THE UNIVERSITY OF MICHIGAN HIGHWAY SAFETY RESEARCH INSTITUTE

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The YAW Stability of tractor-semitrailers during cornering

APPENDICES

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The yaw stability of t	ractor-semit	ailers in steeri	ng-only man	euvers is					
examined by means of com	puter simular	tion and full-sca	le tests.	The tests					
front suspension stiffen	ing elements	installed. Resu	ilts show th	nat while					
tractor yaw instability	can occur we	11 below the roll	over thresh	nold for					
certain vehicles, modified stiffness parameters can eliminate such pre-									
<pre>mature yaw instability. Simulation study of the influence of design and operating variables on</pre>									
tractor yaw stability served to classify the relative importance of differ-									
ent suspension stiffness options, as well as tire mix, fifth wheel place-									
ment, and trailer loadin	g practices.	Results show th	at remarkat	oly low					
design and in-use variab	les.								
A set of measurements	of tractor-	semitrailer ride	vibrations	is also					
reported as an add-on ta	sk to this s	tudy.							
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THE YAW STABILITY OF TRACTOR SEMITRAILERS DURING CORNERING

Appendices

R.D. Ervin R.L. Nisonger C. Mallikarjunarao T.D. Gillespie

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APPENDIX I

SURVEY OF ACCIDENT DATA

In this appendix are presented accident data summarizing the content of the BMCS data file for 1976, as sorted for tractor-semitrailer combinations, only. The data are presented to show the jackknife (JK), overturn (OT), other, and total accidents occurring for trailer body type and cargo type for each of four possible combinations of tractor and trailer axle arrangements. Separate tables are provided for each of the configurations: (2/1), (2/2), (3/1), and no. of semitrailer axles . For each three-line no. of tractor axles (3/2), representing row of data, the top line lists the number of accidents of the JK, OT, and Other type represented in the file, the second line (called Row %) lists the percentage of that vehicle's total accidents which were of the JK, OT, or Other type, and the third line lists the percentage of all JK, OT, or Other accidents in which that particular vehicle category was involved.

Comb. Config. (2/1) - by Trailer Type E 10

		(1) XC	(2) 0T	(3) OTHER	(TOTAL)
Van	(1) (row x) (col x)	36 3.0 85.7	7378.5	896 89.7 81.2	999 100.0 81.1
Flat	(2) (ROM %) (COL %)	000 •• 02	7.7 5.4	92.69 5.4	65 100,0 5,3
Tank	(3) (ROW X) (COL X)	2 ° 1	11.1 3.2	23 85•2 2•1	27 100.0 2.2
Auto Carrier	(4) (70 x) (20 x)		888 • 96	28 190.0 2.5	109.28 2.3
Dump	(8) (Row X) (Col X)	000 •• 000	693 69	190.2 0.2 0.2	109.2 0.2
Unknown	(7) (row x) (col x)	5.1 1.4	7.7 6.5	68 87.2 6.2	78 190.0
Other	(8) (row x) (col x)	200 90 20	18 6 18 18 18 18 18 18 18 18 18 18 18 18 18	27 81.8 2.4	160.33 2.7
* • •	(TOTAL) (ROW X) (COL X)	35 2 8 108 8	100.03	1104 89•6 102•0	1232 1709 B 1708 B

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212 Type OWT aller

100.0 2.5 1934 68.0 89.0 158 169.0 8.2 103.0 49 (TOTAL) 100.0 3.1 27 100.0 1.4 1477 100.0 76.4 126 00.0 6.5 100.0 89 1755 90.7 90.7 (3) 0THER 1342 90.9 42 85.7 2.4 143 88•6 8•0 100.0 0.4 100.0 1.1 27 100.0 80 89.9 4.6 116 92.1 6.6 76 3.9 100.0 8°2 0°0 5 ° N (2) 59 4.0 77.6 0.0 0 5.6 6.6 0.0 0.0 2 N S 103 5.3 100.0 2.9 2.9 50.0 14 8 9 3 6 000 •• 00 0.0 6 4 6 5 8 6 4°5 5×|2 5.1 (5) Refrigerated (ROW %) (COL %) (T0TAL) (R0W %) (C0L %) (7) (ROW X) (COL X) (8) (row x) (col x) (6) (ROW X) (COL X) (3) (ROW X) (COL X) Auto Carrier (ROW X) (COL X) (2) (ROM %) (COL %) (ROH X) (COL X) Other . Unknown Dump Tank Flat Van



ł,		(1)	(Z) 01	(3)	(TOTAL)
Van	(1) (Row %) (Col %)	60 × 20	6 6.7 85.7	01HEI 81 52.9	120 120 54.5
Flat	(2) (ROW %) (COL %)	8 8 • 8 8 8	00 200 200	15 108.0 9.6	150.0 190.0 9.1
Tank	(3) (ROW X) (COL X)	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	00 000 000	6 1 20 6 3 • 9	102.6 3.6
Auto Carrier	(4) (70% %) (70[%)		000 000	28 100 - 0 18 - 3	28 100.0 17.0
Jnknown	(7) (804 %) (Col %)	6.7 20.0	6.1 14.3	86.7 8.5	100.0 0.0
)ther	(8) (80W %) (COL %)	1 9.1 23.0	00 00 00	96 - 59 6 - 5	11 100.0
	(TOTAL) (row x) (col x)	3.0 180.0	4 - 2 100.0	153 92.7 100.0	165 100.0 100.0

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1. (3/ Trailer 14PE

6,66(8 618 182.0 12577 100.0 100.0 352 100.0 2.8 73 160.0 0.6 774 109.0 6.2 212 103.3 (JATUT: 2453 89.8 1208 89.1 82.0 315 89.5 2.8 692 89.4 6.2 (3) 0THER 5867 65 84 6 8 6 387 98.5 3.5 185 87.3 1.7 2213' 88.7 52.3 1487 87.4 13.3 936 7.4 100.0 6 8 6 8 7 $(2) \\ 01 \\ 171 \\ 7.1 \\ 7.1 \\ 50.3$ 156 9.2 16.7 7.1 5.9 13.7 7.5 1.7 1.30.5 199 8.1 21.3 434 30.00 21 2.5 6.2 1.40.2 Ю. 3 0. 2 13.59 13.6 1.79.5 1 (TOTAL) (ROW %) (COL %) (7) (80W %) (col %) (8) (ROW %) (COL %) (6) (ROW %) (COL %) (5) (ROM X) (COL X) (4) (ROM X) (COL X) (3) (ROW 2) (COL 2) (1) (row x) (col x) (2) (2) (2) (2) Auto Carrier Refrigerated Unknown Other Dump Flat Tank Van

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Comb. Coutig. (2/1) - by Trailer Cargo Type

			(2) (12)	(3)	(Total)
Empty	(1) (row x) (col x)	14.00	5.00	188 188 17.0	195 100.0 15.8
Bulk Frt.	(2) (Row %) (Col %)	8 3 - 6 8 2 - 9	83 8•5 9•2	864 88•5 78•3	976 100.0 75.2
Metal, Hvy. Mach.	(3) (ROW X) (COL X)	000 00	22.5 5.4	77 17 77 3 1.5	22 100.0 1.8
Motor Vehićl	es (CoL x)	- M 0 • •	000 00 00	, 18 94.7 1.6	19 183.8 1.5
Bulk Liquids	(6) (row 2) (col 2)	600 60	15°2 25°2 20°2	11 84.6 1.0	100.0 1.1
Misc.	(7) (704 2) (201 2)	0000 •• 99	25.8 1.1	75. 3 0. 3	100.0 0.3 0.3
Unknown	(8) (804 x) (col x)	000 000		100.0 0.3	100.0 202.2
	(T0TAL) (R0W %) (C0L %)	35 2.8 100.0	93 7 5 100 0	1104 89.6 100.0	1232 100.0 100.0

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-by Trailer Cargo Type

			(1) //	(2)	(3) OTUED	(TOTAL)
Empty	CROW CCOL		12.2	000 000 000	314 314 87.2 17.9	360 100.0 18.6
Bulk Frt.	C ROW	222	56 3.9 54.4	67 4.6 [,] 88.2	1321 91.5 75.3	1444 160 · 0 71 · 7
Metal, Hvy. Mach.	(ROW)	() () () () () () () () () () () () () (4°7	0 -1 N N F	39 90.7 2.2	43 199.9 2.2
Motor Vehicles	(KOW) (KOW)		ତ ତ ଭ ତ ତ ତ ତ	202 •• 80	26 100.0 1.5	26 100.0 1.3
Draway/ Towaway	(ROW)		ସ ତ ଦ ଜ ଜ ତ	808 89	100.0 0.1	103.0 0.1
Bulk Liquids	(ROW) (COL)	(%)	5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	10.5 6.6	89 44 208	49 100.0
Misc.	() (row) (col x	(22 G 00	800 80 80	100 3 2 6 2 6 2 6	100.0 0.2
Unknown	CROW 3 CCOL 3		12.5 1.0	0 2 0 • • 0	7 87.5 0.4	8 100 8 20 4
	(TOTAL (ROW) (COL)	199	183 5.3 02.0	76 3.9 100.3	1755 90.7 100.0	1934 188.8 188.8

