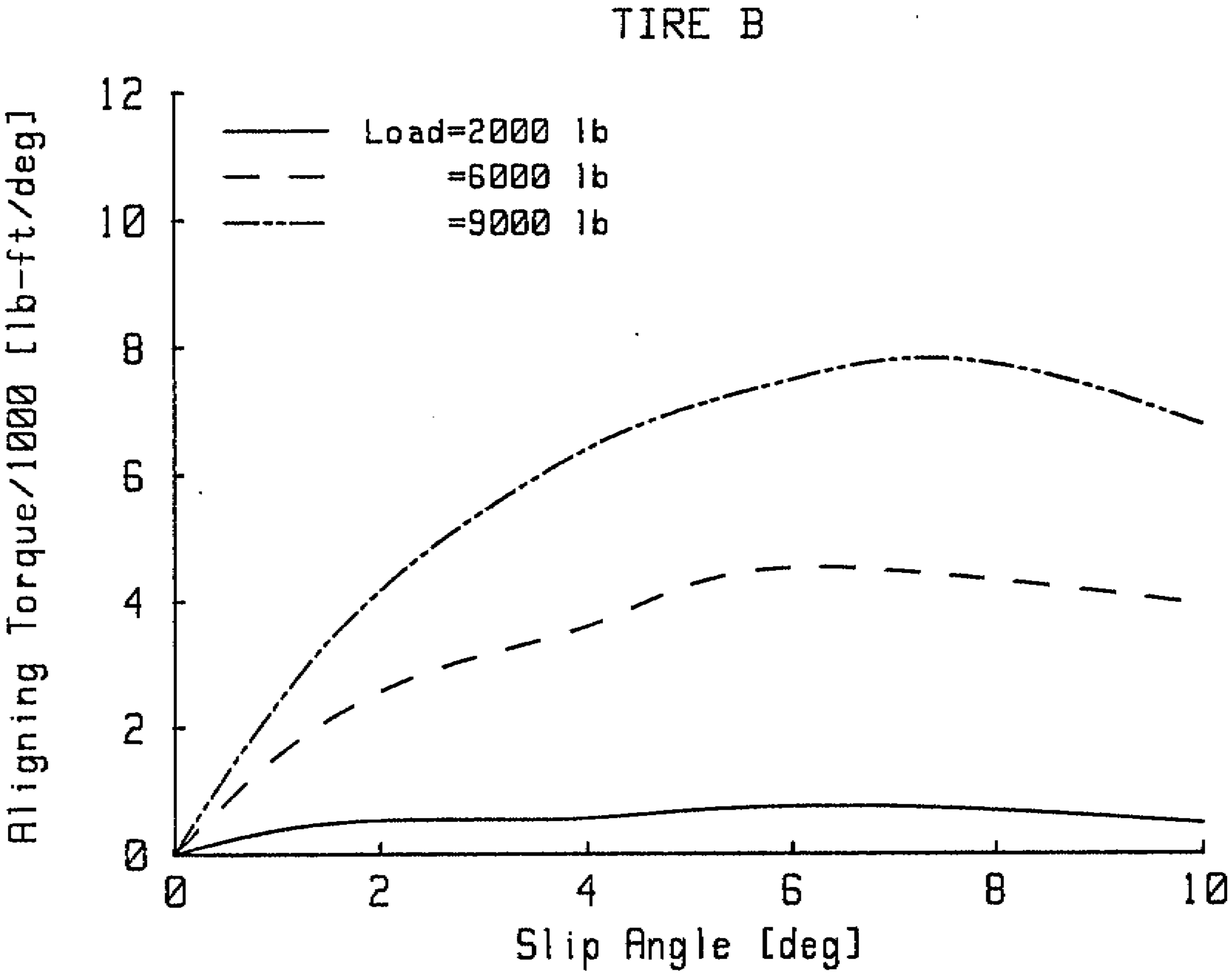

TIRE B
Load=2000 lb
=6000 lb
=9000 lb
Aligning Torque/1000 [lb-ft/deg]
0
2
4
6
8
10
12
Slip Angle [deg]
0
2
4
6
8
10

Fig. 2.2 (b)

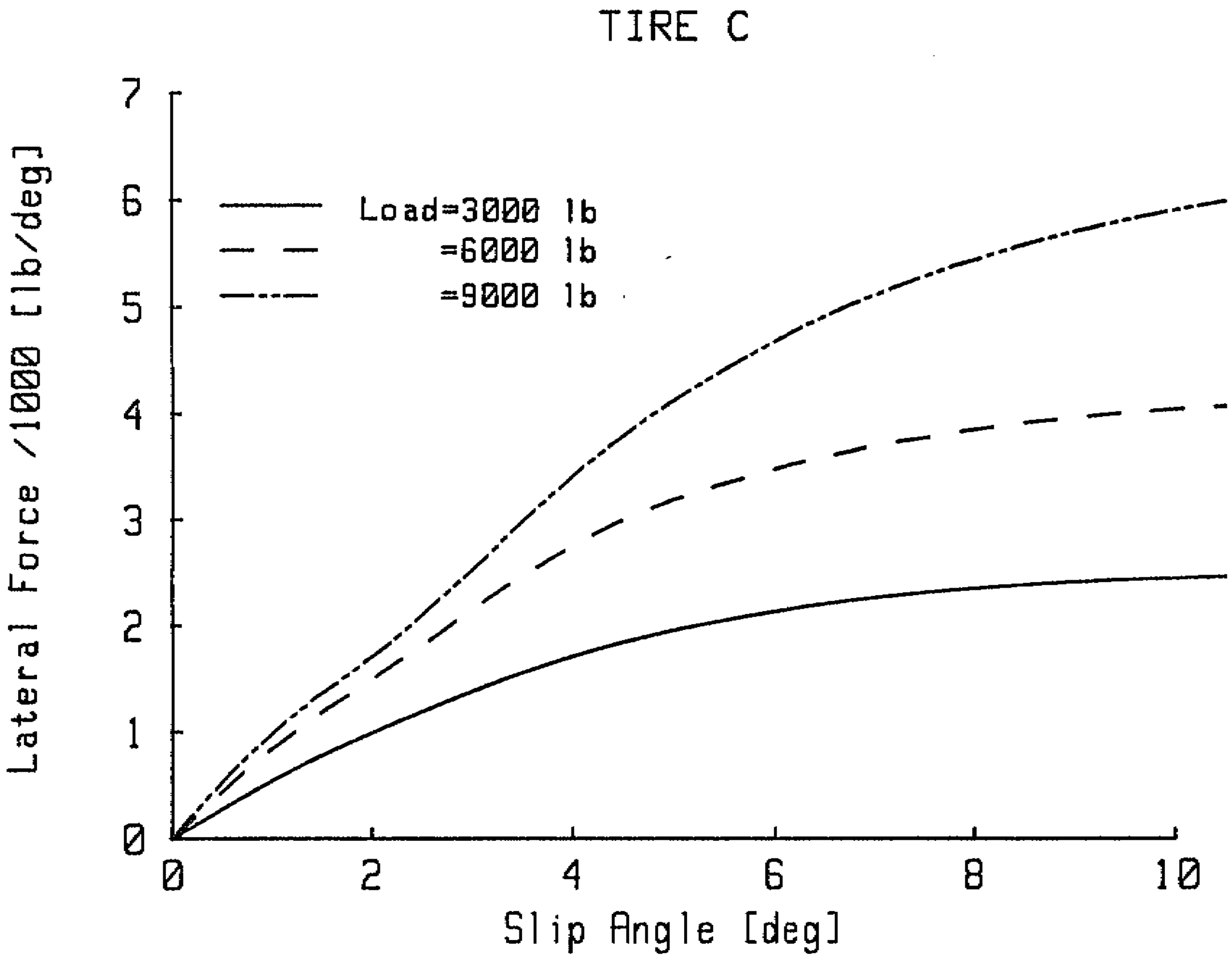

TIRE C
Load=3000 lb
=6000 lb
=9000 lb
Lateral Force /1000 [lb/deg]
0
1
2
3
4
5
6
7
0
2
4
6
8
10
Slip Angle [deg]

Fig. 2.3 (a)

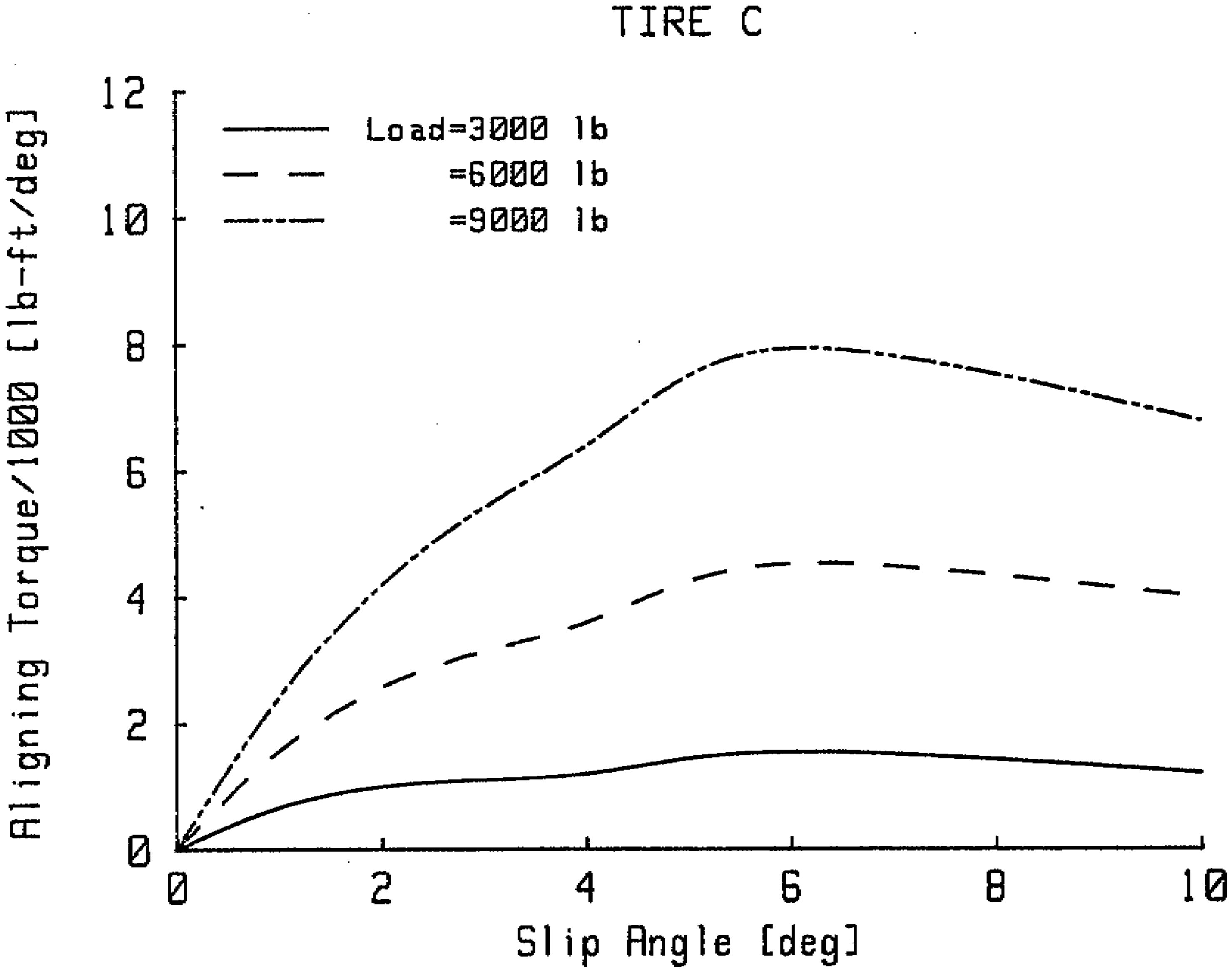

TIRE C
Load=3000 lb
=6000 lb
=9000 lb
Aligning Torque/1000 [lb-ft/deg]
0
2
4
6
8
10
12
Slip Angle [deg]
0
2
4
6
8
10

Fig. 2.3 (b)

It has been shown that among other factors the characteristics of the tires and their placement on the vehicle, the distribution of roll stiffness among the suspensions, the location of the fifth wheel, and the location of the centre of gravity of the payload have significant effects on the handling of an articulated vehicle. The six vehicles and the three types of tire selected in this study, therefore, represent a range of vehicle configurations that are expected to have substantially different lateral dynamic behaviour in both the linear and nonlinear regimes. These will provide a wide range of conditions under which the predictive ability of the various computer simulation models may be evaluated and compared quantitatively.

3. A COMPARISON OF THE CAPABILITIES OF VARIOUS COMPUTER SIMULATION MODELS IN PREDICTING STEADY-STATE STEERING RESPONSES

The steady-state steering responses of the six vehicle configurations described in the preceding section were predicted using the four computer simulation models, that is, the linear yaw plane model, the TBS model, the yaw/roll model, and the Phase 4 model. In the simulations, ramp inputs of front-wheel steering angle as shown in Fig. 3.1 were applied. After the response of the vehicle reached a steady-state, the lateral acceleration and yaw rate of the tractor as functions of the front-wheel steering angle were determined, and the handling diagram for the tractor was plotted (5)(6). The handling diagram illustrates the relationship between the lateral acceleration of the tractor a_y and the parameter ($\ell/R - \delta$), where ℓ is the wheelbase of the tractor, R is the turning radius, and δ is the front-wheel steering angle. The turning radius can be derived from the ratio of the yaw rate, r, to forward speed of the vehicle, V. The steady-state steering behaviour of the vehicle (neutral steer, understeer, or oversteer) can then be determined from the handling diagram. If the slope of the a_y versus ($r\ell/V-\delta$) curve is negative, then understeer behaviour is indicated. If the slope of the curve is positive, then the vehicle exhibits oversteer characteristics. On the other hand, if the slope of the curve is infinite, neutral steer is indicated.

The steering responses of the six vehicle configurations in steady-state turns predicted using the four computer simulation models are given below.

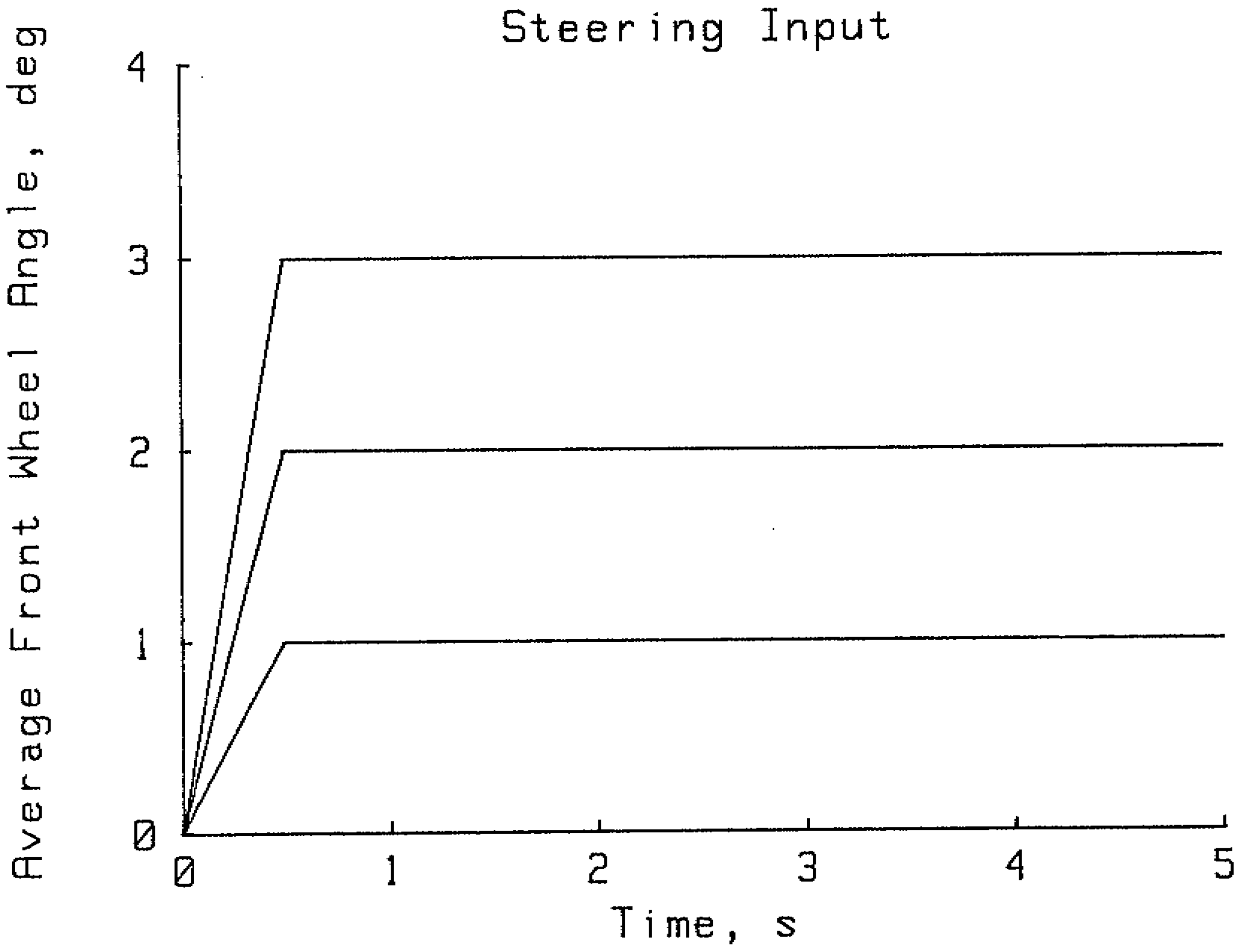


Figure 3.1 Ramp Input of Front-wheel Steering Angle Used in the Simulations

3.1 Vehicle Configuration 1

The steering responses of this vehicle configuration in steady-state turns at a forward speed of 43 mph (63.07 ft/s) on a dry, smooth asphalt surface were predicted using the four computer simulation models. The predicted relationships between the lateral accelerations of the tractor and the front-wheel steering angle, together with the measured data reported in reference (5), are shown in Fig. 3.2. The predicted yaw rates of the tractor as a function of the front-wheel steering angle, together with the measured ones, are shown in Fig. 3.3. Based on the predicted lateral accelerations and yaw rates of the tractor, a handling diagram is drawn as shown in Fig. 3.4. For comparison, the measured data are also shown. It should be noted that the square symbol in the figure represents the values calculated from the measured yaw rates of the tractor shown in Figs. 3.2 at a forward speed of 63.07 ft/sec, whereas the triangular symbol represents the values taken from reference (5). All the measured data shown in Figs. 3.2, 3.3 and 3.4 are for left-turn manoeuvres. The predicted values of yaw rate, $\bar{r}$, lateral acceleration, a_y, roll angle of the tractor, ϕ_1, roll angle of the semitrailer, φ_2, and articulation angle of the semitrailer with respect to the tractor Γ_1 and the corresponding measured values for various average front-wheel steering angles, δ_{av}, are given in Table 3.1

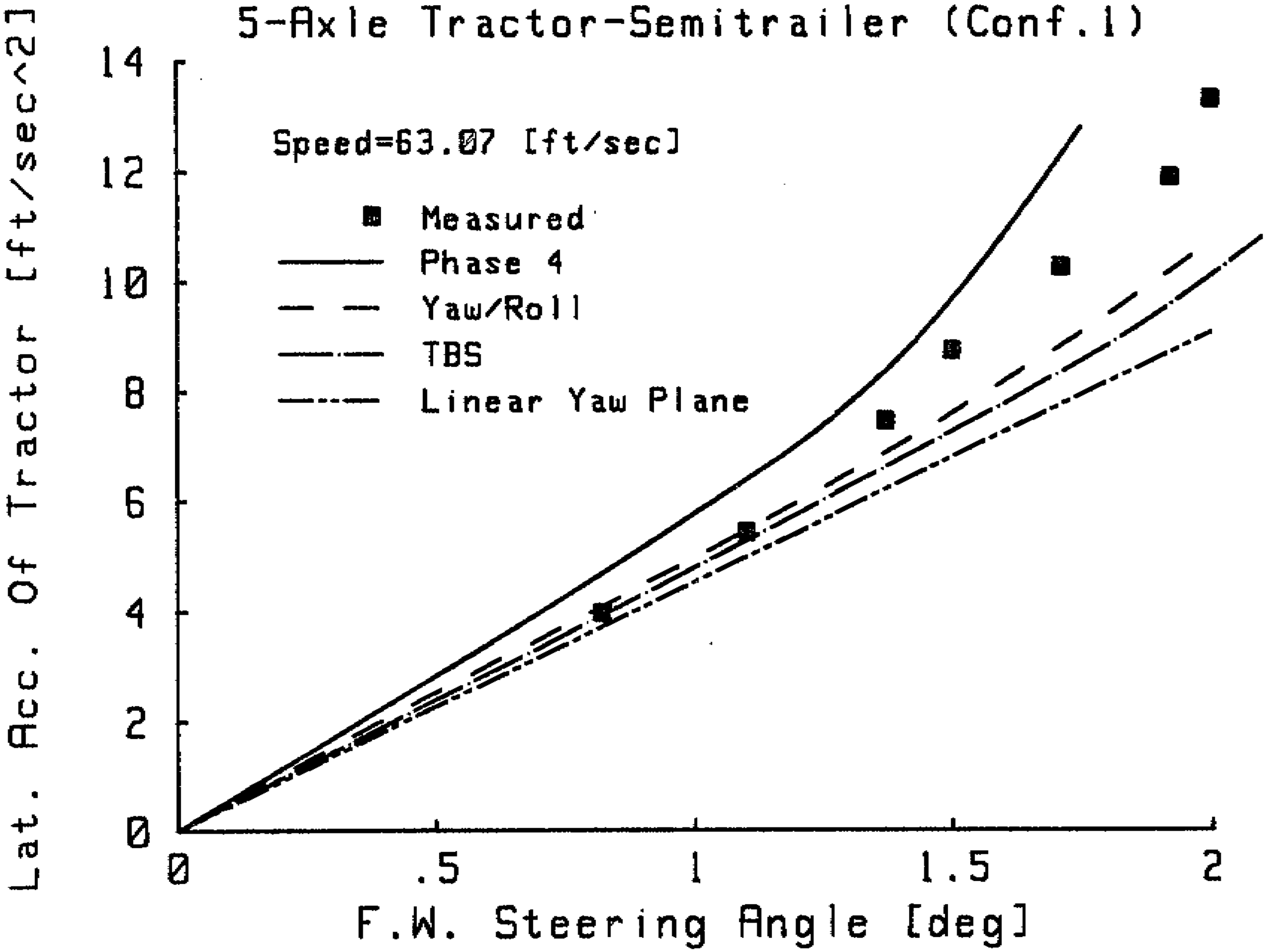


Fig. 3.2 Steady-state Lateral Acceleration Response to Steering Input of Vehicle Configuration 1 Predicted by Various Models

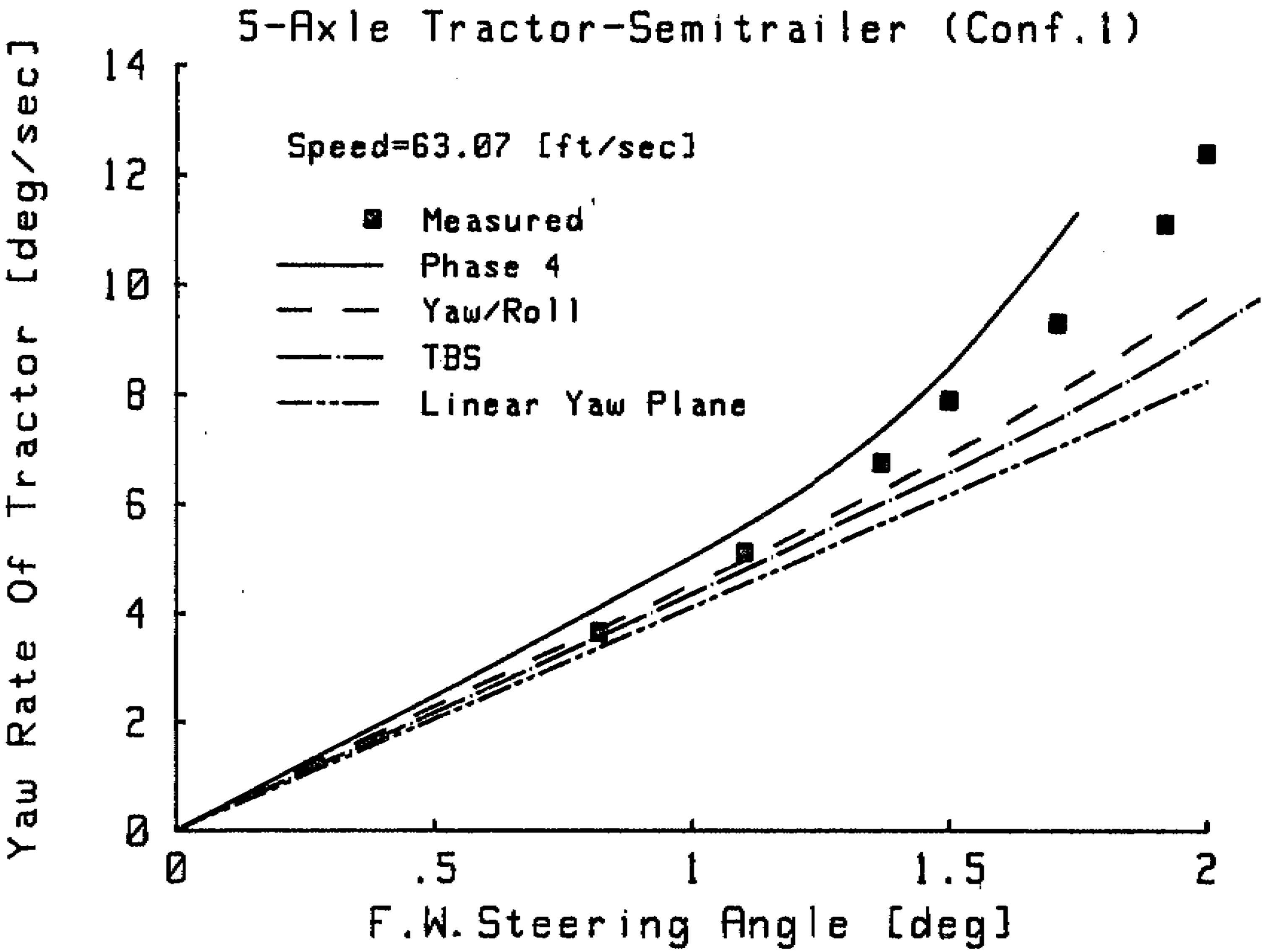


Fig. 3.3 Steady-state Yaw Rate Response to Steering Input of Vehicle Configuration 1 Predicted by Various Models

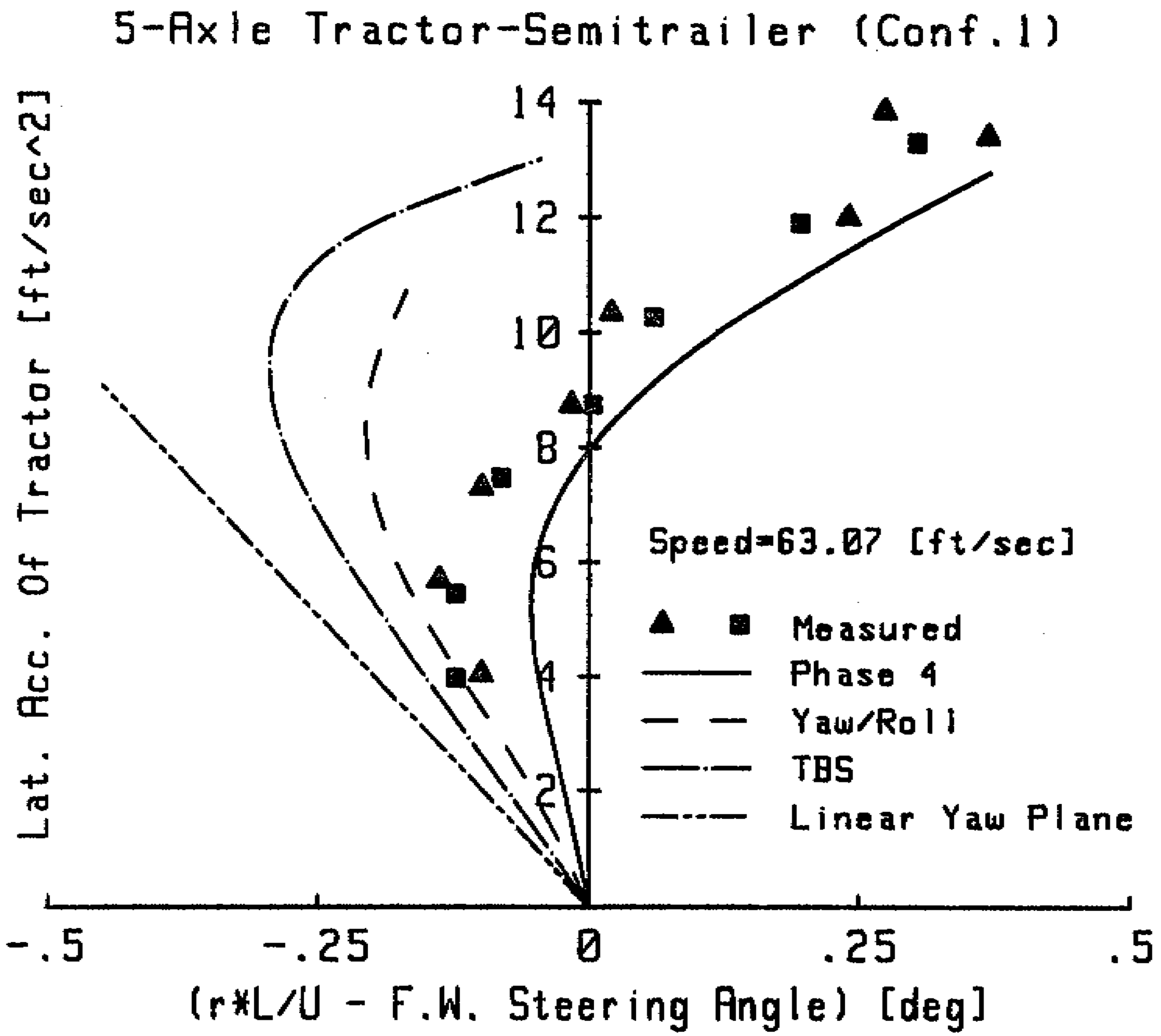


Fig. 3.4 Handling Characteristics of Vehicle Configuration 1
Predicted by Various Models

TABLE 3.1

VEHICLE CONFIGURATION 1

A. Phase 4 Model

δ_{av} [deg]	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ [deg]	ϕ_1 [deg]	ϕ_2 [deg]	Γ_1 [deg]
0.5	62.99	2.48	2.82	-0.034	-1.18	-0.94	1.26
1.0	63.07	5.05	5.77	-0.052	-2.39	-1.94	2.49
1.5	63.06	8.49	9.65	+0.093	-3.94	-3.23	4.05
1.75	63.07	11.31	12.80	+0.372	-5.15	-4.26	4.83

B. Yaw/Roll Model

δ_{av} [deg]	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ [deg]	ϕ_1 [deg]	ϕ_2 [deg]	Γ_1 [deg]
0.5	63.07	2.29	2.52	-0.07	-0.76	-0.76	1.15
1	63.07	4.52	4.97	-0.15	-1.50	-1.50	2.24
1.5	63.07	6.91	7.608	-0.203	-2.29	-2.29	3.40
1.75	63.07	8.25	9.08	-0.202	-2.74	-2.75	4.01
2.0	63.07	9.76	10.73	-0.168	-3.24	-3.25	4.62

C. TBS Model

δ_{av} [deg]	U [ft/sec]	r [deg/sec]	A_y [ft/sec^2]	$r * \ell/U - \delta_{av}$ [deg]	Γ_1 [deg]
0.6	62.97	2.61	2.87	- 0.109	1.3
1.0	63.07	4.36	4.80	- 0.182	2.16
1.2	63.2	5.25	5.80	- 0.217	2.6
1.5	63.07	6.59	7.27	- 0.263	3.26
1.9	63.07	8.55	9.45	- 0.295	4.13
2.1	63.08	9.75	10.81	- 0.271	4.51
2.2	63.08	10.63	11.81	- 0.205	4.53
2.25	63.05	11.75	13.02	- 0.044	4.56

D. Linear Yaw Plane Model

δ_{av} [deg]	U [ft/sec]	r [deg/sec]	A_y [ft/sec^2]	$r * \ell/U - \delta_{av}$ [deg]	Γ_1 [deg]
0.5	63.07	2.06	2.27	- 0.113	1.03
1.5	63.07	6.18	6.80	- 0.340	3.08
2.0	63.07	8.24	9.08	- 0.454	4.12

E. Measurements

δ_{av} (deg)	r (deg/sec)	A_y (ft/sec^2)	Calculated * $r^* \ell/U - \delta_{av}$ (deg)
0.82	3.66	3.97	-0.1333
1.1	5.13	5.44	-0.1375
1.37	6.77	7.47	-0.0998
1.5	7.9	8.75	+0.0178
1.71	9.3	10.27	+0.0349
1.92	11.12	11.9	+0.1664
2.055	12.4	13.3	+0.2715
2.2	12.83	13.7	+0.202

Measured **	
A_y (ft/sec^2)	$r^* \ell/U - \delta$ (deg)
4.04	- 0.1
5.68	- 0.139
7.3	- 0.1
8.75	- 0.017
10.34	+ 0.02
12.0	+ 0.24
13.4	+ 0.37
13.84	+ 0.274

* Calculations based on the measured yaw rates, a forward speed of 63.07 ft/sec, and a wheelbase of 142 in.

** Measured values taken from reference (5)

All measured values are for left-turn manoeuvres

It can be seen from Fig. 3.2 that the lateral accelerations of the tractor predicted using the linear yaw plane model, the TBS model and the yaw/roll model are reasonably close within the range up to 2 degrees of front-wheel steering angle (equivalent to lateral acceleration of approximately 0.3 g). However, there is a significant difference between the lateral accelerations predicted using the Phase 4 model and those predicted using the other three models for front-wheel steering angles greater than 1.5 degrees (equivalent to lateral acceleration of approximately 0.2 g.)

From Fig. 3.2 or Table 3.1, it can be noted that at front-wheel steering angle $\delta_{av} = 1.0^{o}$, the differences between the measured lateral acceleration and the predicted ones using the Phase 4 model, the yaw/roll model, the TBS model, and the linear yaw plane model are 17.5%, 1.2%, 2.3%, and 7.7%, respectively. At front-wheel steering angle $\delta_{av} = 1.5^{o}$, the corresponding differences are 10.3%, 13.1%, 13.8%, and 22.3%, respectively.

As can be seen from Fig. 3.3 or Table 3.1, the differences between the measured yaw rates and the predicted ones using the Phase 4 model, the yaw/roll model, the TBS model and the linear yaw plane model show similar trend as that between the measured lateral accelerations and the predicted ones using the four computer simulation models described above.

Based on the data shown in Figs. 3.2 and 3.3, and Table 3.1, it appears that for lateral accelerations below 0.2 g, the four computer simulation models give similar predictions and the predicted values agree reasonably well with the measured ones. For the lateral acceleration range between 0.2 g and 0.3 g, the Phase 4 model, the yaw/roll model and the TBS model seem to have similar error of prediction, in comparison with the measured values. However, the Phase 4 model overestimates the responses, while the yaw/roll model and the TBS model underestimate them. For lateral accelerations higher than 0.2 g, the linear yaw plane model gives higher error of prediction than the other three models. This is primarily due to the fact that in the linear yaw plane model a linear tire model is used and the load transfer and its effects on tire characteristics have been entirely neglected.

It should also be mentioned that the lateral acceleration which causes an inside tire to lift off the ground predicted by the Phase 4 model, the yaw/roll model and the TBS model is considerably lower than the measured one reported in reference (5).

Fig. 3.4 illustrates the steady-state handling characteristics of Vehicle Configuration 1 as predicted by the four computer simulation models. It can be seen that the lateral acceleration at which the vehicle changes from understeer to oversteer, referred to as the "transition acceleration", predicted using the Phase 4 model is just under 0.2 g. The transition accelerations predicted using the yaw/roll model and the TBS model are approximately 0.25 g and 0.3 g, respectively, while the measured one is approximately 0.2 g. Below the transition acceleration, the Phase 4 model underestimates the understeer level (or "understeer gradient") as compared with the measured data, whereas the TBS model and the linear yaw plane model overestimate the understeer level to varying degrees. The yaw/roll model appears to give the best prediction of the understeer level. It should be mentioned that since a linear tire model is used, the linear yaw plane model is unable to predict any variation of the handling behaviour of the vehicle with lateral acceleration and the predicted understeer level remains a constant.

From Table 3.1, it can be seen that the yaw/roll model, the TBS model, and the linear yaw plane model give similar predictions of the articulation angle of the semitrailer with respect to the tractor, while the Phase 4 model gives a higher prediction than the other three models. It should also be mentioned that the roll angles of the spring masses of the tractor and the semitrailer predicted by the yaw/roll model are essentially the same, whereas those predicted using the Phase 4 model are considerably different.

3.2 Vehicle Configuration 2

As mentioned in Section 2, this vehicle is a modified version of Vehicle Configuration 1, with much higher torsional stiffness of the tractor frame and roll stiffness of the tractor front suspension. These two major modifications tend to make the tractor highly understeer.

It should be pointed out that among the four computer simulation models, only the Phase 4 model takes into account the effects of both the tractor frame torsional stiffness and the roll stiffnesses of the suspensions. The yaw/roll model and the TBS model only take into account the effects of the roll stiffnesses of the suspensions. The tractor frame is assumed to be rigid in these two simulation models. The linear yaw plane model does not include either the tractor frame torsional stiffness or the roll stiffnesses of the suspensions. Consequently, these changes do not affect the predictions made by the linear yaw plane model. The steady-state steering response of Vehicle Configuration 2 predicted using the linear yaw plane model is, therefore, the same as that of Vehicle Configuration 1 described previously.

The predicted steady-state lateral accelerations and yaw rates of the tractor using the four computer simulation models, are shown in Figs. 3.5 and 3.6, respectively. Based on the predictions, a handling diagram is drawn as shown in Fig. 3.7. For comparison, the measured data taken from reference (5) are also included in the figures. The predicted and the measured values for various front-wheel steering angles are also given in Table 3.2.

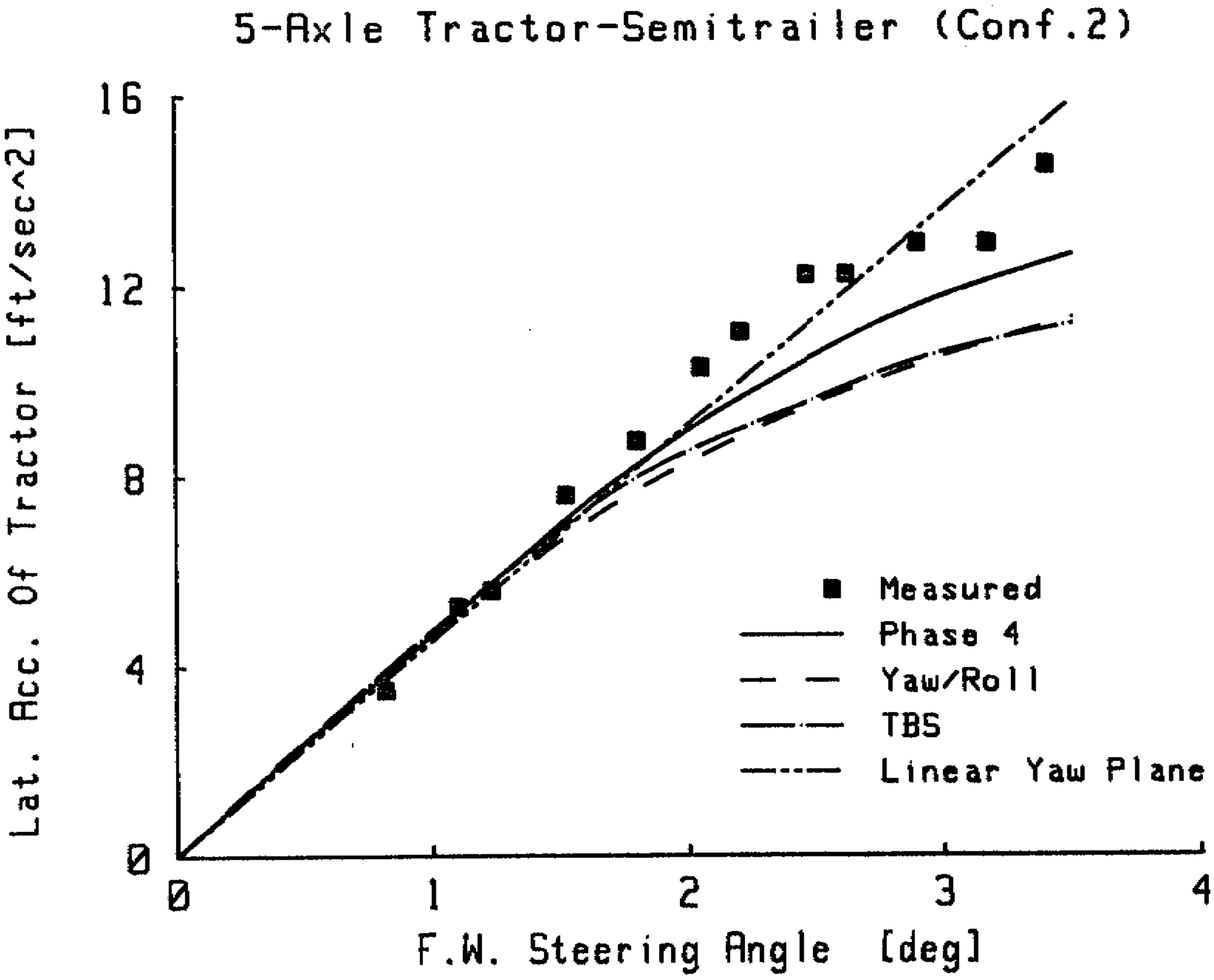


Fig. 3.5 Steady-state Lateral Acceleration Response to Steering input of Vehicle Configuration 2 Predicted by Various Models

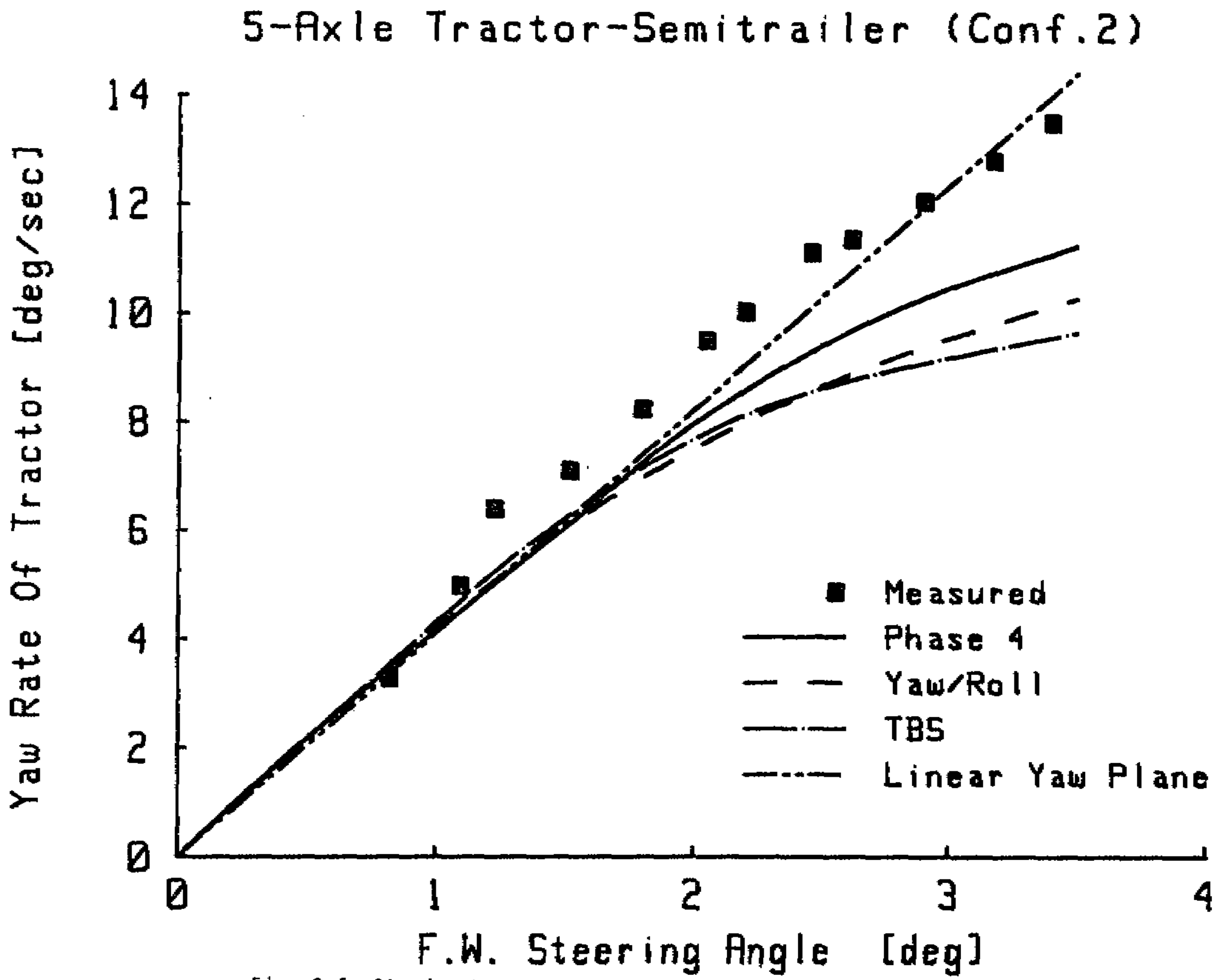


Fig. 3.6 Steady-state Yaw Rate Response to Steering Input of Vehicle Configuration 2 Predicted by Various Models

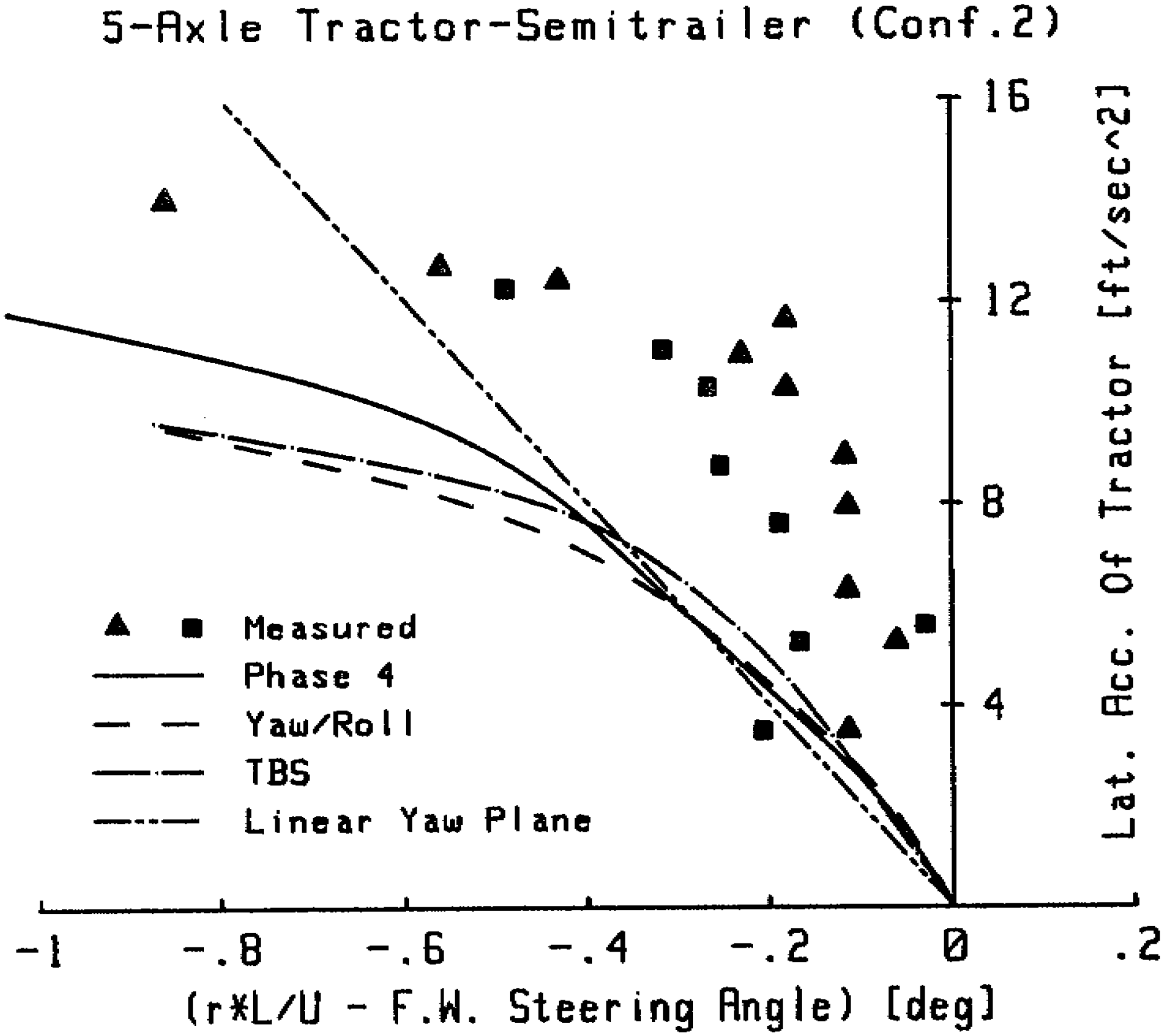


Fig. 3.7 Handling Characteristics of Vehicle Configuration 2 Predicted by Various Models

TABLE 3.2

VEHICLE CONFIGURATION 2

A. Phase 4 Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	63.07	2.18	2.368	-0.091	-0.50	-0.71	1.06
1.0	63.11	4.15	4.65	-0.221	-0.95	-1.37	2.00
1.5	63.10	6.06	6.79	-0.363	-1.39	-2.00	2.85
2.0	63.07	7.98	8.96	-0.502	-1.83	-2.64	3.72
2.5	63.05	9.40	10.55	-0.735	-2.15	-3.10	4.23
3.0	63.07	10.47	11.78	-1.035	-2.39	-3.46	4.55
3.5	63.10	11.25	12.66	-1.390	-2.55	-3.69	4.68

B. Yaw/Roll Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	63.07	2.20	2.42	-0.087	-0.58	-0.58	1.11
1.0	63.07	4.20	4.61	-0.212	-1.11	-1.11	2.08
1.5	63.07	6.05	6.65	-0.364	-1.59	-1.60	2.99
2.0	63.07	7.53	8.29	-0.587	-1.98	-2.0	3.72
2.5	63.07	8.66	9.53	-0.875	-2.28	-2.3	4.25
3.0	63.07	9.55	10.51	-1.208	-2.52	-2.54	4.63
3.5	63.07	10.29	11.32	-1.569	-2.71	-2.74	4.93

C. TBS Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	Γ_1 (deg)
0.5	63.05	2.17	2.39	-0.092	1.08
1.0	63.11	4.31	4.75	-0.191	2.14
1.5	63.07	6.24	6.88	-0.329	3.07
2.0	63.08	7.7	8.53	-0.555	3.74
2.5	63.06	8.63	9.63	-0.880	4.12
2.0	63.05	9.19	10.41	-1.275	4.31
3.5	63.12	9.66	11.2	-1.689	4.4

D. Linear Yaw Plan Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	Γ_1 (deg)
0.5	63.07	2.06	2.27	-0.113	1.03
1.5	63.07	6.18	6.80	-0.340	3.08
2.0	63.07	8.24	9.08	-0.454	6.12
3.5	63.07	14.43	15.89	-0.794	7.21

E. Measurements

δ_{av} (deg)	r (deg/sec)	A_y (ft/sec^2)	Calculated * $r*\ell/U-\delta_{av}$ (deg)
0.82	3.27	3.5	-0.206
1.1	4.98	5.25	-0.165
1.23	6.40	5.6	-0.029
1.52	7.10	7.6	-0.187
1.8	8.24	8.75	-0.254
2.05	9.5	10.3	-0.267
2.2	10.03	11.04	-0.318
2.46	11.12	11.66	-0.373
2.62	11.36	12.25	-0.488
2.9	12.05	12.90	-0.639
3.17	12.8	12.90	-0.768
3.4	13.5	14.54	-0.867

Measured **	
A_y (ft/sec^2)	$r*\ \ell/U-\delta$ (deg)
3.5	-0.113
5.25	-0.06
6.3	-0.113
7.93	-0.113
8.94	-0.116
10.27	-0.18
10.93	-0.23
11.63	-0.18
12.4	-0.43
12.68	-0.56
14.0	-0.86

* Calculations based on the measured yaw rates, a forward speed of 63.07 ft/sec, and a wheelbase of 142 in.

** Measured values taken from reference (5).

It can be seen from Figs. 3.5 and 3.6 that within the range up to 2 degrees of front-wheel steering angle(equivalent to lateral acceleration of approximately 0.25 g) , all four simulation models give practically the same predictions, and the predicted values agree very well with the measured data. Within the range between 2 and 4 degrees of front-wheel steering angle, the linear yaw plane model gives the best overall predictions of lateral acceleration and yaw rate of the tractor, among the four simulation models. For instance, at front-wheel steering angle $\delta_{av} = 3^o$, the differences between the measured lateral acceleration and the predicted ones using the linear yaw plane model, the Phase 4 model, the yaw/roll model and the TBS model are 3.7%, 10.3%, 19.9% and 20.7%, respectively.

Fig. 3.7 shows a comparison of the steady-state handling characteristics of the vehicle predicted using the four simulation models and those measured (5). It can be seen that up to a lateral acceleration of approximately 0.25 g, all four models give essentially the same predictions. Beyond lateral acceleration of 0.25 g, the yaw/roll model and the TBS model give the highest prediction of understeer level (or "understeer gradient"), while the linear yaw plane model gives the lowest prediction. It can also be noted that while the handling characteristics predicted by the Phase 4 model, the yaw/roll model, and the TBS model and the measured ones show similar trend, in quantitative terms there is a significant difference between them. It can, therefore, be said that the agreement between the measured and the predicted handling characteristics using the four models is, in general, poor for lateral acceleration above 0.15 g.

From Table 3.2, it can be seen that all the four models give similar predictions of the articulation angle between the tractor and semitrailer for front-wheel steering angle less than 3.0^{o}. It should also be mentioned that the roll angles of the sprung masses of the tractor and semitrailer predicted by the yaw/roll model are practically the same, while those predicted using the Phase 4 model are noticeably different.

3.3 Vehicle Configuration 3

As can be seen from Table 2.1, the major differences between this vehicle and Vehicle Configurations 1 and 2 are the location of the fifth wheel, which is 14.35 in. ahead of the tractor rear suspension centre for Vehicle Configuration 3, the characteristics of the tires, roll stiffness of the fifth wheel, and the auxiliary roll stiffnesses of the tractor suspensions and the tandem suspensions of the semitrailer.

The steady-state steering responses of this vehicle were predicted using the four computer simulation models at a forward speed of 35.8 mph (52.5 ft/sec) on a dry, smooth asphalt surface. The predicted steady-state lateral accelerations and yaw rates as functions of front-wheel steering angle of the tractor are shown in Figs. 3.8 and 3.9, respectively. Based on the predictions, a handling diagram, illustrating the handling characteristics of the vehicle predicted using the four simulation models, is shown in Fig. 3.10. For this vehicle configuration, no measured data are available. Therefore, the results presented are primarily for illustrating the differences in the predictive ability of various computer simulation models. The predicted values at various front-wheel steering angles are also given in Table 3.3.

As can be seen from the results shown in Figs. 3.8 and 3.9 and in Table 3.3, all four simulation models give similar predictions of lateral acceleration and yaw rate up to front-wheel steering angle of approximately 2.6^{o} (or equivalent to lateral acceleration of approximately 0.28 g).The difference between the highest value of lateral acceleration predicted using the TBS model and the lowest one predicted using the linear yaw plane model at front-wheel steering angle of 2.6^{o} is approximately 10.6%.

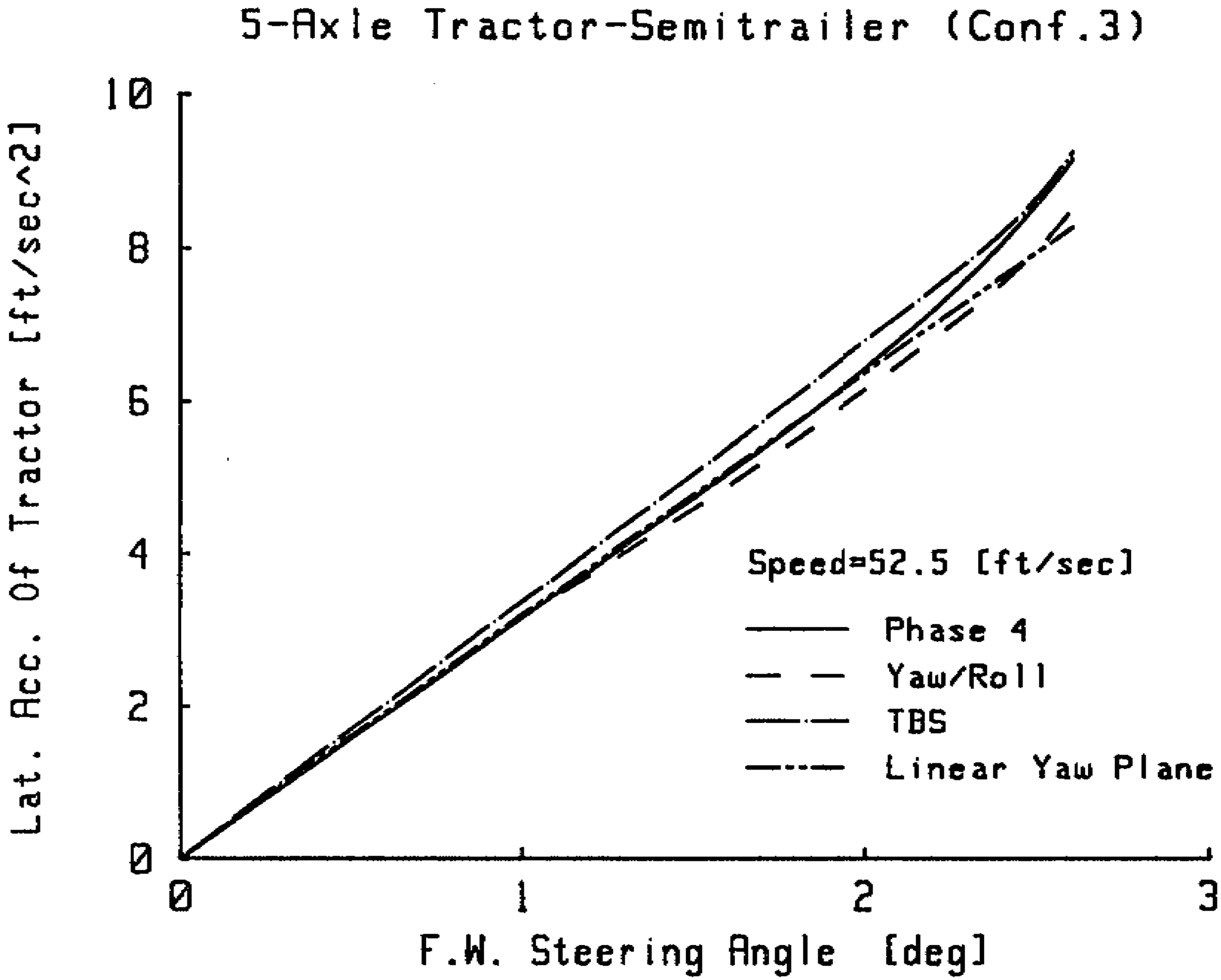


Fig. 3.8 Steady-state Lateral Acceleration
Response to Steering Input of Vehicle
Configuration 3 Predicted by Various Models

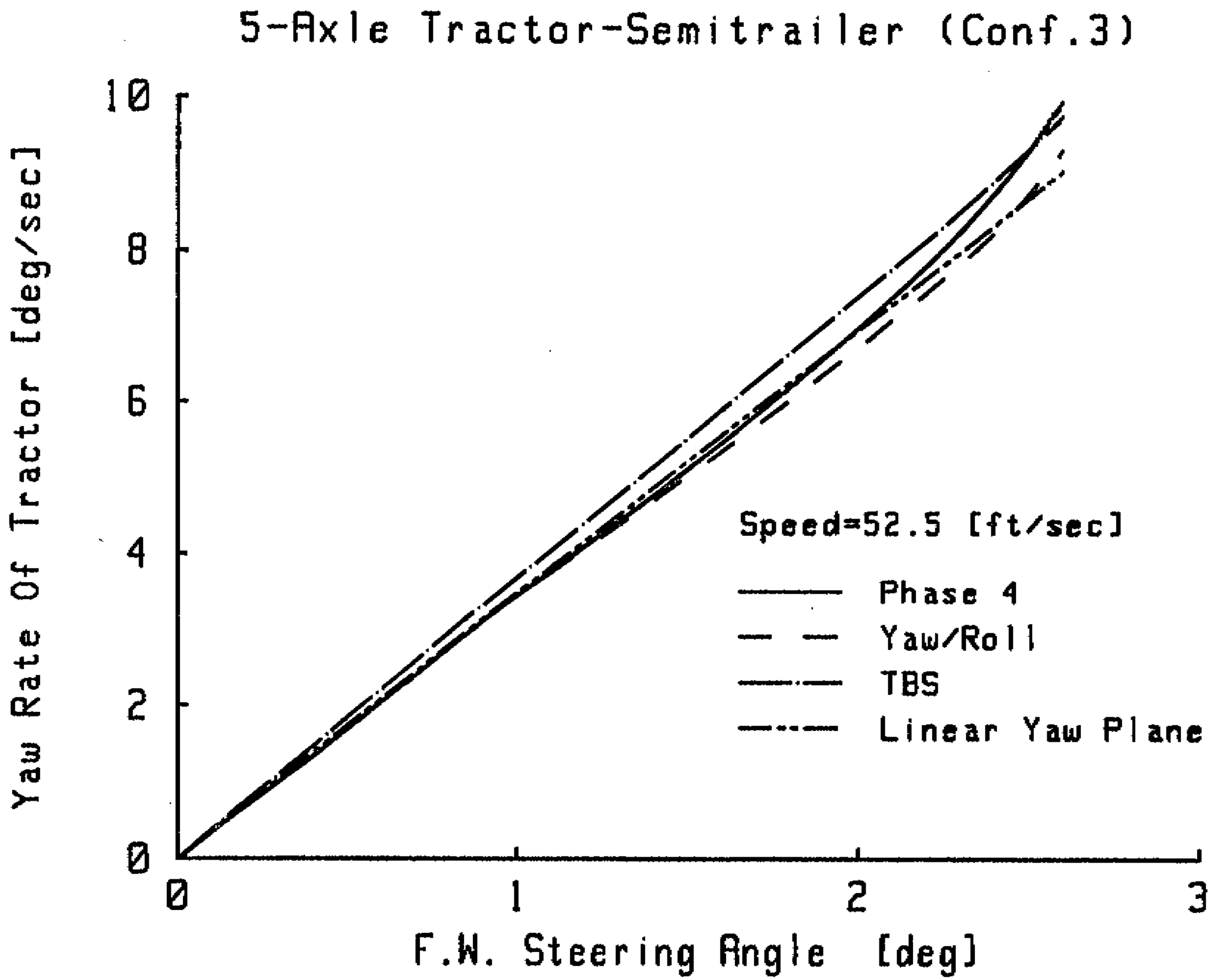


Fig. 3.9 Steady-state Yaw Rate Response to Steering Input of Vehicle Configuration 3 Predicted by Various Models

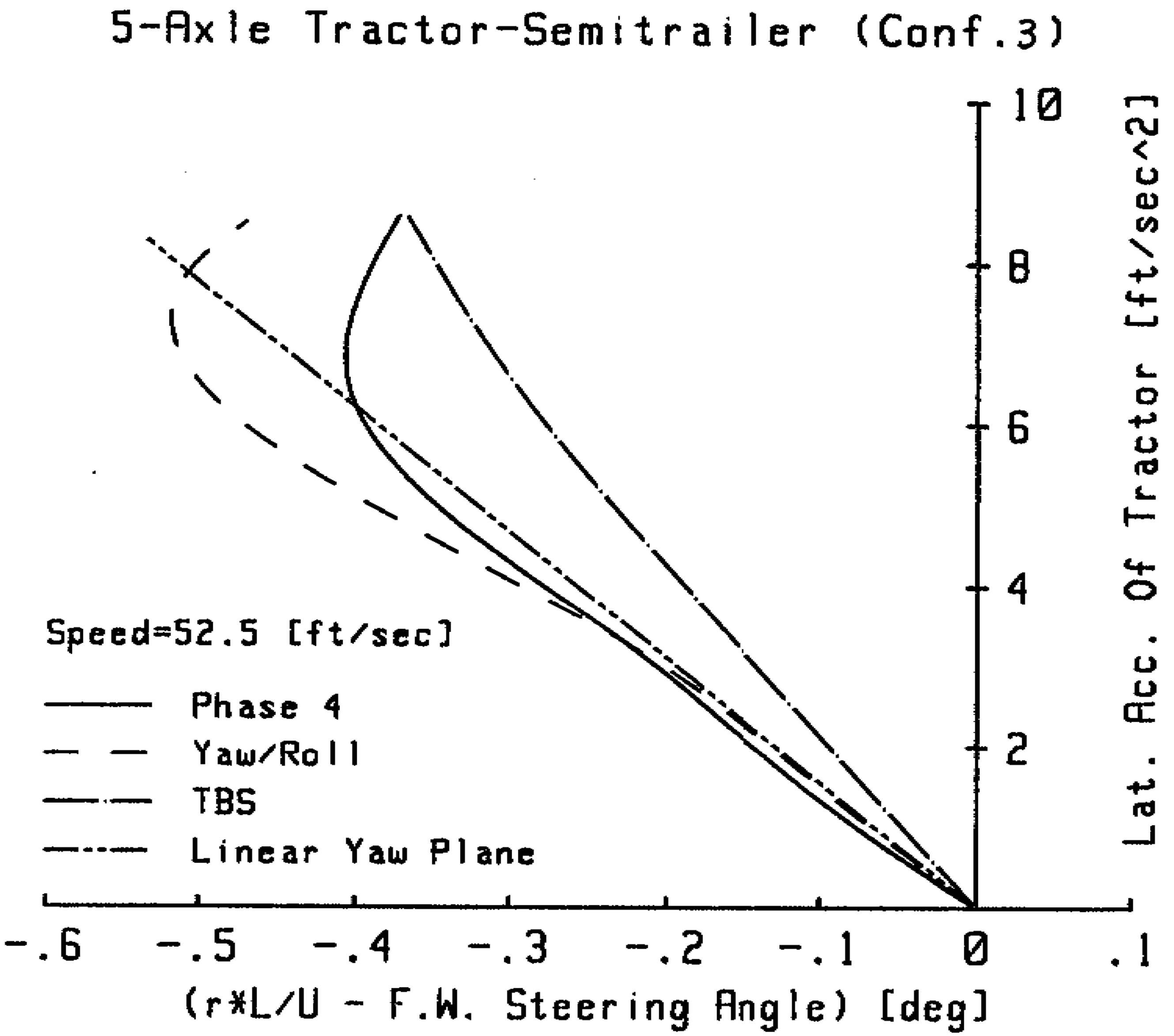


Fig. 3.10 Handling Characteristics of Vehicle Configuration 3 Predicted by Various Models

TABLE 3.3

VEHICLE CONFIGURATION 3

A. Phase 4 Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	52.68	1.69	1.55	-0.115	-0.64	-0.57	1.11
1.0	52.7	3.44	3.15	-0.216	-1.56	-1.39	2.25
1.5	52.6	5.11	4.74	-0.332	-2.56	-2.22	3.33
2.0	52.5	6.98	6.43	-0.404	-3.41	-3.01	4.52
2.5	52.51	9.31	8.60	-0.372	-4.97	-4.5	6.06
2.6	52.49	9.95	9.16	-0.325	-6.63	-6.4	6.56

B. Yaw/Roll Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	52.5	1.73	1.59	-0.105	-0.66	-0.7	1.15
1.0	52.5	3.44	3.148	-0.213	-1.33	-1.41	2.27
1.5	52.5	5.02	4.6	-0.352	-1.96	-2.07	3.31
2.0	52.5	6.73	6.17	-0.461	-2.67	-2.83	4.4
2.5	52.5	8.74	8.01	-0.502	-3.62	-3.85	5.64
2.6	52.5	9.32	8.53	-0.469	-4.09	-4.33	6.02

C. TBS Model

δ_{av} (Deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	Γ_1 (deg)
0.5	52.5	1.84	1.68	-0.079	1.21
1.0	52.5	3.68	3.37	-0.158	2.43
1.5	52.5	5.52	5.06	-0.238	3.64
2.0	52.58	7.4	6.8	-0.308	4.81
2.5	52.53	9.33	8.59	-0.367	5.65
2.6	52.5	9.76	9.27	-0.369	5.57

D. Linear Yaw Plane Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	Γ_1 (deg)
1.0	52.5	3.48	3.19	-0.204	2.29
2.0	52.5	6.96	6.37	-0.409	4.58
2.6	52.5	9.04	8.29	-0.533	5.9

From Fig. 3.10, it can be seen that up to lateral acceleration of approximately 0.15 g, the Phase 4 model, the yaw/roll model and the linear yaw plane model give similar predictions of the understeer level of the vehicle, whereas the TBS model predicts lower understeer level. Both the Phase 4 model and the yaw/roll model predict a transition from understeer to oversteer at a lateral acceleration of approximately 0.2 g, while the TBS model does not predict a transition below 0.25 g of lateral acceleration. As mentioned previously, since a linear tire model is used, the linear yaw plane model is unable to predict any variation of the handling behaviour of the vehicle with lateral acceleration, and the predicted understeer level remains constant.

From Table 3.3, it can be seen that the Phase 4 model gives higher prediction of the articulated angle between the tractor and semitrailer than the models at high front-wheel steering angles. It should also be mentioned that the roll angles of the sprung masses of the tractor and semitrailer predicted by the Phase 4 model are higher than those predicted by the yaw/roll model.

3.4 Vehicle Configuration 4

As shown in Table 2.1, the major differences between this vehicle and Vehicle Configuration 3 are the removal of the auxiliary roll-stiffening device from the tractor front suspension and the installation of a much stiffer roll-stiffening device on the tractor trailing tandem axle. The combined effect is the lowering of the understeer level of this vehicle, in comparison with Vehicle Configuration 3.

The steady-state lateral accelerations and yaw rates as functions of front-wheel steering angle of the tractor predicted using the four computer simulation models are shown in Fig. 3.11 and Fig. 3.12, respectively. The handling characteristics of the vehicle predicted by the computer simulation models are illustrated in Fig. 3.13. The predicted values are also listed in Table 3.4.

As can be seen from the predicted results shown in Figs. 3.11 and 3.12, and in Table 3.4, all four simulation models give essentially the same predictions of lateral acceleration and yaw rate up to front-wheel steering angle of 2 degrees, or lateral acceleration of approximately 0.2 g. Beyond that the differences between the predicted values obtained using the four models increase noticeably. For instance, at a front-wheel steering angle of 2.5 degrees, the differences between the predicted lateral accelerations using the Phase 4 model and those using the yaw/roll model, the TBS model and the linear yaw plane model are 7.5%, 14%, and 20.9%, respectively.