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Comb. Contrg. (3/1) Ley Trailer Cargo Type

			(2)	(3)	(TOTAL)
Empty	(1) (ROW %) (COL %)	000	0 0 0 0 0 0 0 0 0	100.00 17.0	100-26 100-0 15-8
Bulk Frt.	(2) (ROW %) (Col %)	4 4 8 3 6 8 3	7 7.3 100.0	88 88 55 6 55	96 100.0 58.2
Metal, Hvy. Mach.	(3) (row %) (col %)	20.0	803 80 80	80 € € 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	100.0 5.0
Motor Vehicles	(4) (ROW %) (COL %)	000 •• 00	69 •• 890	30 100 6 19 6	33 198.9 18.2
Bulk Liquids	(6) (700 x) (701 x)	222 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	000 •• 00	1 80 8 1 • 3	100 0 1.2
Misc.	(7) (row 2) (col 2)	800 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	000 •• 00	1 00.0 0.7	1 183.8 0.6
Unknown	(8) (Row %) (Col %)	8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	00 •• 000	1 100.0 0.7	1 89 - 0 - 6
2 2	(T0TAL) (R0W %) (C0L %)	3.9 100.0	4.2 100.0	153 92.7 100.0	165 199.0 100.0

-by Tailer Cargo Type Comb. Contrg. (3/2) PO 00 il.

			(2) 01	(3) OTHED	(TOTAL)
Empty	(1) (row %) (col %)	199	1.07	2484 92.0 22.2	(2701 103.0 21.5
Bulk Frt.	(2) (2) (2)	211 2.9 4.8.7	663 9.2 70.8	633 <u>0</u> 87.9 56.5	7204 · 193.0 57.3
Metal, Hvy. Mach.	(3) (row 2) (col 2)	N . 7 9	101 7.7 10.8	1208 91.7 10.8	1318 170.0 10.5
Motor Vehicles	(4) (80W %) (Col %)	. 90 • •	0 • 6 • 6	306 98.1 2.7	312 100.0 2.5
Drawa <i>y/</i> Towaway	(S) (ROW X) (COL X)	58.2 8.2	032 99	S 80 80 80	100.0 0.0
Bulk Liquids	(6) (row x) (col x)	7 0.8 1.6	133 14 4 14 2	782 84•8 7•0	922 100.0 7.3
Misc.	(7) (ROW X) (ÇOL X)	90 90 90 90 90	13.8	81 65 81 65 8 65	1 8 9 9 6 6
Unknown	(8) (ROW 2) (COL 2)	ณ M เก • • @ ณ	10.5 0.5	32 84.2 0.3	38 193.0 0.3
	(T0TAL) (R0M %) (C0L %)	433 3.4 103.2	936 7 4 100 0	11208 89.1 100.0	12577 160.0 100.0

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APPENDIX II

VEHICLE PARAMETER LISTINGS

Listed in this appendix are the parameters used for the purpose of simulating the directional response of tractor-semitrailer-type vehicles using the Phase II simulation [1]*. The eight sets of parameters listings included here correspond to the <u>baseline configuration</u> of each vehicle combination for which a parameter variation study was conducted. The eight vehicle combinations are described below:

- 1) International Harvester tractor/Fruehauf van trailer
- 2) Ford tractor/Fruehauf van trailer
- 3) Ford tractor/Trailmobile flat-bed trailer
- 4) 110" wheelbase, two-axle, C.O.E. tractor/single-axle,40' van trailer
- 5) 140" wheelbase, two-axle, C.O.E. tractor/single-axle,40' van trailer
- 6) 145" wheelbase, three-axle, C.O.E. tractor/tandem-axle,45' van trailer
- 7) 165" wheelbase, three-axle, conventional tractor/tandemaxle, 45' van trailer
- 200" wheelbase, three-axle, conventional tractor/tandemaxle, 45' van trailer

Additional explanation of the meaning of each parameter is given in the Phase II technical report [1].

Tire Data

The tire data (which turns out to be very lengthy if listed for each tire mounted on a vehicle) has not been included in the main listings of

^{*}Numbers in brackets refer to references provided in this appendix at the conclusion of the explanatory text.

each set of vehicle parameters. Rather, the specific tires employed with each vehicle configuration are simply identified by manufacturer and size. Tire parameters, themselves, are then listed for each of the identified tires at the conclusion of the presentation of all vehicle parameters.

With reference to the tire data, it should be noted that the parameters describing the cornering stiffness characteristics were obtained by curve-fitting the measured lateral force-sideslip angle data. A detailed description of the tire model and the definition of the curvefitting parameters is given in Appendix B of [2].

Parameters Values Used in the Parameter Variation Study

The first three data sets were used for the purpose of studying the sensitivity of tractor yaw stability to changes in tractor roll stiffness distribution. The two parameters that are varied are the tractor frame stiffness, TTC, and the auxiliary roll stiffness at the tractor front axle, KRS(1). For each vehicle combination, the parameter TTC was varied from 20,000 in-lb/deg (for the baseline case) to 140,000 in-lb/deg, in steps of 20,000 in-lb/deg; while the parameter KRS(1) was varied from 0.0 in-lb/deg (for the baseline case) to 150,000 in-lb/deg in steps of 25,000 in-lb/deg. For cases in which the tires on the tractor rear axles are replaced by lug tires, tire data corresponding to the Uniroyal 10x20 Fleetmaster Superlug were used.

The data sets four through eight were used for the purpose of studying the influence of the following parameters on the yaw divergency and rollover behavior of tractor-semitrailers:

- Kl Tractor front axle suspension stiffness (lb/in)
- K2 Tractor rear axle suspension stiffness (lb/in)
- K3 Trailer suspension stiffness (lb/in)
- BB Longitudinal distance of fifth wheel from the midpoint of the tractor tandem (in)
- PZ Height of payload center of gravity above ground level (in)

The values of these five parameters for each of the 24 configurations are given in Table II.1. Once again, for cases in which the tractor rear tires are replaced by lug tires, tire data corresponding to the Uniroyal 10x20 Fleetmaster Superlug were used.

Estimation of Frame Compliance Parameters TTC and TRSTF

In the modified version of the Phase II tractor-semitrailer model the roll compliances of the tractor and trailer frame are represented by the lumped-stiffness parameters TTC and TRSTF, respectively. In reality, both the mass and compliance pertaining to the sprung masse elements are distributed along the length of the tractor and trailer frames. Hence, unless proper care is taken in estimating these parameters, the calculations made using the model can be in error (especially for the cases in which the structures are highly compliant). The method adopted for calculating these parameters is presented in the following paragraphs.

<u>Tractor Frame Stiffness Parameter TTC</u>. Typical layouts of engines and transmissions of commercial tractors cause the sprung mass of the tractor to be located near the front axle. Typical torsional compliance values for the portion of the tractor frame that extends from the tractor sprung mass center to the front axle are small, and thus can be neglected for the purposes of these simulations. The tractor frame stiffness parameter, TTC, can thus be defined as the measured (or estimated) torsional stiffness of the entire length of the frame from tractor front axle to the tractor rear axle.

<u>Trailer Frame Stiffness Parameter TRSTF</u>. Unlike the tractor, the trailer frame compliance and mass are more evenly distributed along the length of the frame. Hence, two problems arise with regard to representing the trailer as a lumped parameter model.

 Due to the distributed nature of both the mass and the frame compliance, the measured (or estimated) static torsional frame stiffness cannot be used directly as the value for the lumped stiffness parameter TRSTF (as was possible for TTC).

Table II.1

		AR ANLE	MOT	50 850 850	000 2000 11000	000 5000 5000	68 78 88	550 B50 850	2000 12000 12000	0.0 0.0 0.0	000 5000 5000	68 78 68	100 1100 1100	00091 000 91 0009	0.0 0.0 0.0	000 8000 8000	68 78 88	100 1100 1100	00091 00091 0000	0.0 0.0 0.0	3000 0000 000		100 1100 1100	0009 10000 10000	0.0 0.0 0.	000 800 800	68 78 88	(F) (F)
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			susp. vess	X	X 2	88	X d	×	×	86	×	ď	X	X	à	×	à	X	X 2	0	×	6	×	×	0	*	2	
			TRAILER STIFF.	110 11 0 2 AVIE	COLE TRACTOR -	SINGLE AXLE	40' TRAILER	IAN W.B. ZAXIE	COLE TREETOR-		SINGLE AXLE	40' TRAILER	LAS THA ZAXIE	142 W.B. JAANS		TANDEH AXLE	45' TRAILER	DE TANE	DIVIC (.O.M. CO)	CONV. IKALION -	TANDEM AXLE	45' TRAILER	JINC BII.	200 Marchan 002	CONV. TRALTOR-	TANDEM AXLE	4 S' TRAILER	

* NOTE: "-' denotes , value same as stat in column O

 There is no provision in the model for incorporating the compliance of that portion of the frame which extends from the trailer sprung mass center to the trailer rear axles.