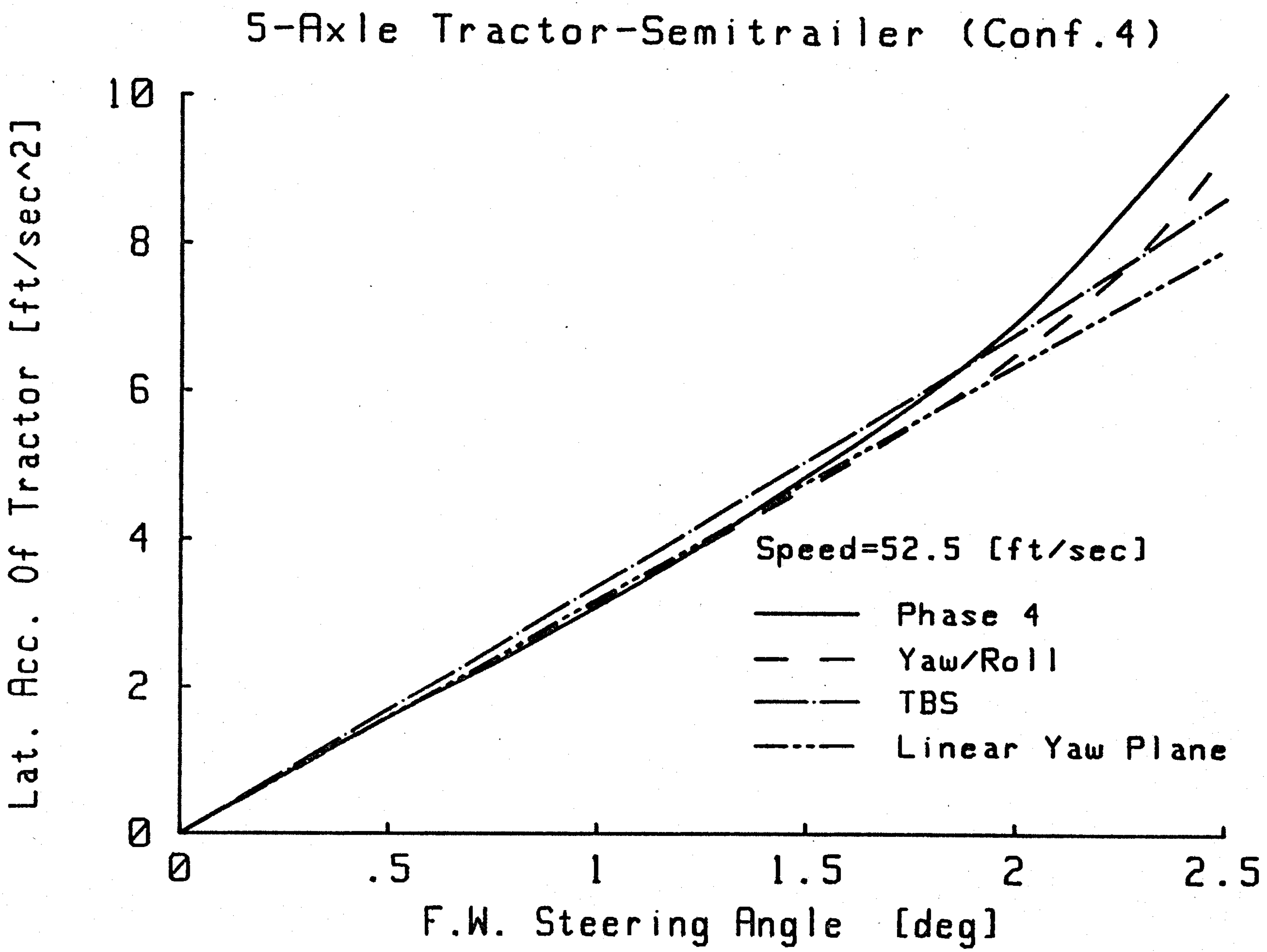


Fig. 3.11 Steady-state Lateral Acceleration Response to Steering Input of Vehicle Configuration 4 Predicted by Various Models

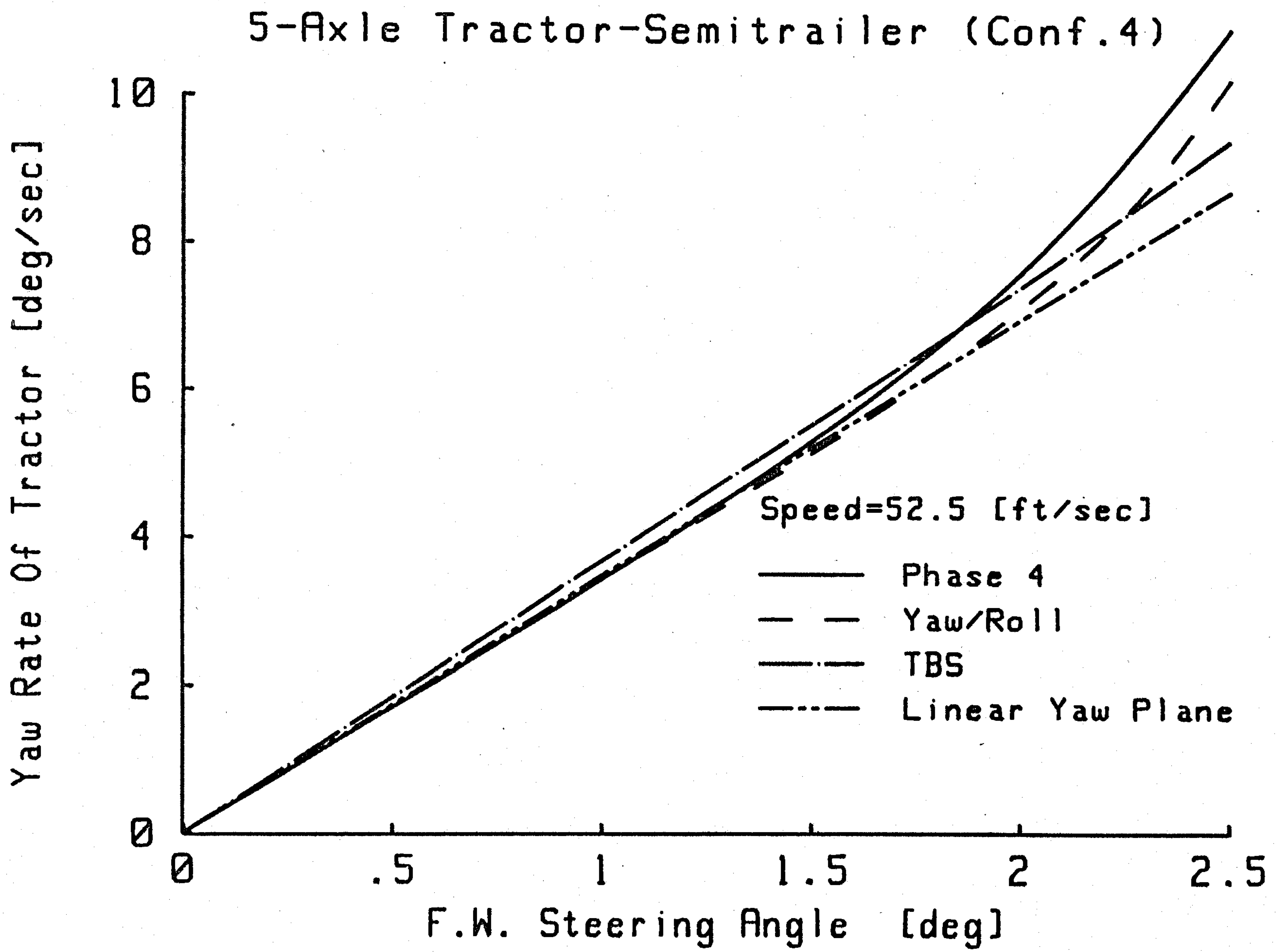


Fig. 3.12 Steady-state Yaw Rate Response to Steering Input of Vehicle Configuration 4 Predicted by Various Models

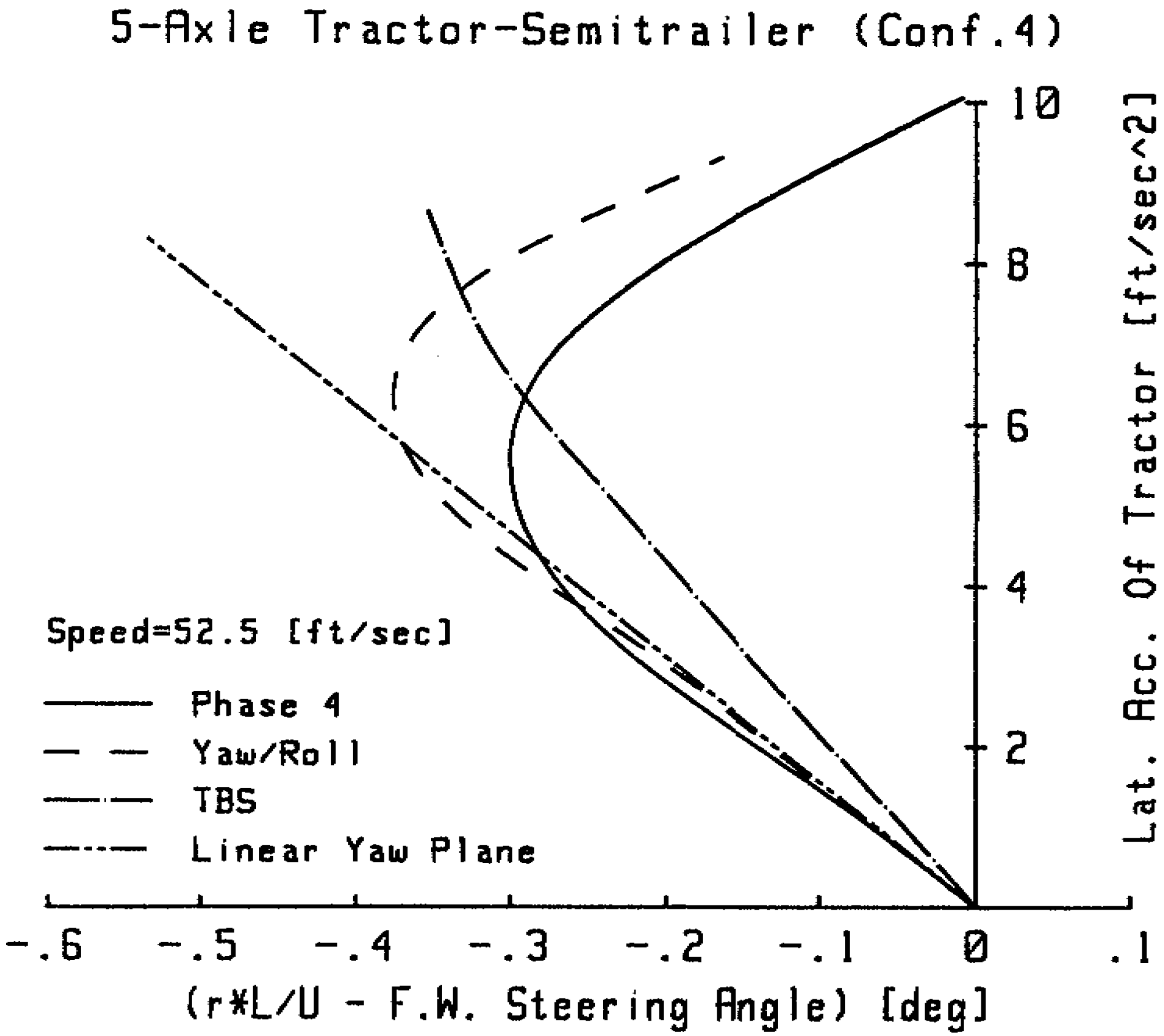


Fig. 3.13 Handling Characteristics of Vehicle Configuration 4
Predicted by Various Models

TABLE 3.4

VEHICLE CONFIGURATION 4

A. Phase 4 Model

δ_{av} (deg)	U (ft/sec)	r (deg)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	52.54	1.71	1.58	-0.109	-0.75	-0.59	1.12
1.0	52.76	3.43	3.08	-0.219	-1.69	-1.37	2.28
1.5	52.59	5.30	4.85	-0.291	-2.49	-2.08	3.52
1.75	52.6	6.36	5.82	-0.299	-2.07	-2.51	4.20
2.0	52.61	7.59	6.96	-0.268	-3.58	-3.04	5.04
2.25	52.51	9.10	8.44	-0.199	-4.35	-3.72	6.11
2.5	52.5	10.90	10.06	-0.008	-8.16	-7.90	7.41

B. Yaw/Roll Model

δ_{av} (deg)	U (ft/sec)	r (deg)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	52.5	1.73	1.58	-0.105	-0.6	-0.65	1.15
1.0	52.5	3.45	3.16	-0.211	-1.22	-1.33	2.30
1.5	52.5	5.14	4.70	-0.325	-1.83	-1.99	3.43
1.75	52.5	6.06	5.54	-0.365	-2.16	-2.35	4.04
2.0	52.5	7.11	6.52	-0.375	-2.57	-2.80	4.75
2.25	52.5	8.39	7.66	-0.332	-3.09	-3.39	5.62
2.5	52.5	10.22	9.31	-0.164	-4.18	-4.59	6.89

C. TBS Model

δ_{av} (deg)	U (ft/sec)	r (deg)	A_y (ft/sec^2)	$r*\ell/U - \delta_{av}$ (deg)	Γ_1 (deg)
0.5	52.5	1.84	1.69	- 0.079	1.21
1.0	52.5	3.68	3.37	- 0.158	2.43
1.5	52.5	5.53	5.07	- 0.236	3.64
2.0	52.5	7.4	6.8	- 0.308	4.83
2.5	52.52	9.39	8.65	- 0.353	5.66

D. Linear Yaw Plane Model

δ_{av} (deg)	U (ft/sec)	r (deg)	A_y (ft/sec^2)	$r*\ell/U - \delta_{av}$ (deg)	Γ_1 (deg)
1.0	52.5	3.48	3.19	- 0.204	2.29
2.0	52.5	6.96	6.37	- 0.409	4.58
2.5	52.5	8.7	7.96	- 0.511	5.72
2.6	52.5	9.04	8.29	- 0.537	5.9

From Fig. 3.13, it can be seen that up to a lateral acceleration of approximately 0.125 g, the Phase 4 model, the yaw/roll model and the linear yaw plane model give essentially the same predictions of the understeer level of the vehicle, whereas the TBS model predicts a lower level of understeer. The Phase 4 model predicts a transition from understeer to oversteer at a lateral acceleration of approximately 0.175 g, while the yaw/roll model predicts the transition occurring at a slightly higher lateral acceleration of approximately 0.2 g. The TBS model does not predict a transition below 0.28 g of lateral acceleration, and as mentioned previously, the linear yaw plane model is unable to predict any variation of the handling behaviour of the vehicle with lateral acceleration.

From Table 3.4, it can be seen that the TBS model and the linear yaw plane model give similar predictions of the articulation angle. The Phase 4 model and the yaw/roll model however, generally give higher predictions of articulation angle than the other two models. It can be also noted that the roll angles of the sprung masses of the tractor and semitrailer predicted by the Phase 4 model are generally higher than those predicted by the yaw/roll model, when the front-wheel steering angle is greater than 2 degrees.

3.5 Vehicle Configuration 5

It can be seen from Table 2.1, the basic difference between this vehicle and Vehicle Configuration 4 is the location of the fifth wheel. In this vehicle, the fifth wheel is situated at the centre of the rear suspension of the tractor, whereas in Vehicle Configuration 4, the fifth wheel is located ahead of the tractor rear suspension centre. The rearward shift of the fifth wheel location generally reduces the understeer level of the tractor.

The steady-state lateral accelerations and yaw rates as functions of front-wheel steering angle of the tractor predicted using the four computer simulation models are shown in Figs. 3.14 and 3.15 respectively. The handling characteristics of the vehicle predicted by the computer simulation models are shown in Fig. 3.16. The predicted values are also listed in Table 3.5.

As can be seen from the predicted results shown in Figs. 3.14 and 3.15 and in Table 3.5, all four simulation models give essentially the same predictions of lateral acceleration and yaw rate up to front-wheel steering angle of 1.5 degrees (or lateral acceleration of 0.15 g approximately). Beyond that the differences between the predicted values obtained using the four models increase noticeably. For instance, at front-wheel steering angle of 2.0 degrees, the differences between the predicted lateral acceleration using the Phase 4 model and those using the yaw/roll model, the TBS model and the linear yaw plane model are 6.8%, 19.6%, and 25.2% respectively.

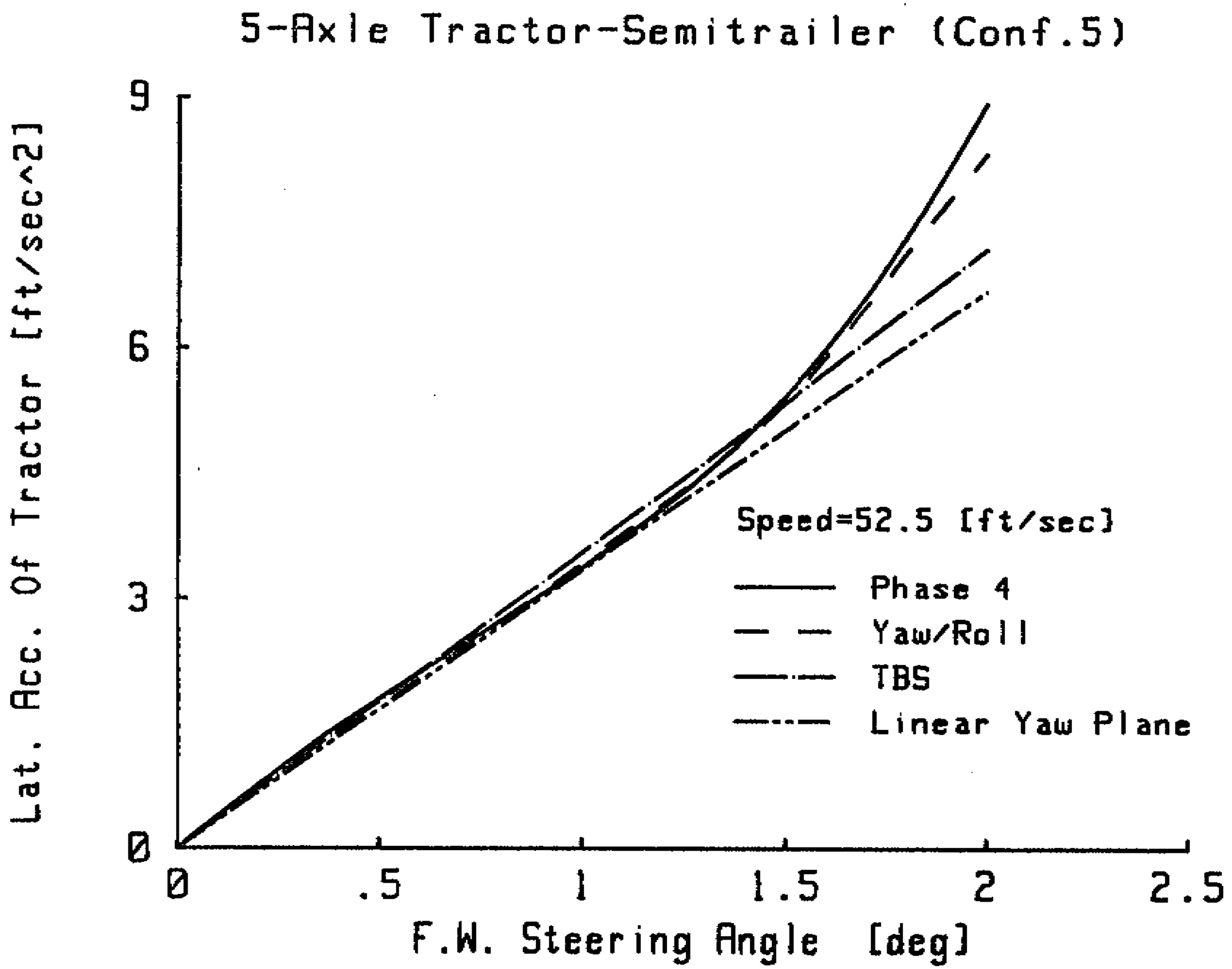


Fig. 3.14 Steady-state lateral acceleration response to steering input of Vehicle Configuration 5 predicted by various models

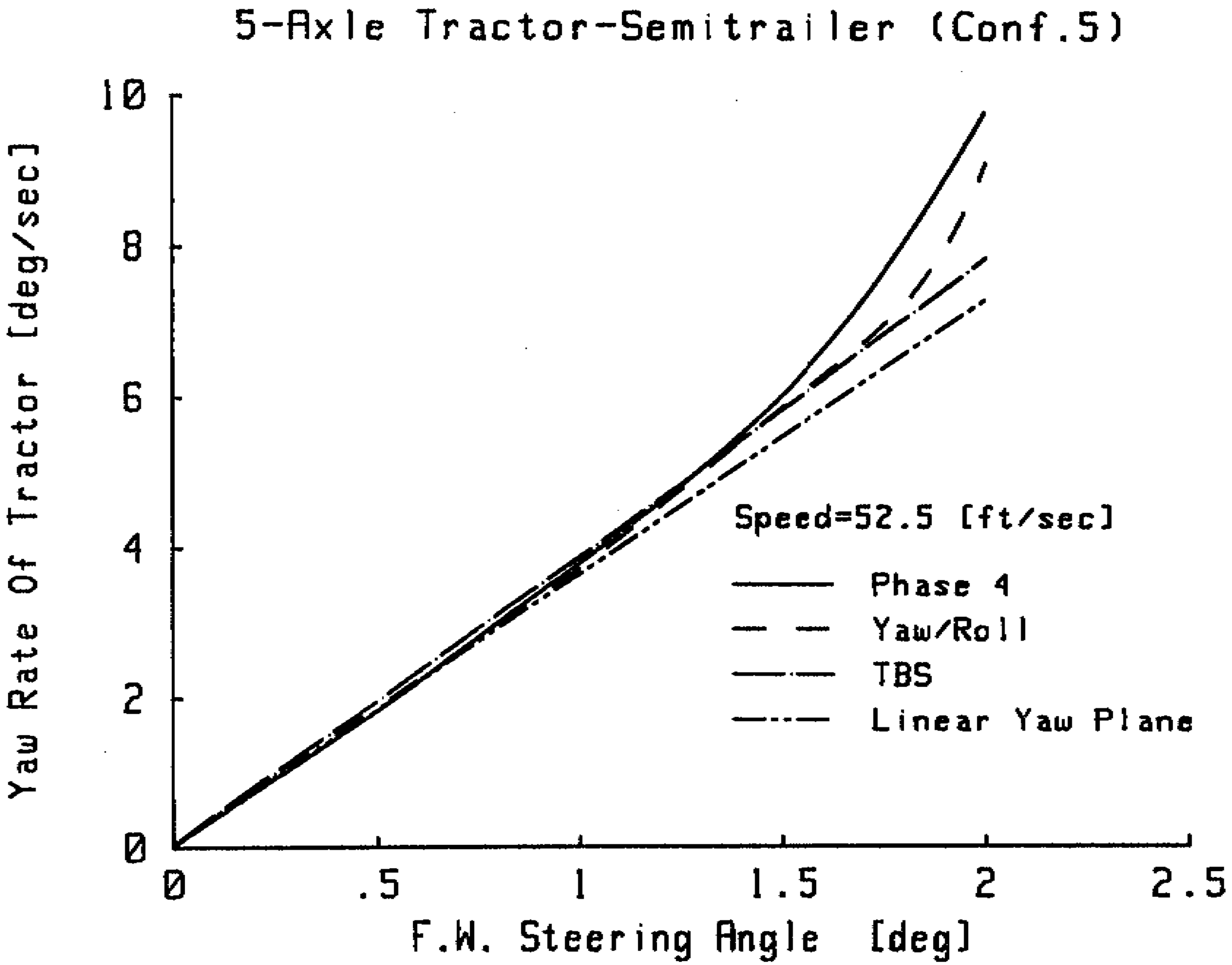


Fig. 3.15 Steady-state yaw rate response to steering input of Vehicle Configuration 5 Predicted by various models

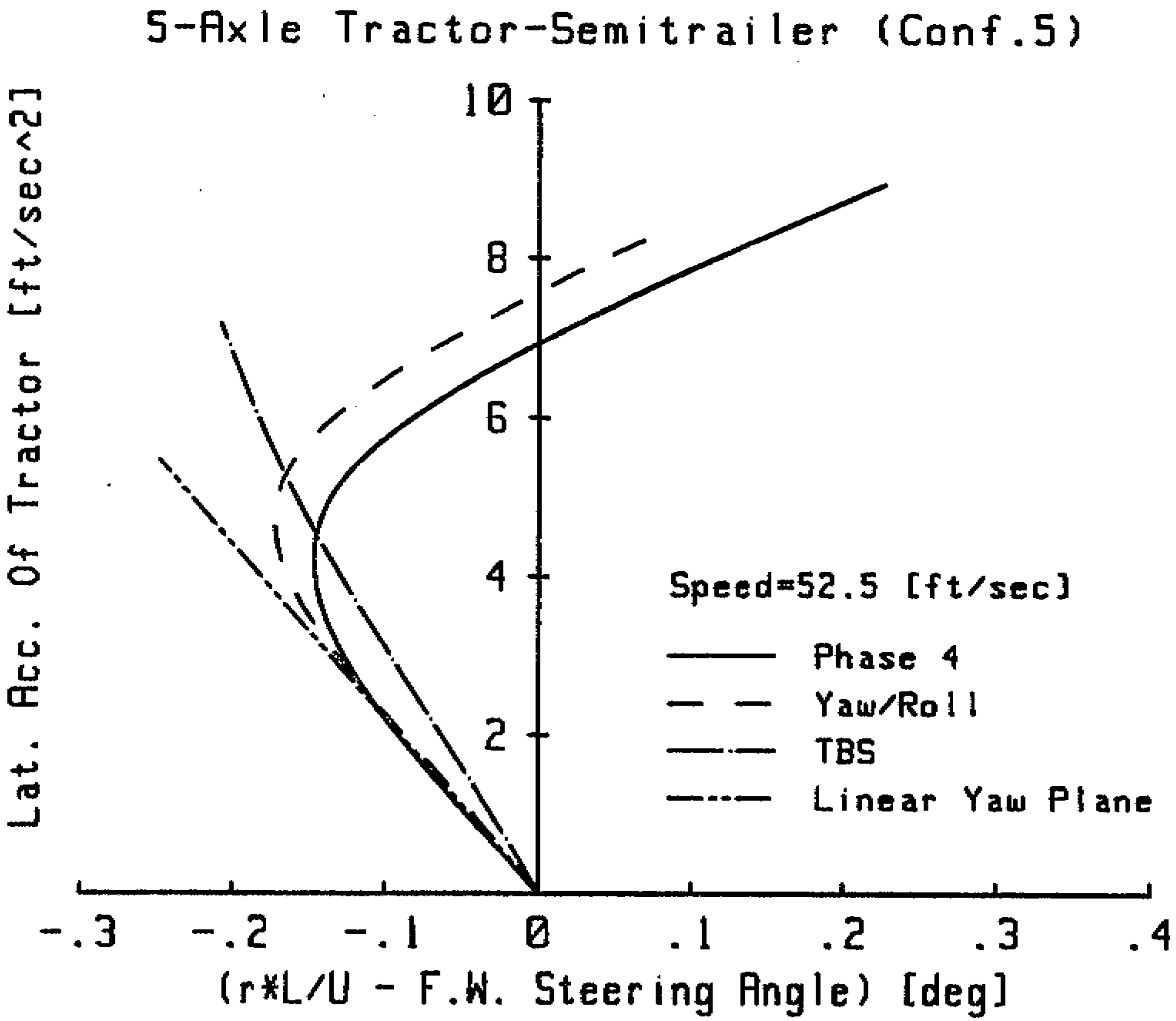


Fig. 3.16 Handling characteristics of Vehicle Configuration 5 predicted by various models

TABLE 3.5

VEHICLE CONFIGURATION 5

A. Phase 4 Model

δ_{av} (deg)	U (ft/sec)	r (deg)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	52.5	1.82	1.80	-0.084	-0.92	-0.73	1.27
1.0	52.71	3.79	3.37	-0.137	-1.81	-1.49	2.62
1.5	52.51	6.01	5.42	-0.126	-2.73	-2.40	4.23
1.75	52.5	7.64	6.93	-0.0037	-3.34	-2.99	5.31
2.0	52.52	9.75	8.94	+0.228	-4.51	-4.02	6.82

B. Yaw/Roll Model

δ_{av} (deg)	U (ft/sec)	r (deg)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	Γ_1 (deg)
0.5	52.5	1.86	1.70	-0.075	-0.64	-0.70	1.29
1.0	52.5	3.73	3.41	-0.147	-1.3	-1.42	2.59
1.5	52.5	5.85	5.35	-0.163	-2.04	-2.23	4.07
1.75	52.5	6.95	6.80	-0.161	-2.55	-2.85	5.1
2.0	52.5	9.10	8.33	+0.08	-3.32	-3.64	6.36

C. TBS Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r*\ell/U - \delta_{av}$ (deg)	Γ_1 (deg)
0.5	52.5	1.94	1.77	- 0.057	1.30
1.0	52.5	3.87	3.55	- 0.115	2.59
1.5	52.51	5.83	5.35	- 0.168	3.90
1.75	52.5	6.83	6.26	- 0.189	4.53
2.0	52.49	7.84	7.19	- 0.208	5.15

D. Linear Yaw Plane Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r*\ell/U - \delta_{av}$ (deg)	Γ_1 (deg)
0.5	52.5	1.82	1.67	- 0.084	1.22
1.0	52.5	3.65	3.34	- 0.166	2.44
2.0	52.5	7.3	6.69	- 0.331	4.89

It can be seen from Fig. 3.16 that up to lateral acceleration of 0.1 g, the Phase 4 model, the yaw/roll model and the linear yaw plane model give practically the same prediction of understeer level, whereas the TBS model predicts lower level of understeer. The Phase 4 model predicts a transition from understeer to oversteer at a lateral acceleration of approximately 0.125 g, while the yaw/roll model predicts the transition occurring at a slightly higher lateral acceleration. The TBS model does not predict a transition below 0.25 g of lateral acceleration, while the linear yaw plane model is unable to predict any changes in the handling behaviour of the vehicle.

From Table 3.5, it can be noted that there are noticeable differences between the articulation angles predicted using the four models. The Phase 4 model gives the highest prediction, while the linear yaw plane model gives the lowest prediction. It can also be seen that the roll angles of the sprung masses of the tractor and semitrailer predicted using the Phase 4 model are generally higher than those predicted using the yaw/roll model.

3.6 Vehicle Configuration 6

This vehicle is a tractor-semitrailer-full trailer combination. The steady-state steering response of this vehicle configuration was simulated using the Phase 4 model, the yaw/roll model and the linear yaw plane model at a forward speed of 21.5 mph (31.5 ft/sec). The TBS model was not used in the simulation, as it is not designed for simulating this type of vehicle combination in its present form.

The steady-state lateral accelerations and yaw rates as functions of front-wheel steering angle of the tractor predicted using the three computer simulation models are shown in Figs. 3.17 and 3.18, respectively. The handling characteristics of the vehicle predicted using the various models are illustrated in Fig. 3.19. The predicted values are also listed in Table 3.6.

As can be seen from Figs. 3.17 and 3.18 and from Table 3.6, all three simulation models give practically the same predictions of lateral acceleration and yaw rate of the tractor up to front-wheel steering angle of 4.5 degrees (or lateral acceleration of approximately 0.25 g). The differences between the lateral acceleration predicted by the Phase 4 model and those by the yaw/roll model and the linear yaw plane model at front-wheel steering angle of 4.5 degrees are only 0.5 % and 4.7 % respectively.

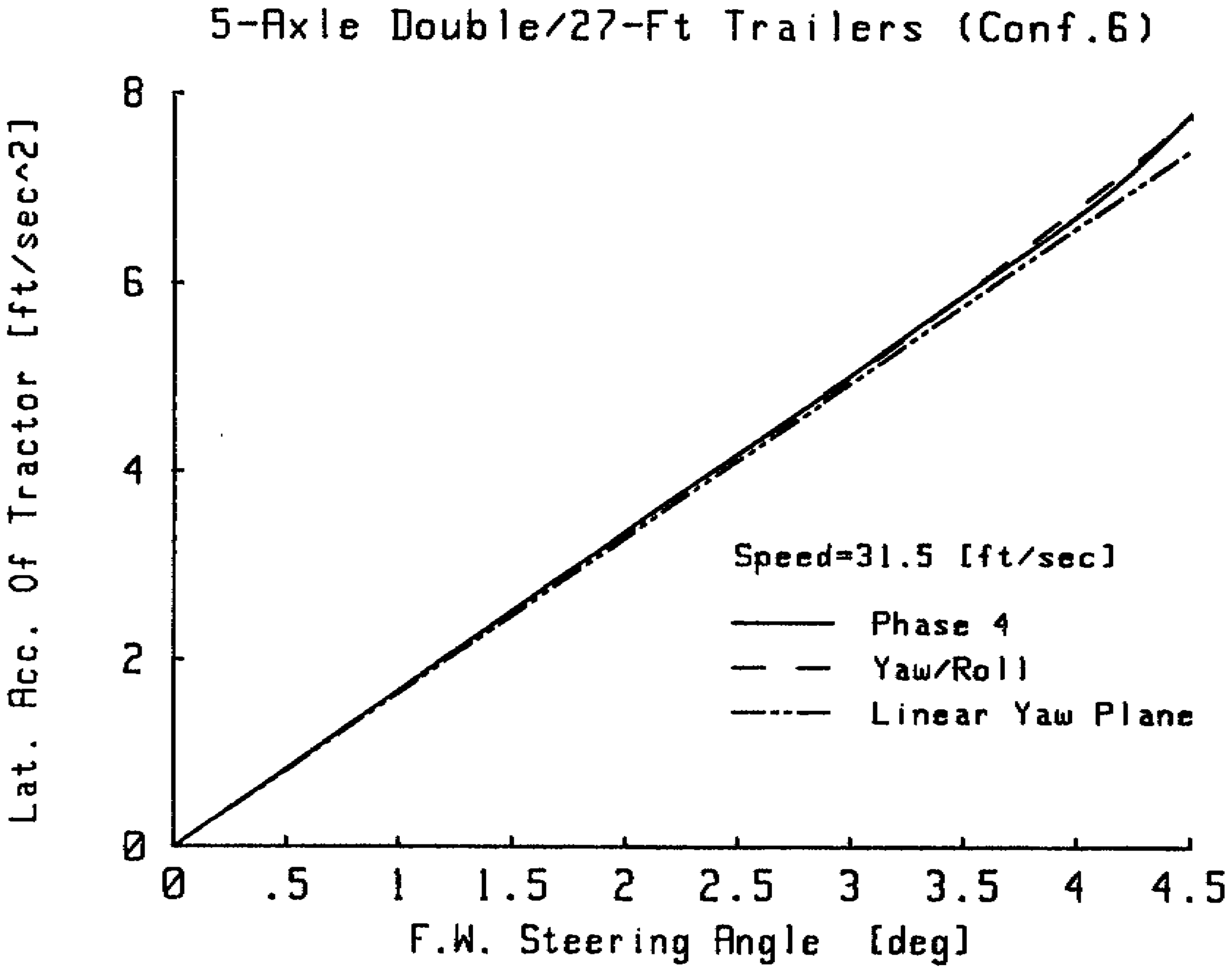


Fig. 3.17 Steady-state lateral acceleration response to steering input of Vehicle Configuration 6 predicted by various models

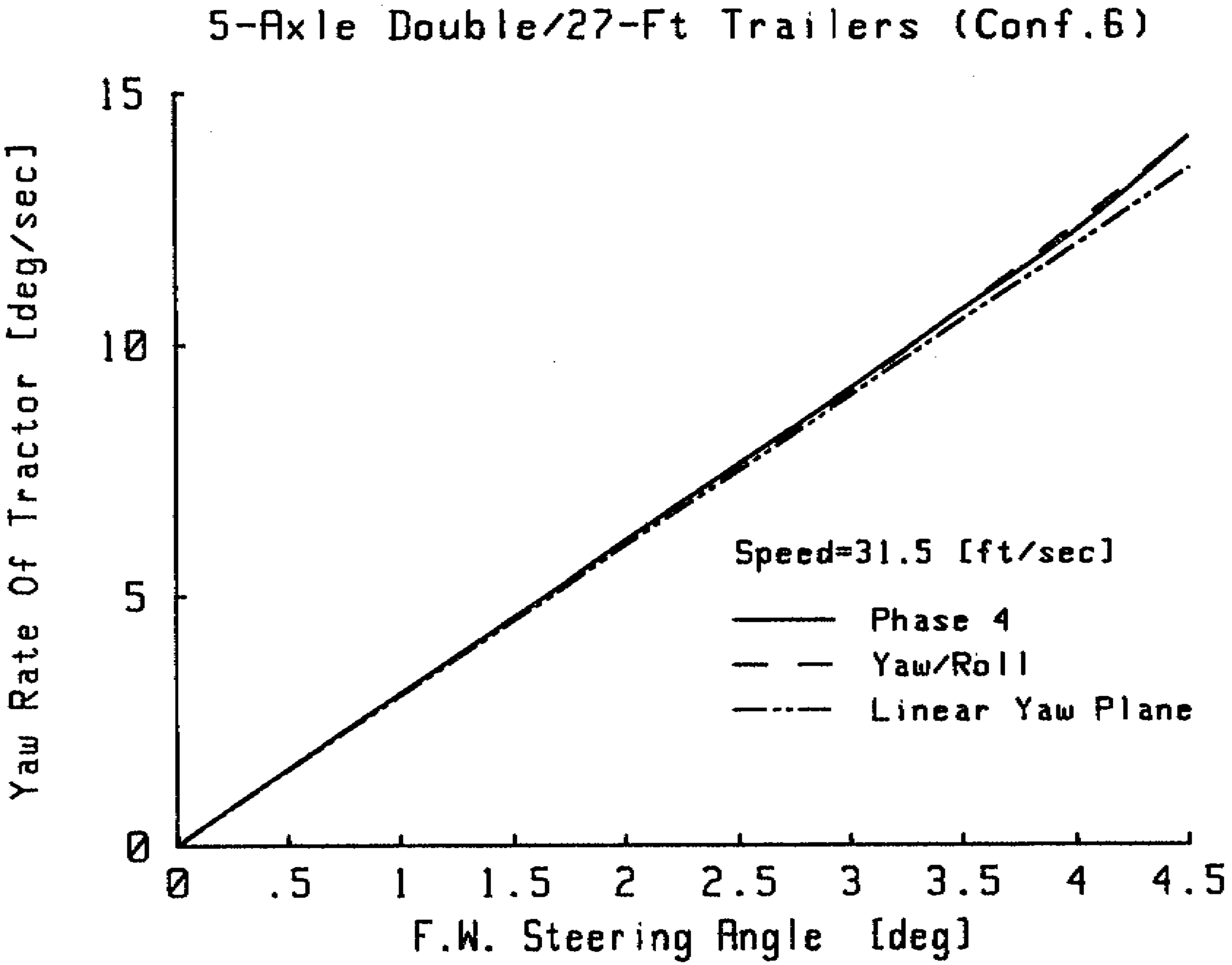


Fig. 3.18 Steady-state yaw rate response to steering input of Vehicle Configuration 6 predicted by various models

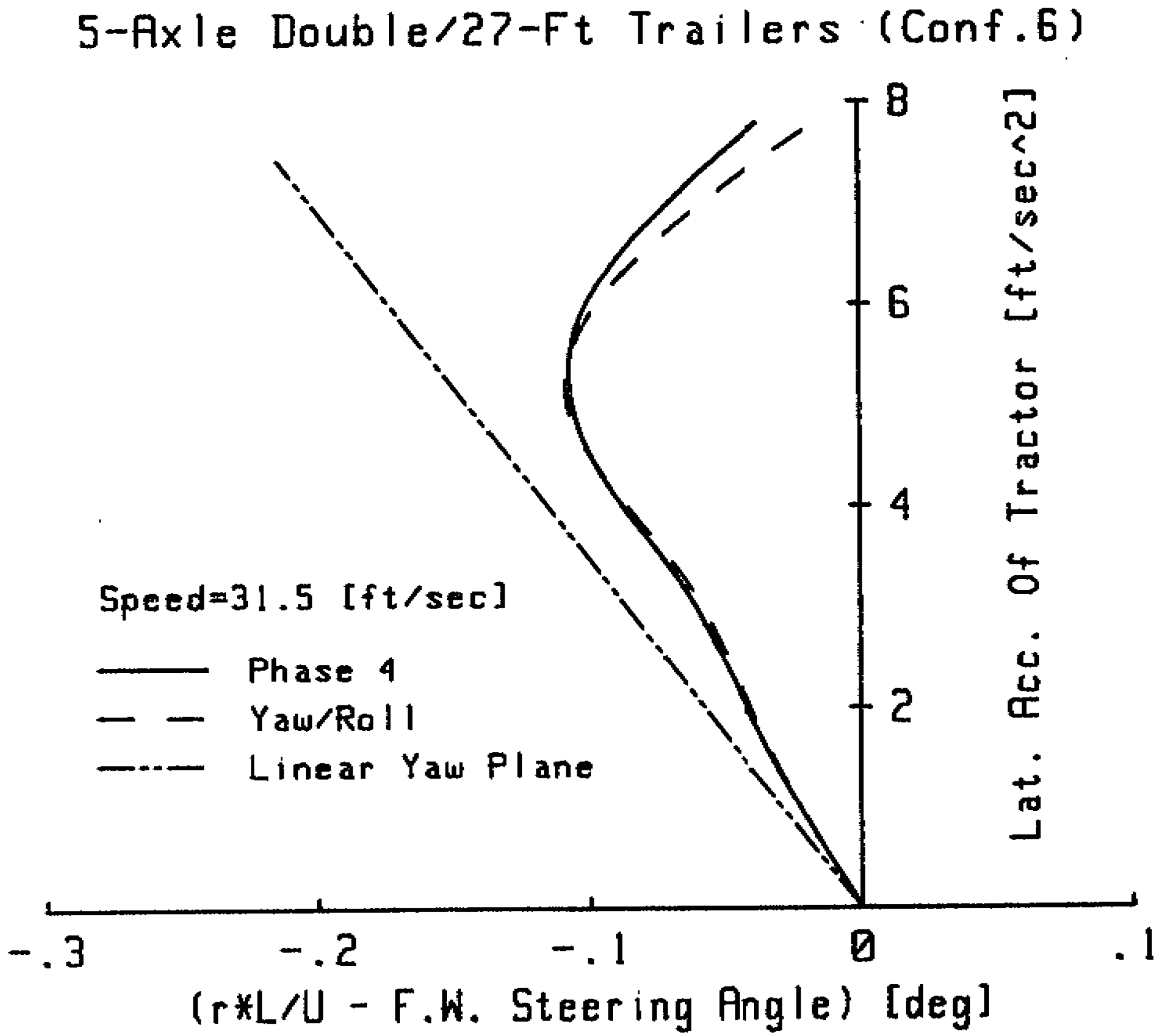


Fig. 3.19 Handling characteristics of Vehicle Configuration 6 predicted by various models

TABLE 3.6

VEHICLE CONFIGURATION 6

A. Phase 4 Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	ϕ_3 (deg)	Γ_1 (deg)	Γ_2 (deg)
1.0	31.53	3.04	4.67	- 0.036	- 0.51	- 0.43	- 0.35	1.93	2.89
2.0	31.55	6.09	3.36	- 0.069	- 1.25	- 1.09	- 0.88	3.880	5.83
2.5	31.7	7.63	4.19	- 0.093	- 1.63	- 1.42	- 1.20	4.88	7.47
3.0	31.51	9.14	5.03	- 0.098	- 2.07	- 1.79	- 1.48	5.82	8.99
3.5	31.5	10.7	5.88	- 0.103	- 2.45	- 2.15	- 1.79	6.79	10.56
4.0	31.5	12.28	6.72	- 0.101	- 2.94	- 2.61	- 2.10	7.82	14.04
4.5	31.68	14.14	7.80	- 0.037	- 3.96	- 3.14	- 2.60	8.90	

B. Yaw/Roll Model

δ_{av} (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U-\delta_{av}$ (deg)	ϕ_1 (deg)	ϕ_2 (deg)	ϕ_3 (deg)	Γ_1 (deg)	Γ_2 (deg)
1.0	31.5	3.04	1.67	- 0.035	- 0.65	- 0.68	- 0.55	1.95	2.9
2.0	31.5	6.09	3.35	- 0.067	- 1.31	- 1.36	- 1.12	3.9	5.82
2.5	31.5	7.62	4.19	- 0.081	- 1.64	- 1.71	- 1.41	4.87	7.30
3.0	31.5	9.11	5.01	- 0.108	- 1.97	- 2.05	- 1.68	5.81	8.75
3.5	31.5	10.71	5.88	- 0.1	- 2.34	- 2.44	- 2.06	6.80	10.58
4.0	31.5	12.39	6.81	- 0.067	- 2.76	- 2.87	- 2.37	7.82	12.29
4.5	31.5	14.12	7.76	- 0.0175	- 3.18	- 3.32	- 2.74	8.88	14.07

C. Linear Yaw Plane Model

δ (deg)	U (ft/sec)	r (deg/sec)	A_y (ft/sec^2)	$r^*\ell/U - \delta_{av}$ (deg)	Γ_1 (deg)	Γ_2 (deg)
1.0	31.5	3.0	1.65	- 0.048	1.91	2.91
2.0	31.5	6.0	3.3	- 0.095	3.82	5.84
3.0	31.5	8.99	4.95	- 0.146	5.74	8.86
4.5	31.5	13.5	7.43	- 0.214	8.59	13.09

NOTE: ϕ_1 - roll angle of the tractor

ϕ_2 - roll angle of the semitrailer

ϕ_3 - roll angle of the full-trailer

Γ_1 - articulation angle between the tractor and the semitrailer

Γ_2 - articulation angle between the semitrailer and the full-trailer

As can be seen from Fig. 3.19, the Phase 4 model and the yaw/roll model give essentially the same prediction of the handling characteristics of the vehicle. Both models predict a transition from understeer to oversteer at a lateral acceleration of approximately 0.15 g. The linear yaw plane model predicts a higher level of understeer than the other two models. As mentioned previously, the linear yaw plane model is unable to predict changes in the handling behaviour of the vehicle.