With reference to Figure II.1, we note that a steady turn of lateral acceleration, a_y , causes a total roll moment of $(M \cdot a_y \cdot h_T)$ to act on the frame. If the mass and stiffness are uniformly distributed, it can be shown that the twist deflection, ϕ , at the midpoint of the frame with respect to the ends is given by

$$\phi = \frac{Mh_{T}a_{y}}{8K}$$
(1)

If the trailer is to be represented by a lumped parameter model and if an authentic deflection, ϕ , is to take place, then the springs that connect the sprung mass to the fifth wheel and to the rear suspension should have a torsional stiffness of 4K each. Therefore, the value used for TRSTF is four times the measured (or estimated) stiffness of the trailer frame.

Next, the influence of the compliance in the trailer frame, which extends from the sprung mass c.g. to the trailer suspension, is accounted for by using suitable values for the trailer suspension roll center height and roll stiffness.

A schematic view of the rear section of the trailer is shown in Figure II.2. From static equilibrium, it can be shown that the moment, T, transmitted to the trailer sprung mass from the trailer rear suspension is given by the expression:

$$T = SMY(h_{2} + \frac{K_{2}h_{1}}{(K_{1} + K_{2})}) + \frac{K_{1}K_{2}}{K_{1} + K_{2}} (\phi_{1} - \phi_{3})$$
$$= SMY \cdot h_{eq} + K_{eq} \cdot (\phi_{1} - \phi_{3})$$

or







h_t = height of sprung mass c.g. above the frame compliance axis
 M = Sprung mass of the trailer
 a_y = Lateral acceleration of the turn
 k = Static stiffness of the trailer



.



Figure II.2

$$RCH_{eq} = RCH + h_{1} + h_{2} - h_{eq}$$

$$RCH_{eq} = RCH + \frac{h_{1}K_{1}}{(K_{1}+K_{2})}$$

$$K_{eq} = \frac{K_{1}K_{2}}{K_{1}+K_{2}}$$

$$KRS = K_{eq} - K_{1}$$

$$KRS = \frac{-K_{1}^{2}}{(K_{1}+K_{2})}$$

Therefore, the actual roll center height, RCH, of the trailer suspension is replaced by the equivalent roll center height, RCH_{eq}. The reduction in the effective stiffness of the trailer suspension is accounted for by using a negative auxiliary roll stiffness of $-K_1^2/(K_1+K_2)$.

The above method was adopted for computing the parameters, TRSTF, KRS(3), and RCH(3) for the flat-bed trailer in this study. The stiffness of the van trailer frame was found to be sufficiently high (almost four times the stiffness of the trailer suspension) that no correction was found necessary.

References

- Bernard, J.E., Winkler, C.B., and Fancher, P.S. "A Computer-Based Mathematical Method for Predicting the Directional Response of Trucks and Tractor-Trailers." Phase II Technical Report: Motor Truck Braking and Handling Performance Study, Report No. UM-HSRI-PF-73-1, Highway Safety Research Institute, University of Michigan, June 1, 1973.
- Moncarz, H., Bernard, J.E., Gupta, R., and Fancher, P.S. "Vehicle-In-Use Limit Performance and Tire Factors, Appendix B." Final Report, Contract No. DOT-HS-031-3-693, Report No. UM-HSRI-PF-75-1-3, Highway Safety Research Institute, University of Michigan, January 31, 1975.

VEHICLE PARAMETER LISTINGS

	HSRI TRACTOR-TRAIL	FR HANDLING STMULATION
	PAG	E NO 1
IHC-TRACTOR	R VAN TRLER LOADED, 10X22, 10X20 FIRESTONE-TIRES	*1A3 1B3*
INPUT PARAME	ETER TABLE	
SYMBOL	DESCRIPTION INITIAL '	VALUE
KEY(1)	TRACTOR AXLE KEY: 0 FOR SINGLE AXLE	
	1 FOR WALKING BEAM	
	2 FOR 4 ELLIPTIC LEAF	2
KEY(2)	TRAILER AXLE KEY	2
AAi	HURIZUNTAL DISTANCE FURM TRACTUR FRUNT	34 00
222	HODIZONTAL DISTANCE FROM TRACTOR PEAR	24.00
AR2	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	24-00
AA4	HORIZONTAL DISTANCE FROM TRACTOR FRONT	21000
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	1.00
AA5	HORIZONTAL DISTANCE FROM TRACTOR REAR	
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	1.00
ААб	VERTICAL DISTANCE FROM AXLE DOWN TO	
	TRACTOR TORQUE ROD (IN)	0.0
AA/ .	ANGLE BETWEEN TRACTOR TORQUE ROD AND	0.0
110	HORIZONIAL (DEG) HORIZONTAL DISTANCE EDOM AVIE CENTED	0.0
ANU	FORWARD TO TRACTOR TOROUE ROD (IN)	0.0
229	HORIZONTAL DISTANCE FROM TRAILER FRONT	0.0
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA10	HORIZONTAL DISTANCE FROM TRAILER REAR	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA12	HORIZONTAL DISTANCE FROM TRAILER FRONT	
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA13	HORIZONTAL DISTANCE FROM TRAILER REAR	6 55
2214	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	0.25
AA14	TRALE DISTANCE FROM ALL DOWN TO	7 00
AA15	ANGLE BETWEEN TRAILER TOROUE ROD AND	
	HORIZONTAL (DEG)	15.01
AA16	HORIZONTAL DISTANCE FROM AXLE CENTER	
	FORWARD TO TRAILER TORQUE ROD (IN)	5.50
Al	HORIZONTAL DISTANCE FROM TRACTOR CG TO	35.00
30	CENTER OF TRACTOR FRONT SUSPENSION (IN)	35.90
R2	CENTER OF TRACTOR REAR SUSPENSION (IN)	106.10
A3	HORIZONTAL DISTANCE FROM TRAILER CG TO	200020
	5TH WHEEL (IN)	230.50
A4	HORIZONTAL DISTANCE FROM TRAILER CG TO	
	CENTER OF TRAILER SUSPENSION (IN)	179.50
ALPHA1	STATIC DISTANCE, TRACTOR FRONT AXLE TO	
	GROUND (IN)	20.30
ALPHA2	CROWND (IN)	20 30
AT DHA 3	STATIC DISTANCE TRAILER AVIE(S) TO	20.30
APLIND	GROUND (IN)	19,50
ANl	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
	FRONT TIRES	0.250
AN2	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
	FRONT TANDEM TIRES	0.250
AN 3	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	0.050
A NI A	REAR TANDEM TIRES TTDE DEESSUDE DIST FUNCTION FOR TRATIOR	0.250
AN4	FRONT TANDEM TIRES	0.250
AN 5	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	
	REAR TANDEM TIRES	0.250
BB	HORIZONTAL DISTANCE FROM 5TH WHEEL TO MIDPOINT	
	OF TRACTOR REAR SUSPENSION (IN)	0.0
CI	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT	10.00
C2	VISCOUS DAMPING: REBOUND ON TRACTOR FRONT	10.00
	SUSPENSION (LB-SEC/IN)	20.00
C3	VISCOUS DAMPING: JOUNCE ON TRACTOR REAR	
	SUSPENSION (LB-SEC/IN)	10.00
C4	VISCOUS DAMPING: REBOUND ON TRACTOR REAR	30.00
C5	VISCOUS DAMPING: JOUNCE ON TRATIER	20.00
~ 5	SUSPENSION (LB-SEC/IN)	10.00
C6	VISCOUS DAMPING: REBOUND ON TRAILER	
	SUSPENSION (LB-SEC/IN)	20.00