From Table 3.6, it can be seen that all three models give similar predictions of the articulation angle between the tractor and semitrailer and that between the semitrailer and full-trailer. It can also be noted that the Phase 4 model and the yaw/roll model give similar predictions of the roll angles of the sprung masses of the tractor, semitrailer and full-trailer.

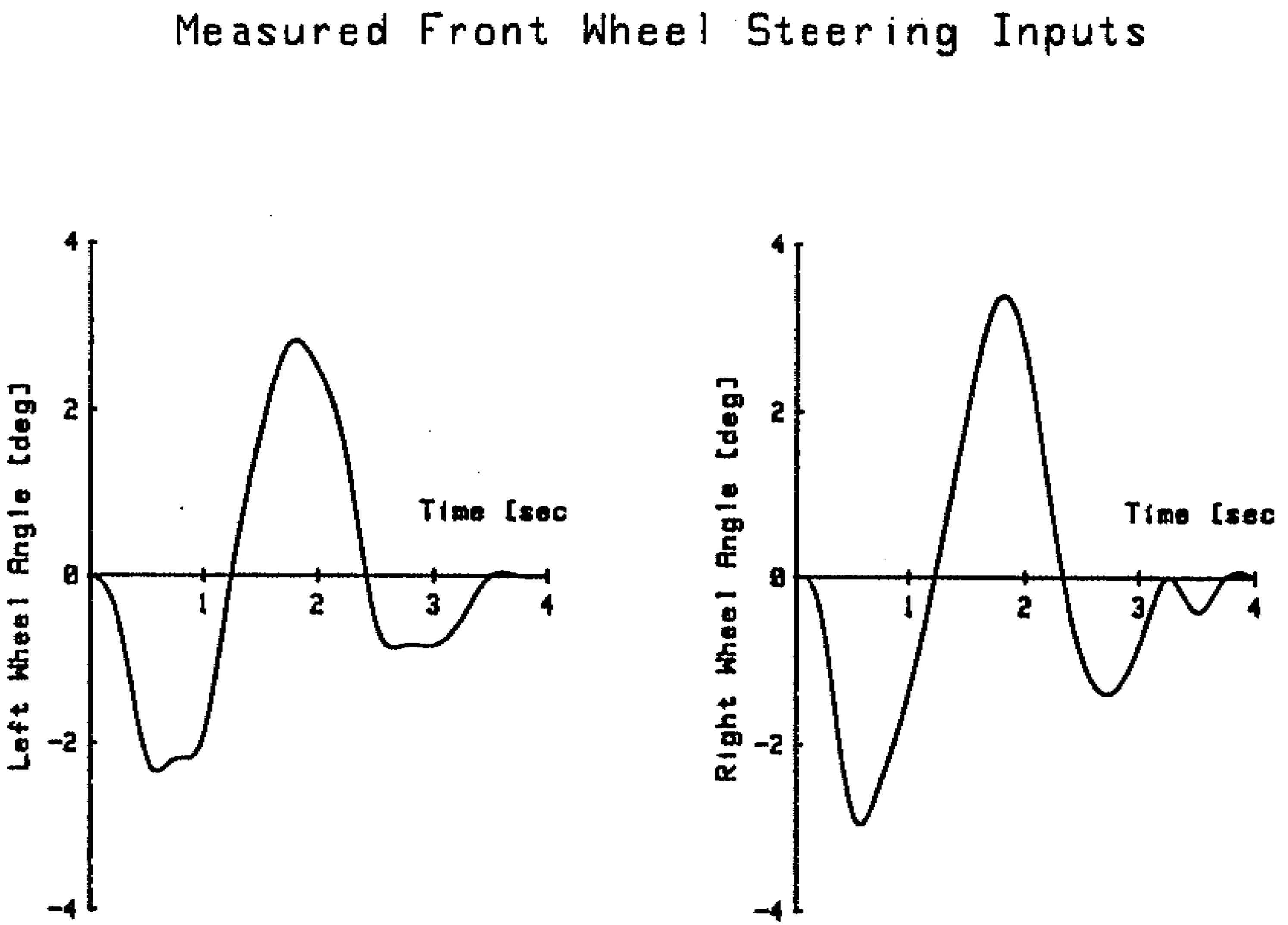
4. A COMPARISON OF VARIOUS COMPUTER SIMULATION MODELS FOR PREDICTING STEERING RESPONSES IN LANE-CHANGE TYPE TRANSIENT MANOEUVRES

This section examines the abilities of various computer simulation models in predicting the directional response to steering in lane-change (obstacle-avoidance) type transient manoeuvres. The lateral acceleration, yaw rate and articulation angle of Vehicle Configuration 1 in a moderate lane-change type transient manoeuvre were predicted using the Phase 4 model, the yaw/roll model, the TBS model and the linear yaw plane model. The simulated results were compared with the measured data reported in reference (7). In addition, the directional responses to steering of Vehicle Configurations 3 and 6 in a more severe lane-change manoeuvre were also simulated using the four computer simulation models. The results of this study provide quantitative information for evaluation the abilities of various computer models for simulating the transient directional behaviour of articulated vehicles.

4.1 Steering Response of Vehicle Configuration 1 in a Lane-Change Manoeuvre

The transient directional response to steering input of Vehicle Configuration 1 was predicted using the four computer simulation models. In the simulations, the left and right front-wheel angles as functions of time measured during a test, shown in Fig. 4.1, were used as inputs (7). The tractor lateral acceleration, semitrailer lateral acceleration, tractor yaw rate, semitrailer yaw rate, and articulation angle of Vehicle Configuration 1 as functions of time during the lane-change manoeuvre, at a forward speed of 43 mph (63.04 ft/sec), were predicted using the four models, and are shown in Figs. 4.2, 4.3, 4.4, 4.5 and 4.6, respectively. For comparison, the measured data reported in reference (7) were also shown in the figures.

It can be seen that the responses of the tractor and semitrailer predicted by the four models generally follow the same trend as that measured. However, there are differences between the predicted peak values and the measured ones. For instance, the differences between the measured peak value of tractor lateral acceleration and those predicted using the Phase 4 model, the yaw/roll model, the TBS model and the linear yaw plane model are approximately 16%, 10%, 33% and 46%, respectively, as shown in Fig. 4.2. The agreement between the measured peak value of semitrailer lateral acceleration and those predicted is better than that for the tractor lateral acceleration. The differences between the measured peak value of semitrailer lateral acceleration and those predicted using the Phase 4 model, the yaw/roll model, the TBS model and the linear yaw plane model are approximately 20%, 8%, 12% and 20%, respectively, as can be seen from Fig. 4.3.



Measured Front Wheel Steering Inputs

Fig. 4.1 Front-wheel steering inputs to the simulation of moderate lane-change manoeuvres

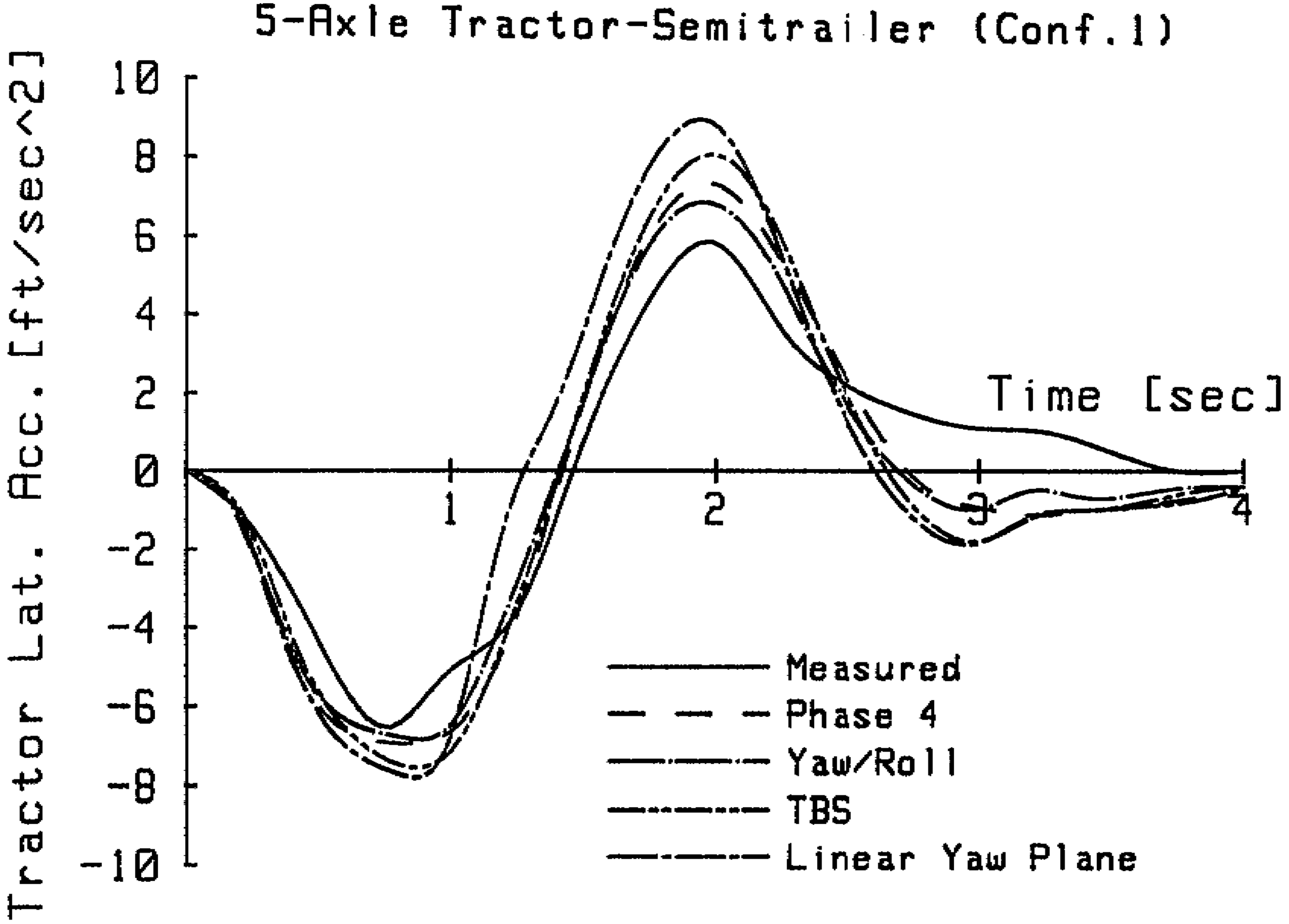


Fig. 4.2 Variation of tractor lateral acceleration with time of Vehicle Configuration 1 in a lane-change manoeuvre predicted by various models

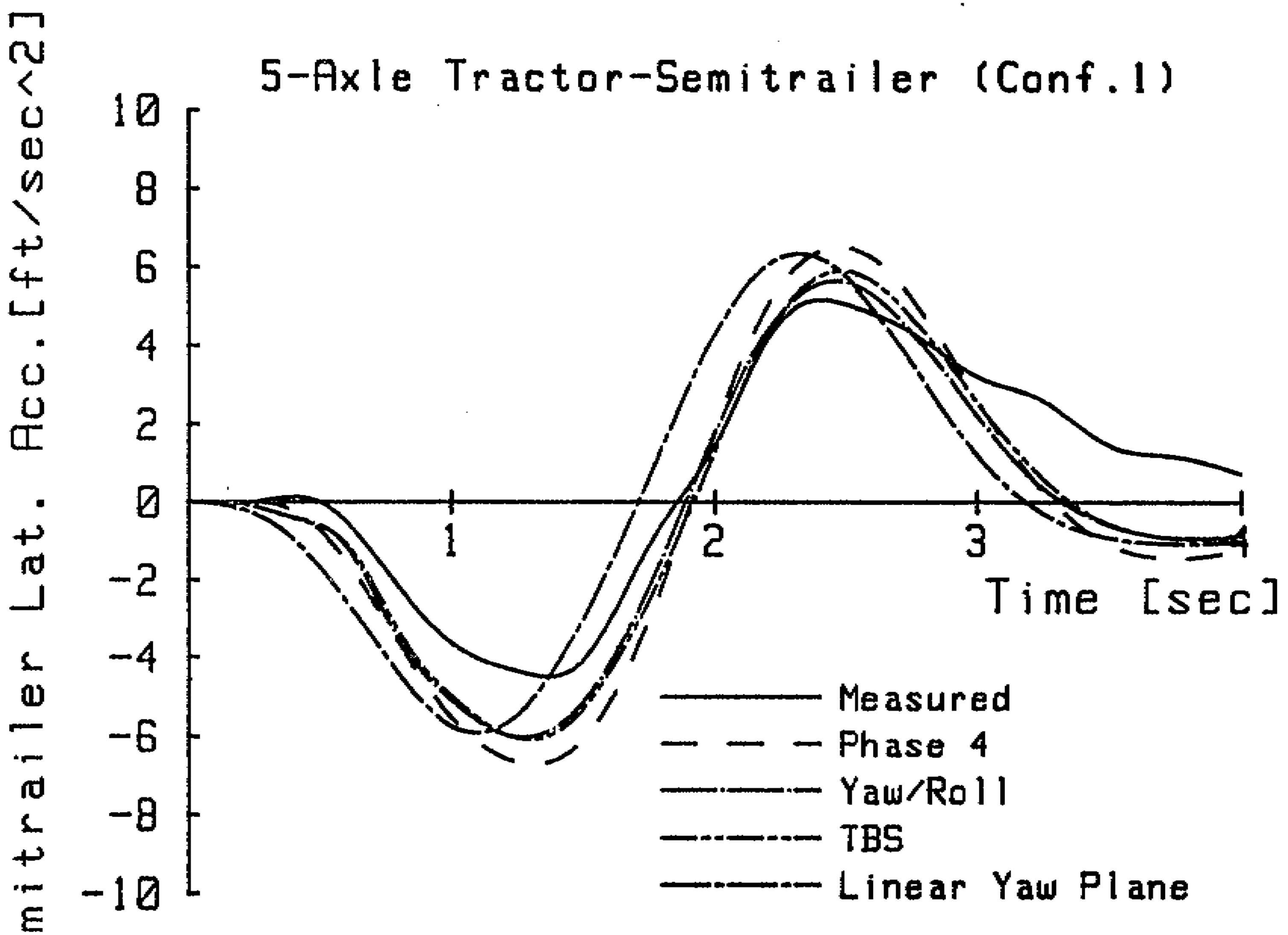


Fig. 4.3 Variation of semitrailer lateral acceleration with time Vehicle Configuration 1 in a lane-change manoeuvre predicted by various models

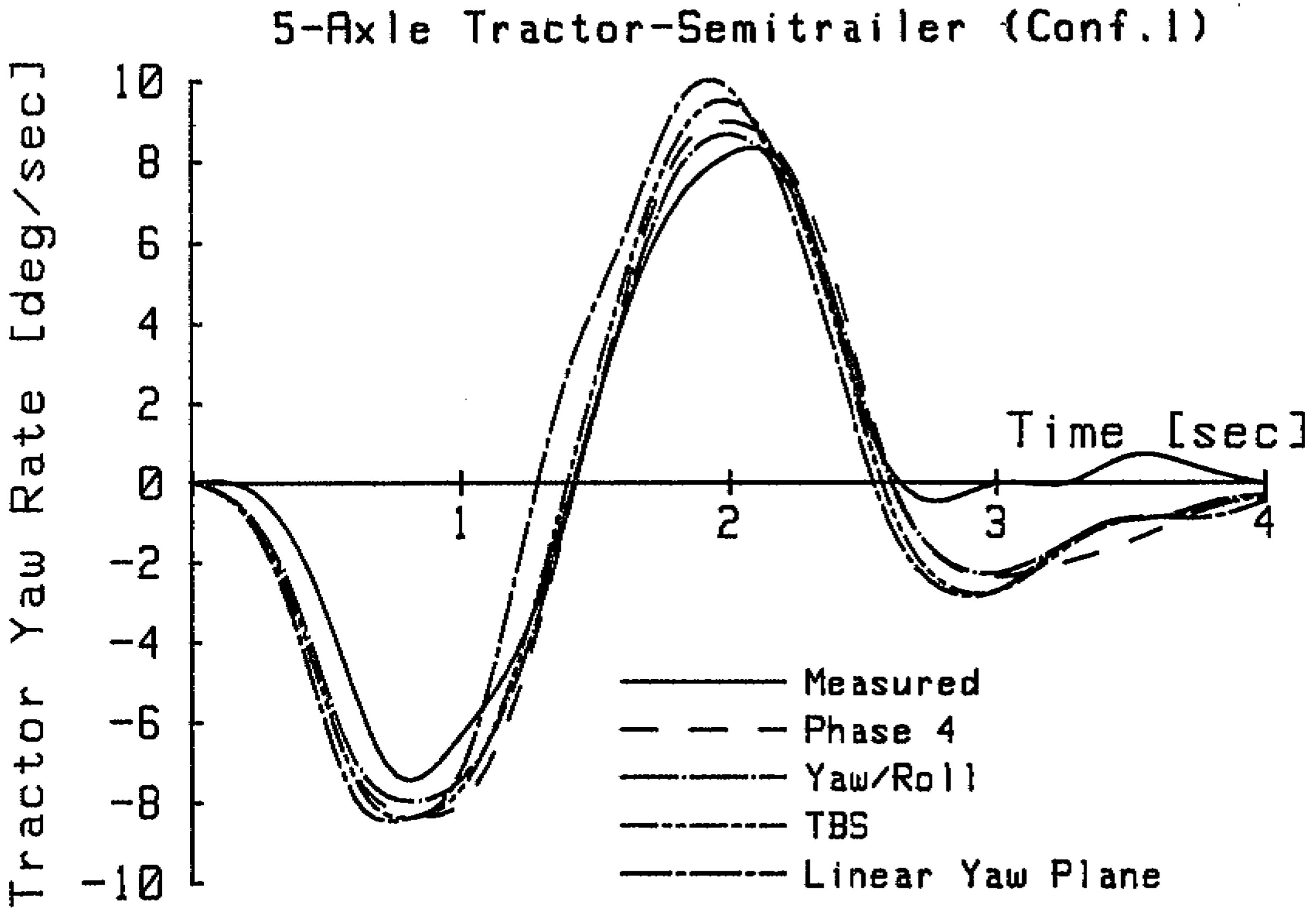


Fig. 4.4 Variation of tractor yaw rate with time of Vehicle Configuration 1 in a lane-change manoeuvre predicted by various models

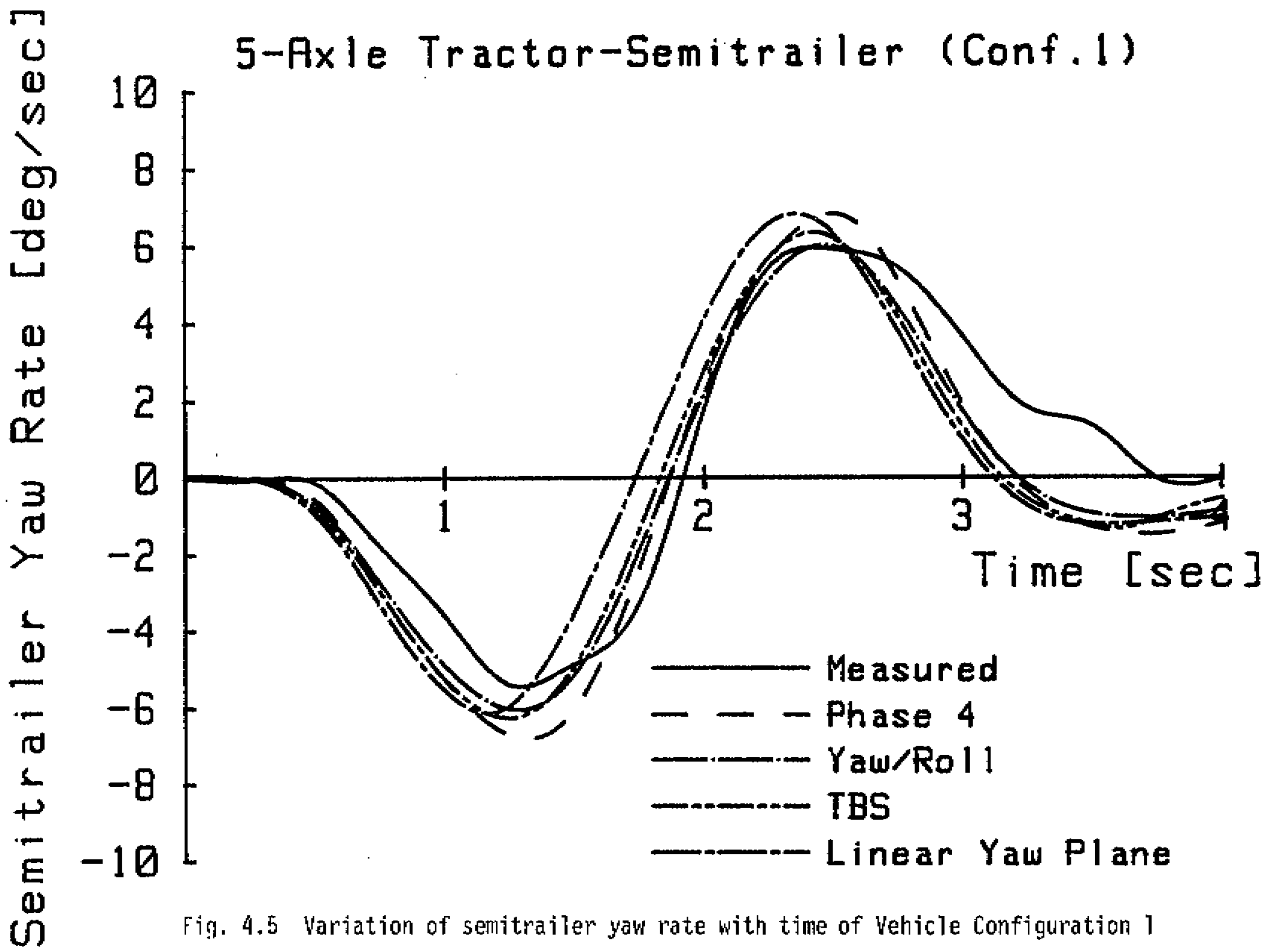


Fig. 4.5 Variation of semitrailer yaw rate with time of Vehicle Configuration 1 in a lane-change manoeuvre predicted by various models

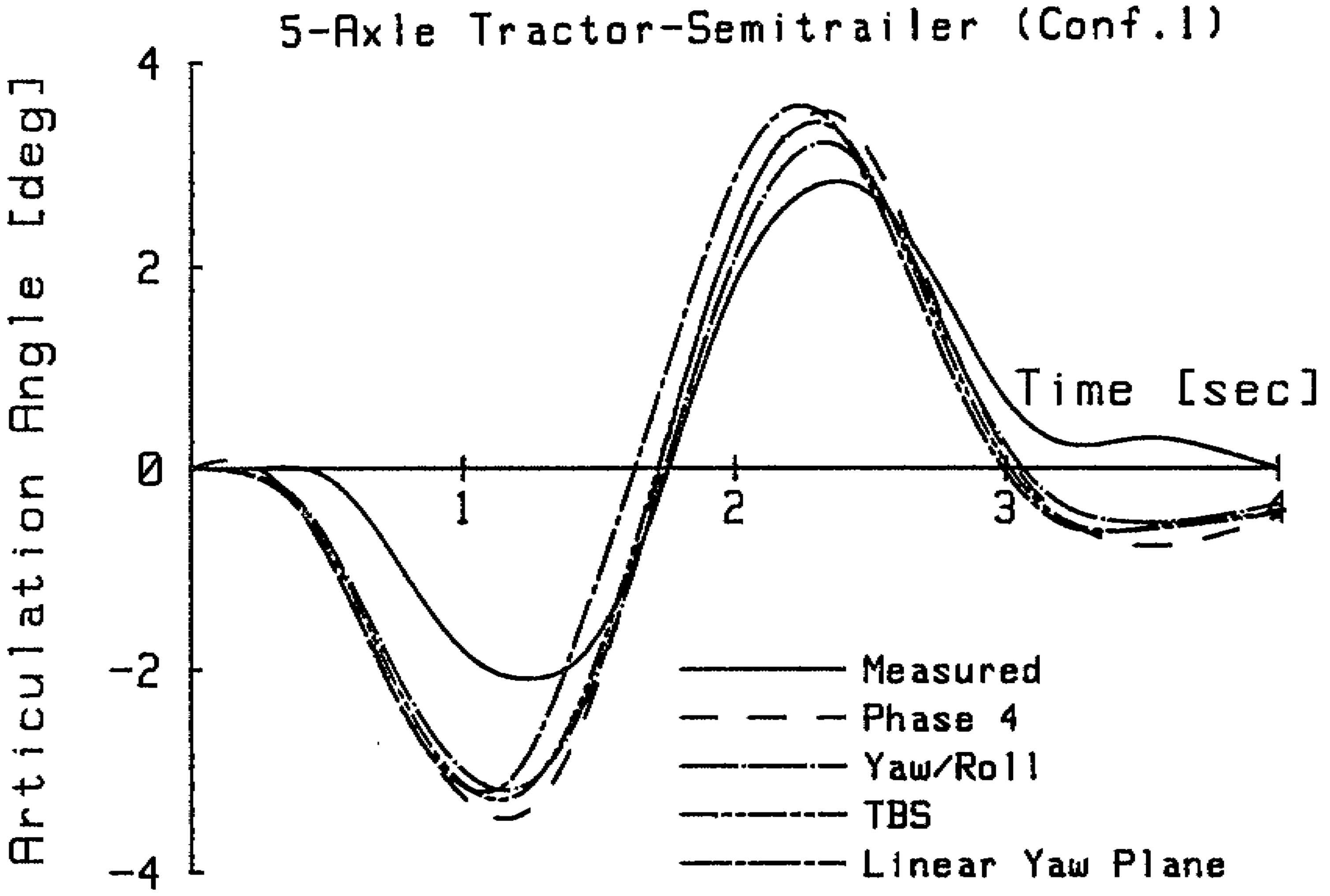


Fig. 4.6 Variation of articulation angle with time of Vehicle Configuration 1 in a lane-change manoeuvre predicted by various models

The agreement between the measured tractor yaw rate response and those predicted using the four models appears to be reasonable. The differences between the measured peak value of tractor yaw rate and those predicted using the Phase 4 model, the yaw/roll model, the TBS model, and the linear yaw plane model are approximately 9.8%, 4.9%, 15.8% and 21.9%, respectively, as can be seen from Fig. 4.4. The measured semitrailer yaw rate response and those predicted using the four models again show reasonable agreement. The differences between the measured peak value of semitrailer yaw rate and those predicted using the Phase 4 model, the yaw/roll model, the TBS model and the linear yaw plane model are approximately 13.3 %, 0 %, 3.3 %, and 13.3 %, respectively, as shown in Fig. 4.5. The articulation angle responses predicted using the four models are reasonably close. The differences between the peak values of articulation angle predicted using the four models are within 10 %. However, there is a noticeable difference between the measured and predicted peak values of articulation angle. For instance, the difference between the measured and the predicted peak value of articulated angle using the Phase 4 model is approximately 22 %, as can be seen from Fig. 4.6.

It should also be noted from the figures that there is a phase shift between the measured and predicted responses, and that there is a significant difference between the measured and predicted responses during the period from 2.5 to 4 seconds.

4.2 Steering Response of Vehicle Configuration 3 in a Severe Lane-Change Manoeuvre

The transient directional response to steering input of Vehicle Configuration 3 (a 5-axle tractor-semitrailer) in a severe lane-change (obstacle-avoidance) type manoeuvre at a forward speed of 35.8 mph (52.5 ft/sec) was predicted using the four computer simulation models. In the simulations, the time history of the average front-wheel steering angle shown in Fig. 4.7 was used as input to the computer simulation models. It can be noted from Fig. 4.7 that the amplitude of the front-wheel steering angle is 6 degrees and that the steering input in the lane-change manoeuvre is completed in 2 seconds. This represents a severe (rapid) lane-change type manoeuvre, as compared with that described in Section 4.1.

The tractor yaw rate, semitrailer yaw rate, tractor lateral acceleration and semitrailer lateral acceleration of Vehicle Configuration 3 predicted using various computer simulation models are shown in Figs. 4.8, 4.9, 4.10 and 4.11, respectively. There is no measured data available for comparison. The information shown in the figures, therefore, only serves the purposes of illustrating the difference in the predictions made by various models.

It can be seen from Figs. 4.8 and 4.9 that the yaw rate responses of the tractor and semitrailer predicted using the four computer simulation models are essentially the same. The differences in the peak values of yaw rate of the tractor predicted using the four models are less than 9.3 %. while those of the semitrailer are within the range of 5.7 %.

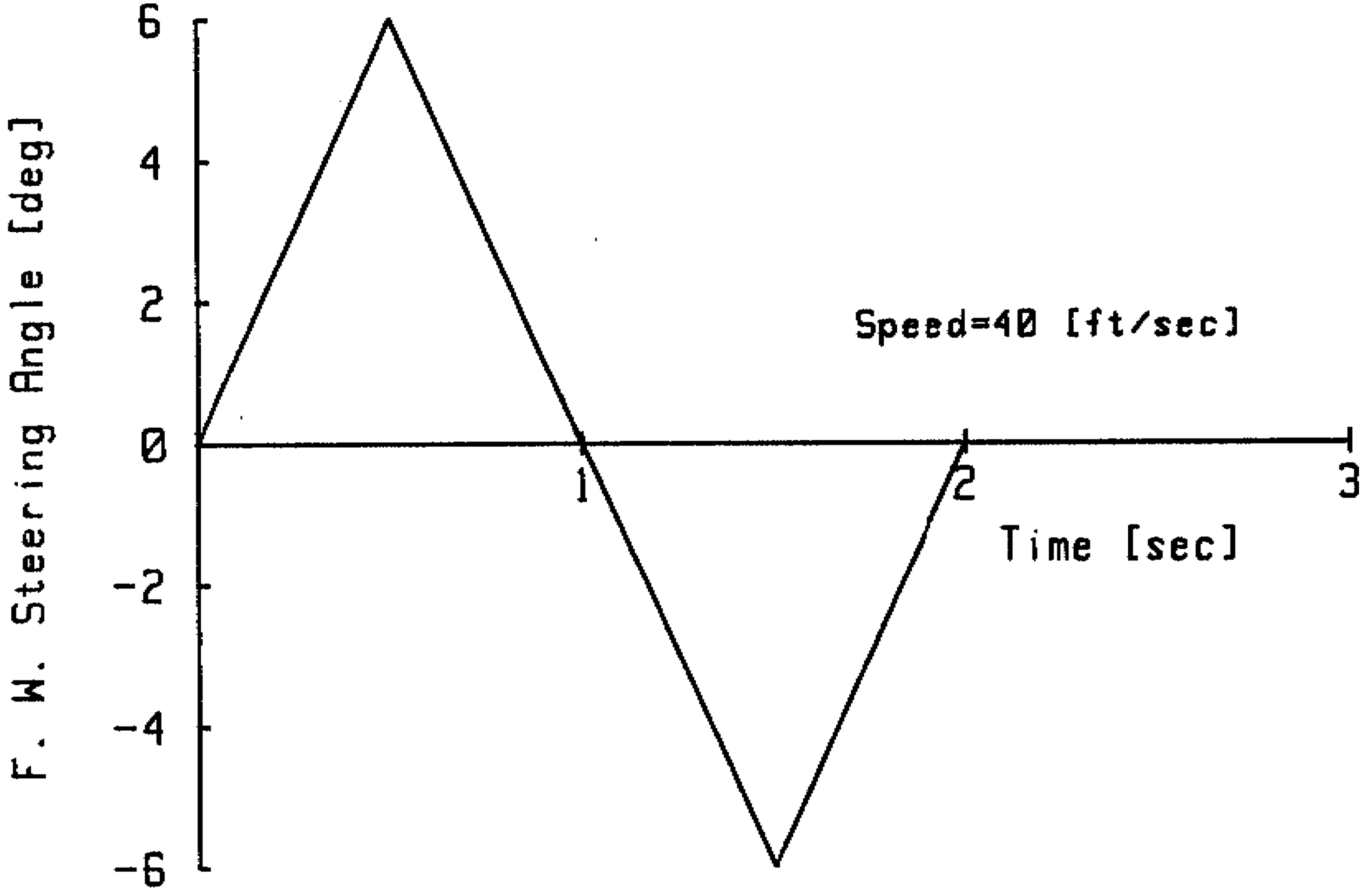


Fig. 4.7 Front-wheel steering inputs to the simulation of severe (rapid) lane-change manoeuvres

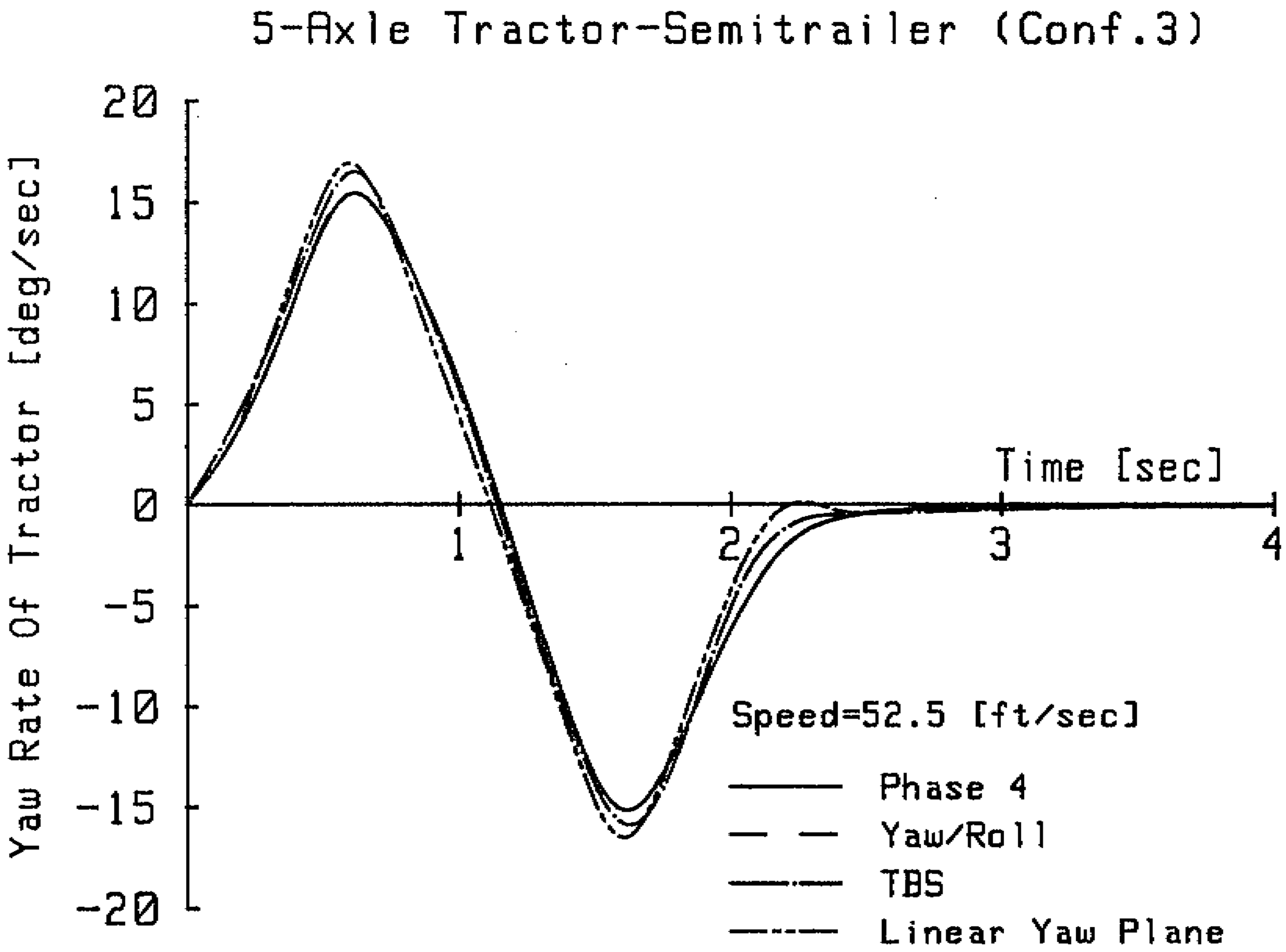


Fig. 4.8 Variation of tractor yaw rate with time of Vehicle Configuration 3 in a severe lane-change manoeuvre predicted by various models

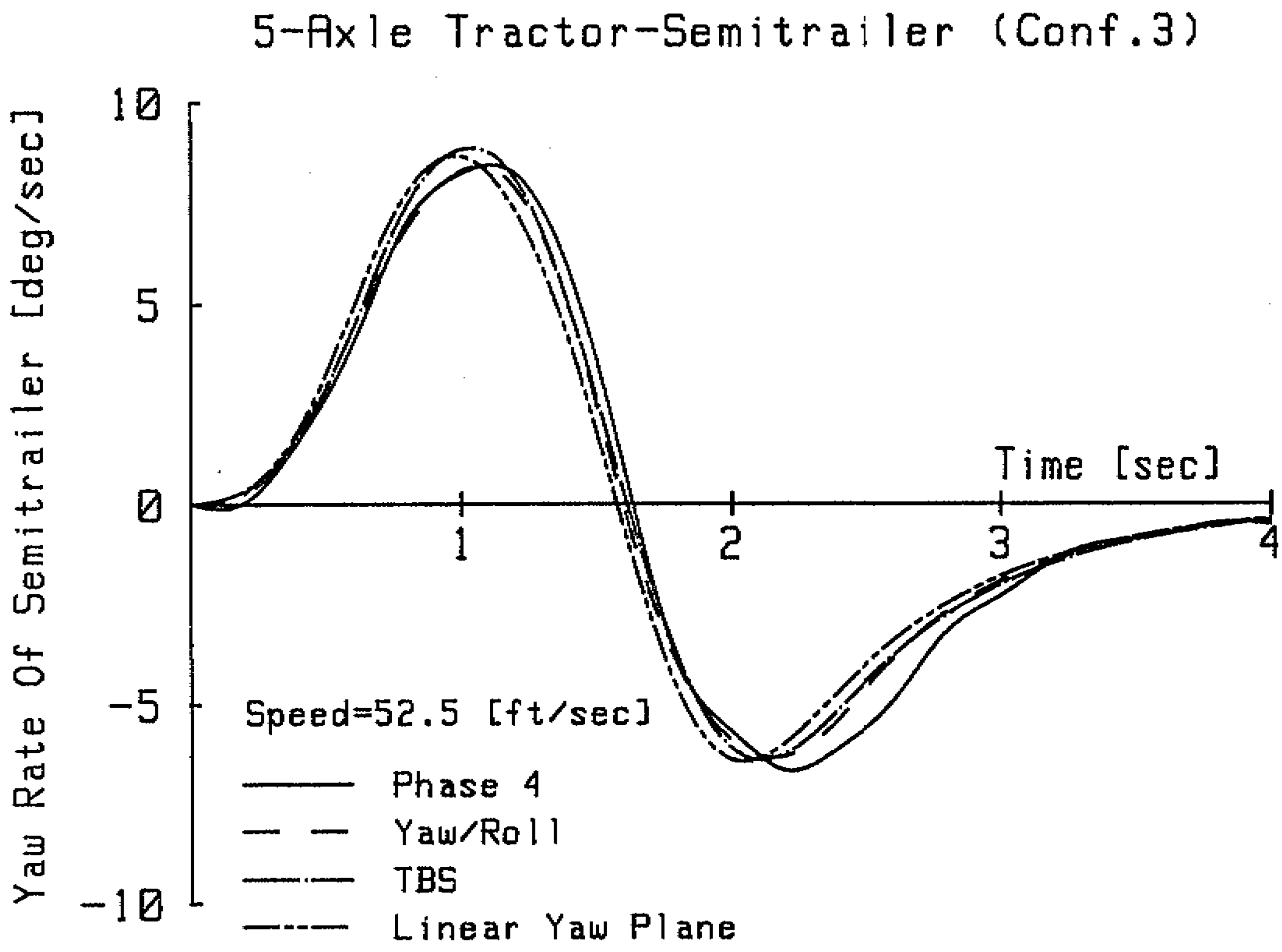


Fig. 4.9 Variation of semitrailer yaw rate with time of Vehicle Configuration 3 in a severe lane-change manoeuvre predicted by various models

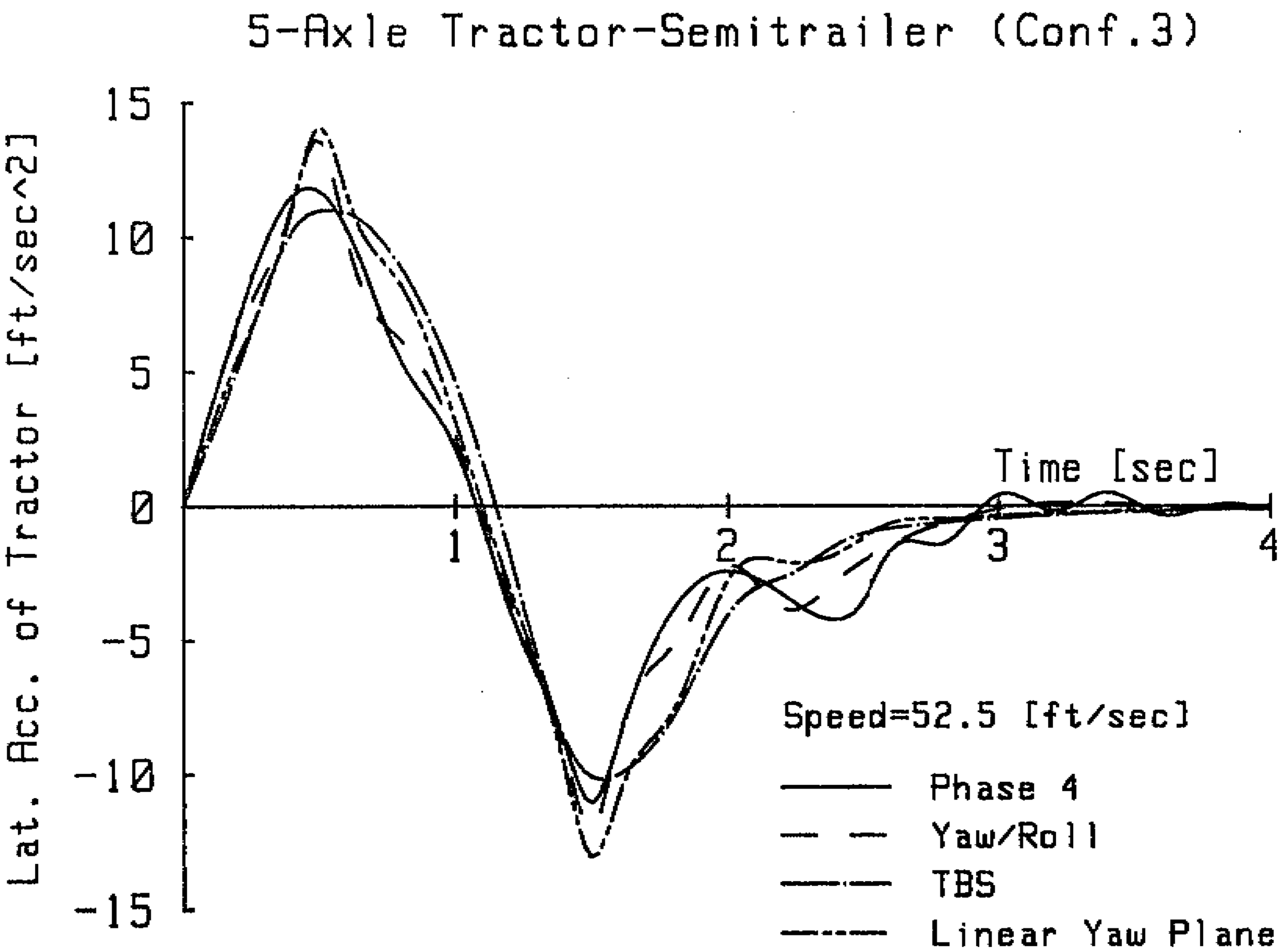


Fig. 4.10 Variation of tractor lateral acceleration with time of Vehicle Configuration 3 in a severe lane-change manoeuvre predicted by various models

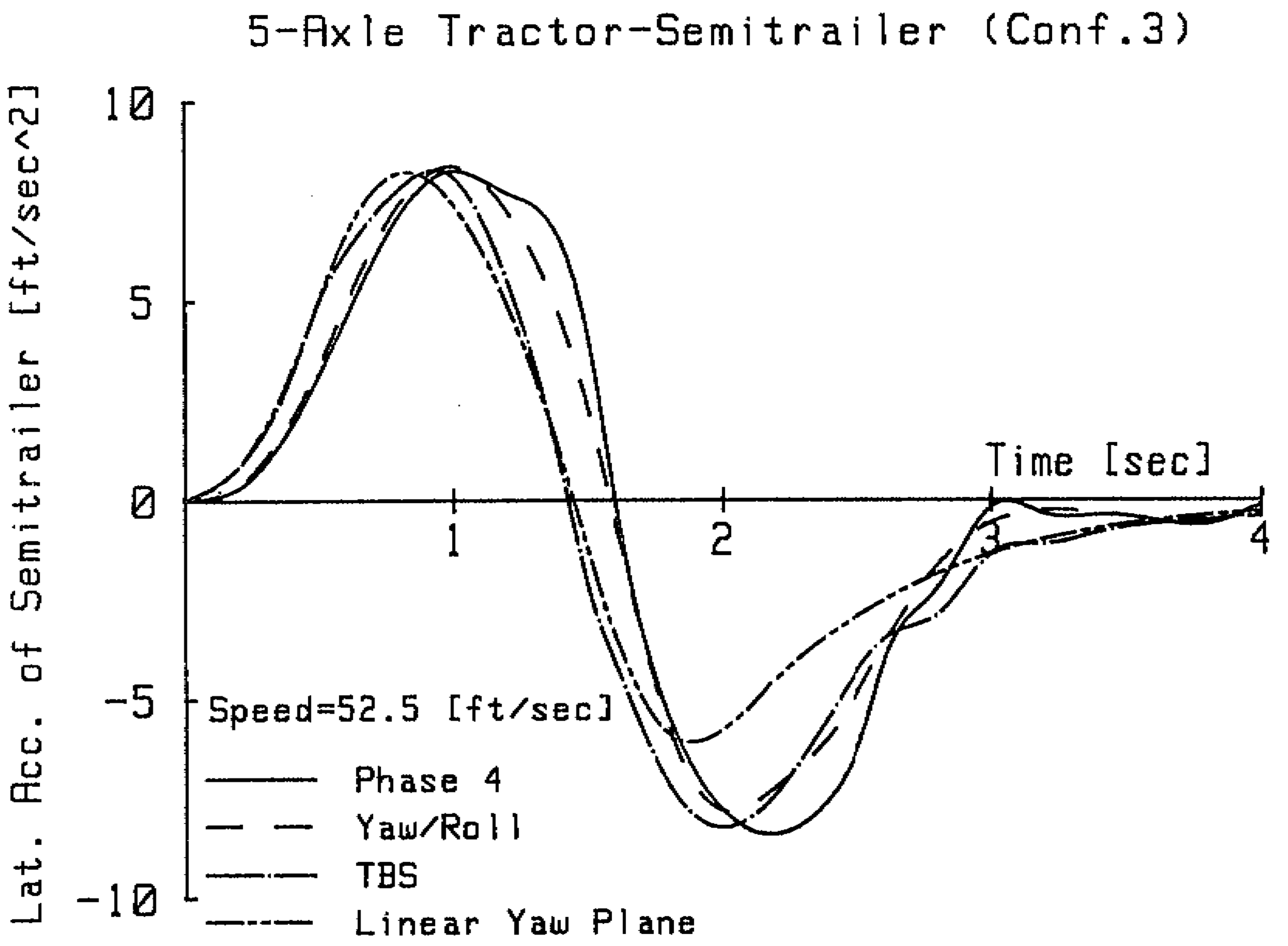


Fig. 4.11 Variation of semitrailer lateral acceleration with time of Vehicle Configuration 3 in a severe lane-change manoeuvre predicted by various models

As can be seen from Figs. 4.10 and 4.11, the characteristics of the lateral acceleration response of the tractor and semitrailer predicted using the four computer simulation models show noticeable differences in phase and in peak value. For instance, the differences in the peak value of tractor lateral acceleration predicted using the Phase 4 model and those predicted using the yaw/roll model, the TBS model and the linear yaw plane model are 15.2 %, 7.1 % and 19.2 %, respectively.

4.3 Steering Response of Vehicle Configuration 6 in a Severe Lane-Change Manoeuvre

The transient directional response to steering input of Vehicle Configuration 6 (a tractor-semitrailer-full trailer) in a severe lane-change manoeuvre at a forward speed of 27.3 mph (40 ft/sec), was predicted using the Phase 4 model, the yaw/roll model, and the linear yaw plane model. The TBS model was not used in the simulation, as it is not designed, in its present form, for simulating this type of vehicle combination. The steering input to the various simulation models is the same as that shown in Fig. 4.7.

The yaw rates of the tractor, semitrailer and full trailer (pup trailer) and the lateral accelerations of the tractor, semitrailer and full trailer of Vehicle Configuration 6 predicted using the three computer simulation models are shown in Figs. 4.12, 4.13, 4.14, 4.15, 4.16 and 4.17, respectively.

It can be seen from Figs. 4.12 and 4.13 that the yaw rate responses of the tractor and semitrailer predicted using the three computer simulation models are quite close. The differences in the peak values of yaw rate of the tractor predicted using the three models are less than 9.8 %, while those of the semitrailer are less than 2.8 %. The yaw rate responses of the full trailer (pup trailer) predicted using the Phase 4 model and the yaw/roll model are essentially identical, as can be seen from Fig. 4.14. However, there is a significant difference in the yaw rate response characteristics predicted using the linear yaw plane model and those predicted using the Phase 4 model and the yaw/roll model, and the difference in the peak value of yaw rate is approximately 15 %.

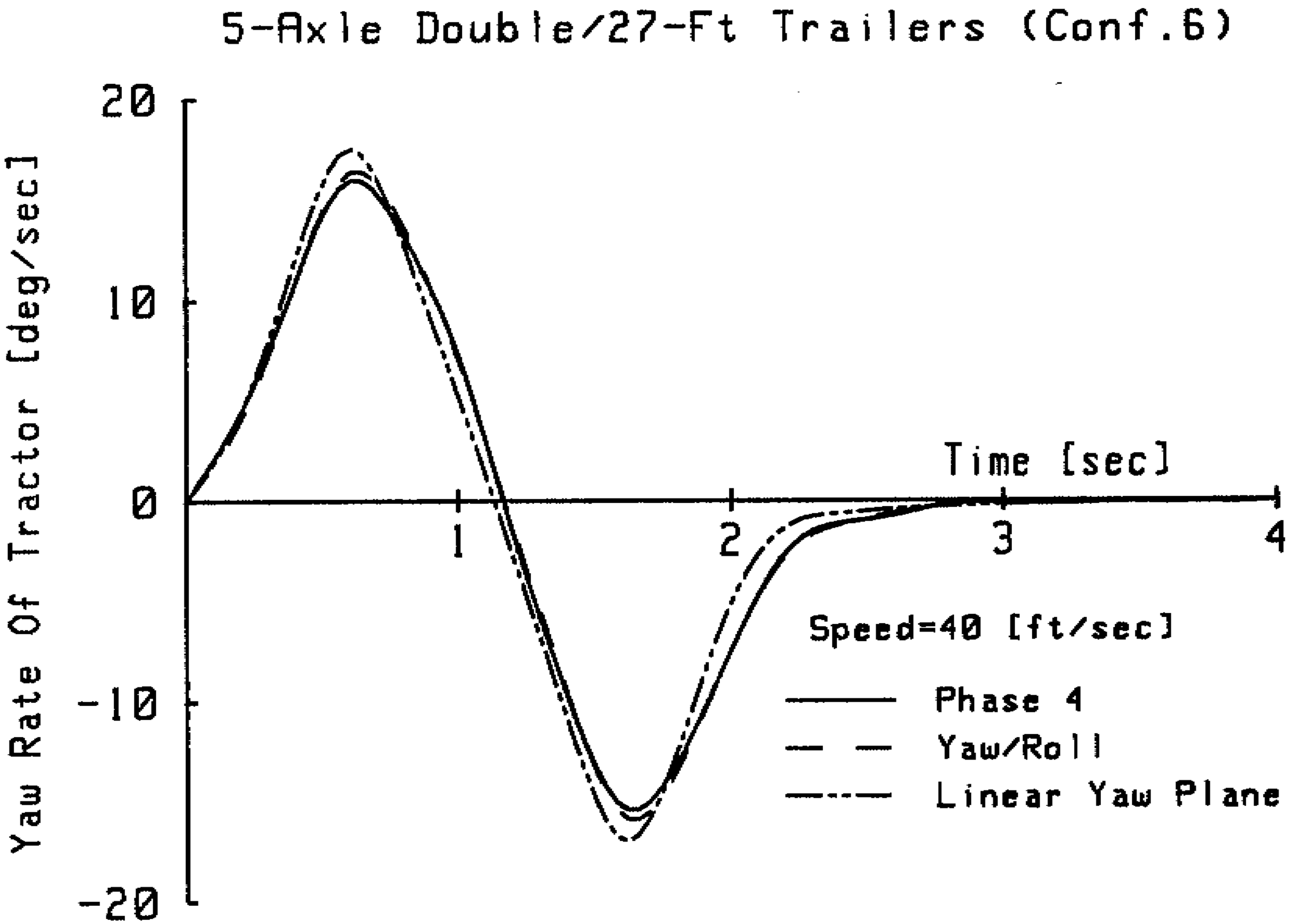


Fig. 4.12 Variation of tractor yaw rate with time of Vehicle Configuration 6 in a severe lane-change manoeuvre predicted by various models

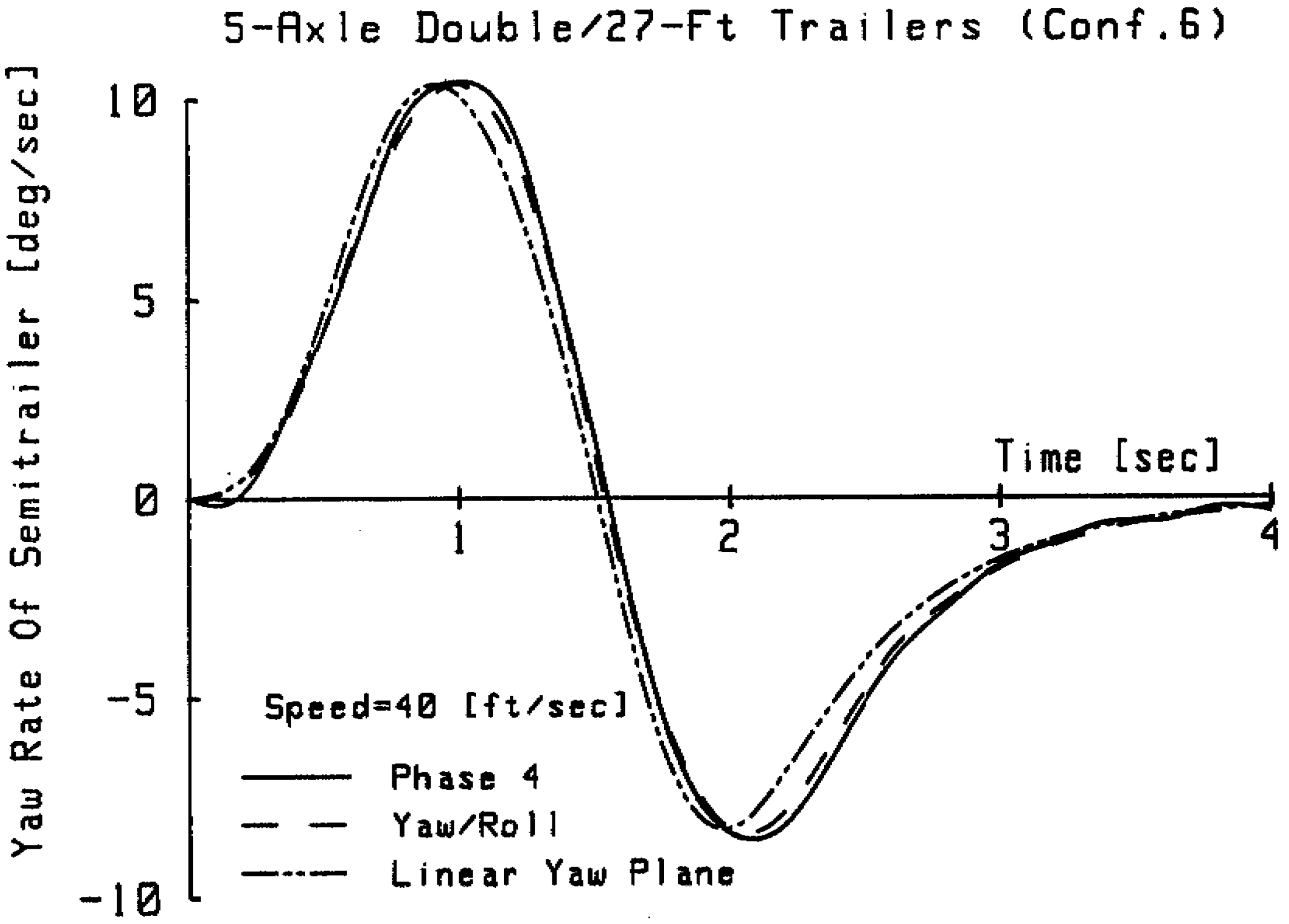


Fig. 4.13 Variation of semitrailer yaw rate with time of Vehicle Configuration 6 in a severe lane-change manoeuvre predicted by various models

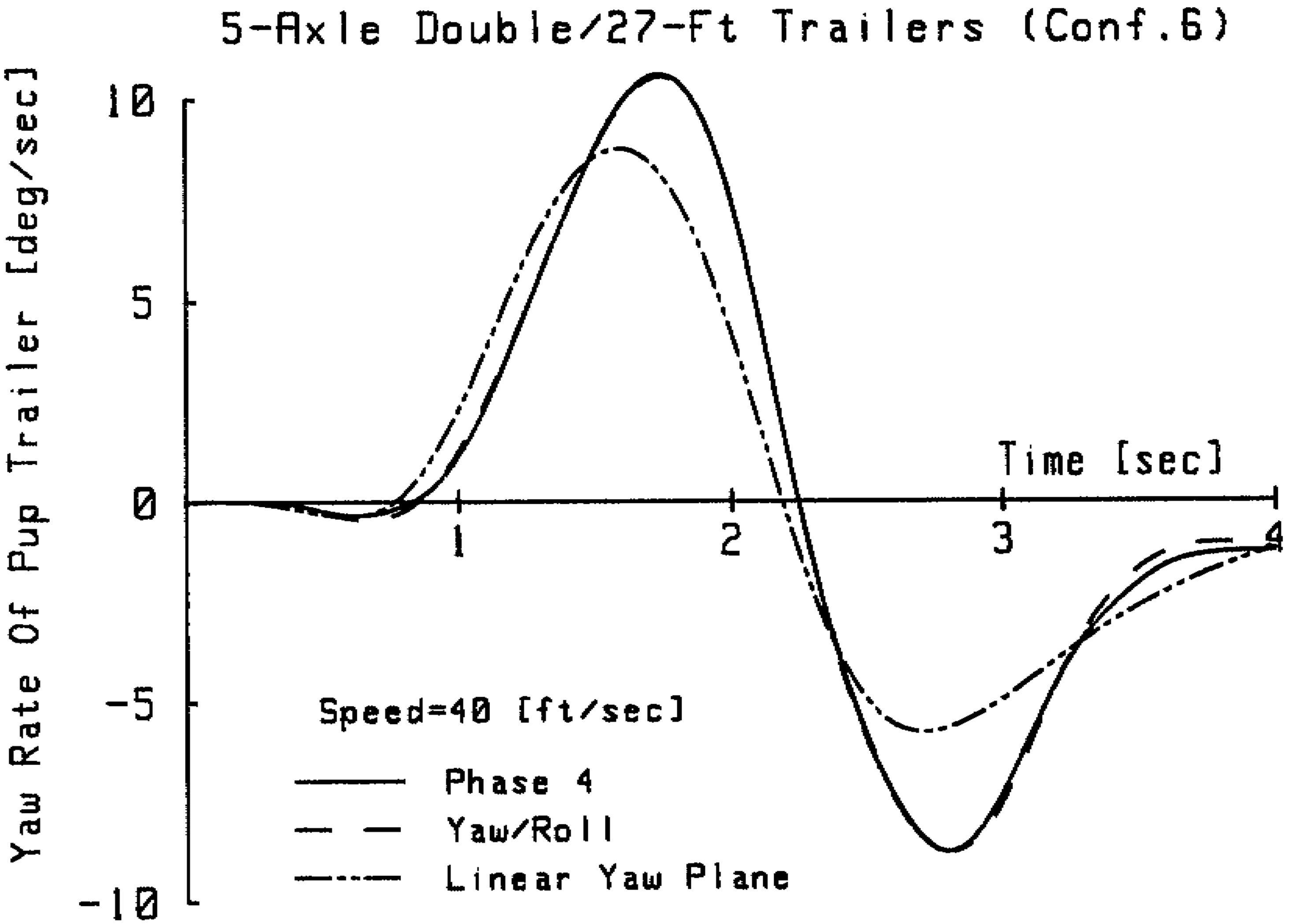


Fig. 4.14 Variation of pup trailer yaw rate with time of Vehicle Configuration 6 in a severe lane-change manoeuvre predicted by various models

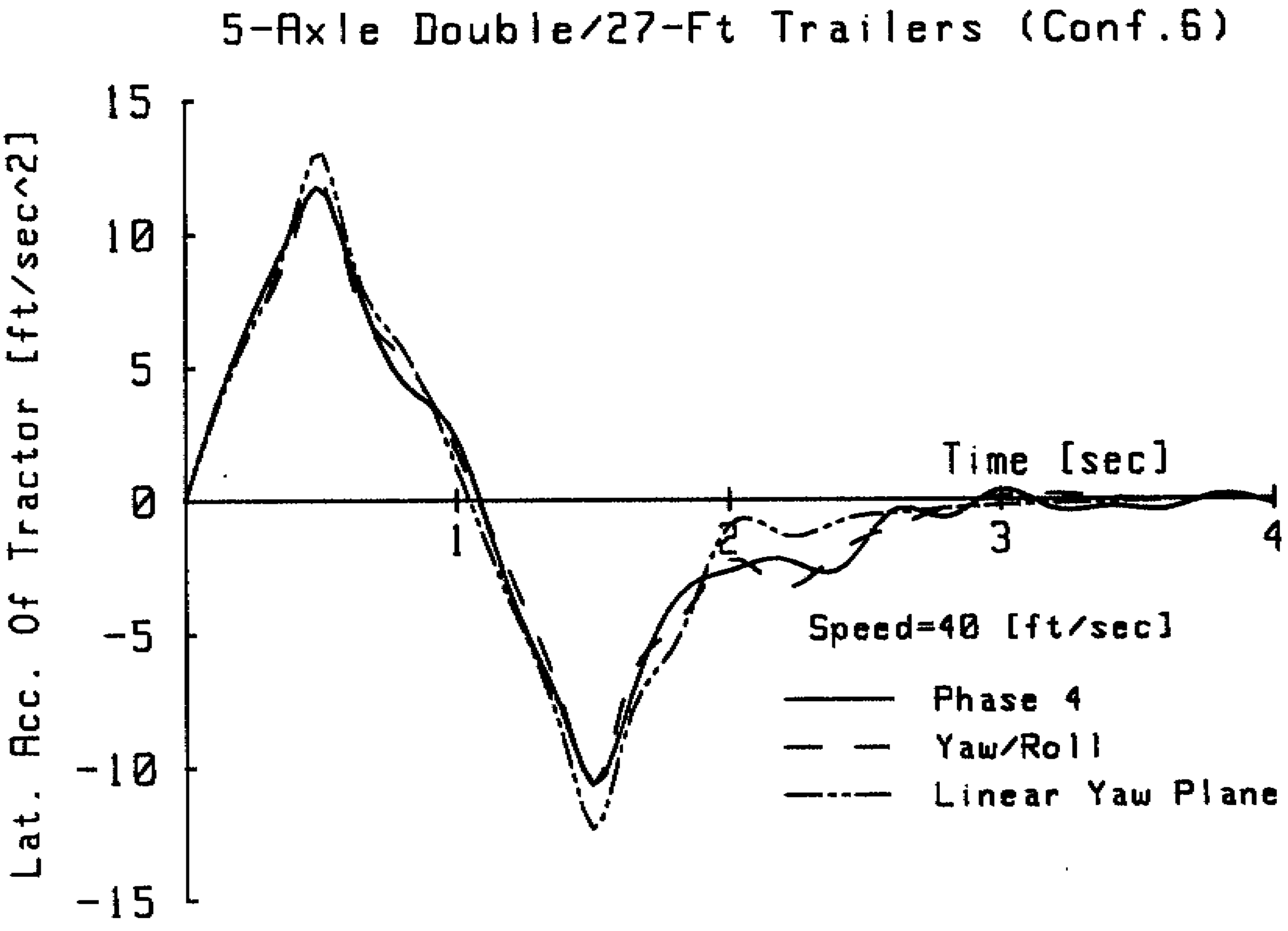


Fig. 4.15 Variation of tractor lateral acceleration with time of Vehicle Configuration 6 in a severe lane-change manoeuvre predicted by various models

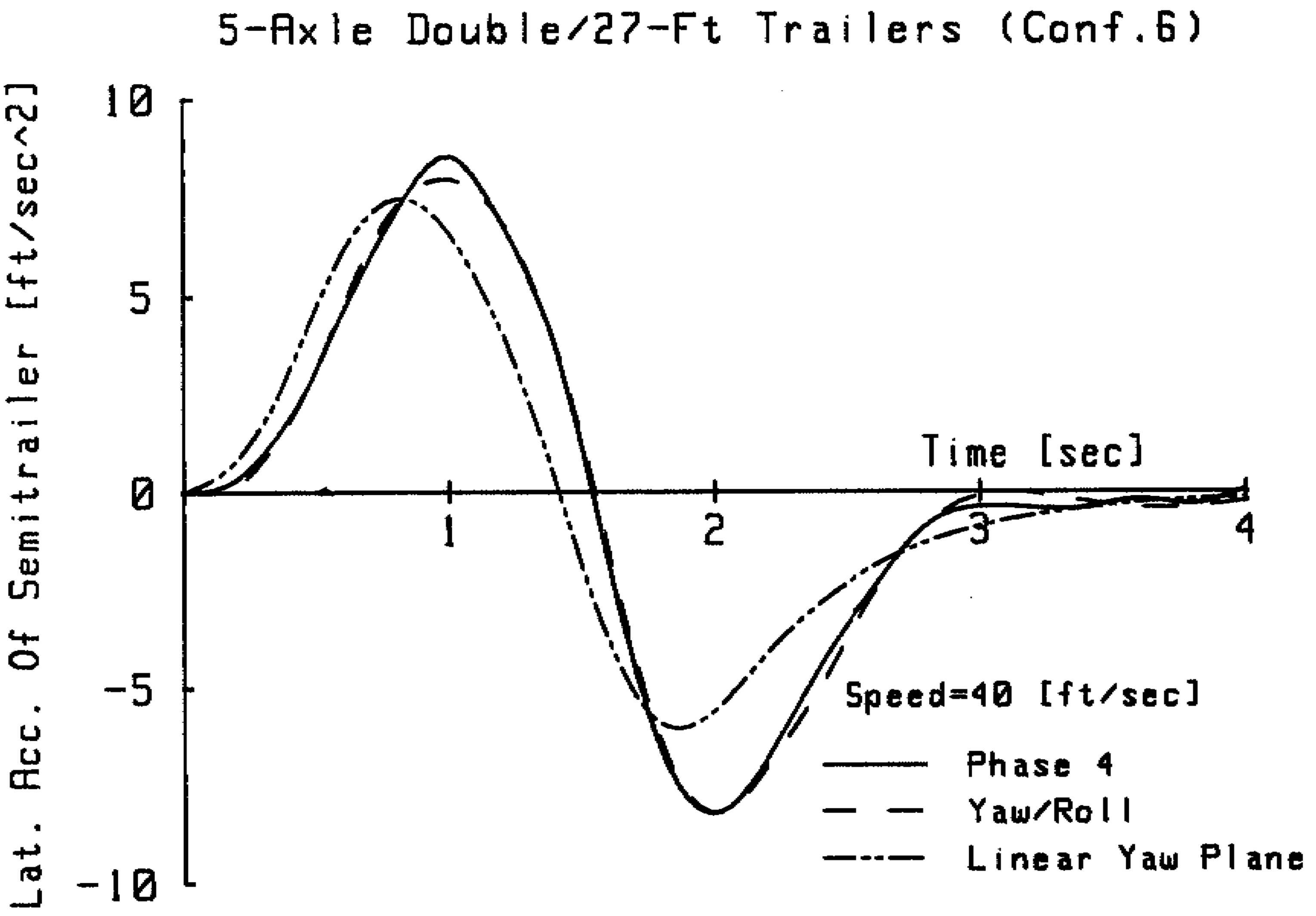


Fig. 4.16 Variation of semitrailer lateral acceleration with time of Vehicle Configuration 6 in a severe lane-change manoeuvre predicted by various models

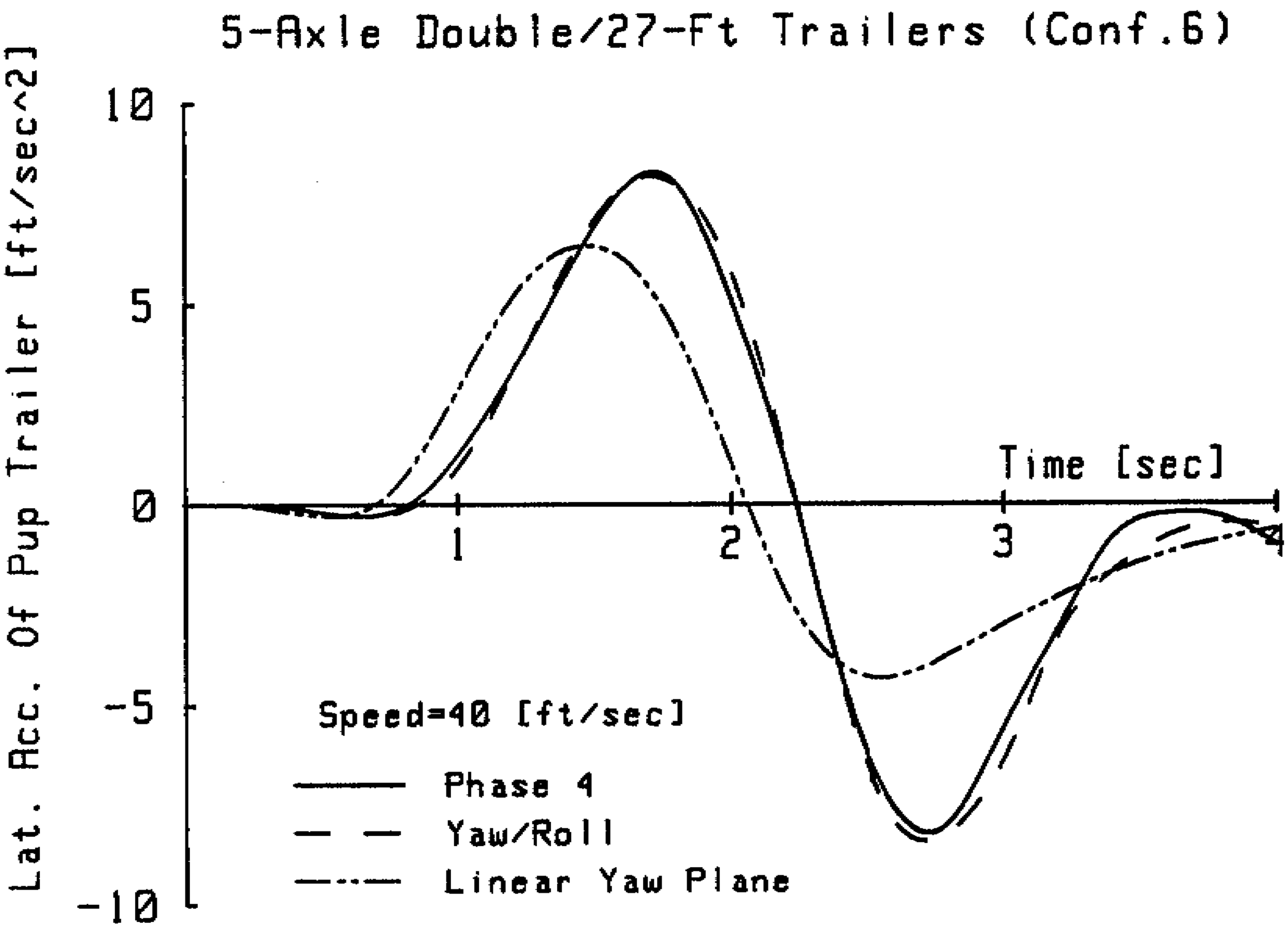


Fig. 4.17 Variation of pup trailer lateral acceleration with time for Vehicle Configuration 6 in a severe lane-change manoeuvre predicted by various models

From Fig. 4.15, it can be seen that the lateral acceleration responses of the tractor predicted using the three computer simulation models are similar, and that the differences in the peak value of lateral acceleration are within 9.9 %. The lateral acceleration responses of the semitrailer and of the full trailer(pup trailer)predicted using the Phase 4 model and the yaw/roll model are essentially the same, as can be seen from Figs. 4.16 and 4.17. However, there is a noticeable difference between the characteristics of the lateral acceleration responses of the semitrailer and the full trailer predicted using the linear yaw plane model and those predicted using the other two models. For instance, the difference between the peak value of lateral acceleration of the semitrailer predicted using the linear yaw plane model and that predicted using the other two models is approximately 13 %, while that for the full trailer is approximately 22.6 %. Furthermore, there is a significant phase shift between the responses predicted using the linear yaw plane model and those predicted using the Phase 4 model and the yaw/roll model.

5. A PARAMETRIC SENSITIVITY STUDY OF THE STATIC ROLL MODEL

As mentioned previously in Section 1.5, the static roll model was developed for the purpose of determining the rollover threshold of articulated vehicles during steady-state turning manoeuvres. This model is based on a number of simplifying assumptions. However, it requires a considerable amount of vehicle input data, some of which can only be obtained using special apparatus. For instance, the model requires, among others, the following vehicle parameters as inputs:

A. Tractor frame torsional stiffness;
B. Coulomb friction present in the tractor frame;
C. Equivalent trailer structural and fifth wheel compliance;
D. Separation of fifth wheel plates (Lash)

If no existing data are available for the vehicle to be simulated, then these parameters have to be measured. For some of the parameters, such as the equivalent tractor frame torsional stiffness, even if the equipment is available, there appears to be a lack of generally accepted procedures for measuring it, as the value of the equivalent torsional stiffness depends on the loading conditions as well as the type of constraint used in the tests. It appears, therefore, that while the model represents a simplication of the actual vehicle system, the acquisition of appropriate input data to the model could be quite involved. Thus, it seems useful to conduct an evaluation of the significance of certain input parameters to the simulated results. If it is found that the simulated results are not sensitive to certain input parameters, then the considerable effort that may be required to measure them may not be justified. This would also provide guidance for the revision of the original model, so as to make it more useful to the practising engineer.

In this section, the sensitivity of the simulated results to the four input parameters mentioned above is evaluated. In the evaluation, a 5-axle dirt truck(from File 25 of a UMTRI magnetic tape dated November 25, 1981) was used. The basic parameters of this vehicle are given in Appendix G. In the study, the values of the four parameters are varied within a certain range and the corresponding simulated results are obtained. The results of the sensitivity study are described below.