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CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	
CFI	(LBS/DEG) MAXIMUM COULOMB FRICTION, TRACTOR FRONT	-1.00
	SUSPENSION (LB)	500.00
CF2	MAXIMUM COULOMB FRICTION, TRACTOR REAR	500 00
CF3	MAXIMUM COULOMB FRICTION, TRAILER	500.00
	SUSPENSION (LB)	1500.00
CS1	LONGITUDINAL STIFFNESS, TRACTOR FRONT	-1 00
CS2	LONGITUDINAL STIFFNESS, TRACTOR FRONT	-1.00
	TANDEM TIRES (LBS)	-1.00
CS3	LONGITUDINAL STIFFNESS, TRACTOR REAR TANDEM TIRES (LBS)	-1.00
CS4	LONGITUDINAL STIFFNESS, TRAILER FRONT	
005	TANDEM TIRES (LBS)	-1.00
(2)	TANDEM TIRES (LBS)	-1.00
D	VERTICAL DISTANCE FROM 5TH WHEEL	
ו גיד זיבר	CONNECTION TO TRACTOR CG (IN)	8.80
DELIAI	TRACTOR FRONT AXLE (IN)	19.40
DELTA3	STATIC VERTICAL DISTANCE, TRAILER CG TO	
DT 2	TRAILER AXLE (IN)	49.50
012	SUSPENSION (IN)	13.00
DT3	DISTANCE BETWEEN DUAL TIRES, TRAILER	
FAI	SUSPENSION (IN)	13.00
1.41	FRONT TIRES	0.002
FA2	FRICTION REDUCTION PARAMETER FOR TRACTOR	
FA3	FRONT TANDEM TIRES FRICTION REDUCTION PARAMETER FOR TRACTOR	0.002
••••	REAR TANDEM TIRES	0.002
FA4	FRICTION REDUCTION PARAMETER FOR TRAILER	
FA5	FRICTION REDUCTION PARAMETER FOR TRAILER	0.0
	REAR TANDEM TIRES	0.0
IXX	TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA	10166 00
IYY	TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA	10100.00
	(IN-LB-SEC**2)	69955.00
122	(IN-LB-SEC**2)	69955.00
IXZ	TRACTOR PITCH PLANE CROSS MOMENT	
τπνν	(IN-LB-SEC**2)	0.0
1177	(IN-LB-SEC**2)	73000.00
ITYY	(IN-LB-SEC**2) MASS PITCH MOMENT OF INER	789869.00
ITZZ	TRAILER YAW MOMENT OF INERTIA	789869 00
ITXZ	TRAILER PITCH PLANE CROSS MOMENT	/09009.00
	(IN-LB-SEC**2)	0.0
JAI	ROLL MOMENT OF TRACTOR FRONT AXLE (IN-LB-SEC**2)	3719.00
JA2	ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE	3719.00
T A J	(IN-LB-SEC**2)	4458.00
JAS	(IN-LB-SEC**2)	4100.00
JS1	POLAR MOMENT OF TRACTOR FRONT WHEELS	
JS2	(IN-LB-SEC**2) POLAR MOMENT OF TRACTOR FRONT TANDEM WHEELS	103.00
	(IN-LB-SEC**2)	231.00
JS3	POLAR MOMENT OF TRACTOR REAR TANDEM WHEELS	
JS4	(IN-LB-SECT2) POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS	231.00
	(IN-LB-SEC**2)	231.00
122	PULAR MOMENT OF TRAILER REAR TANDEM WHEELS (IN-LB-SEC**2)	231 00
Kl	SPRING RATE, TRACTOR FRONT SUSPENSION	201.00
K7	(LB/IN)	1012.50
	(LB/IN)	3000.00
КЗ	SPRING RATE, TRAILER SUSPENSION (LE/IN)	19175.00

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KRS1	FRONT AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0
KRS2	REAR AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0
KRS3	TRAILER AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0
AKRS	TRACTOR TR TANDEM AUX ROLL STIFFNESS(IN-LB/I	DEG) 78000.00
KTl	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5700.00
KT2	SPRING RATE, TRACTOR FRONT TANDEM TIRES	
	(LB/IN)	5700.00
KT 3	SPRING RATE, TRACTOR REAR TANDEM TIRES	
	(LB/IN)	5700.00
KT4	SPRING RATE, TRAILER FRONT TANDEM TIRES	
	(LB/IN)	5300.00
KT5	SPRING RATE, TRAILER REAR TANDEM TIRES	
	(LB/IN)	5300.00

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FIFTH WHEEL SPRING RATE

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ROTATION WH5DFL (DEG)SPRING RATE MC5 (IN-LBS/DEG)0.00.20000E+08

TRACTOR FRAME ROLL SPRING RATE

	ROTATION TTDFL(DEG) SPRING RATE TTC(IN-LES/DF 0.0 0.20000E+05	EG)
TRSTF	TRAILER FRAME ROLL STIFFNESS(IN-LB/DEG)	1500000.00
PW	WEIGHT OF PAYLOAD (LBS)	40600.00
PJl	POLL MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	37500.00
PJ2	PITCH MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	1727000.00
PJ3	YAW MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	1727000.00
PX	HORIZONTAL DISTANCE FROM MIDPOINT OF REAR	
50	SUSPENSION TO PAYLOAD MASS CENTER (IN)	182.00
Ρ2	VERTICAL DISTANCE FROM GROUND TO PAYLOAD	64 50
ושמת	MADD CENTER (IN) Doll Center Heicum Melomor Edonm	64.50
RCHI	SUSPENSION (IN)	24 55
RCH2	ROLL CENTER HELCHT TRACTOR REAR	24.))
NONZ	SUSPENSION (IN)	22.00
RCH3	ROLL CENTER HEIGHT, TRAILER SUSPENSION (IN	25.60
RS1	COMPLIANCE STEER (DEG/IN)	0.0
RSC1	ROLL STEER COEFFICIENT, TRACTOR FRONT	
	SUSPENSION	0.0
RSC2	ROLL STEER COEFFICIENT, TRACTOR REAR	
	SUSPENSION	0.10
RSC3	ROLL STEER COEFFICIENT, TRAILER SUSPENSION	0.10
SYl	HORIZONTAL DISTANCE FROM TRACTOR BODY	
	X-AXIS TO TRACTOR FRONT SUSPENSION (IN)	16.30
SY2	HORIZONTAL DISTANCE FROM TRACTOR BODY	
	X-AXIS TO TRACTOR REAR SUSPENSION (IN)	17.50
SY3	HORIZONTAL DISTANCE FROM TRAILER BODY	10.00
TTME	X-AXIS TO TRAILER SUSPENSION (IN) MAXIMUM DEAL TIME FOD SIMULATION (SEC)	19.00
TIME	MAXIMUM REAL TIME FOR SIMULATION (SEC)	4.00
TRA1	HALF TRACK, TRACTOR FRONT AXLE (IN)	36 00
TRAS	HALF TRACK, TRATLER AXLE(S) (IN)	36.00
VEL	INITIAL VELOCITY (FT/SEC)	73.33
W1	SPRUNG WEIGHT OF TRACTOR (LBS)	10316.00
W2	SPRUNG WEIGHT OF TRAILER (LBS)	14281.00
WSl	WEIGHT OF TRACTOR FRONT SUSPENSION (LBS)	1190.00
WS 2	WEIGHT OF TRACTOR FRONT TANDEM	
	SUSPENSION (LBS)	2340.00
WS 3	WEIGHT OF TRACTOR REAR TANDEM SUSPENSION	
	(LBS) Vetcum of monters from ministry	2170.00
W54	WEIGHT OF TRAILER FRONT TANDEM	1520 00
WS 5	SUSPENSION (LDS) Weight of traiter read tandem suspension	1520.00
	(LBS)	1520.00
	()	

BRAK	E PARAME	TERS:	<pre>FQ(1,1,1) FQ(1,2,1) FQ(2,1,1) FQ(2,2,1) FQ(3,1,1) FQ(3,2,1) FQ(4,1,1) FQ(4,2,1) FQ(4,2,1) FQ(5,1,1) FQ(5,2,1)</pre>	= 0.05 = 0.05 = 0.07 = 0.07 = 0.07 = 0.17 = 0.17 = 0.17 = 0.17	0 TQ(1, 0 TQ(1, 5 TQ(2, 5 TQ(2, 5 TQ(3, 5 TQ(3, 5 TQ(4, 5 TQ(4, 5 TQ(4, 5 TQ(5, 5 TQ(5,	$\begin{array}{rrrrr} 1,2) &=& 0\\ 2,2) &=& 0\\ 1,2) &=& 0\\ 2,2) &=& 0\\ 1,2) &=& 0\\ 2,2) &=& 0\\ 1,2) &=& 0\\ 2,2) &=& 0\\ 1,2) &=& 0\\ 2,2) &=& 0\end{array}$.270 .270 .245 .245 .245 .245 .303 .303 .303 .303	
	TABLE 1:	TIME NO. 01 0 0500	VS PRESSU F POINTS: 0.0 0.0	RE (PSI 2)			
•	INPUT PA Symbol	RAMETE	R TABLE F SCRIPTION	OR BRAK	E FORCE	CALCULA LEFT SI	TION SUBR INIT DE	OUTINE IAL VALUE
	IBRT	BR	AKE TYPE		AXLE 2,	LEFT SI	DE	NONE
	IBRT	BR	AKE TYPE		AXLE 3,	LEFT SI	DE	NONE
	IBRT	BR	AKE TYPE		AXLE 4,	LEFT SI	DE	NONE
	IBRT	BR	AKE TYPE		AXLE 5,	LEFT SI	DE	NONE
	IBRT	BR	AKE TYPE					NONE
	TABLE 2 0. 8.	2: TIME LEFT NO. (.00	VS STEER SIDE OF POINTS 0.0 12.0	ANGLE : 2	(DEG)			
	TABLE 3 0. 8.	3: TIME RIGH NO. (0000	VS STEER I SIDE DF POINTS 0.0 12.0	ANGLE : 2	(DEG)			
	PARAMETE G1 G2 G3 THERE W1	ERS FOR	INCLINE GRAVI GRAVI GRAVI NO WIND T	SURFACE TY X CO TY Y CO TY Z CO 'HIS RUN	: MPONENT MPONENT MPONENT		0.0 0.0 1.000	
THE	ANTILOCK	SYSTE	M WILL NC	T BE US	ED THIS	RUN		
	*** ENI) INPUT	***					

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EMPTY 179.500 LOADED DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN) DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN) ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) 181.349 69.000 65.671 111054.063 2517592.000 2517038.000 72999.938 789858.500 789868.500

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THE STATIC LOADS ON THE TIRES ARE AXLE NUMBER LOAD

1	8897.938
2	15781.398
3	15611.398
4	16823.133
5	16823.133

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73937.000 TOTAL

THE TRACTOR TOTAL SPRUNG MASS CENTER IS 62.844 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 192914.500 IN LB SEC**2.