5.1 Tractor Frame Torsional Stiffness

The effects of the equivalent torsional stiffness of the tractor frame on the rollover threshold, expressed in terms of the maximum lateral acceleration ($a_{y\ max}$) allowed without causing rollover, were examined using the static roll model. Three values of the equivalent torsional stiffness: 40,000 (measured value for the 5-axle, dirt truck), 500,000 and 9,000,000 in-lb/deg (equivalent to a very rigid tractor frame) were used in the simulation. The results are shown in Table 5.1.

Table 5.1

Effects of Tractor Frame Torsional Stiffness

Tractor frame torsional stiffness, in-lb/deg	Rollover threshold, $a_{y\ max}$, g	Roll angle of the first sprung mass, ϕ_1, deg	Roll angle of second sprung mass, ϕ_2, deg	Roll angle of third sprung mass, ϕ_3, deg
40,000	0.35	6.01	5.40	5.78
500,000	0.35	5.5	5.42	5.80
9,000,000	0.35	5.47	5.42	5.80

It can be seen from Table 5.1 that within the range of 40,000 to 9,000,000 in-lb/deg, the torsional stiffness of the tractor frame has no effect whatsoever on the rollover threshold of the vehicle simulated. It has a minor effect on the simulated roll angle of the first sprung mass. However, the difference is less than 9 % when the torsional stiffness varies from 40,000 to 9,000,000 in-lb/deg. Table 5.1 also indicates that the torsional stiffness of the tractor frame has essentially no effect on the simulated roll angles of the second and third sprung masses.

5.2 Coulomb Friction Present in the Tractor Frame

The effects of the Coulomb type friction present in the tractor frame on the rollover threshold of the vehicle were evaluated using the static roll model. Three values of Coulomb friction: 11,000 (measured value for the 5-axle, dirt truck), 5,500 and 0 lb, were used in the simulations. The results are given in Table 5.2.

Table 5.2

Effects of Coulomb Friction Present in the Tractor Frame

Coulomb friction, lb	Rollover threshold, $a_{y\,max}$, g	Roll angle of first sprung mass, ϕ_1, deg	Roll angle of second sprung mass, ϕ_2, deg	Roll angle of third sprung mass, ϕ_3, deg
11,000	0.35	6.01	5.4	5.78
5,500	0.35	6.11	5.4	5.78
0	0.35	6.22	5.4	5.78

As can be seen from Table 5.2, within the range of 0 to 11,000 lb, the Coulomb friction present in the tractor frame has no effect at all on the rollover threshold, and the roll angles of the second and third sprung masses of the vehicle simulated. It has a very slight effect on the simulated roll angle of the first sprung mass. However, the difference is less than 3.5 %, when the Coulomb friction varies from 0 to 11,000 lb.

5.3 Equivalent Trailer Structural and Fifth Wheel Compliance

The effects of the equivalent trailer structural and fifth wheel compliance on the rollover threshold of the vehicle were assessed using the static roll model. Three values of the equivalent torsional stiffness of the trailer structure and fifth wheel: 1,000,000 (measured value for the 5-axle dirt truck), 500,000, and 9,000,000 in-lb/deg (equivalent to rigid), were used in the simulations. The results are summarized in Table 5.3.

Table 5.3

Effects of Equivalent Trailer Structural and Fifth Wheel Compliance

Equivalent torsional stiffness of trailer structure & 5th wheel, in-lb/deg	Rollover threshold, $a_{y\,max}$ g	Roll angle of the 1st sprung mass, ϕ_1, deg.	Roll angle of the 2nd sprung mass, ϕ_2, deg	Roll angle of the 3rd sprung mass, ϕ_3, deg
1,000,000	0.35	6.01	5.4	5.78
500,000	0.35	5.72	5.02	5.78
9,000,000	0.35	6.26	5.74	5.78

As shown in Table 5.3, the equivalent trailer structural and fifth wheel compliance has no effect whatsoever on the rollover threshold and the roll angle of the third sprung mass. It has only a slight effect on the simulated roll angles of the first and the second sprung masses, ϕ_1 and ϕ_2. The difference in the simulated roll angle ϕ_1 is approximately 4.8 %, when the equivalent torsional stiffness is reduced from 1,000,000 to 500,000 in-lb/deg, while the difference is 4.2 %, when the stiffness is increased from 1,000,000 to 9,000,000 in-lb/deg. For the simulated roll angle ϕ_2, the difference is approximately 7 %, when the torsional stiffness changes from 1,000,000 to 500,000 in-lb/deg, whereas the difference is 6.3 % when the stiffness varies from 1,000,000 to 9,000,000 in-lb/deg.

5.4 Separation of Fifth Wheel Plates (Lash)

The effects of the separation of fifth wheel plates (lash) on the roll behaviour of the vehicle were evaluated using the static roll model. In the simulation, the lash was varied from 0 (measured value for the 5-axle, dirt truck) to 2 in. It is found that within this range, the lash has practically no effect on the rollover threshold and the roll angles of the first, second, and third sprung masses.

The effects of the overturning stiffness of the tires on the roll behaviour of the vehicle were also examined. The measured values of the overturning stiffness of the tires on the first axle, second axle and third axle of the 5-axle, dirt truck, were 1,000, 2,000, and 2,000 in-lb/deg, respectively. No effect on the rollover threshold of the vehicle has been found by ignoring the overturning stiffness of the tires.

After the individual effects of the tractor frame torsional stiffness, Coulomb friction present in the tractor frame and trailer structural and fifth wheel compliance and separation of the fifth wheel plates had been examined, their combined effects on the roll behaviour of the 5-axle dirt truck were evaluated. For the evaluation, certain parameters of the baseline vehicle were modified. The modified values of these parameters are: tractor frame torsional stiffness of 9,000,000 in-lb/deg (essentially a rigid frame), zero Coulomb friction, and equivalent torsional stiffness of trailer structure and fifth wheel of 9,000,000 in-lb/deg (essentially a rigid connection), no lash in the fifth wheel plates and zero overturning stiffness of the tires. The rollover threshold and the corresponding roll angles of the sprung masses of the modified vehicle were predicted using the static roll model and compared with that of the baseline vehicle with measured values shown in Tables 1, 2 and 3. The results are given in Table 5.4.

Table 5.4

A Comparison of the Roll Behaviour of

The Modified and The Baseline Vehicle

Vehicle Type	Rollover Threshold, $a_{y\,max}$, g	Roll angle of first sprung mass, ϕ_1, deg	Roll angle of second sprung mass, ϕ_2, deg	Roll angle of third sprung mass, ϕ_3, deg
Baseline Vehicle	0.35	6.01	5.40	5.78
Modified Vehicle	0.35	5.76	5.72	5.78

From Table 5.4, it can be seen that the changing of the tractor frame torsional stiffness, Coulomb friction present in the tractor frame, and trailer structural and fifth wheel compliance, lash in the fifth wheel plates and overturning stiffness of tires in the ranges shown, has no effect on the rollover threshold and the corresponding roll angle of the third sprung mass. Their combined effects on the roll angles of the first and second sprung masses are slight. For instance, the difference in the simulated roll angle of the first sprung mass between the modified and the baseline vehicle is only 4.2 %, and the difference in the simulated roll angle of the second sprung mass between the two vehicles is approximately 6 %.

6. DISCUSSIONS

Based on the results of this study, the following observations are made:

A. In comparison with the measured data available, the steady-state steering responses of tractor-semitrailers with different design features predicted using the Phase 4 model, the yaw/roll model, the TBS model, and the linear yaw plane model all have varying degrees of error (see Figs. 3.2, 3.3, 3.5 and 3.6.). It appears that a more sophisticated simulation model, such as the Phase 4 model, does not necessarily give a more accurate prediction than a simpler model, such as the TBS model or the linear yaw plane model,under certain circumstances. For instance, for Vehicle Configuration 2, of which the tractor is highly understeer, the simple model (i.e., the linear yaw plane model) appears to give the best overall prediction in the lateral acceleration range up to approximately 0.4 g (see Fig. 3.5).

For the six vehicle configurations examined in this study, it appears that there are no significant differences in the steady-state steering responses predicted using the four simulation models in the lateral acceleration range up to approximately 0.25 g.

B. There are significant differences in handling characteristics predicted using the four simulation models in most cases. Since the linear yaw plane model does not take into account the effects of load transfer and uses a linear tire model, it is not capable of predicting changes in handling behaviour with lateral acceleration. On the other hand, the Phase 4 model, the yaw/roll model, and the TBS model take into account the effects of load transfer and the non-linear behaviour of tires to varying degrees. Consequently, these three models can predict changes in handling behaviour with lateral acceleration (see Figs. 3.4 and 3.7). It should be noted, however, that the predictions made by these three models are still noticeably different from the measured data available.

It should be pointed out that the parameter ($r\ell/U - \delta_{av}$) used to characterize vehicle handling behaviour is very sensitive to the errors in the values of yaw rate r, forward speed U, and the front wheel steering angle δ_{av}. A small error in the values of r, U, and δ_{av} will result in a significant error in the value of the parameter ($r\ell/U - \delta_{av}$). For example, if the wheelbase ℓ of a vehicle is 142 in., and the nominal values of r, U and δ_{av} are 10 deg/s, 63.07 ft/s, and 1.7 deg., respectively, then a ±5% error in these values will result in an error in the value of ($r\ell/U - \delta_{av}$) ranging from -150% to + 160%. Even a ±1% error in these values will result in an error of ±31% in the value of ($r\ell/U - \delta_{av}$). This would cause problems in using this parameter to characterize the handling behaviour in practice.

C. The transient steering responses of tractor-semitrailers predicted using the four simulation models are qualitatively similar in many cases. However, in comparison with the measured data available, all the predictions have varying degrees of error, as can be seen from Figs. 4.2 to 4.6. It appears that a more sophisticated model, such as the Phase 4 model, is not necessarily better than a simpler model, such as the TBS model or the linear yaw plane model, in predicting the transient responses of tractor-semitrailers like Vehicle Configuration 1.

For tractor semitrailers in severe lane-change manoeuvres, the transient steering responses, particularly the yaw rate responses, predicted using various models are quite close, as can be seen from Figs. 4.8 and 4.9.

For doubles, such as Vehicle Configuration 6, in severe lane-change manoeuvres, the yaw rate responses of the tractor and semitrailers predicted using the various models are similar (see Figs. 4.12 and 4.13). However, there is a noticeable difference between the yaw rate responses of the full trailer predicted using the linear yaw plane model and those predicted using the Phase 4 model and the yaw/roll model (see Fig. 4.14).

D. The results of a parametric sensitivity study of the static roll model indicate that some of the parameters, such as the tractor frame torsional stiffness, Coulomb friction in the tractor frame, equivalent trailer structural and fifth wheel compliance, separation of fifth wheel plates, and the overturning stiffness of tires, have little, if any, effects on the rollover threshold of the articulated vehicle examined in this study. This may indicate that the static roll model could be simplified, at least for certain applications. This would greatly reduce the number of input data required and hence the effort needed to obtain them.

E. To aid engineering practitioners in industry to utilize the various simulation models in a cost-effective manner, defining the appropriate areas of application of different models is of significance. This will provide guiding principles for the practitioner to select the appropriate model for a particular application. To achieve this objective, it appears that further work on the experimental evaluation of various models will be required.

F. Based on the results of this study, it appears that a sophisticated simulation model does not necessarily guarantee a more accurate prediction than a simpler one. On the other hand, a sophisticated model generally requires a large number of input data. Many of them can only be obtained using special measuring equipment. Quite often, even if the equipment is available, the cost of obtaining the required data is high. It appears that a comprehensive parametric sensitivity study of these sophisticated models may be useful. The objective is to evaluate the relative significance of various parameters to vehicle dynamic behaviour. If some of the parameters are judged to have an insignificant effect, then they may be excluded. This will make it easier and less costly for the user of the models to obtain input data.

G. Some of the simulation models evaluated in this study have primarily been developed by researchers and for researchers. They are not structured in a "user-friendly" manner. The procedure for inputting data to these models is not particularly convenient to an ordinary user and considerable effort may be required to interpret the outputs. To make the simulation techniques more useful to engineering practitioners, further work on streamlining the structure of the models, particularly the input and output, is recommended.

H. Based on the results of this study and on the current state of the simulation techniques for the lateral dynamics of articulated vehicles, a more realistic goal, for the foreseeable future, for the development of computer simulation models is to provide a common basis for evaluating the dynamic performance of different vehicles on a relative basis, rather than to accurately reproduce their actual dynamic behaviour in minute detail.

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APPENDIX A

Vehicle Configuration 1

Input Data Files

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                         RRRR      T   A   A  C
                         R R       T   AAAAA  C
                         R  R      T   A   A  C
                         R   R     T   A   A   CCCC

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608     1 25,0.0,0.2
610     1 5,1.7,2 0
612     1.75,2.0,3.33
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616     2.25,1.4,0.64
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620     2 75,-0.83,-1.39
622     3 0,-0.83,-0.83
624     3 25,-0.5,0 0
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8400    01
8700    0.
9700    1.
9800    28000
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14300   103.
14400   01
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14600   50.
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17800   2340.
17900   1500.
18000   10
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18200   4450.
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18700   72
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19700   13.
19800   -1
19900   20000

20000   0
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20200   5700
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20700   0
20800   0
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26900   950.
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6100   0101010202
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6900   0607
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7200   4000 ,80.,143.,157 ,189 ,194.,158
7300   6000 ,130.,261.,297.,354 ,373 ,329.
7400   8000 ,179.,387.,499 ,532 ,562 ,473.
7500   9000 ,200.,452.,533 ,624.,630 ,565.
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7700   2
7800   0.,0.
7900    5,-1.5,-1.5
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                   R   R    T    A   A   CCCC

TTTTTTTTTT  BBBBBBBB      SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF      11
TTTTTTTTTT  BBBBBBBB      SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF      11
    TT      BB      BB  SS          CC          OO      OO  NN      NN  FF            1111
    TT      BB      BB  SS          CC          OO      OO  NN      NN  FF            1111
    TT      BB      BB  SS          CC          OO      OO  NNNN    NN  FF              11
    TT      BB      BB  SS          CC          OO      OO  NNNN    NN  FF              11
    TT      BBBBBBBB      SSSSSS    CC          OO      OO  NN  NN  NN  FFFFFFFF        11
    TT      BBBBBBBB      SSSSSS    CC          OO      OO  NN  NN  NN  FFFFFFFF        11
    TT      BB      BB          SS  CC          OO      OO  NN    NNNN  FF              11
    TT      BB      BB          SS  CC          OO      OO  NN    NNNN  FF              11
    TT      BB      BB          SS  CC          OO      OO  NN      NN  FF              11          ..
    TT      BB      BB          SS  CC          OO      OO  NN      NN  FF              11          ..
    TT      BBBBBBBB    SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF            111111        ..
    TT      BBBBBBBB    SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF            111111        ..

DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
DD      DD  AA      AA      TT          ;;;;      1111
DD      DD  AA      AA      TT          ;;;;      1111
DD      DD  AA      AA      TT                      11
DD      DD  AA      AA      TT                      11
DD      DD  AA      AA      TT          ;;;;        11
DD      DD  AA      AA      TT          ;;;;        11
DD      DD  AAAAAAAAAA      TT          ;;;;        11
DD      DD  AAAAAAAAAA      TT          ;;;;        11
DD      DD  AA      AA      TT            ;;        11
DD      DD  AA      AA      TT            ;;        11
DDDDDDDD    AA      AA      TT          ;;        111111
DDDDDDDD    AA      AA      TT          ;;        111111

                   RRRR   TTTTT   AAA    CCCC
                   R   R    T    A   A  C
                   R   R    T    A   A  C
                   RRRR     T    A   A  C
                   R R      T    AAAAA  C
                   R  R     T    A   A  C
                   R   R    T    A   A   CCCC

VAX/VMS  RTAC      TBSCONF1 21-APR-1985 15:22   LPB0: 21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF1.DAT;1      VAX/VMS
VAX/VMS  RTAC      TBSCONF1 21-APR-1985 15:22   LPB0: 21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF1.DAT;1      VAX/VMS
VAX/VMS  RTAC      TBSCONF1 21-APR-1985 15:22   LPB0: 21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF1.DAT;1      VAX/VMS
```

```
09:53 APR 22 '85 TBSCONF1.F88ELGIP

N                                                           0.1
Y                                                           N
Y                                                           Y
05                                                          N
000
1111
16016.
57921.
192937.45
2775481.5
50.
49.5
63.11
78.89
238.17
171.83
0.0
40.25
36.
36.
48.5
39.
62.35
0.0
.08
0.
0.
43.
4.0
30.
730.
690.
615.
Y
0.9
0.0
0.
0.
02
0.,0.,0.,0.,0.,0.,0.
5.,0.,0.,0.,0.,0.,0.
3
0.0,0.0
.5,-.5
8.,.5
N
N
N
Y
0.0
N
N
N
N
N
N
06
01,08,03,07,05,21
```

```
VAX/VMS   RTAC        LYPCONF1 21-APR-1985 12 43   LPBO. 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF1.DAT;1        VAX/VMS
VAX/VMS   RTAC        LYPCONF1 21-APR-1985 12.43   LPBO  21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF1.DAT;1        VAX/VMS
VAX/VMS   RTAC        LYPCONF1 21-APR-1985 12 43   LPBO  21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF1.DAT;1        VAX/VMS

                        RRRR   TTTTT   AAA    CCCC
                        R   R    T    A   A  C
                        R   R    T    A   A  C
                        RRRR     T    A   A  C
                        R R      T    AAAAA  C
                        R  R     T    A   A  C
                        R   R    T    A   A   CCCC

LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF      11
LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF      11
LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF            1111
LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF            1111
LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF              11
LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF              11
LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF        11
LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF        11
LL              YY      PP          CC          OO      OO  NN    NNNN  FF              11
LL              YY      PP          CC          OO      OO  NN    NNNN  FF              11
LL              YY      PP          CC          OO      OO  NN      NN  FF              11        . .
LL              YY      PP          CC          OO      OO  NN      NN  FF              11        ....
LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            111111      ....
LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            111111      ....

DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
DD      DD  AA      AA      TT          ;;;;      1111
DD      DD  AA      AA      TT          ;;;;      1111
DD      DD  AA      AA      TT                      11
DD      DD  AA      AA      TT                      11
DD      DD  AA      AA      TT          ;;;;        11
DD      DD  AA      AA      TT          ;;;;        11
DD      DD  AAAAAAAAAA      TT          ;;;;        11
DD      DD  AAAAAAAAAA      TT          ;;;;        11
DD      DD  AA      AA      TT            ;;        11
DD      DD  AA      AA      TT            ;;        11
DDDDDDDD    AA      AA      TT          ;;        111111
DDDDDDDD    AA      AA      TT          ;;        111111

                        RRRR   TTTTT   AAA    CCCC
                        R   R    T    A   A  C
                        R   R    T    A   A  C
                        RRRR     T    A   A  C
                        R R      T    AAAAA  C
                        R  R     T    A   A  C
                        R   R    T    A   A   CCCC

VAX/VMS   RTAC        LYPCONF1 21-APR-1985 12:43   LPBO: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF1.DAT;1        VAX/VMS
VAX/VMS   RTAC        LYPCONF1 21-APR-1985 12:43   LPBO: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF1.DAT;1        VAX/VMS
VAX/VMS   RTAC        LYPCONF1 21-APR-1985 12:43   LPBO: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF1.DAT;1        VAX/VMS
```

```
 100    05-AXLE TERACTOR-SEMITRAILER (CONF  1 & 2 )
 200    16016 0,57951 0
 300    192915 0,2775432.0
 400    63.11,53.89,103 09,147.08,196 58,0 0,0,0,0.0,0.0,0.0,0.0
 500    78.89,230.17
 600    1460 0,2760 0,2760 0,2460 0,2460 0,0.0
 650    0.,0.,0 ,0.,0.
 700    63 07,0 1,10 0,1,0
 800    220 ,400 ,400.,400.,400.,0.0
 850    0 ,0.,0.,0.,0
 900    20000.,20000.,20000 ,28000.,0 0,0.0
 950    0 ,0.,0 ,0 ,0
1000    13 0,13.0,13.0,13.0,0 0,0.0,0.0,0.0,0 0,0.0,0 0
1100    6 0,0.01,.1
1200    03
1300    0.0,0 0
1400    0.5,-2 0
1500    6.0,-2.0
```

APPENDIX B

Vehicle Configuration 2

Input Data Files

```
VAX/VMS  RTAC         P4CONF2 21-APR-1985 11:35   LPB0:  21-APR-1985 11:35   DISK$VAXUSER1:[USER1.RTAC]P4CONF2.DAT;1
VAX/VMS  RTAC         P4CONF2 21-APR-1985 11:35   LPB0:  21-APR-1985 11:35   DISK$VAXUSER1:[USER1.RTAC]P4CONF2.DAT;1
VAX/VMS  RTAC         P4CONF2 21-APR-1985 11:35   LPB0:  21-APR-1985 11:35   DISK$VAXUSER1:[USER1.RTAC]P4CONF2.DAT;1

                          RRRR    TTTTT   AAA     CCCC
                          R   R     T    A   A   C
                          R   R     T    A   A   C
                          RRRR      T    A   A   C
                          R R       T    AAAAA   C
                          R  R      T    A   A   C
                          R   R     T    A   A    CCCC

    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    222222
    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    222222
    PP      PP  44    44    CC          OO      OO  NN      NN  FF          22      22
    PP      PP  44    44    CC          OO      OO  NN      NN  FF          22      22
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF                  22
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF                  22
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF          22
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF          22
    PP                44    CC          OO      OO  NN    NNNN  FF              22
    PP                44    CC          OO      OO  NN    NNNN  FF              22
    PP                44    CC          OO      OO  NN      NN  FF            22            ...
    PP                44    CC          OO      OO  NN      NN  FF            22            ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF          2222222222      ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF          2222222222      . .

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                          RRRR    TTTTT   AAA     CCCC
                          R   R     T    A   A   C
                          R   R     T    A   A   C
                          RRRR      T    A   A   C
                          R R       T    AAAAA   C
                          R  R      T    A   A   C
                          R   R     T    A   A    CCCC

VAX/VMS  RTAC         P4CONF2 21-APR-1985 11:35   LPB0:  21-APR-1985 11:35   DISK$VAXUSER1:[USER1.RTAC]P4CONF2.DAT;1
VAX/VMS  RTAC         P4CONF2 21-APR-1985 11:35   LPB0:  21-APR-1985 11:35   DISK$VAXUSER1:[USER1.RTAC]P4CONF2.DAT;1
VAX/VMS  RTAC         P4CONF2 21-APR-1985 11:35   LPB0:  21-APR-1985 11:35   DISK$VAXUSER1:[USER1.RTAC]P4CONF2.DAT;1
```

```
100     5-AXLE TRACTOR-SEMITRAILER (CONF 2)
200     01
300     65
400     003
500     0 ,0
600     0 5,-3 12,-2. 80
700     10 ,-3. 12,-2. 08
800     02
900     0 ,0.
1000    10.,0
1200    6 0
1300    0 1
1400    00
1500    11100000
1600    142
1700    8097.93
1800    7118.07
1900    39.7
2000    18166.6
2100    69955
2200    69955
2300    0 0
2400    0 0
2500    40 5
2600    120000.
2700    36.
2800    1012 5
4000    10.
4100    500
4200    3719
4300    24 53
4400    0 00
4500    109385.
4600    32 6
4700    80 5
4800    1190
4900    0
5500    -1
5600    03
5700    2000 ,6000.,9000
5800    01
5900    63.
6000    06
6100    0 ,0
6200    1 , 218
6300    3., 5325
6400    4 ,,6555
6600    7 , 897
6650    10 ,1.022
6700    06
6800    0.,0.
6900    1.,.127
7000    3.,.337
7100    4 , 423
7300    7 ,.617
7350    10 ,.737
7400    06
7500    0.,0.
7600    1.,.092
7700    3.,.254
7800    4.,.321
8000    7.,.402
```

```
8050    10., 591
8100    01
8200    0.
8400    01
8700    0
9700    1
9800    28000
13800   0 0
13900   1320
14100   5700
14200   20. 3
14300   103
14400   01
14500   50
14600   50
14700   0 0
14800   1500
17000   10.
17100   250
17200   4450
17300   22.
17400   0 1
17500   0 0
17600   35.
17700   72
17800   2340.
17900   1500.
18000   10
18100   250
18200   4458
18300   22
18400   0 1
18500   78000.
18600   35.
18700   72
18800   2170 0
18900   13
19000   -1
19100   28000.
19200   0 0
19300   1200.
19400   5700
19500   20. 3
19600   115
19700   13.
19800   -1
19900   28000
20000   0
20100   1200
20200   5700.
20300   20. 3
20400   115.
20500   0. 05
20600   0 25
20700   0.
20800   0
20900   0
21000   0 075
21100   0. 25
21200   0.
21300   0. 075
21400   .25
```

```
21500   0
21900   410
22000   6252 29
22100   11068 71
22200   69
22300   73000
22400   789869.
22500   789869.
22600   40600.
22700   182.
22800   64. 5
22900   37500
23000   1727000
23100   1727000
23200   01
23300   49 5
23400   50.
23500   0. 0
23600   9587. 5
25800   10.
25900   950
26000   4100
26100   25 6
26200   0. 1
26300   0
26400   38.
26500   72.
26600   1520.
26700   9507 5
26800   0
26900   1500
27000   4100
27100   25 6
27200   0. 1
27300   0
27400   38
27500   72
27600   1520
27700   13
27800   -2
27900   03
27902   2000 ,6000.,9000.
27904   01
27906   63
27908   06
27910   0 ,0
27912   1.,.183
27914   3.,.468
27916   4.,.586
27920   7.,.83
27922   10.,.968
27924   06
27926   0 ,0.
27928   1.,.114
27930   3 ,.310
27932   4.,.394
27936   7.,.593
27938   10.,.735
27940   06
27942   0.,0
27944   1.,.002
27946   3.,.229
```

```
27948   4 , 294
27952   7 , 459
27954   10 ,.584
27956   01
27970   0
27989   01
27994   0.
27997   1
27998   28000.
28000   0.
28100   1200.
28200   5300.
28300   19. 5
28400   115.
28500   13.
28600   -2.
28700   28000.
28800   0.
28900   1200.
29000   5300.
29100   19. 5
29200   115.
29300   0. 175
29400   .25
29500   0.
29600   .175
29700   .25
29800   0. 0
29900   -1
30000   00
```

```
VAX/VMS  RTAC          YRCONF2 21-APR-1985 11:41   LPB0:  21-APR-1985 11:41   DISK$VAXUSER1:[USER1.RTAC]YRCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC          YRCONF2 21-APR-1985 11:41   LPB0:  21-APR-1985 11:41   DISK$VAXUSER1:[USER1.RTAC]YRCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC          YRCONF2 21-APR-1985 11:41   LPB0:  21-APR-1985 11:41   DISK$VAXUSER1:[USER1.RTAC]YRCONF2.DAT;1          VAX/VM

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    222222
    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    222222
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          22      22
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          22      22
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF                  22
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF                  22
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF          22
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF          22
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF              22
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF              22
        YY      RR    RR    CC          OO      OO  NN      NN  FF            22            ....
        YY      RR    RR    CC          OO      OO  NN      NN  FF            22            ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF          2222222222      ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF          2222222222      ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT        ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT        ;;;;        11
    DD      DD  AA      AA      TT            ;;;;      1111
    DD      DD  AA      AA      TT            ;;;;      1111
    DD      DD  AA      AA      TT                        11
    DD      DD  AA      AA      TT                        11
    DD      DD  AA      AA      TT            ;;;;        11
    DD      DD  AA      AA      TT            ;;;;        11
    DD      DD  AAAAAAAAAA      TT            ;;;;        11
    DD      DD  AAAAAAAAAA      TT            ;;;;        11
    DD      DD  AA      AA      TT              ;;        11
    DD      DD  AA      AA      TT              ;;        11
    DDDDDDDD    AA      AA      TT            ;;        111111
    DDDDDDDD    AA      AA      TT            ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC          YRCONF2 21-APR-1985 11:41   LPB0:  21-APR-1985 11:41   DISK$VAXUSER1:[USER1.RTAC]YRCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC          YRCONF2 21-APR-1985 11:41   LPB0:  21-APR-1985 11:41   DISK$VAXUSER1:[USER1.RTAC]YRCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC          YRCONF2 21-APR-1985 11:41   LPB0:  21-APR-1985 11:41   DISK$VAXUSER1:[USER1.RTAC]YRCONF2.DAT;1          VAX/VM
```

```
100    5-AXLE TRACTOR-SEMITRAILER (CONF. 2 )
200    0205
300    63 07,4 , 1, 02
400    3,2
500    10316.,54881.
600    10166.,111054 06
700    69955 ,2517592 06
800    69955 ,2517038
900    39 7,65.671
1000   8897 929,15781.399,15611.377,16823 137,16823.137
1100   1190.,2340 ,2170.,1520.,1520
1200   3719 ,4458 ,4458.,4100.,4100.
1300   35.9,-81.1,-131.1,-156.6,-206.1
1400   20 3,20.3,20.3,19.5,17.5
1500   24.55,22 ,22.,25.6,25.6
1600   16.3,17 5,17.5,19.,17.
1700   40.25,36 ,36.,36 ,36
1800   0.0,13 ,13.,13 ,13.,
1900   5700 ,5700.,5700 ,5300.,5300.
2000   0.,.1,.1,.1,.1
2100   109385,0.,70000 ,0.,0.
2200   500 ,250.,250 ,950 ,950.
2300   10 ,10.,10.,10.,10.
2500   -106.1,229
2600   48 5
2700   9999999.
2800   01
2900   03
3000   0102020303
3100   03
3200   -10125.,-10.
3300   0.0,0.0,
3400   10125 ,10.
3500   03
3600   -15000.,-10
3700   0 0,0.0,
3800   15000.,10
3900   03
4000   -95875 ,-10
4100   0 0,0.0,
4200   95875.,10
4400   02
4500   0101010202
4600   0607
4700   0.0,1 0,3.,4.,5.,7.,10
4800   2000.,436.,1065 ,1311.,1506 ,1794 ,2044.
4900   4000 ,635.,1657.,2072 ,2430.,2957.,3442.
5000   6000 ,764.,2021 ,2539.,3019.,3704 ,4422.
5100   8000.,831.,2225.,2827.,3384.,4190.,5086
5200   9000.,830.,2284.,2909.,3487.,4341.,5319.
5300   0607
5400   0.0,1 0,3.,4.,5.,7 ,10.
5500   2000.,365.,736 ,1171 ,1371 ,1660.,1935.
5600   4000 ,556.,1503.,1910.,2283 ,2814 ,3400.
5700   6000.,686.,1858 ,2363 ,2821 ,3570 ,4408.,
5800   8000.,737.,2025 ,2596 ,3135.,4012 ,5030.,
5900   9000.,742 ,2058 ,2646 ,3213 ,4131 ,5256.
6000   02
6100   0101010202
6200   0607
6300   0 0,1.0,3.,4.,5 ,7.,10.
6400   2000.,44 ,77 ,84.,85 ,79 ,59.
6500   4000.,103.,205.,236.,252 ,245.,187.
6600   6000.,153.,341.,376.,431.,435.,333.
6700   8000.,205.,472 ,550.,622 ,600.,470.
6800   9000.,227.,537.,637.,716 ,673.,550
6900   0607
7000   0 ,1.,3.,4.,5.,7.,10.
7100   2000.,31.,44 ,46 ,56.,61 ,39.
7200   4000.,80 ,143.,157.,189.,194.,158.
7300   6000.,130.,261.,299.,354.,373.,329.
7400   8000.,179.,307.,459.,532.,562.,473.
7500   9000.,200 ,452 ,533.,624.,650.,565
7600   1.
7700   2
7800   0.,0.
7900   ,5,-1.5,-1.5
```

```
VAX/VMS  RTAC        TBSCONF2 21-APR-1985 15:22   LPB0:  21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF2.DAT;1          VAX/VMS
VAX/VMS  RTAC        TBSCONF2 21-APR-1985 15:22   LPB0:  21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF2.DAT;1          VAX/VMS
VAX/VMS  RTAC        TBSCONF2 21-APR-1985 15:22   LPB0:  21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF2.DAT;1          VAX/VMS

                              RRRR   TTTTT   AAA    CCCC
                              R   R    T    A   A  C
                              R   R    T    A   A  C
                              RRRR     T    A   A  C
                              R R      T    AAAAA  C
                              R  R     T    A   A  C
                              R   R    T    A   A   CCCC

TTTTTTTTTT  BBBBBBBB    SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    222222
TTTTTTTTTT  BBBBBBBB    SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    222222
    TT      BB      BB  SS        CC          OO      OO  NN      NN  FF          22      22
    TT      BB      BB  SS        CC          OO      OO  NN      NN  FF          22      22
    TT      BB      BB  SS        CC          OO      OO  NNNN    NN  FF                  22
    TT      BB      BB  SS        CC          OO      OO  NNNN    NN  FF                  22
    TT      BBBBBBBB      SSSSSS  CC          OO      OO  NN  NN  NN  FFFFFFFF          22
    TT      BBBBBBBB      SSSSSS  CC          OO      OO  NN  NN  NN  FFFFFFFF          22
    TT      BB      BB        SS  CC          OO      OO  NN    NNNN  FF              22
    TT      BB      BB        SS  CC          OO      OO  NN    NNNN  FF              22
    TT      BB      BB        SS  CC          OO      OO  NN      NN  FF            22              ..
    TT      BB      BB        SS  CC          OO      OO  NN      NN  FF            22              ..
    TT      BBBBBBBB    SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FF          2222222222        ..
    TT      BBBBBBBB    SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FF          2222222222        ..

DDDDDDDD      AAAAAA    TTTTTTTTTT     ;;;;      11
DDDDDDDD      AAAAAA    TTTTTTTTTT     ;;;;      11
DD      DD  AA      AA      TT         ;;;;    1111
DD      DD  AA      AA      TT         ;;;;    1111
DD      DD  AA      AA      TT                   11
DD      DD  AA      AA      TT                   11
DD      DD  AA      AA      TT         ;;;;      11
DD      DD  AA      AA      TT         ;;;;      11
DD      DD  AAAAAAAAAA      TT         ;;;;      11
DD      DD  AAAAAAAAAA      TT         ;;;;      11
DD      DD  AA      AA      TT           ;;      11
DD      DD  AA      AA      TT           ;;      11
DDDDDDDD    AA      AA      TT         ;;      111111
DDDDDDDD    AA      AA      TT         ;;      111111

                              RRRR   TTTTT   AAA    CCCC
                              R   R    T    A   A  C
                              R   R    T    A   A  C
                              RRRR     T    A   A  C
                              R R      T    AAAAA  C
                              R  R     T    A   A  C
                              R   R    T    A   A   CCCC

VAX/VMS  RTAC        TBSCONF2 21-APR-1985 15:22   LPB0:  21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF2.DAT;1          VAX/VMS
VAX/VMS  RTAC        TBSCONF2 21-APR-1985 15:22   LPB0:  21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF2.DAT;1          VAX/VMS
VAX/VMS  RTAC        TBSCONF2 21-APR-1985 15:22   LPB0:  21-APR-1985 15:22   DISK$VAXUSER1:[USER1.RTAC]TBSCONF2.DAT;1          VAX/VMS
```

```
09:54 APR 22 '85 TBSCONF2.FBBELGIP

N
Y                                                                   0.1
Y                                                                   N
05                                                                  Y
000                                                                 N
1111
16016.
57921.
192937.45
2775481.5
50.
49.5
63.11
78.89
238.17
171.83
0.0
40.25
36.
36.
48.5
39.
62.35
0.0
.49
0.
0.
43.
4.0
30.
730.
690.
615.
Y
0.9
0.0
0.
0.
02
0.,0.,0.,0.,0.,0.,0.
5.,0.,0.,0.,0.,0.,0.
3
0.0,0.0
.5,-.5
8.,.5
N
N
N
Y
0.0
N
N
N
N
N
N
06
04,00,03,07,05,21
```

```
VAX/VMS  RTAC        LYPCONF2 21-APR-1985 12:43   LPB0: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC        LYPCONF2 21-APR-1985 12:43   LPB0: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC        LYPCONF2 21-APR-1985 12:43   LPB0: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF2.DAT;1          VAX/VM

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

   LL          YY      YY  PPPPPPPP     CCCCCCCC    DDDDDD    NN      NN  FFFFFFFFFF    222222
   LL          YY      YY  PPPPPPPP     CCCCCCCC    DDDDDD    NN      NN  FFFFFFFFFF    222222
   LL          YY      YY  PP      PP  CC          DD      DD  NN      NN  FF          22      22
   LL          YY      YY  PP      PP  CC          DD      DD  NN      NN  FF          22      22
   LL            YY  YY    PP      PP  CC          DD      DD  NNNN    NN  FF                  22
   LL            YY  YY    PP      PP  CC          DD      DD  NNNN    NN  FF                  22
   LL              YY      PPPPPPPP    CC          DD      DD  NN  NN  NN  FFFFFFFF          22
   LL              YY      PPPPPPPP    CC          DD      DD  NN  NN  NN  FFFFFFFF          22
   LL              YY      PP          CC          DD      DD  NN    NNNN  FF              22
   LL              YY      PP          CC          DD      DD  NN    NNNN  FF              22
   LL              YY      PP          CC          DD      DD  NN      NN  FF            22            .
   LL              YY      PP          CC          DD      DD  NN      NN  FF            22            . .
   LLLLLLLLLL      YY      PP            CCCCCCCC    DDDDDD    NN      NN  FF            2222222222    . .
   LLLLLLLLLL      YY      PP            CCCCCCCC    DDDDDD    NN      NN  FF            2222222222    . .