THE TRAILER MASS CENTER IS \$238.169 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS \$2775432.000 IN LB Sec**2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR	FRONT TIRES	:	FIRESTONE	10X22	RIB
TRACTOR	LEADING TANDEM TIRES	:	FIRESTONE	10X22	RIB
TRACTOR	TRAILING TANDEM TIRES	:	FIRESTONE	10X22	RIB
TRAILER	LEADING TANDEM TIRES	:	FIRESTONE	10X20	RIB
TRAILER	TRAILING TANDEM TIRES		FIRESTONE	10X20	RIB

*** BEGIN OUTPUT ***
HSRI TRACTOR-TRAILER HANDLING SIMULATION

FORD TRACTO	D-VAN TDATIED INADED FIDESTONE-10420 DIB	PAGE NO 1
INPUT PARAM	ETER TABLE	"IAZ IDZ"
SYMBOL	DESCRIPTION INITI	AL VALUE
KEY(1)	TRACTOR AXLE KEY: 0 FOR SINGLE AXLE	
	1 FOR WALKING BEAM	
	2 FOR 4 ELLIPTIC LEAF	0
KEY(2)	TRAILER AXLE KEY	2
AA9	HORIZONTAL DISTANCE FROM TRAILER FRONT	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AAIO	HORIZONTAL DISTANCE FROM TRAILER REAR	10 50
כוגא	HORIZONWAL DISWANCE EDON WRALLED EDONW	18.50
nn ± 2	TEAE-EDAME CONTACT TO LOAD LEVELED DIN (IN	6 25
513	HORIZONTAL DISTANCE FROM TRALLER REAR	0.25
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA14	VERTICAL DISTANCE FROM AXLE DOWN TO	0.25
	TRAILER TORQUE ROD (IN)	7.00
AA15	ANGLE BETWEEN TRAILER TOROUE ROD AND	
	HORIZONTAL (DEG)	15.00
AA16	HORIZONTAL DISTANCE FROM AXLE CENTER	
	FORWARD TO TRAILER TORQUE ROD (IN)	5.50
Al	HORIZONTAL DISTANCE FROM TRACTOR CG TO	
	CENTER OF TRACTOR FRONT SUSPENSION (IN)	36.00
A2	HORIZONTAL DISTANCE FROM TRACTOR CG TO	
	CENTER OF TRACTOR REAR SUSPENSION (IN)	98.50
AJ	HORIZONTAL DISTANCE FROM TRAILER CG TO	
24	DIR WRELL (IN) Horizonwil distince from writer of wo	230.50
C 7	CENTED OF TRAILER CG TU	170 50
ALDHA]	STATIC DISTANCE TRACTOR FROM AVE TO	1/9.50
ABLINE	GROUND (IN)	10 50
ALPHA2	STATIC DISTANCE, TRACTOR REAR AXLE(S) TO	19.50
	GROUND (IN)	19.50
ALPHA3	STATIC DISTANCE, TRAILER AXLE(S) TO	19.50
	GROUND (IN)	19.50
ANI	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
	FRONT TIRES	0.250
AN 2	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
	REAR TIRES	0.250
AN 3	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	
2214	FRONT TANDEM TIRES	0.250
A194	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	0.050
BB	HORIZONTAL DISTANCE EDOM 5TH WHEEL TO MIDDO	U.200
20	OF TRACTOR REAR SUSPENSION (IN)	100
C1	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT	0.0
	SUSPENSION (LB-SEC/IN)	10.00
C2	VISCOUS DAMPING: REBOUND ON TRACTOR FRONT	
	SUSPENSION (LB-SEC/IN)	20.00
C3	VISCOUS DAMPING: JOUNCE ON TRACTOR REAR	
	SUSPENSION (LB-SEC/IN)	10.00
C4	VISCOUS DAMPING: REBOUND ON TRACTOR REAR	
<u> </u>	SUSPENSION (LB-SEC/IN)	20.00
65	VISCOUS DAMPING: JOUNCE ON TRAILER	
CE	VISCOUS DAMBING, BEROUND ON TRAILER	10.00
0	SUSPENSION (LE-SEC/IN)	20.00
CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	20.00
	(LBS/DEG)	-1.00
CF1	MAXIMUM COULOMB FRICTION. TRACTOR FRONT	1.00
	SUSPENSION (LB)	500.00
CF2	MAXIMUM COULOMB FRICTION, TRACTOR REAR	
	SUSPENSION (LB)	750.00
CF3	MAXIMUM COULOMB FRICTION, TRAILER	
CE1	SUSPENSION (LB)	1500.00
CD1	LUNGITUDINAL STIFFNESS, TRACTOR FRONT	
CS2	IING (LDD) Iongitudinai stiffness meastrop dead	28000.00
	TIRES (LRS)	28000 00
CS3	LONGITUDINAL STIFFNESS, TRATLER FRONT	20000.00
-	TANDEM TIRES (LBS)	28000.00
CS4	LONGITUDINAL STIFFNESS, TRAILER REAR	
	TANDEM TIRES (LBS)	28000.00

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D	VERTICAL DISTANCE FROM 5TH WHEEL	
	CONNECTION TO TRACTOR CG (IN)	4.80
DELTAl	STATIC VERTICAL DISTANCE, TRACTOR CG TO	
	TRACTOR FRONT AXLE (IN)	24.18
DELTAJ	STATIC VERTICAL DISTANCE, TRAILER CG TO	
Cm O	TRAILER AXLE (IN)	49.50
012	SUSDENSION (IN)	12.00
DT 3	DISTANCE BETWEEN DUAL TIRES TRATIER	13.00
	SUSPENSION (IN)	13 00
FAl	FRICTION REDUCTION PARAMETER FOR TRACTOR	10.00
	FRONT TIRES	0.0
FA2	FRICTION REDUCTION PARAMETER FOR TRACTOR	
	REAR TIRES	0.0
FA3	FRICTION REDUCTION PARAMETER FOR TRAILER	
E3 4	FRONT TANDEM TIRES	0.0
ra4	FRICTION REDUCTION PARAMETER FOR TRAILER	0.0
TXX	TRACTOR SPRING MASS ROLL MOMENT OF INFORTA	0.0
	(IN-LB-SEC**2)	18000 00
IYY	TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA	10000.00
	(IN-LB-SEC**2)	74174.00
IZZ	TRACTOR YAW MOMENT OF INERTIA	
	(IN-LB-SEC**2)	74174.00
IXZ	TRACTOR PITCH PLANE CROSS MOMENT	
TAVV	(IN-LB-SEC**2)	0.0
1177	INALLER SPRUNG MASS RULL MOMENT OF INERTIA	7.000 00
TTVV	(IN-LD-BEC**2) MASS DITCH MOMENT OF INFO	790860 00
ITZZ	TRAILER YAW MOMENT OF INERTIA	/89809.00
	(IN-LB-SEC**2)	789869.00
ITXZ	TRAILER PITCH PLANE CROSS MOMENT	
	(IN-LB-SEC**2)	0.0
JAl	ROLL MOMENT OF TRACTOR FRONT AXLE	
78.0	(IN-LE-SEC**2)	3719.00
JAZ	RULL MOMENT OF TRACTOR REAR AXLE	4450.00
TA 3	ROLL MOMENT OF TRATIER REAR AVIE	4408.00
	(IN-LB-SEC**2)	4100.00
JS1	POLAR MOMENT OF TRACTOR FRONT WHEELS	1100.00
	(IN-LB-SEC**2)	103.00
JS2	POLAR MOMENT OF TRACTOR REAR WHEELS	
	(IN-LB-SEC**2)	231.00
JS3	POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS	
75 /	(IN-LB-SEC**2)	231.00
54	PULAR MOMENT OF TRAILER REAR TANDEM WHEELS	223 00
K)	SPRING RATE, TRACTOR FRONT SUSPENSION	231.00
	(LB/IN)	917 50
К2	SPRING RATE, TRACTOR REAR SUSPENSION	217.20
	(LB/IN)	11000.00
КЗ	SPRING RATE, TRAILER SUSPENSION (LB/IN)	19175.00
KRS1	FRONT AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KRS2	REAR AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KR53	TRAILER AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KT)	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5300.00
	(IR/IN)	5300 00
ктз	SPRING RATE, TRAILER FRONT TANDEM TIRES	5500.00
	(LB/IN)	5300.00
KT4	SPRING RATE, TRAILER REAR TANDEM TIRES	
	(LB/IN)	5300.00