   DDDDDDDD      AAAAAA    TTTTTTTTTT      ::::        11
   DDDDDDDD      AAAAAA    TTTTTTTTTT      ::::        11
   DD      DD  AA      AA      TT          ::::      1111
   DD      DD  AA      AA      TT          ::::      1111
   DD      DD  AA      AA      TT                      11
   DD      DD  AA      AA      TT                      11
   DD      DD  AA      AA      TT          ::::        11
   DD      DD  AA      AA      TT          ::::        11
   DD      DD  AAAAAAAAAA      TT          ::::        11
   DD      DD  AAAAAAAAAA      TT          ::::        11
   DD      DD  AA      AA      TT            ::        11
   DD      DD  AA      AA      TT            ::        11
   DDDDDDDD    AA      AA      TT          ::        111111
   DDDDDDDD    AA      AA      TT          ::        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC        LYPCONF2 21-APR-1985 12:43   LPB0: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC        LYPCONF2 21-APR-1985 12:43   LPB0: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF2.DAT;1          VAX/VM
VAX/VMS  RTAC        LYPCONF2 21-APR-1985 12:43   LPB0: 21-APR-1985 12:48   DISK$VAXUSER1:[USER1.RTAC]LYPCONF2.DAT;1          VAX/VM
```

```
100    05-AXLE 1FRACTOR-SEMITRAILER (CONF. 1 & 2 )
200    16016 0,57751.0
300    192915 0,2775432 0
400    63.11,53 87,103.09,147 08,196 58,0 0,0,0,0.0,0.0,0.0,0.0
500    78.89,238.17
600    1460 0,2760.0,2760.0,2460 0,2460.0,0.0
650    0.,0.,0 ,0.,0.
700    63.07,0.1,10.0,1 0
800    220 ,400.,400.,400 ,400 ,0.0
850    0.,0.,0.,0.,0.
900    28000.,28000.,28000.,28000. ,0.0,0.0
950    0.,0.,0.,0.,0.
1000   13.0,13.0,13 0,13.0,0 0,0.0,0.0,0.0,0.0,0.0,0.0
1100   6.0,0.01,.1
1200   03
1300   0.0,0 0
1400   0.5,-2.0
1500   6.0,-2 0
```

APPENDIX C

Vehicle Configuration 3

Input Data Files

```
VAX/VMS  RTAC         P4CONF3 21-APR-1985 11:35   LPB0: 21-APR-1985 11:36   DISK$VAXUSER1:[USER1.RTAC]P4CONF3.DAT;1
VAX/VMS  RTAC         P4CONF3 21-APR-1985 11:35   LPB0: 21-APR-1985 11:36   DISK$VAXUSER1:[USER1.RTAC]P4CONF3.DAT;1
VAX/VMS  RTAC         P4CONF3 21-APR-1985 11:35   LPB0: 21-APR-1985 11:36   DISK$VAXUSER1:[USER1.RTAC]P4CONF3.DAT;1

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF   333333
    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF   333333
    PP      PP  44    44    CC          OO      OO  NN      NN  FF         33      33
    PP      PP  44    44    CC          OO      OO  NN      NN  FF         33      33
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF                 33
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF                 33
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF         33
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF         33
    PP                44    CC          OO      OO  NN    NNNN  FF                 33
    PP                44    CC          OO      OO  NN    NNNN  FF                 33
    PP                44    CC          OO      OO  NN      NN  FF         33      33      ....
    PP                44    CC          OO      OO  NN      NN  FF         33      33      ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF           333333        ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF           333333        ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         P4CONF3 21-APR-1985 11:35   LPB0: 21-APR-1985 11:36   DISK$VAXUSER1:[USER1.RTAC]P4CONF3.DAT;1
VAX/VMS  RTAC         P4CONF3 21-APR-1985 11:35   LPB0: 21-APR-1985 11:36   DISK$VAXUSER1:[USER1.RTAC]P4CONF3.DAT;1
VAX/VMS  RTAC         P4CONF3 21-APR-1985 11:35   LPB0: 21-APR-1985 11:36   DISK$VAXUSER1.[USER1.RTAC]P4CONF3.DAT;1
```

```
100    5-AXLE TRACTOR-SEMITRAILER (CONF. 3)
200    01
300    33.
400    003
500    0.,0.
600    0.5,2.5,2.5
700    10.,2.5,2.5
800    04
900    0.,0.
1000   2.5,0.
1100   2.6,0.
1200   10.,0.
1300   4.
1400   0.1
1500   00
1600   11100000
1700   144.
1800   8960.
1900   6540.
2000   44.
2100   15000.
2200   75000.
2300   75000.
2400   0.0
2500   14.35
2600   48.0
2700   50000.
2800   36
2900   -119.
3000   04
3100   -20000.,-20.
3200   0.,0.
3300   9250.,7.2
3400   25000.,7.5
3500   0.00
3600   -20000.,-20.
3700   0.,0.
3800   8040.,7.2
3900   25000.,7.5
4000   0.08
4100   0.
4200   0.
4300   3719.
4400   23.
4500   0.00
4600   1500.
4700   32.
4800   80.0
4900   1200.
5500   0.0
5600   -1.
5700   07
5800   3000.,6000.,9000.
5900   01
6000   66.
6100   06
6200   0.,0.
6300   1.,.183
6400   2.,.333
6500   4.,.575
6600   6.,.708
6700   12.,.833
6800   06
6900   0.,0.
7000   1.,.143
7100   2.,.252
7200   4.,.458
7300   6.,.581
7400   12.,.673
7500   06
7600   0.,0.
7700   1.,.107
7800   2.,.194
7900   4.,.380
8000   6.,.518
8100   12.,.685
8200   05
8300   0.
8400   .04
8500   .1
8600   .5
8700   1.
8800   05
8900   0.
9000   4.
9100   8.
9200   12.
9300   16.
9400   1.,1.,.9,.3,.1
9500   1.,1.,.9,.3,.1
9600   1.,1.,.9,.35,.13
9700   1.,1.,.9,.42,.17
9800   1.,1.,.9,.48,.22
9900   -2.
10000  03
10100  3000.,6000.,9000.
10200  01
10300  66.
10400  05
10500  0.,0.
10600  .1,.68
10700  .2,.80
10800  .3,.77
10900  1.0,.55
11000  05
11100  0.,0.
11200  .1,.59
11300  .2,.75
11400  .3,.73
11500  1.,.50
11600  05
11700  0.,0.
11800  .1,.44
11900  .2,.70
12000  .3,.69
12100  1.,.45
12200  05
12300  0.
12400  .04
12500  .1
12600  .5
12700  1.
12800  05
12900  0.
13000  4.
13100  8.
13200  12.
13300  16
13400  1.,1.,1.,1.,1.
13500  1.,1.,1.,1.,1.
13600  .75,.75,.75,.95,1.
13700  .5,.5,.6,.9,.95
13800  .4,.4,.45,.85,.95
13900  0.0
14000  -1600.
14100  0.,0.,5.0,0.8,
14200  4500.
14300  19.5
14400  103.
14500  01
14600  48.
14700  50.
14800  0.0
14900  -121.
15000  09
15100  -20000.,-11.
15200  0.,-1.
15300  0.,0.
15400  4000.,1.
15500  6500.,1.5
15600  9500.,2.
15700  13000.,2.5
15800  17000.,3.
15900  50000.,4.0
16000  0.02
16100  -25000.,-11.
16200  0.,-.8
16300  0.,0.2
16400  3000.,1.
16500  5000.,1.5
16600  8000.,2
16700  11500.,2.5
16800  15500.,3.
16900  40000.,4
17000  0.02
17100  0.0
17200  0.0
17300  4458.
17400  29.
17500  0.0
17600  6000.
17700  38.
17800  72.
17900  2300.
18000  -121.
18100  0.
18200  0.
18300  4458.
18400  29.
18500  0.
18600  6000.
18700  38.
18800  72.
18900  2300.
19000  13.
19100  -1.
19200  -2.
19300  0.0
19400  1200.
19500  4500.
19600  19.5
19700  115.
19800  13.
19900  -1.
20000  -2.
20100  0.
20200  1200.
20300  4500.
20400  19.5
20500  115.
20600  0.05
20700  0.25
20800  1000.
20900  0
21000  0
21100  0.075
21200  0.25
21300  1500.
21400  0.075
21500  0.25
21600  1500.
21700  432.
21800  4500.
21900  7500.
22000  60.0
22100  60000.
22200  750000.
22300  750000.
22400  52500.
22500  213.94
22600  85.0
22700  132000
22800  3050000
22900  3100000.
23000  01
23100  48.0
23200  50.
23300  0.0
23400  -122.
23500  09
23600  -30000.,-11.
23700  0.,-1.5
23800  0.,0.
23900  3375.,0.5
24000  7312.,1.
24100  11812.,1.5
24200  16875.,2.
24300  22500.,2.5
24400  56250.,3.
24500  0.02
24600  -35000.,-11.
24700  0.,-1.3
24800  0.,0.2
24900  1687.,0.5
25000  5625.,1.
25100  10125.,1.5
25200  15187.,2.
25300  20812.,2.5
25400  45000.,3.
25500  0.02
25600  0.0
25700  0.0
25800  4100.
25900  29.
26000  0.
26100  10000.
26200  38.
26300  72.
26400  1500.
26500  -122.
26600  0.
26700  0.
26800  4100.
26900  29.
27000  0.
27100  10000.
27200  38.
27300  72.
27400  1500.
27500  13.
27600  -1.
27700  -2.
27800  0.
27900  1200.
28000  4500.
28100  19.5
28200  115.
28300  13.
28400  -1.
28500  -2.
28600  0.
28700  1200.
28800  4500.
28900  19.5
29000  115.
29100  0.175
29200  .25
29300  1500.
29400  0.175
29500  .25
29600  1500.
29700  -1
29800  00
```

```
VAX/VMS  RTAC         YRCONF3 21-APR-1985 11:55   LPB0: 21-APR-1985 11:55   DISK$VAXUSER1:[USER1.RTAC]YRCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         YRCONF3 21-APR-1985 11:55   LPB0: 21-APR-1985 11:55   DISK$VAXUSER1:[USER1.RTAC]YRCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         YRCONF3 21-APR-1985 11:55   LPB0: 21-APR-1985 11:55   DISK$VAXUSER1:[USER1.RTAC]YRCONF3.DAT;1          VAX/V

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    333333
    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    333333
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          33      33
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          33      33
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF                  33
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF                  33
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF        33
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF        33
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF                  33
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF                  33
        YY      RR    RR    CC          OO      OO  NN      NN  FF          33      33      ....
        YY      RR    RR    CC          OO      OO  NN      NN  FF          33      33      ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF            333333        ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF            333333        ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         YRCONF3 21-APR-1985 11:55   LPB0: 21-APR-1985 11:55   DISK$VAXUSER1:[USER1.RTAC]YRCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         YRCONF3 21-APR-1985 11:55   LPB0: 21-APR-1985 11:55   DISK$VAXUSER1:[USER1.RTAC]YRCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         YRCONF3 21-APR-1985 11:55   LPB0: 21-APR-1985 11:55   DISK$VAXUSER1:[USER1.RTAC]YRCONF3.DAT;1          VAX/V
```

```
 100    5-AXLE TRACROR-SEMITRAILER (CONF.  3 )
 200    0205
 300    52 5.6 ,.1,.02
 400    0302
 500    7700.,61500.
 600    15000.,204440.
 700    75000 ,3812523
 800    75000 ,3850003.
 900    44.,81.3
1000    12000 ,17000.,17000 ,17000.,17000.
1100    1200 ,2300 ,2300.,1500 ,1500.
1200    3719 ,4458 ,4458 ,4100 ,4100.
1300    28.8,-91.2,-139 2,-190.2,-238.2
1400    19.5,19 5,19.5,19 5,19 5
1500    23 ,27.,27.,29.,29
1600    16 ,19.,19 ,19.,19
1700    40 ,29.5,29 5,29 5,29 5
1000    0.,13 ,13.,13 ,13
1900    4500.,4500.,4500 ,4500.,4500.
2000    0 ,0.,0 ,0.,0
2100    1500.,6000.,6000.,10000 ,10000.
2200    300 ,1000.,1000.,1000.,1000.
2300    0 ,0.,0 ,0.,0.
2400    -100 85,217.8
2500    48
2600    1000000.
2700    01
2800    03
2900    0102020303
3000    04
3100    -20000 ,-20
3200    0.,0.
3300    8645.,7.2
3400    25000.,7.5
3500    09
3600    -22500 ,-11.
3700    0.,-1
3800    0.,0.
3900    3500.,1.
4000    5750.,1.5
4100    8750.,2.
4200    12250 ,2.5
4300    16250.,3.
4400    45000.,4.
4500    09
4600    -32500 ,-11.
4700    0 ,-1.5
4800    0.,0.
4900    2531.,0.5
5000    6469.,1.
5100    10969.,1.5
5200    16031.,2.
5300    21656.,2.5
5400    50625 ,3
5500    01
5600    0101010101
5700    0406
5800    0.,1.0,2.0,4.0,6.0,12 0
5900    3000 ,540.,990.,1710 ,2130.,2470.
6000    6000 ,1140.,1500.,2760 ,3400.,4140
6100    9000 ,990.,1710.,3420 ,4680.,6210.
```

```
6200    02
6300    0102020202
6400    0407
6500    0.0,1.0,3 0,4.0,5 0.7 0,10 0
6600    3000.,55.,72.,100.,120.,125.,100.
6700    6000.,130.,261.,300 ,354.,373.,332.
6800    9000.,200 ,452.,533.,625.,650.,565.
6900    0405
7000    0 ,1.,2.,3.,4.
7100    3000.,29.,42.,44 ,38
7200    6000.,92.,150.,157.,146.
7300    9000 ,152 ,269.,329.,335
7400    1.
7600    003
7700    0 ,0.,0
7000    0 5,2.5,2 5
7900    10.,2.5,2 5
```

```
VAX/VMS   RTAC        TBSCONF3 21-APR-1985 15:23   LPDO:  21-APR-1985 15:23   DISK$VAXUSER1:[USER1.RTAC]TBSCONF3.DAT;1        VAX/
VAX/VMS   RTAC        TBSCONF3 21-APR-1985 15:23   LPDO:  21-APR-1985 15:23   DISK$VAXUSER1:[USER1.RTAC]TBSCONF3.DAT;1        VAX/
VAX/VMS   RTAC        TBSCONF3 21-APR-1985 15:23   LPDO:  21-APR-1985 15:23   DISK$VAXUSER1:[USER1.RTAC]TBSCONF3.DAT;1        VAX/

                         RRRR    TTTTT    AAA     CCCC
                         R   R     T     A   A   C
                         R   R     T     A   A   C
                         RRRR      T     A   A   C
                         R R       T     AAAAA   C
                         R  R      T     A   A   C
                         R   R     T     A   A    CCCC

 TTTTTTTTTT  BBBBBBBB    SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    333333
 TTTTTTTTTT  BBBBBBBB    SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    333333
     TT      BB    BB  SS          CC          OO    OO  NN      NN  FF          33    33
     TT      BB    BB  SS          CC          OO    OO  NN      NN  FF          33    33
     TT      BB    BB  SS          CC          OO    OO  NNNN    NN  FF                33
     TT      BB    BB  SS          CC          OO    OO  NNNN    NN  FF                33
     TT      BBBBBBBB    SSSSSS    CC          OO    OO  NN  NN  NN  FFFFFFFF        33
     TT      BBBBBBBB    SSSSSS    CC          OO    OO  NN  NN  NN  FFFFFFFF        33
     TT      BB    BB          SS  CC          OO    OO  NN    NNNN  FF                33
     TT      BB    BB          SS  CC          OO    OO  NN    NNNN  FF                33
     TT      BB    BB          SS  CC          OO    OO  NN      NN  FF          33    33     ..
     TT      BB    BB          SS  CC          OO    OO  NN      NN  FF          33    33    ....
     TT      BBBBBBBB  SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF            333333      ..
     TT      BBBBBBBB  SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF            333333      ..

 DDDDDDDD      AAAAAA    TTTTTTTTTT     ;;;;       11
 DDDDDDDD      AAAAAA    TTTTTTTTTT     ;;;;       11
 DD      DD  AA      AA      TT         ;;;;     1111
 DD      DD  AA      AA      TT         ;;;;     1111
 DD      DD  AA      AA      TT                    11
 DD      DD  AA      AA      TT                    11
 DD      DD  AA      AA      TT         ;;;;       11
 DD      DD  AA      AA      TT         ;;;;       11
 DD      DD  AAAAAAAAAA      TT         ;;;;       11
 DD      DD  AAAAAAAAAA      TT         ;;;;       11
 DD      DD  AA      AA      TT           ;;       11
 DD      DD  AA      AA      TT           ;;       11
 DDDDDDDD    AA      AA      TT         ;;       111111
 DDDDDDDD    AA      AA      TT         ;;       111111

                         RRRR    TTTTT    AAA     CCCC
                         R   R     T     A   A   C
                         R   R     T     A   A   C
                         RRRR      T     A   A   C
                         R R       T     AAAAA   C
                         R  R      T     A   A   C
                         R   R     T     A   A    CCCC

VAX/VMS   RTAC        TBSCONF3 21-APR-1985 15:23   LPDO:  21-APR-1985 15:23   DISK$VAXUSER1:[USER1.RTAC]TBSCONF3.DAT;1        VAX/VM
VAX/VMS   RTAC        TBSCONF3 21-APR-1985 15:23   LPDO:  21-APR-1985 15:23   DISK$VAXUSER1:[USER1.RTAC]TBSCONF3.DAT;1        VAX/VM
VAX/VMS   RTAC        TBSCONF3 21-APR-1985 15:23   LPDO:  21-APR-1985 15:23   DISK$VAXUSER1:[USER1.RTAC]TBSCONF3.DAT;1        VAX/VM
```

```
09:54 APR 22 '85 TBSCONF3.F88ELGIP

N
Y
Y                                                            0.1
05                                                           N
000                                                          Y
1111                                                         N
15500.
64500.
214217.
4202900.
48.
48.
60.76
83.24
227.72
204.2
14.35
40.
36.
36.
48.
34.83
78.43
0.0
.11
0.0
0.0
37.
8.
30.
800.
620.
620.
Y
0.9
0.0
0.0
0.
02
0.,0.,0.,0.,0.,0.,0.
5.,0.,0.,0.,0.,0.,0.
02
0.0,0.0
.5,2.5
N
N
N
Y
0.0
N
N
N
N
N
N
06
04,08,03,07,05,21
0.2
```

```
VAX/VMS  RTAC         LYPCONF3 21-APR-1985 12:58   LPBO:  21-APR-1985 12:58   DISK$VAXUSER1:[USER1.RTAC]LYPCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         LYPCONF3 21-APR-1985 12:58   LPBO:  21-APR-1985 12:58   DISK$VAXUSER1:[USER1.RTAC]LYPCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         LYPCONF3 21-APR-1985 12:58   LPBO:  21-APR-1985 12:58   DISK$VAXUSER1:[USER1.RTAC]LYPCONF3.DAT;1          VAX/V

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    333333
    LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    333333
    LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          33      33
    LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          33      33
    LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF                  33
    LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF                  33
    LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF          33
    LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF          33
    LL              YY      PP          CC          OO      OO  NN    NNNN  FF                  33
    LL              YY      PP          CC          OO      OO  NN    NNNN  FF                  33
    LL              YY      PP          CC          OO      OO  NN      NN  FF          33      33       .
    LL              YY      PP          CC          OO      OO  NN      NN  FF          33      33       .
    LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            333333         . ..
    LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            333333         . ..

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         LYPCONF3 21-APR-1985 12:58   LPBO:  21-APR-1985 12:58   DISK$VAXUSER1:[USER1.RTAC]LYPCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         LYPCONF3 21-APR-1985 12:58   LPBO:  21-APR-1985 12:58   DISK$VAXUSER1:[USER1.RTAC]LYPCONF3.DAT;1          VAX/V
VAX/VMS  RTAC         LYPCONF3 21-APR-1985 12:58   LPBO:  21-APR-1985 12:58   DISK$VAXUSER1:[USER1.RTAC]LYPCONF3.DAT;1          VAX/V
```

```
 100   05-AXLE TRACTOR-SEMITRAILER (CONF. 3 & 4 )
 200   15500. ,64500.
 300   214217. ,4202700.
 400   60.76,59.24,107.24,180 28,228.28,0 ,0.,0 ,0.,0 ,0.
 500   68.89,227.723
 600   1600.,2480 ,2480.,2400 ,2480.,0.
 700   0.,0.,0.,0.,0.
 800   52.5,.1,10.,1.05
 900   267.,400.,400.,400.,400.,0
1000   0.,0 ,0.,0.,0.
1100   28000 ,28000.,28000.,28000 ,0.,0.
1200   0.,0.,0 ,0.
1300   13.,13.,13.,13.,0 ,0.,0 ,0.,0.,0
1400   8., 001.,1
1500   03
1600   0.,0
1700   .5,2 6
1800   10.,2 6
```

APPENDIX D

Vehicle Configuration 4

Input Data Files

```
VAX/VMS  RTAC         P4CONF4 21-APR-1985 11:35   LPB0: 21-APR-1985 11:37    DISK$VAXUSER1:[USER1.RTAC]P4CONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         P4CONF4 21-APR-1985 11:35   LPB0: 21-APR-1985 11:37    DISK$VAXUSER1:[USER1.RTAC]P4CONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         P4CONF4 21-APR-1985 11:35   LPB0: 21-APR-1985 11:37    DISK$VAXUSER1:[USER1.RTAC]P4CONF4.DAT;1          VAX/VMS

                         RRRR  TTTTT  AAA   CCCC
                         R   R   T   A   A C
                         R   R   T   A   A C
                         RRRR    T   A   A C
                         R R     T   AAAAA C
                         R  R    T   A   A C
                         R   R   T   A   A  CCCC

    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44    44
    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44    44
    PP      PP  44    44    CC          OO      OO  NN      NN  FF          44    44
    PP      PP  44    44    CC          OO      OO  NN      NN  FF          44    44
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF          44    44
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF          44    44
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
    PP                44    CC          OO      OO  NN    NNNN  FF                44
    PP                44    CC          OO      OO  NN    NNNN  FF                44
    PP                44    CC          OO      OO  NN      NN  FF                44        ....
    PP                44    CC          OO      OO  NN      NN  FF                44        ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF                44        ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF                44        ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR  TTTTT  AAA   CCCC
                         R   R   T   A   A C
                         R   R   T   A   A C
                         RRRR    T   A   A C
                         R R     T   AAAAA C
                         R  R    T   A   A C
                         R   R   T   A   A  CCCC

VAX/VMS  RTAC         P4CONF4 21-APR-1985 11:35   LPB0: 21-APR-1985 11:37    DISK$VAXUSER1:[USER1.RTAC]P4CONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         P4CONF4 21-APR-1985 11:35   LPB0: 21-APR-1985 11:37    DISK$VAXUSER1:[USER1.RTAC]P4CONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         P4CONF4 21-APR-1985 11:35   LPB0: 21-APR-1985 11:37    DISK$VAXUSER1:[USER1.RTAC]P4CONF4.DAT;1          VAX/VMS
```

```
  100    5-AXLE TRACTOR-SEMITRAILER (CONF.4)
  200    01
  300    54.5
  400    003
  500    0.,0.
  600    0.5,2.5,2.5
  700    10.,2.5,2.5
  800    04
  900    0.,0
 1000    2.5,0.
 1100    2.6,0.
 1200    10.,0.
 1300    0.
 1400    0.1
 1500    00
 1600    11100000
 1700    144.
 1800    8960.
 1900    6540.
 2000    44.
 2100    15000.
 2200    75000.
 2300    75000.
 2400    0.0
 2500    14.35
 2600    48.0
 2700    50000.
 2800    36.
 2900    -119.
 3000    04
 3100    -20000.,-20.
 3200    0.,0.
 3300    9250.,7.2
 3400    25000.,7.5
 3500    0.08
 3600    -20000.,-20.
 3700    0.,0
 3800    8040.,7.2
 3900    25000.,7.5
 4000    0.08
 4100    0.
 4200    0.
 4300    3719.
 4400    23.
 4500    0.00
 4600    0.0
 4700    32.
 4800    80.0
 4900    1200.
 5500    0.0
 5600    -1
 5700    03
 5800    3000.,6000.,9000.
 5900    01
 6000    66.
 6100    06
 6200    0.,0.
 6300    1.,.103
 6400    2.,.333
 6500    4.,.575
 6600    6.,.708
 6700    12.,.833
 6800    06
 6900    0.,0.
 7000    1.,.143
 7100    2.,.252
 7200    4.,.458
 7300    6.,.581
 7400    12.,.693
 7500    06
 7600    0.,0.
 7700    1.,.107
 7800    2.,.194
 7900    4.,.300
 8000    6.,.518
 8100    12.,.685
 8200    05
 8300    0.
 8400    .04
 8500    .1
 8600    .5
 8700    1.
 8800    05
 8900    0.
 9000    4.
 9100    8.
 9200    12.
 9300    16.
 9400    1.,1.,.9,.3,.1
 9500    1.,1.,.9,.3,.1
 9600    1.,1.,.9,.35,.13
 9700    1.,1.,.9,.42,.17
 9800    1.,1.,.9,.48,.22
 9900    -2.
10000    03
10100    3000.,6000.,7000.
10200    01
10300    66.
10400    05
10500    0.,0.
10600    .1,.68
10700    .2,.80
10800    .3,.77
10900    1.0,.55
11000    05
11100    0.,0.
11200    .1,.59
11300    .2,.75
11400    .3,.73
11500    1.,.50
11600    05
11700    0.,0.
11800    .1,.44
11900    .2,.70
12000    .3,.69
12100    1.,.45
12200    05
12300    0.
12400    .04
12500    .1
12600    .5
12700    1
12800    05
12900    0.
13000    4.
13100    8.
13200    12.
13300    16.
13400    1.,1.,1.,1.,1.
13500    1.,1.,1.,1.,1.
13600    .75,.75,.75,.95,1.
13700    .5,.5,.6,.9,.95
13800    .4,.4,.45,.85,.95
13900    0.0
14000    -1600.
14100    0.,0.,5.0,0.8,
14200    4500.
14300    19.5
14400    103.
14500    01
14600    48.
14700    50
14800    0.0
14900    -121.
15000    09
15100    -20000.,-11.
15200    0.,-1.
15300    0.,0.
15400    4000.,1.
15500    6500.,1.5
15600    9500.,2
15700    13000.,2.5
15800    17000.,3.
15900    50000.,4.0
16000    0.02
16100    -25000.,-11.
16200    0.,-.8
16300    0.,0.2
16400    3000.,1.
16500    5000.,1.5
16600    8000.,2.
16700    11500.,2.5
16800    15500.,3.
16900    40000.,4
17000    0.02
17100    0.0
17200    0.0
17300    4458.
17400    29.
17500    0.0
17600    0.0
17700    38.
17800    72.
17900    2300.
18000    -121.
18100    0.
18200    0
18300    4458.
18400    29.
18500    0.
18600    78000.
18700    38.
18800    72
18900    2300.
19000    13.
19100    -1.
19200    -2
19300    0.0
19400    1200.
19500    4500.
19600    19.5
19700    115.
19800    13.
19900    -1.
20000    -2.
20100    0.
20200    1200.
20300    4500.
20400    19.5
20500    115.
20600    0.05
20700    0.25
20800    1000.
20900    0
21000    0
21100    0.075
21200    0.25
21300    1500.
21400    0.075
21500    0.25
21600    1500.
21700    432.
21800    4500.
21900    7500
22000    60.0
22100    60000.
22200    750000.
22300    750000.
22400    52500.
22500    213.94
22600    85.0
22700    132000.
22800    3050000.
22900    3100000
23000    01
23100    48.0
23200    50.
23300    0.0
23400    -122.
23500    09
23600    -30000.,-11.
23700    0.,-1.5
23800    0.,0.
23900    3375.,0.5
24000    7312.,1.
24100    11812.,1.5
24200    16875.,2
24300    22500.,2.5
24400    56250.,3
24500    0.02
24600    -39000.,-11.
24700    0.,-1.5
24800    0.,0.2
24900    1687.,0.5
25000    5625.,1.
25100    10125.,1.5
25200    15187.,2.
25300    20812.,2.5
25400    45000.,3.
25500    0.02
25600    0.0
25700    0.0
25800    4100.
25900    29.
26000    0.
26100    0.0
26200    38.
26300    72.
26400    1500.
26500    -122.
26600    0.
26700    0.
26800    4100.
26900    29.
27000    0.
27100    0.
27200    38.
27300    72.
27400    1500.
27500    13.
27600    -1.
27700    -2.
27800    0.
27900    1200.
28000    4500.
28100    19.5
28200    115.
28300    13
28400    -1.
28500    -2.
28600    0.
28700    1200.
28800    4500.
28900    19.5
29000    115.
29100    0.175
29200    .25
29300    1500.
29400    0.175
29500    .25
29600    1500.
29700    -1
29800    00
```

```
VAX/VMS  RTAC         YRCONF4 21-APR-1985 11:57   LPB0:  21-APR-1985 11:57   DISK$VAXUSER1:[USER1.RTAC]YRCONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF4 21-APR-1985 11:57   LPB0:  21-APR-1985 11:57   DISK$VAXUSER1:[USER1.RTAC]YRCONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF4 21-APR-1985 11:57   LPB0   21-APR-1985 11:57   DISK$VAXUSER1:[USER1.RTAC]YRCONF4.DAT;1          VAX/VMS

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44      44
    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44      44
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          44      44
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          44      44
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF          44      44
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF          44      44
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF                  44
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF                  44
        YY      RR    RR    CC          OO      OO  NN      NN  FF                  44     ....
        YY      RR    RR    CC          OO      OO  NN      NN  FF                  44     ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF                  44     ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF                  44     ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         YRCONF4 21-APR-1985 11:57   LPB0:  21-APR-1985 11:57   DISK$VAXUSER1:[USER1.RTAC]YRCONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF4 21-APR-1985 11:57   LPB0:  21-APR-1985 11:57   DISK$VAXUSER1:[USER1.RTAC]YRCONF4.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF4 21-APR-1985 11:57   LPB0:  21-APR-1985 11:57   DISK$VAXUSER1:[USER1.RTAC]YRCONF4.DAT;1          VAX/VMS
```

```
 100    5-AXLE TRACROR-SEMITRAILER (CONF  4 )
 200    0205
 300    52.5,6., 1.,02
 400    0302
 500    7700.,61500.
 600    15000 ,204440
 700    75000 ,3812523
 800    75000.,3850083
 900    44 ,81 3
1000    12000.,17000.,17000.,17000.,17000.
1100    1200.,2300 ,2300 ,1500.,1500
1200    3719.,4458.,4458 ,4100.,4100.
1300    28.8,-91.2,-137.2,-190 2,-238.2
1400    19.5,19 5,19.5,19 5,19 5
1500    23.,29.,29.,29 ,29
1600    16.,19.,19.,19 ,19
1700    40.,29.5,29.5,29.5,29.5
1800    0.,13 ,13 ,13 ,13.
1900    4500.,4500.,4500 ,4500 ,4500.
2000    0.,0.,0 ,0.,0.
2100    0 ,0.,78000.,0.,0
2200    300.,1000.,1000.,1000 ,1000.
2300    0 ,0 ,0.,0.,0
2400    -100 85,217.8
2500    48.
2600    1000000.
2700    01
2800    03
2900    0102020303
3000    04
3100    -20000.,-20
3200    0 ,0.
3300    8645.,7 2
3400    25000 ,7.5
3500    09
3600    -22500 ,-11.
3700    0 ,-1
3800    0 ,0.
3900    3500 ,1.
4000    5750.,1 5
4100    8750.,2
4200    12250.,2 5
4300    16250.,3
4400    45000 ,4.
4500    09
4600    -32500.,-11
4700    0 ,-1 5
4800    0.,0.
4900    2531.,0 5
5000    6469.,1
5100    10969.,1 5
5200    16031.,2
5300    21656.,2 5
5400    50625.,3
5500    01
5600    0101010101
5700    0406
5800    0.,1.0,2.0,4 0,6.0,12.0
5900    3000 ,540 ,990.,1710 ,2130 ,2490
6000    6000 ,840.,1500 ,2760 ,3400 ,4140
6100    9000 ,970 ,1710 ,3420 ,4600 ,6210
```

```
6200    02
6300    0102020202
6400    0407
6500    0 0,1.0,3.0,4.0,5.0,7 0,10.0
6600    3000.,55.,92 ,100.,120.,125.,100.
6700    6000.,130.,261 ,300.,354.,373.,332.
6800    9000.,200 ,452.,533.,625 ,650.,565.
6900    0405
7000    0.,1 ,2.,3 ,4.
7100    3000.,29.,42.,44 ,38.
7200    6000.,92.,150 ,157.,146.
7300    9000.,152.,269 ,329.,335
7400    1.
7600    003
7700    0.,0 ,0.
7800    0.5,2 5,2 5
7900    10.,2 5,2.5
```

```
VAX/VMS  RTAC         TBSCONF4 30-APR-1985 12:54   LPB0: 30-APR-1985 12:55   TBSCONF4.DAT;1                                 VAX/V
VAX/VMS  RTAC         TBSCONF4 30-APR-1985 12:54   LPB0: 30-APR-1985 12:55   TBSCONF4.DAT;1                                 VAX/V
VAX/VMS  RTAC         TBSCONF4 30-APR-1985 12:54   LPB0: 30-APR-1985 12:55   TBSCONF4.DAT;1                                 VAX/V

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    TTTTTTTTTT  BBBBBBBB      SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44    44
    TTTTTTTTTT  BBBBBBBB      SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44    44
        TT      BB      BB  SS          CC          OO      OO  NN      NN  FF          44    44
        TT      BB      BB  SS          CC          OO      OO  NN      NN  FF          44    44
        TT      BB      BB  SS          CC          OO      OO  NNNN    NN  FF          44    44
        TT      BB      BB  SS          CC          OO      OO  NNNN    NN  FF          44    44
        TT      BBBBBBBB      SSSSSS    CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
        TT      BBBBBBBB      SSSSSS    CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
        TT      BB      BB          SS  CC          OO      OO  NN    NNNN  FF                44
        TT      BB      BB          SS  CC          OO      OO  NN    NNNN  FF                44
        TT      BB      BB          SS  CC          OO      OO  NN      NN  FF                44
        TT      BB      BB          SS  CC          OO      OO  NN      NN  FF                44
        TT      BBBBBBBB    SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF                44
        TT      BBBBBBBB    SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF                44

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         TBSCONF4 30-APR-1985 12:54   LPB0: 30-APR-1985 12:55   TBSCONF4.DAT;1                                 VAX/V
VAX/VMS  RTAC         TBSCONF4 30-APR-1985 12:54   LPB0: 30-APR-1985 12:55   TBSCONF4.DAT;1                                 VAX/V
VAX/VMS  RTAC         TBSCONF4 30-APR-1985 12:54   LPB0: 30-APR-1985 12:55   TBSCONF4.DAT;1                                 VAX/V
```

```
09:55 APR 22 '85 TBSCUNF4.FBBELGIP

N
Y                                                          0.1
Y                                                          N
05                                                         Y
000                                                        N
1111
15500.
64500.
214217.
4202900.
48.
48.
60.76
83.24
227.72
204.2
14.35
40.
36.
36.
48.
34.83
78.43
0.0
.06
0.0
0.0
37.
8.
30.
800.
620.
620.
Y
0.9
0.0
0.0
0.
02
0.,0.,0.,0.,0.,0.,0.
5.,0.,0.,0.,0.,0.,0.
02
0.0,0.0
.5,2.5
N
N
N
Y
0.0
N
N
N
N
N
N
06
04,08,03,07,05,21
0.2
```

```
VAX/VMS   RTAC        LYPCONF4 21-APR-1985 13:00   LPBO: 21-APR-1985 13:00   DISK$VAXUSER1:[USER1.RTAC]LYPCONF4.DAT;1         VAX/VM
VAX/VMS   RTAC        LYPCONF4 21-APR-1985 13:00   LPBO: 21-APR-1985 13:00   DISK$VAXUSER1:[USER1.RTAC]LYPCONF4.DAT;1         VAX/VM
VAX/VMS   RTAC        LYPCONF4 21-APR-1985 13:00   LPBO: 21-APR-1985 13:00   DISK$VAXUSER1:[USER1.RTAC]LYPCONF4.DAT;1         VAX/VM

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

   LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44      44
   LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  44      44
   LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          44      44
   LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          44      44
   LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF          44      44
   LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF          44      44
   LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
   LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF    4444444444
   LL              YY      PP          CC          OO      OO  NN    NNNN  FF                  44
   LL              YY      PP          CC          OO      OO  NN    NNNN  FF                  44
   LL              YY      PP          CC          OO      OO  NN      NN  FF                  44      ..
   LL              YY      PP          CC          OO      OO  NN      NN  FF                  44      ..
   LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF                  44      ..
   LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF                  44      ..

   DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
   DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
   DD      DD  AA      AA      TT          ;;;;      1111
   DD      DD  AA      AA      TT          ;;;;      1111
   DD      DD  AA      AA      TT                      11
   DD      DD  AA      AA      TT                      11
   DD      DD  AA      AA      TT          ;;;;        11
   DD      DD  AA      AA      TT          ;;;;        11
   DD      DD  AAAAAAAAAA      TT          ;;;;        11
   DD      DD  AAAAAAAAAA      TT          ;;;;        11
   DD      DD  AA      AA      TT            ;;        11
   DD      DD  AA      AA      TT            ;;        11
   DDDDDDDD    AA      AA      TT          ;;        111111
   DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS   RTAC        LYPCONF4 21-APR-1985 13:00   LPBO: 21-APR-1985 13:00   DISK$VAXUSER1:[USER1.RTAC]LYPCONF4.DAT;1         VAX/VMS
VAX/VMS   RTAC        LYPCONF4 21-APR-1985 13:00   LPBO: 21-APR-1985 13:00   DISK$VAXUSER1:[USER1.RTAC]LYPCONF4.DAT;1         VAX/VMS
VAX/VMS   RTAC        LYPCONF4 21-APR-1985 13:00   LPBO: 21-APR-1985 13:00   DISK$VAXUSER1:[USER1.RTAC]LYPCONF4.DAT;1         VAX/VMS
```

```
 100   05-AXLE TRACTOR-SEMITRAILER (CONF  3 & 4 )
 200   15500 ,64500.
 300   214217 ,4202700
 400   60.76,59.24,107 24,180.28,220 28,0. ,0 ,0. ,0. ,0. ,0.
 500   68.89,227.723
 600   1600 ,2480. ,2400 ,2480. ,2480. ,0.
 700   0. ,0. ,0. ,0. ,0
 800   52 5. .1,10. ,1 05
 900   267 ,400 ,400 ,400. ,400. ,0.
1000   0. ,0 ,0. ,0 ,0
1100   28000. ,28000. ,28000 ,28000. ,0. ,0.
1200   0. ,0 ,0. ,0
1300   13 ,13. ,13 ,13 ,0. ,0. ,0. ,0. ,0 ,0.
1400   8. , .001, .1
1500   03
1600   0. ,0
1700    5,2.6
1800   10. ,2.6
```

APPENDIX E

Vehicle Configuration 5

Input Data Files

```
VAX/VMS  RTAC        P4CONF5 21-APR-1985 14:19    LPB0:  21-APR-1985 14:19    DISK$VAXUSER1:[USER1.RTAC]P4CONF5.DAT;1
VAX/VMS  RTAC        P4CONF5 21-APR-1985 14:19    LPB0:  21-APR-1985 14:19    DISK$VAXUSER1:[USER1.RTAC]P4CONF5.DAT;1
VAX/VMS  RTAC        P4CONF5 21-APR-1985 14:19    LPB0:  21-APR-1985 14:19    DISK$VAXUSER1:[USER1.RTAC]P4CONF5.DAT;1

                         RRRR    TTTTT   AAA    CCCC
                         R   R     T    A   A  C
                         R   R     T    A   A  C
                         RRRR      T    A   A  C
                         R R       T    AAAAA  C
                         R  R      T    A   A  C
                         R   R     T    A   A   CCCC

PPPPPPPP    44      44      CCCCCCCC    DDDDDD    NN      NN  FFFFFFFFFF  5555555555
PPPPPPPP    44      44      CCCCCCCC    DDDDDD    NN      NN  FFFFFFFFFF  5555555555
PP      PP  44      44    CC          DD      DD  NN      NN  FF          55
PP      PP  44      44    CC          DD      DD  NN      NN  FF          55
PP      PP  44      44    CC          DD      DD  NNNN    NN  FF          555555
PP      PP  44      44    CC          DD      DD  NNNN    NN  FF          555555
PPPPPPPP    4444444444    CC          DD      DD  NN  NN  NN  FFFFFFFF          55
PPPPPPPP    4444444444    CC          DD      DD  NN  NN  NN  FFFFFFFF          55
PP                  44    CC          DD      DD  NN    NNNN  FF                  55
PP                  44    CC          DD      DD  NN    NNNN  FF                  55
PP                  44    CC          DD      DD  NN      NN  FF          55      55        ....
PP                  44    CC          DD      DD  NN      NN  FF          55      55        ....
PP                  44      CCCCCCCC    DDDDDD    NN      NN  FF            555555          ....
PP                  44      CCCCCCCC    DDDDDD    NN      NN  FF            555555          ....

DDDDDDDD        AAAAAA      TTTTTTTTTT      ;;;;        11
DDDDDDDD        AAAAAA      TTTTTTTTTT      ;;;;        11
DD      DD    AA      AA        TT          ;;;;      1111
DD      DD    AA      AA        TT          ;;;;      1111
DD      DD    AA      AA        TT                      11
DD      DD    AA      AA        TT                      11
DD      DD    AA      AA        TT          ;;;;        11
DD      DD    AA      AA        TT          ;;;;        11
DD      DD    AAAAAAAAAA        TT          ;;;;        11
DD      DD    AAAAAAAAAA        TT          ;;;;        11
DD      DD    AA      AA        TT            ;;        11
DD      DD    AA      AA        TT            ;;        11
DDDDDDDD      AA      AA        TT          ;;        111111
DDDDDDDD      AA      AA        TT          ;;        111111

                         RRRR    TTTTT   AAA    CCCC
                         R   R     T    A   A  C
                         R   R     T    A   A  C
                         RRRR      T    A   A  C
                         R R       T    AAAAA  C
                         R  R      T    A   A  C
                         R   R     T    A   A   CCCC

VAX/VMS  RTAC        P4CONF5 21-APR-1985 14:19    LPB0:  21-APR-1985 14:19    DISK$VAXUSER1:[USER1.RTAC]P4CONF5.DAT;1
VAX/VMS  RTAC        P4CONF5 21-APR-1985 14:19    LPB0:  21-APR-1985 14:19    DISK$VAXUSER1:[USER1.RTAC]P4CONF5.DAT;1
VAX/VMS  RTAC        P4CONF5 21-APR-1985 14:19    LPB0:  21-APR-1985 14:19    DISK$VAXUSER1:[USER1.RTAC]P4CONF5.DAT;1
```

```
100    5-AXLE TRACTOR-SEMITRAILER (CONF. 5 )
200    01
300    53.5
400    003
500    0.,0.
600    0.5,1.5,1.5
700    10.,1.5,1.5
800    04
900    0.,0.
1000   2.5,0.
1100   2.6,0.
1200   10.,0.
1300   8.
1400   0.1
1500   00
1600   11100000
1700   144.
1800   8960.
1900   6540.
2000   44.
2100   15000.
2200   75000.
2300   75000.
2400   0.0
2500   0.
2600   40.0
2700   50000.
2800   36.
2900   -119.
3000   04
3100   -20000.,-20.
3200   0.,0.
3300   9250.,7.2
3400   25000.,7.5
3500   0.08
3600   -20000.,-20.
3700   0.,0.
3800   8040.,7.2
3900   25000.,7.5
4000   0.08
4100   0.
4200   0.
4300   3719.
4400   23.
4500   0.00
4600   0.0
4700   32.
4800   80.0
4900   1200.
5500   0.0
5600   -1.
5700   03
5800   3000.,6000.,9000.
5900   01
6000   66.
6100   06
6200   0.,0.
6300   1.,.183
6400   2.,.333
6500   4.,.575
6600   6.,.708
6700   12.,.833
6800   06
6900   0.,0.
7000   1.,.143
7100   2.,.252
7200   4.,.450
7300   6.,.501
7400   12.,.693
7500   06
7600   0.,0.
7700   1.,.107
7800   2.,.194
7900   4.,.380
8000   6.,.518
8100   12.,.685
8200   05
8300   0.
8400   .04
8500   .1
8600   .3
8700   1.
8800   05
8900   0.
9000   4.
9100   8.
9200   12.
9300   16.
9400   1.,1.,.9,.3,.1
9500   1.,1.,.9,.3,.1
9600   1.,1.,.9,.35,.13
9700   1.,1.,.9,.42,.17
9800   1.,1.,.9,.48,.22
9900   -2.
10000  03
10100  3000.,6000.,9000.
10200  01
10300  66.
10400  05
10500  0.,0.
10600  .1,.68
10700  .2,.80
10800  .3,.77
10900  1.0,.55
11000  05
11100  0.,0.
11200  .1,.59
11300  .2,.75
11400  .3,.73
11500  1.,.50
11600  05
11700  0.,0.
11800  .1,.44
11900  .2,.70
12000  .3,.69
12100  1.,.45
12200  05
12300  0.
12400  .04
12500  .1
12600  .3
12700  1.
12800  05
12900  0.
13000  4
13100  8
13200  12.
13300  16.
13400  1.,1.,1.,1.,1.
13500  1.,1.,1.,1.,1.
13600  .75,.75,.75,.95,1.
13700  .5,.5,.6,.9,.95
13800  .4,.4,.45,.85,.95
13900  0.0
14000  -1600.
14100  0.,0.,.5,0.,0.,0.
14200  4500.
14300  19.5
14400  103
14500  01
14600  48.
14700  30.
14800  0.0
14900  -121.
15000  09
15100  -20000.,-11.
15200  0.,-1
15300  0.,0.
15400  4000.,1
15500  6500.,1.5
15600  9500.,2.
15700  13000.,2.5
15800  17000.,3
15900  50000.,4.0
16000  0.02
16100  -25000.,-11.
16200  0.,-.8
16300  0.,0.2
16400  3000.,1
16500  5000.,1.5
16600  8000.,2
16700  11500.,2.5
16800  15500.,3.
16900  40000.,4
17000  0.02
17100  0.0
17200  0.0
17300  4450.
17400  29.
17500  0.0
17600  0.0
17700  38.
17800  72.
17900  2300.
18000  -121
18100  0
18200  0
18300  4450
18400  27.
18500  0.
18600  78000.
18700  38
18800  72.
18900  2300.
19000  13.
19100  -1
19200  -2.
19300  0.0
19400  1200.
19500  4500.
19600  19.5
19700  115
19800  13.
19900  -1.
20000  -2
20100  0.
20200  1200.
20300  4500.
20400  19.5
20500  115.
20600  0.05
20700  0.25
20800  1000.
20900  0
21000  0
21100  0.075
21200  0.25
21300  1500.
21400  0.075
21500  0.25
21600  1500.
21700  432.
21800  4500.
21900  7500.
22000  60.0
22100  60000.
22200  750000.
22300  750000.
22400  52500.
22500  213.94
22600  85.0
22700  132000.
22800  3050000.
22900  3100000.
23000  01
23100  48.0
23200  50.
23300  0.0
23400  -122.
23500  09
23600  -30000.,-11.
23700  0.,-1.5
23800  0.,0.
23900  3375.,0.5
24000  7312.,1.
24100  11812.,1.5
24200  16875.,2.
24300  22500.,2.5
24400  56250.,3.
24500  0.02
24600  -35000.,-11.
24700  0.,-1.3
24800  0.,0.2
24900  1687.,0.5
25000  5625.,1.
25100  10125.,1
25200  15187.,2
25300  20812.,2
25400  45000.,3
25500  0.02
25600  0.0
25700  0.0
25800  4100.
25900  29.
26000  0.
26100  0.0
26200  38.
26300  72.
26400  1500.
26500  -122.
26600  0.
26700  0.
26800  4100.
26900  29.
27000  0.
27100  0.
27200  38.
27300  72.
27400  1500.
27500  13.
27600  -1.
27700  -2.
27800  0.
27900  1200.
28000  4500.
28100  19.5
28200  115.
28300  13.
28400  -1.
28500  -2.
28600  0.
28700  1200.
28800  4500.
28900  19.5
29000  115.
29100  0.175
29200  .25
29300  1500.
29400  0.175
29500  .25
29600  1500.
29700  -1
29800  00
```

```
VAX/VMS  RTAC         YRCONF1 21-APR-1985 11:39   LPB0: 21-APR-1985 11:39   DISK$VAXUSER1:[USER1.RTAC]YRCONF1.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF1 21-APR-1985 11:39   LPB0: 21-APR-1985 11:39   DISK$VAXUSER1:[USER1.RTAC]YRCONF1.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF1 21-APR-1985 11:39   LPB0: 21-APR-1985 11:39   DISK$VAXUSER1:[USER1.RTAC]YRCONF1.DAT;1          VAX/VMS

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF
    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF
        YY      RR    RR    CC          OO      OO  NN      NN  FF
        YY      RR    RR    CC          OO      OO  NN      NN  FF
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         YRCONF1 21-APR-1985 11:39   LPB0: 21-APR-1985 11:39   DISK$VAXUSER1:[USER1.RTAC]YRCONF1.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF1 21-APR-1985 11:39   LPB0: 21-APR-1985 11:39   DISK$VAXUSER1:[USER1.RTAC]YRCONF1.DAT;1          VAX/VMS
VAX/VMS  RTAC         YRCONF1 21-APR-1985 11:39   LPB0: 21-APR-1985 11:39   DISK$VAXUSER1:[USER1.RTAC]YRCONF1.DAT;1          VAX/VMS
```

```
100    5-AXLE TRACROR-SEMITRAILER (CONF  5 )
200    0205
300    52.5,8., 1.,.02
400    0302
500    9700.,61500
600    15000.,204440
700    75000.,3012523.
800    75000.,3850083.
900    44.,81.3
1000   8960.,18520.,18520.,17000.,17000.
1100   1200.,2300.,2300.,1500.,1500.
1200   3719.,4458.,4458.,4100.,4100.
1300   28.8,-91.2,-139.2,-190.2,-238.2
1400   19.5,19.5,19.5,19.5,19.5
1500   23.,29.,29.,29.,29
1600   16.,19.,19.,19.,19.
1700   40.,29.5,29.5,29.5,29.5
1800   0.,13.,13.,13.,13.
1900   4500.,4500.,4500.,4500.,4500.
2000   0.,0.,0.,0.,0.
2100   0.,0.,78000.,0.,0.
2200   300.,1000.,1000.,1000.,1000
2300   0.,0.,0.,0.,0.
2400   -115.2,217.8
2500   48
2600   1000000.
2700   01
2800   03
2900   0102020303
3000   04
3100   -20000.,-20
3200   0.,0.
3300   8645.,7.2
3400   25000.,7.5
3500   09
3600   -22500.,-11.
3700   0.,-1
3800   0.,0.
3900   3500.,1.
4000   5750.,1.5
4100   8750.,2.
4200   12250.,2.5
4300   16250.,3
4400   45000.,4.
4500   09
4600   -32500.,-11.
4700   0.,-1.5
4800   0.,0
4900   2531.,0.5
5000   6469.,1
5100   10969.,1.5
5200   16031.,2.
5300   21656.,2.5
5400   50625.,3.
5500   01
5600   0101010101
5700   0406
5800   0.,1.0,2.0,4.0,6.0,12.0
5900   3000.,540.,990.,1710.,2130.,2490.
6000   6000.,840.,1500.,2760.,3400.,4140.
6100   9000.,990.,1710.,3420.,4680.,6210.
6200   02
6300   0102020202
6400   0407
6500   0.0,1.0,3.0,4.0,5.0,7.0,10.0
6600   3000.,55.,92.,100.,120.,125.,100
6700   6000.,130.,261.,300.,354.,373.,332.
6800   9000.,200.,452.,533.,625.,650.,565
6900   0405
7000   0.,1.,2.,3.,4
7100   3000.,29.,42.,44.,30.
7200   6000.,92.,150.,157.,146
7300   9000.,152.,269.,329.,335.
7400   1
7600   003
7700   0.,0.,0.
7800   0.5,1.75,1.75
7900   10.,1.75,1.75
```

```
VAX/VMS   RTAC        TBSCONF5 21-APR-1985 15:25   LPBO:  21-APR-1985 15:28   TBSCONF5.DAT;1        VAX/
VAX/VMS   RTAC        TBSCONF5 21-APR-1985 15:25   LPBO:  21-APR-1985 15:28   TBSCONF5.DAT;1        VAX/
VAX/VMS   RTAC        TBSCONF5 21-APR-1985 15:25   LPBO:  21-APR-1985 15:28   TBSCONF5.DAT;1        VAX/

                      RRRR   TTTTT   AAA    CCCC
                      R   R    T    A   A  C
                      R   R    T    A   A  C
                      RRRR     T    A   A  C
                      R R      T    AAAAA  C
                      R  R     T    A   A  C
                      R   R    T    A   A   CCCC

  TTTTTTTTTT  BBBBBBBB      SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  5555555555
  TTTTTTTTTT  BBBBBBBB      SSSSSSSS    CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  5555555555
      TT      BB      BB  SS          CC          OO      OO  NN      NN  FF          55
      TT      BB      BB  SS          CC          OO      OO  NN      NN  FF          55
      TT      BB      BB  SS          CC          OO      OO  NNNN    NN  FF          555555
      TT      BB      BB  SS          CC          OO      OO  NNNN    NN  FF          555555
      TT      BBBBBBBB      SSSSSS    CC          OO      OO  NN  NN  NN  FFFFFFFF          55
      TT      BBBBBBBB      SSSSSS    CC          OO      OO  NN  NN  NN  FFFFFFFF          55
      TT      BB      BB          SS  CC          OO      OO  NN    NNNN  FF                  55
      TT      BB      BB          SS  CC          OO      OO  NN    NNNN  FF                  55
      TT      BB      BB          SS  CC          OO      OO  NN      NN  FF          55      55
      TT      BB      BB          SS  CC          OO      OO  NN      NN  FF          55      55
      TT      BBBBBBBB    SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF            555555
      TT      BBBBBBBB    SSSSSSSS      CCCCCCCC    OOOOOO    NN      NN  FF            555555

  DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
  DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
  DD      DD  AA      AA      TT          ;;;;      1111
  DD      DD  AA      AA      TT          ;;;;      1111
  DD      DD  AA      AA      TT                      11
  DD      DD  AA      AA      TT                      11
  DD      DD  AA      AA      TT          ;;;;        11
  DD      DD  AA      AA      TT          ;;;;        11
  DD      DD  AAAAAAAAAA      TT          ;;;;        11
  DD      DD  AAAAAAAAAA      TT          ;;;;        11
  DD      DD  AA      AA      TT            ;;        11
  DD      DD  AA      AA      TT            ;;        11
  DDDDDDDD    AA      AA      TT          ;;        111111
  DDDDDDDD    AA      AA      TT          ;;        111111

                      RRRR   TTTTT   AAA    CCCC
                      R   R    T    A   A  C
                      R   R    T    A   A  C
                      RRRR     T    A   A  C
                      R R      T    AAAAA  C
                      R  R     T    A   A  C
                      R   R    T    A   A   CCCC

VAX/VMS   RTAC        TBSCONF5 21-APR-1985 15:25   LPBO:  21-APR-1985 15:28   TBSCONF5.DAT;1        VAX/V
VAX/VMS   RTAC        TBSCONF5 21-APR-1985 15:25   LPBO   21-APR-1985 15 28   TBSCONF5.DAT;1        VAX/V
VAX/VMS   RTAC        TBSCONF5 21-APR-1985 15:25   LPBO   21-APR-1985 15 28   TBSCONF5.DAT;1        VAX/V
```

```
09:55 APR 22 '85 TBSCONF5.F0BELGIP
N
Y
Y
05
000                                                    0.1
1111                                                   N
15500.                                                 Y
64500.                                                 N
214217.
4202900.
48.
48.
60.76
83.24
227.72
204.2
0.0
40.
36.
36.
48.
34.83
78.43
0.0
.06
0.0
0.0
35.85
8.
30.
700.
720.
620.
Y
0.9
0.0
0.0
0.
02
0.,0.,0.,0.,0.,0.,0.
5.,0.,0.,0.,0.,0.,0.
02
0.0,0.0
.5,.5
N
N
N
Y
0.0
N
N
N
N
N
N
06
04,08,03,07,05,21
0.2
```

```
VAX/VMS  RTAC         LYPCONF5 21-APR-1985 14:18   LPB0: 21-APR-1985 14:18   DISK$VAXUSER1:[USER1.RTAC]LYPCONF5.DAT;1        VAX.
VAX/VMS  RTAC         LYPCONF5 21-APR-1985 14:18   LPB0: 21-APR-1985 14:18   DISK$VAXUSER1:[USER1.RTAC]LYPCONF5.DAT;1        VAX.
VAX/VMS  RTAC         LYPCONF5 21-APR-1985 14:18   LPB0: 21-APR-1985 14:18   DISK$VAXUSER1:[USER1.RTAC]LYPCONF5.DAT;1        VAX.

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  5555555555
    LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF  5555555555
    LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          55
    LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          55
    LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF          555555
    LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF          555555
    LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF          55
    LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF          55
    LL              YY      PP          CC          OO      OO  NN    NNNN  FF                  55
    LL              YY      PP          CC          OO      OO  NN    NNNN  FF                  55
    LL              YY      PP          CC          OO      OO  NN      NN  FF          55      55      .  .
    LL              YY      PP          CC          OO      OO  NN      NN  FF          55      55      ....
    LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            555555        ....
    LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            555555        ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         LYPCONF5 21-APR-1985 14:18   LPB0: 21-APR-1985 14:18   DISK$VAXUSER1:[USER1.RTAC]LYPCONF5.DAT;1        VAX.
VAX/VMS  RTAC         LYPCONF5 21-APR-1985 14:18   LPB0: 21-APR-1985 14:18   DISK$VAXUSER1:[USER1.RTAC]LYPCONF5.DAT;1        VAX.
VAX/VMS  RTAC         LYPCONF5 21-APR-1985 14:18   LPB0: 21-APR-1985 14:18   DISK$VAXUSER1:[USER1.RTAC]LYPCONF5.DAT;1        VAX.
```

```
100    05-AXLE TRACTOR-SEMITRAILER (CONF. 5 )
200    15500 ,64500
300    214217 ,4202700
400    60 76,59.24,107 24,100 28,228.28,0 ,0.,0 ,0.,0.,0
500    83.241,227.723
600    1400.,2880 ,2800 ,2480 ,2400
700    0 ,0.,0 ,0.,0.
800    52.5.,1,10.,1.05
900    240.,420.,420.,400.,400
1000   0 ,0.,0.,0.,0.
1100   20000 ,28000.,20000.,20000.,0 ,0
1200   0.,0.,0.,0.
1300   13.,13 ,13.,13 ,0 ,0.,0.,0 ,0 ,0
1400   8 ,.001,.1
1500   03
1600   0 ,0.
1700   .5,.5
1800   10., 5
```

APPENDIX F

Vehicle Configuration 6

Input Data Files

```
VAX/VMS  RTAC         P4CONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:53   DISK$VAXUSER1:[USER1.RTAC]P4CONF6.DAT;1         VAX/
VAX/VMS  RTAC         P4CONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:53   DISK$VAXUSER1:[USER1.RTAC]P4CONF6.DAT;1         VAX/
VAX/VMS  RTAC         P4CONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:53   DISK$VAXUSER1:[USER1.RTAC]P4CONF6.DAT;1         VAX/

                         RRRR   TTTTT   AAA   CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    666666
    PPPPPPPP    44    44      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    666666
    PP      PP  44    44    CC          OO      OO  NN      NN  FF          66
    PP      PP  44    44    CC          OO      OO  NN      NN  FF          66
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF          66
    PP      PP  44    44    CC          OO      OO  NNNN    NN  FF          66
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF    66666666
    PPPPPPPP    4444444444  CC          OO      OO  NN  NN  NN  FFFFFFFF    66666666
    PP                44    CC          OO      OO  NN    NNNN  FF          66      66
    PP                44    CC          OO      OO  NN    NNNN  FF          66      66
    PP                44    CC          OO      OO  NN      NN  FF          66      66      ....
    PP                44    CC          OO      OO  NN      NN  FF          66      66      ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF            666666        ....
    PP                44      CCCCCCCC    OOOOOO    NN      NN  FF            666666        ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA   CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC         P4CONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:53   DISK$VAXUSER1:[USER1.RTAC]P4CONF6.DAT;1         VAX/
VAX/VMS  RTAC         P4CONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:53   DISK$VAXUSER1:[USER1.RTAC]P4CONF6.DAT;1         VAX/
VAX/VMS  RTAC         P4CONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:53   DISK$VAXUSER1:[USER1.RTAC]P4CONF6.DAT;1         VAX/
```

```
100    5-AXLE DOUBLE / 27-FT TRAILERS (CONF. 6 )
200    02
300    33.5
400    003
500    0.,0.
600    0.5,4.5,4.5
700    10.,4.5,4.5
800    04
900    0.,0.
1000   2.5,0.
1100   2.6,0.
1200   10.,0.
1300   8.
1400   0.1
1500   00
1600   11100000
1700   120.
1800   8960.
1900   4240.
2000   44.
2100   15000.
2200   75000.
2300   75000.
2400   0.0
2500   8.73
2600   48.0
2700   20000.
2800   36.
2900   -119.
3000   04
3100   -20000.,-20.
3200   0.,0.
3300   9250.,7.2
3400   25000.,7.5
3500   0.08
3600   -20000.,-20.
3700   0.,0.
3800   8040.,7.2
3900   25000.,7.5
4000   0 08
4100   0.
4200   0.
4300   3719.
4400   23.
4500   0.00
4600   1500.
4700   32.
4800   80.0
4900   1200.
5000   0.0
5600   -1.
5700   03
5800   3000.,6000.,9000.
5900   01
6000   66.
6100   06
6200   0.,0.
6300   1.,.103
6400   2.,.333
6500   4.,.575
6600   6.,.708
6700   12.,.833
6800   06
6900   0.,0.
7000   1.,.143
7100   2.,.252
7200   4.,.458
7300   6.,.581
7400   12.,.693
7500   06
7600   0.,0.
7700   1.,.107
7800   2.,.194
7900   4.,.380
8000   6.,.518
8100   12.,.685
8200   05
8300   0.
8400   .04
8500   .1
8600   .5
8700   1.
8800   05
8900   0.
9000   4.
9100   8.
9200   12.
9300   16.
9400   1.,1.,.9,.3,.1
9500   1.,1.,.9,.3,.1
9600   1.,1.,.9,.35,.13
9700   1.,1.,.9,.42,.17
9800   1.,1.,.9,.48,.22
9900   -2.
10000  03
10100  3000.,6000.,9000.
10200  01
10300  66.
10400  05
10500  0.,0.
10600  .1,.68
10700  .2,.80
10800  .3,.77
10900  1.0,.55
11000  05
11100  0.,0.
11200  .1,.59
11300  .2,.75
11400  .3,.73
11500  1.,.50
11600  05
11700  0.,0.
11800  .1,.44
11900  .2,.70
12000  .3,.69
12100  1.,.45
12200  05
12300  0.
12400  .04
12500  .1
12600  .5
12700  1.
12800  05
12900  0.
13000  4.
13100  8.
13200  12.
13300  16.
13400  1.,1.,1.,1.,1.
13500  1.,1.,1.,1.,1.
13600  .75,.75,.75,.95,1.
13700  .5,.5,.6,.9,.95
13800  .4,.4,.45,.85,.95
13900  0.0
14000  -1600.
14100  0.,0.,5.0,0.8,
14200  4500.
14300  19.5
14400  103.
14500  00
14600  -131.
14700  09
14800  -26600.,-11.
14900  0.,-1.
15000  0.,0.
15100  5300.,1.
15200  8650.,1.5
15300  12650.,2.
15400  17300.,2.5
15500  22600.,3.
15600  66000.,4.0
15700  0.02
15800  -33000.,-11.
15900  0.,-.8
16000  0.,.2
16100  4000.,1.
16200  6650.,1.5
16300  10650.,2.
16400  15300.,2.5
16500  20600.,3.
16600  53000.,4.
16700  0.02
16800  0.0
16900  0.0
17000  4458.
17100  29.
17200  0.0
17300  8000.
17400  38.
17500  72.
17600  2300.
17700  13.
17800  -1.
17900  -2.
18000  0.0
18100  1200.
18200  4500.
18300  19.5
18400  115.
18500  0.05
18600  0.25
18700  1000.
18800  0
18900  0
19000  0.075
19100  0.25
19200  1500.
19300  252.
19400  2250.
19500  3750.
19600  60.0
19700  30000.
19800  93750.
19900  93750.
20000  25800.
20100  117.7
20200  85.0
20300  65000.
20400  375000.
20500  375000.
20600  36.
20700  44.
20800  00
20900  -132.
21000  09
21100  -37000.,-11.
21200  0.,-1.5
21300  0.,0.
21400  3750.,0.5
21500  8125.,1.
21600  13100.,1.5
21700  18750.,2.
21800  25000.,2.5
21900  62000.,3.
22000  0.02
22100  -44000.,-11.
22200  0.,-1.3
22300  0.,0.2
22400  1875.,0.5
22500  6250.,1.
22600  11250.,1.5
22700  16875.,2.
22800  23125.,2.5
22900  50000.,3.
23000  0.02
23100  0.0
23200  0.0
23300  4100.
23400  29.
23500  0.
23600  10000.
23700  38.
23800  72.
23900  1500.
24000  13.
24100  -1.
24200  -2.
24300  0.
24400  1200.
24500  4500.
24600  19.5
24700  115.
24800  0.175
24900  .25
```

```
25000    1500.            31100    1500.
25100    01               31200    -1
25200    80.              31300    00
25300    0.
25400    40.
25500    252.
25600    4250.
25700    4250.
25800    60.0
25900    36000.
26000    115000.
26100    115000.
26200    26500.
26300    126.
26400    85.0
26500    65000.
26600    375000.
26700    375000.
26800    00
26900    -132.
27000    0.0
27100    0.0
27200    4100.
27300    29.
27400    0.
27500    10000.
27600    38.
27700    72.
27800    1500.
27900    13.
28000    -1.
28100    -2.
28200    0.
28300    1200.
28400    4500.
28500    19.5
28600    115.
28700    00
28800    -132.
28900    0.0
29000    0.0
29100    4100.
29200    29.
29300    0.
29400    10000.
29500    38.
29600    72.
29700    1500.
29800    13.
29900    -1.
30000    -2.
30100    0.
30200    1200.
30300    4500.
30400    19.5
30500    115.
30600    0.225
30700    .25
30800    1500.
30900    0.275
31000    .25
```

```
VAX/VMS  RTAC      YRCONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:54   DISK$VAXUSER1:[USER1.RTAC]YRCONF6.DAT;1        VA
VAX/VMS  RTAC      YRCONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:54   DISK$VAXUSER1:[USER1.RTAC]YRCONF6.DAT;1        VA
VAX/VMS  RTAC      YRCONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:54   DISK$VAXUSER1:[USER1.RTAC]YRCONF6.DAT;1        VA

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    666666
    YY      YY  RRRRRRRR      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    666666
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          66
    YY      YY  RR      RR  CC          OO      OO  NN      NN  FF          66
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF          66
      YY  YY    RR      RR  CC          OO      OO  NNNN    NN  FF          66
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF    66666666
        YY      RRRRRRRR    CC          OO      OO  NN  NN  NN  FFFFFFFF    66666666
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF          66      66
        YY      RR  RR      CC          OO      OO  NN    NNNN  FF          66      66
        YY      RR    RR    CC          OO      OO  NN      NN  FF          66      66    ....
        YY      RR    RR    CC          OO      OO  NN      NN  FF          66      66    ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF            666666      ....
        YY      RR      RR    CCCCCCCC    OOOOOO    NN      NN  FF            666666      ....

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS  RTAC      YRCONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:54   DISK$VAXUSER1:[USER1.RTAC]YRCONF6.DAT;1        VAX.
VAX/VMS  RTAC      YRCONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:54   DISK$VAXUSER1:[USER1.RTAC]YRCONF6.DAT;1        VAX.
VAX/VMS  RTAC      YRCONF6 30-APR-1985 12:53   LPB0:  30-APR-1985 12:54   DISK$VAXUSER1:[USER1.RTAC]YRCONF6.DAT;1        VAX.
```

```
100    5-AXLE DOUBLE / 27-FT TRAILERS (CONF. 6 )
200    0405
300    40.,8.,1.,.02
400    02010101
500    9700.,30300.,1000.,31000.
600    15000.,101204.,1900.,108375
700    75000.,475638.,2560.,497375.
800    75000.,469434.,2560.,490000.
900    44.,81.3,44.,80.7
1000   10000.,17500.,17500.,17500.,17500.
1100   1200.,2300.,1500.,1500.,1500.
1200   3719.,4458.,4100.,4100.,4100.
1300   24.,-96.,-119.,0.,-126.
1400   19.5,19.5,19.5,19.5,19.5
1500   23.,29.,29.,29.,29.
1600   16.,19.,19.,19.,19.
1700   40.,29.5,29.5,29.5,29.5
1800   0.,13.,13.,13.,13.
1900   4500.,4500.,4500.,4500.,4500.
2000   0.,0.,0.,0.,0
2100   1500.,8000.,10000.,10000.,10000
2200   300.,1000.,1000.,1000.,1000
2300   0.,0.,0.,0.,0.
2400   -87.27,133.07,-154.93,80.,0.,126.
2500   48.,44.,48
2600   1000000.,0.,1000000.
2700   010304
2800   03
2900   0102030303
3000   04
3100   -20000.,-20.
3200   0.,0.
3300   8645.,7.2
3400   25000.,7.5
3500   07
3600   -29000.,-11.
3700   0.,-1
3800   0.,0.
3900   4650.,1.
4000   7650.,1.5
4100   11650.,2.
4200   16300.,2.5
4300   21600.,3
4400   59500.,4.
4500   09
4600   -40500.,-11.
4700   0.,-1.5
4800   0.,0.
4900   2812.,0.5
5000   7108.,1.
5100   12175.,1.5
5200   17713.,2
5300   24063.,2.5
5400   56000.,3.
5500   01
5600   0101010101
5700   0406
5800   0.,1.0,2.0,4.0,6.0,12.0
5900   3000.,540.,990.,1710.,2130.,2490.
6000   6000.,840.,1500.,2760.,3480.,4140.
6100   9000.,990.,1710.,3420.,4680.,6210.
```

```
6200   02
6300   0102020202
6400   0407
6500   0.0,1.0,3.0,4.0,5.0,7.0,10.0
6600   3000.,55.,92.,100.,120.,125.,100.
6700   6000.,130.,261.,300.,354.,373.,332.
6800   9000.,200.,452.,533.,625.,650.,565.
6900   0405
7000   0.,1.,2.,3.,4.
7100   3000.,29.,42.,44.,38.
7200   6000.,92.,150.,157.,146.
7300   9000.,152.,269.,329.,335.
7400   1.
7600   006
7700   0.,0.
7800   0.5,6.,6.
7900   1.,0.,0
8000   1.5,-6.,-6.
8100   2.,0.,0
8200   4.,0.,0.
```

```
VAX/VMS   RTAC        LYPCONF6 30-APR-1985 12:53   LPBO: 30-APR-1985 12:55   DISK$VAXUSER1:[USER1.RTAC]LYPCUNF6.DAT;1        VAX/
VAX/VMS   RTAC        LYPCONF6 30-APR-1985 12:53   LPBO: 30-APR-1985 12.55   DISK$VAXUSER1:[USER1 RTAC]LYPCONF6.DAT;1        VAX/
VAX/VMS   RTAC        LYPCONF6 30-APR-1985 12:53   LPBO: 30-APR-1985 12:55   DISK$VAXUSER1.[USER1.RTAC]LYPCONF6.DAT;1        VAX/

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

    LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    666666
    LL          YY      YY  PPPPPPPP      CCCCCCCC    OOOOOO    NN      NN  FFFFFFFFFF    666666
    LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          66
    LL          YY      YY  PP      PP  CC          OO      OO  NN      NN  FF          66
    LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF          66
    LL            YY  YY    PP      PP  CC          OO      OO  NNNN    NN  FF          66
    LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF    66666666
    LL              YY      PPPPPPPP    CC          OO      OO  NN  NN  NN  FFFFFFFF    66666666
    LL              YY      PP          CC          OO      OO  NN    NNNN  FF          66      66
    LL              YY      PP          CC          OO      OO  NN    NNNN  FF          66      66
    LL              YY      PP          CC          OO      OO  NN      NN  FF          66      66
    LL              YY      PP          CC          OO      OO  NN      NN  FF          66      66
    LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            666666
    LLLLLLLLLL      YY      PP            CCCCCCCC    OOOOOO    NN      NN  FF            666666

    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;        11
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT          ;;;;      1111
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT                      11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AA      AA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AAAAAAAAAA      TT          ;;;;        11
    DD      DD  AA      AA      TT            ;;        11
    DD      DD  AA      AA      TT            ;;        11
    DDDDDDDD    AA      AA      TT          ;;        111111
    DDDDDDDD    AA      AA      TT          ;;        111111

                         RRRR   TTTTT   AAA    CCCC
                         R   R    T    A   A  C
                         R   R    T    A   A  C
                         RRRR     T    A   A  C
                         R R      T    AAAAA  C
                         R  R     T    A   A  C
                         R   R    T    A   A   CCCC

VAX/VMS   RTAC        LYPCONF6 30-APR-1985 12:53   LPDO: 30-APR-1905 12.55   DISK$VAXUSER1:[USER1.RTAC]LYPCONF6.DAT;1        VAX/
VAX/VMS   RTAC        LYPCONF6 30-APR-1985 12:53   LPDO: 30-APR-1985 12:55   DISK$VAXUSER1:[USER1.RTAC]LYPCONF6.DAT;1        VAX/
VAX/VMS   RTAC        LYPCONF6 30-APR-1985 12:53   LPBO: 30-APR-1985 12:55   DISK$VAXUSER1:[USER1.RTAC]LYPCONF6.DAT;1        VAX/
```

```
 100   5-AXLE DOUBLE / 27-FT TRAILER (CONF. 6 )
 200   13200.,47800 ,2300.,32500.
 300   132646.64,525908 56,2560.,621580 25
 400   38.545,81 455,0.,113.323,0 ,0.
 500   0.,0.,126.,0.,0.
 600   72.725,138.677,149 323,80.,0.,126.
 700   1500.,2800.,0.,2800.,0.,0.
 800   2800.,0.,2800.,0 ,0.
 900   31.5,0 1,10.,1.05
1000   266.7,400.,0 ,400.,0.,0.
1100   400 ,0.,400.,0.,0.
1200   28000.,0.,28000 ,0.,0.,28000.
1300   0.,28000.,0.,0.
1400   13.,0.,13.,0.,0.,13.,0.,13.,0.,0.
1500   8 ,.001, 1
1600   03
1700   0 ,0.
1800   .5,2.
1900   10.,2.
```

APPENDIX G

Basic Parameters of a 5-axle, Dirt Truck

WU1 = 1500 (lb) Weight of first unsprung mass

WU2 = 3000 (lb) Weight of second unsprung mass

WU3 = 4000 (lb) Weight of third unsprung mass

WAX1 = 18,000 (lb) Vertical load on the first axle

WAX2 = 26,000 (lb) Vertical load on the second axle

WAX3 = 26,000 (lb) Vertical load on the third axle

T1 = 40.25 (in.) Half track width of the inner tires on the first axle

T2 = 29 (in.) Half track width of the inner tires on the second axle

T3 = 29 (in.) Half track width of the inner tires on the third axle

A1 = 0 (in.) Dual tire spacing on the first axle

A2 = 13 (in.) Dual tire spacing on the second axle

A3 = 13 (in.) Dual tire spacing on the third axle

S1 = 16 (in.) Half spring spacing at the first axle

S2 = 19 (in.) Half spring spacing at the second axle

S3 = 19 (in.) Half spring spacing at the third axle

ZS1 = 44 (in.) Height of c.g. of the first sprung mass, above ground level

ZS2 = 44 (in.) Height of c.g. of the second sprung mass, above ground level

ZS3 = 84.6 (in.) Height of c.g. of the third sprung mass, above ground level

R1 = 21 (in.) Rolling radius of tires on the first axle

R2 = 20 (in.) Rolling radius of tires on the second axle

R3 = 20 (in.) Rolling radius of tires on the third axle

HR1 = 22 (in.) Height of roll centre of the first suspension above ground level

HR2 = 29 (in.) Height of roll centre of the second suspension above ground level

HR3 = 29 (in.) Height of roll centre of the third suspension above ground level

ZS = 48 (in.) Height of the fifth wheel centre above ground level

MFR = 40,000 (lb/deg.) Tractor Frame torsional stiffness

ZFR = 34 (in.) Tractor frame torsional axis height above ground level

KT11 = 8000 (lb/in.) Vertical stiffness of tires per side on the first axle

KT21 = 10,000 (lb/in.) Vertical stiffness of tires per side on the second axle

KT31 = 10,000 (lb/in.) Vertical stiffness of tires per side on the third axle

KRS1 = 0 (lb/in./deg.) Auxiliary roll stiffness of the first suspension

KRS2 = 20,000 (lb/in./deg.) Auxiliary roll stiffness of the second suspension

KRS3 = 0 (lb/in./deg.) Auxiliary roll stiffness of the third suspension

LASH5 = 0.1 (in.) Lash in the fifth wheel

COULFR = 11,000 (in.lb/deg.) Coulomb friction present in the tractor frame

M5 = 1,000,000 (in./lb/deg.) Torsional stiffness of the fifth wheel

MOMSEP = 900,000 (in./lb) Roll moment that causes separation of the fifth wheel plates

WS = 30,000 (lb) Vertical load on the fifth wheel

WS2 = 500 (lb) Weight of the second sprung mass

KOVT1 = 1000 (in./lb/deg.) Overturning stiffness of the tires on the first axle

KOVT2 = 2000 (in./lb/deg.) Overturning stiffnesses of the tires on the second axle

KOVT3 = 2000 (in./lb/deg.) Overturning stiffnesses of the tires on the third axle

a) First Suspension Spring Table

Force (lb)	Deflection (in.)
-10,000	-5
14,250	7.13
40,000	7.25

b) Second Suspension Spring Table

Force (lb)	Deflection (in.)
-20,000	-10
20,000	10

c) Third Suspension Spring Table

Force (lb)	Deflection (in.)
-15,000	-1.75
0	-0.75
0	0
15,000	1