FIFTH WHEEL SPRING RATE

ROTATION WH5DFL (DEG)SPRING RATE MC5 (IN-LBS/DEG)0.00.20000E+08

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TRACTOR FRAME ROLL SPRING RATE

ROTATION TTDFL(DEG)SPRING RATE TTC(IN-LBS/DEG)0.00.20000E+05

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TRSTF TRAILER FRAME ROLL STIFFNESS(IN-LB/DEG) 1500000.00

	PW	WEIGHT OF PAYLOAD (LBS)	30200.00
	PJ1	POLL MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2)	25636.00
	PJ2	PITCH MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2)	728816.00
	PJ3	YAW MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2)	728816.00
	PX	HORIZONTAL DISTANCE FROM MIDPOINT OF REAR SUSPENSION TO PAYLOAD MASS CENTER (IN)	105.50
	PZ	VERTICAL DISTANCE FROM GROUND TO PAYLOAD	64 50
	RCH1	ROLL CENTER HEIGHT, TRACTOR FRONT	04.50
	RCH2	ROLL CENTER HEIGHT, TRACTOR REAR	21.00
	RCH3	ROLL CENTER HEIGHT, TRAILER SUSPENSION (IN	31.00 25.60
	RS1	COMPLIANCE STEER (DEG/IN)	0.0
	RSC1	ROLL STEER COEFFICIENT, TRACTOR FRONT SUSPENSION	0.14
	RSC2	ROLL STEER COEFFICIENT, TRACTOR REAR SUSPENSION	-0.02
	RSC3	ROLL STEER COEFFICIENT, TRAILER SUSPENSION	0.10
	511	X-AXIS TO TRACTOR FRONT SUSPENSION (IN)	17.00
	SY2	HORIZONTAL DISTANCE FROM TRACTOR BODY	20.00
	SY3	HORIZONTAL DISTANCE FROM TRAILER BODY	20.00
	TIMF	X-AXIS TO TRAILER SUSPENSION (IN) MAXIMUM REAL TIME FOR SIMULATION (SEC)	19.00
	TRA1	HALF TRACK, TRACTOR FRONT AXLE (IN)	38.50
	TRA2	HALF TRACK, TRACTOR REAR AXLE(S) (IN)	36.00
	VEL	INITIAL VELOCITY (FT/SEC)	36.00
	Wl	SPRUNG WEIGHT OF TRACTOR (LBS)	10331.00
	W2	SPRUNG WEIGHT OF TRAILER (LBS)	14281.00
	WS1 WS2	WEIGHT OF TRACTOR FRONT SUSPENSION (LBS) WEIGHT OF TRACTOR REAR SUSPENSION	1190.00
	WC 3	(LBS)	2340.00
	NG J	SUSPENSION (LBS)	1520.00
	WS4	WEIGHT OF TRAILER REAR TANDEM SUSPENSION	
			1520.00
BRAF	E PARAMETERS	5: $TQ(1,1,1) = 0.050 TQ(1,1,2) = 0.270$	
		TQ(1,2,1) = 0.050 TQ(1,2,2) = 0.270 TQ(2,1,1) = 0.075 TQ(2,1,2) = 0.245	
		TQ(2,2,1) = 0.075 TQ(2,2,2) = 0.245	
		TQ(3,1,1) = 0.175 TQ(3,1,2) = 0.303	
		TQ(3,2,1) = 0.175 TQ(3,2,2) = 0.303 TQ(4,1,1) = 0.175 TQ(4,1,2) = 0.303	
		TQ(4,2,1) = 0.175 TQ(4,2,2) = 0.303 TQ(4,2,1) = 0.175 TQ(4,2,2) = 0.303	
	TABLE 1: TIN	TE VS PRESSURE (PST)	
	NO.	OF POINTS: 2	
	0.0 0.0500		
	SYMBOL	DESCRIPTION DESCRIPTION SUBRO	UTINE AL VALUE
	IBRT	AXLE 1, LEFT SIDE BRAKE TYPE	NONF
	IBRT	AXLE 2, LEFT SIDE	NONE
	TROT	AXLE 3, LEFT SIDE	NONE
	IDKI	AXLE 4, LEFT SIDE	NONÉ
	IBRT	BRAKE TYPE	NONE

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 TABLE
 2:
 TIME VS STEER ANGLE (DEG)

 LEFT SIDE
 NO. OF POINTS:
 2

 0.0
 0.0
 8.0000
 12.0000

TABLE 3: TIME VS STEER ANGLE (DEG) RIGHT SIDE NO. OF POINTS: 2 0.0 0.0 8,0000 12.0000

PARAMETERS F	OR	INCLINE SUR	F	ACE:	
Gl		GRAVITY	Х	COMPONENT	0.0
G 2		GRAVITY	Y	COMPONENT	0.0
G 3		GRAVITY	Z	COMPONENT	1.000

THERE WILL BE NO WIND THIS RUN

THE ANTILOCK SYSTEM WILL NOT BE USED THIS RUN

*** END INPUT ***

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DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN)EMPTYLOADEDDISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN)179.500129.258ROLL MOMENT OF TRAILER SPRUNG MASS CIN-LB-SEC**2)72999.93899144.500PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)789868.5001656718.000YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)789868.5001656718.000

THE STATIC LOADS ON THE TIRES ARE AXLE NUMBER LOAD

1	8755.832
2	19128.434
3	16748.867
4	16748.867

TOTAL 61382.000

THE TRACTOR TOTAL SPRUNG MASS CENTER IS 49.538 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 138571.500 IN LB SEC**2.

THE TRAILER MASS CENTER IS 289.010 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 1792376.000 IN LB SEC**2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR TRACTOR	FRONT TIRES REAR TIRES	:	FIRESTONE	10X20 F 10X20 F	NIB NIB
TRAILER	LEADING TANDEM TIRES TRAILING TANDEM TIRES	:	FIRESTONE	10X20 F	RIB RIB

*** BEGIN OUTPUT ***

HSRI TRACTOR-TRAILER HANDLING SIMULATION

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FORD TRACTON	R-FLAT-BED-TRAILER-FIRESTONE 10.00X20 RIB *1A2 ETER TABLE	IGE NO 1 ! 182*
SYMBOL	DESCRIPTION INITIAL	. VALUE
KEY(1)	TRACTOR AXLE KEY: 0 FOR SINGLE AXLE	
	1 FOR WALKING BEAM	
	2 FOR 4 ELLIPTIC LEAF	0
KEY(2)	TRAILER AXLE KEY	2
AA9	HORIZONTAL DISTANCE FROM TRAILER FRONT	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AAIU	HORIZONTAL DISTANCE FROM TRAILER REAR	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AAIZ	HORIZONTAL DISTANCE FROM TRAILER FRONT	C 25
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA13	HORIZONTAL DISTANCE FROM TRAILER REAR	6 95
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA14	VERTICAL DISTANCE FROM AXLE DOWN TO	7 00
	ANGLE REFUERN TRATIER TOROUS DOD AND	/.00
AAIJ	HORIZONTAL (DEC)	15 00
2215	HORIZONIAL (DEG) Horizonali dicalner from lyir cenarr	15.00
ANT 0	FORMADD TO TRAILER TOPOUR DOD (IN)	5 50
۵۱	HORIZONTAL DISTANCE FROM TRACTOR CC TO	5.50
<u>n</u> -	CENTED OF TRACTOR FRONT SUSPENSION (IN)	36 00
<u>۵</u> 2	HORIZONTAL DISTANCE FROM TRACTOR CC TO	30.00
n2	CENTER OF TRACTOR REAR SUSPENSION (IN)	98 50
23	HORIZONTAL DISTANCE FROM TRALLER CC TO	30.30
A.J	STH WHEEL (IN)	232 00
24	HORIZONTAL DISTANCE FROM TRAILER CG TO	232.00
717	CENTER OF TRALLER SUSPENSION (IN)	176 00
ALPHA]	STATIC DISTANCE, TRACTOR FRONT AXIE TO	170.00
	GROUND (IN)	19 50
ALPHA2	STATIC DISTANCE, TRACTOR REAR AVIE(S) TO	17.50
	GROUND (IN)	19 50
ALPHA3	STATIC DISTANCE, TRAILER AXLE(S) TO	19.30
	GROUND (IN)	19 50
ANI	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	19.30
	FRONT TIRES	0 250
AN 2	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	0.230
	REAR TIRES	0 250
AN 3	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	0.230
	FRONT TANDEM TIRES	0.250
AN4	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	01200
	REAR TANDEM TIRES	0.250
BB	HORIZONTAL DISTANCE FROM 5TH WHEEL TO MIDPOIN	IT
	OF TRACTOR REAR SUSPENSION (IN)	0.0
C1	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT	
	SUSPENSION (LB-SEC/IN)	10.00
C2	VISCOUS DAMPING: REBOUND ON TRACTOR FRONT	
	SUSPENSION (LB-SEC/IN)	20.00
C3	VISCOUS DAMPING: JOUNCE ON TRACTOR REAR	
	SUSPENSION (LB-SEC/IN)	10.00
C4	VISCOUS DAMPING: REBOUND ON TRACTOR REAR	
	SUSPENSION (LB-SEC/IN)	20.00
C5	VISCOUS DAMPING: JOUNCE ON TRAILER	
	SUSPENSION (LB-SEC/IN)	10.00
C6	VISCOUS DAMPING: REBOUND ON TRAILER	
	SUSPENSION (LB-SEC/IN)	20.00
CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	
6 53	(LBS/DEG)	-1.00
CFI	MAXIMUM COULOMB FRICTION, TRACTOR FRONT	
GD 2	SUSPENSION (LB)	500.00
CF2	MAXIMUM COULOMB FRICTION, TRACTOR REAR	
CE 2	SUSPENSION (LB)	750.00
CrS	MAXIMUM COULOME FRICTION, TRAILER	
(2)	SUSPENSION (LB)	1500.00
	TIRES (LBS)	
CS2	LONGITUDINAL STIFFNESS TRACTOR DEAD	5000.00
	TIRES (LBS)	8000 00
CS3	LONGITUDINAL STIFFNESS. TRAILER FRONT	
	TANDEM TIRES (LBS)	8000.00
CS4	LONGITUDINAL STIFFNESS, TRAILER REAR	
	TANDEM TIRES (LBS) 2	8000.00

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D	VERTICAL DISTANCE FROM 5TH WHEEL	
	CONNECTION TO TRACTOR CG (IN)	4.80
DELTAI	TRACTOR FRONT AVIE (IN)	24.30
DELTAR	STATIC VERTICAL DISTANCE TRATIER CC TO	24.18
52211.5	TRAILER AXLE (IN)	25 00
DT2	DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR	23.00
	SUSPENSION (IN)	13.00
DT3	DISTANCE BETWEEN DUAL TIRES, TRAILER	
	SUSPENSION (IN)	13.00
FAI	FRICTION REDUCTION PARAMETER FOR TRACTOR	
EN 2	FRUNT TIRES EDICATON DEDUCATION DEDEMEMED FOR ADECADD	0.0
1.7.2	REAR TIRES	0 0
FA3	FRICTION REDUCTION PARAMETER FOR TRAILER	0.0
	FRONT TANDEM TIRES	0.0
FA4	FRICTION REDUCTION PARAMETER FOR TRAILER	
	REAR TANDEM TIRES	0.0
1XX	TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA	
†VV	(IN-LB-SEC**2) TRACTOR CREWNS MASS RITCH MOMENT OF INTERTA	18000.00
111	(TN-IB-SEC**2)	74174 00
IZZ	TRACTOR YAW MOMENT OF INERTIA	/41/4.00
	(IN-LB-SEC**2)	74174.00
IXZ	TRACTOR PITCH PLANE CROSS MOMENT	
	(IN-LB-SEC**2)	0.0
ITXX	TRAILER SPRUNG MASS ROLL MOMENT OF INERTIA	
T M3/3/	(IN-LB-SEC**2)	69029.00
	TRATIER VAN MOMENT OF INFRITA	58/432.00
1144	(IN-LB-SEC**2)	587432.00
ITXZ	TRAILER PITCH PLANE CROSS MOMENT	
	(IN-LB-SEC**2)	0.0
JAl	ROLL MOMENT OF TRACTOR FRONT AXLE	
	(IN-LB-SEC**2)	3719.00
JA2	(TN-IB-SEC**2)	4458 00
JA3	ROLL MOMENT OF TRAILER REAR AXLE	4450.00
	(IN-LB-SEC**2)	4100.00
JSl	POLAR MOMENT OF TRACTOR FRONT WHEELS	
	(IN-LB-SEC**2)	103.00
JS2	POLAR MOMENT OF TRACTOR REAR WHEELS	
100	(IN-LB-SEC**2)	231.00
122	(TN-IB-SEC**2)	231 00
JS4	POLAR MOMENT OF TRAILER REAR TANDEM WHEELS	231.00
	(IN-LB-SEC**2)	231.00
Кl	SPRING RATE, TRACTOR FRONT SUSPENSION	
	(LB/IN)	917.50
K2	SPRING RATE, TRACTOR REAR SUSPENSION	11000 00
רש	(LB/IN) SDDING DATE TRATIER SUSPENSION (IB/IN)	8887 00
KRSI	FRONT AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0
KRS2	REAR AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KRS3	TRAILER AUXILIARY ROLL STIFFNESS (IN-LB/DEG -	-68015.00
KT1	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5300.00
KT2	SPRING RATE, TRACTOR REAR TIRES	5200 00
ደጥን	(LE/IN) Soding dame tratier fromt tandem tires	5300.00
NIJ	(LB/IN)	5300.00
KT4	SPRING RATE, TRAILER REAR TANDEM TIRES	
	(LB/IN)	5300.00

FIFTH WHEEL SPRING RATE

ROTATION WH5DFL (DEG)	SPRING RATE MC5 (IN-LBS/DEG)
0.0	0.20000E+08

TRACTOR FRAME ROLL SPRING RATE

ROTATION TTDFL(DEG) SPRING RATE TTC(IN-LBS/DEG) 0.0 0.20000E+05

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TRSTF TRAILER FRAME ROLL STIFFNESS(IN-LB/DEG) 48000.00

	PW	WEIGHT OF PAYLOAD (LBS)	31200.00
	PJ1	POLL MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2)	27045.00
	PJ2	PITCH MOMENT OF INERTIA OF PAYLOAD	761726 00
	PJ3	YAW MOMENT OF INERTIA OF PAYLOAD	/01/30.00
	PX	(IN-LB-SEC**2) HORIZONTAL DISTANCE FROM MIDPOINT OF REAR	761736.00
	PZ	SUSPENSION TO PAYLOAD MASS CENTER (IN) VERTICAL DISTANCE FROM GROUND TO PAYLOAD	109.40
		MASS CENTER (IN)	67.50
	RCHI	SUSPENSION (IN)	21.00
	RCH2	ROLL CENTER HEIGHT, TRACTOR REAR SUSPENSION (IN)	31.00
	RCH3	ROLL CENTER HEIGHT, TRAILER SUSPENSION (IN	41.10
	RSI	COMPLIANCE STEER (DEG/IN)	0.0
	RSCI	SUSPENSION	0.14
	RSC2	ROLL STEER COEFFICIENT, TRACTOR REAR	-0.02
	RSC3	ROLL STEER COEFFICIENT, TRAILER SUSPENSION	-0.02
	SYl	HORIZONTAL DISTANCE FROM TRACTOR BODY	•••••
	SY2	X-AXIS TO TRACTOR FRONT SUSPENSION (IN) HORIZONTAL DISTANCE FROM TRACTOR RODY	17.00
	012	X-AXIS TO TRACTOR REAR SUSPENSION (IN)	20.00
	SY 3	HORIZONTAL DISTANCE FROM TRAILER BODY	
	TIMF	X-AXIS TO TRAILER SUSPENSION (IN) MAXIMUM REAL TIME FOR SIMULATION (SEC)	19.00
	TRA1	HALF TRACK, TRACTOR FRONT AXLE (IN)	38.50
	TRA2	HALF TRACK, TRACTOR REAR AXLE(S) (IN)	36.00
	TRA3	HALF TRACK, TRAILER AXLE(S) (IN)	36.00
	VEL WI	SPRING WEICHT OF TRACTOR (LPC)	73.33
	W2	SPRUNG WEIGHT OF TRALLER (LBS)	10331.00
	WS1	WEIGHT OF TRACTOR FRONT SUSPENSION (LBS)	1190.00
	WS2	WEIGHT OF TRACTOR REAR SUSPENSION	2240 00
	WS 3	WEIGHT OF TRAILER FRONT TANDEM	2340.00
	WS4	SUSPENSION (LBS) WEIGHT OF TRAILER REAR TANDEM SUSPENSION	1520.00
		(LBS)	1520.00
BRA	KE PARAMETERS	S: TQ(1,1,1) = 0.050 TQ(1,1,2) = 0.270	
		TQ(1,2,1) = 0.050 TQ(1,2,2) = 0.270	
		TQ(2,1,1) = 0.075 TQ(2,1,2) = 0.245 TQ(2,2,1) = 0.075 TQ(2,2,2) = 0.045	
		TQ(2,2,1) = 0.075 TQ(2,2,2) = 0.245 TQ(3,1,1) = 0.175 TQ(3,1,2) = 0.303	
		TQ(3,2,1) = 0.175 TO(3,2,2) = 0.303	
		TQ(4,1,1) = 0.175 TQ(4,1,2) = 0.303	
		TQ(4,2,1) = 0.175 TQ(4,2,2) = 0.303	
	TABLE 1: TTM	IE VS PRESSURE (DST)	
	NO.	OF POINTS: 2	
	0.0	0.0	
	0.0500	0.0	
	INPUT PARAME SYMBOL	TER TABLE FOR BRAKE FORCE CALCULATION SUBRO DESCRIPTION INITI	UTINE Al Value
	IBRT	AXLE 1, LEFT SIDE BRAKE TYPE	NONE
	IBRT	AXLE 2, LEFT SIDE	NONE
		AXLE 3, LEFT SIDE	NONE
	IBRT	BRAKE TYPE AXLE 4, LEFT SIDE	NONE
	IBRT	BRAKE TYPE	NONE

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 TABLE
 2: TIME VS STEER ANGLE (DEG) LEFT SIDE NO. OF POINTS: 2

 0.0
 0.0

 8.0000
 12.0000

 TABLE
 3: TIME VS STEER ANGLE (DEG) RIGHT SIDE NO. OF POINTS: 2

 0.0
 0.0

 8.0000
 12.0000

PARAMETERS	FOR	INCLINE SUP	RFZ	ACE:	
Gl		GRAVITY	Х	COMPONENT	0.0
G 2		GRAVITY	Y	COMPONENT	0.0
G 3		GRAVITY	Z	COMPONENT	1.000

THERE WILL BE NO WIND THIS RUN

THE ANTILOCK SYSTEM WILL NOT BE USED THIS RUN

*** END INPUT ***

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EMPTY LOADED DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN) DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN) 176.000 126.030 44.500 61.757 ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) 69028.938 106748.438 PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) 587431.938 1449345.000 YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) 587431.938 1438671.000

THE STATIC LOADS ON THE TIRES ARE AXLE NUMBER LOAD 1 8755.832 2 17949.996

2	17949.996
3	15889.086
4	15889.086

TOTAL 58484.000

THE TRACTOR TOTAL SPRUNG MASS CENTER IS 49.538 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 138571.500 IN LB SEC**2.

THE TRAILER MASS CENTER IS 290.556 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 1568243.000 IN LB SEC**2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR TRACTOR	FRONT TIRES REAR TIRES	: :	FIRESTONE	10X20 10X20	RIB RIB
TRAILER TRAILER	LEADING TANDEM TIRES TRAILING TANDEM TIRES	::	FIRESTONE FIRESTONE	10X20 10X20	RIB RIB

*** BEGIN OUTPUT ***

HSRI TRACTOR-TRAILER HANDLING SIMULATION PAGE NO 1

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2AXLE 110 IN	N. WHEEL BASE TRACTOR-VAN TRAILER RUN# 1	
INPUT PARAMI	ETER TABLE	
SYMBOL	DESCRIPTION INITIA	AL VALUE
KEI(I)	1 FOR WALKING BEAM	
	2 FOR 4 ELLIPTIC LEAF	0
KEY(2)	TRAILER AXLE KEY	0
Al	HORIZONTAL DISTANCE FROM TRACTOR CG TO	22.00
22	CENTER OF TRACTOR FRONT SUSPENSION (IN)	31.90
82	CENTER OF TRACTOR REAR SUSPENSION (IN)	78.10
A3	HORIZONTAL DISTANCE FROM TRAILER CG TO	
	5TH WHEEL (IN)	212.20
A4	HORIZONTAL DISTANCE FROM TRAILER CG TO	105 00
אנסאאן	STATIC DISTANCE TRACTOR FRONT AXIE TO	195.80
	GROUND (IN)	19.50
ALPHA2	STATIC DISTANCE, TRACTOR REAR AXLE(S) TO	
	GROUND (IN)	19.50
ALPHA3	STATIC DISTANCE, TRAILER AXLE(S) TO	10 50
AN1	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	19.50
	FRONT TIRES	0.250
AN 2	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
	REAR TIRES	0.250
AN 3	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	0 250
BB	HORIZONTAL DISTANCE FROM 5TH WHEEL TO MIDPO	INT
	OF TRACTOR REAR SUSPENSION (IN)	21.00
C1	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT	
C 2	SUSPENSION (LB-SEC/IN)	10.00
C2	SUSPENSION (IB-SEC/IN)	20 00
C3	VISCOUS DAMPING: JOUNCE ON TRACTOR REAR	20.00
	SUSPENSION (LB-SEC/IN)	10.00
C4	VISCOUS DAMPING: REBOUND ON TRACTOR REAR	
C5	SUSPENSION (LB-SEC/IN) VISCOUS DAMPING: JOUNCE ON TRATIER	20.00
05	SUSPENSION (LB-SEC/IN)	10.00
C6	VISCOUS DAMPING: REBOUND ON TRAILER	20000
	SUSPENSION (LB-SEC/IN)	20.00
CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	1 00
CEL	AXIMUM COULOMB FRICTION, TRACTOR FRONT	-1.00
	SUSPENSION (LB)	500.00
CF2	MAXIMUM COULOMB FRICTION, TRACTOR REAR	
	SUSPENSION (LB)	750.00
CF3	MAXIMUM COULOMB FRICTION, TRAILER	750 00
CS1	LONGITUDINAL STIFFNESS, TRACTOR FRONT	/20.00
	TIRES (LBS)	28000.00
CS2	LONGITUDINAL STIFFNESS, TRACTOR REAR	
C53	TIRES (LES) Longitudinal stiffness traited tipes	28000.00
(5)	(LBS)	28000.00
D	VERTICAL DISTANCE FROM 5TH WHEEL	200000000
	CONNECTION TO TRACTOR CG (IN)	4.50
DELTA1	STATIC VERTICAL DISTANCE, TRACTOR CG TO	24 50
DELTA3	STATIC VERTICAL DISTANCE. TRAILER CG TO	24.50
	TRAILER AXLE (IN)	37.80
DT2	DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR	
כשת	SUSPENSION (IN)	13.00
010	SUSPENSION (IN)	13 00
FAl	FRICTION REDUCTION PARAMETER FOR TRACTOR	10.00
	FRONT TIRES	0.0
r AZ	FRICTION REDUCTION PARAMETER FOR TRACTOR	0 0
FA3	FRICTION REDUCTION PARAMETER FOR TRAILER	0.0
	TIRES	0.0

IXX	TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2)	11906.00
IYY	TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2)	49440.00
IZZ	TRACTOR YAW MOMENT OF INERTIA	
	(IN-LB-SEC**2)	49440.00
IXZ	TRACTOR PITCH PLANE CROSS MOMENT	
	(IN-LB-SEC**2)	0.0
ITXX	TRAILER SPRUNG MASS ROLL MOMENT OF INERTIA	
	(IN-LB-SEC**2)	14843.00
ITYY	(IN-LB-SEC**2) MASS PITCH MOMENT OF INER	422207.00
ITZZ	TRAILER YAW MOMENT OF INERTIA	
T	(IN-LB-SEC**2)	422207.00
ITX2	(IN IR SECTOR)	0 0
ואד	(IN-LD-BLC-2) Boli Moment of TRACTOR FRONT AVIE	0.0
JAI	(TN-IB-SEC**2)	3719 00
2 47	ROLL MOMENT OF TRACTOR REAR AXLE	5/19.00
UN2	(IN-LB-SEC**2)	4458.00
JA3	ROLL MOMENT OF TRAILER AXLE	
••••	(IN-LB-SEC**2)	4100.00
JS1	POLAR MOMENT OF TRACTOR FRONT WHEELS	
	(IN-LB-SEC**2)	103.00
JS2	POLAR MOMENT OF TRACTOR REAR WHEELS	
		231.00
723	THE COC++2)	121 00
27	(IN-LB-BLUAAZ) CODING DAME MDACMOD EDONM SUSDENSION	231.00
K1	(IR/IN)	1100 00
K2	SPRING RATE, TRACTOR REAR SUSPENSION	1100.00
	(LB/TN)	8000.00
КЗ	SPRING RATE, TRAILER SUSPENSION (LB/IN)	8000.00
KRS1	FRONT AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KRS2	REAR AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KRS3	TRAILER AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0
KTl	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5300.00
KT2	SPRING RATE, TRACTOR REAR TIRES	
	(LB/IN)	5300.00
KT3	SPRING RATE, TRAILER TIRES	
	(LB/IN)	5300.00

FIFTH WHEEL SPRING RATE

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ROTATION WH5DFL (DEG)SPRING RATE MC5 (IN-LBS/DEG)0.00.20000E+08

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TRACTOR FRAME ROLL SPRING RATE

	ROTATION TTDFL(DEG) 0.0	SPRING RAT	re TTC(IN-LE 150E+05	BS/DEG)	
TRSTF PW	TRAILER FRAME RO WEIGHT OF PAYLOA	OLL STIFFNESS AD (LBS)	S(IN-LB/DEG)	1500 29	000.00 010.00
PJI	(IN-LB-SEC**2)	INERTIA OF PZ	LICAD	50	659.00
PJ2	PITCH MOMENT OF (IN-LB-SEC**2)	INERTIA OF H	PAYLOAD	1421	650.00
PJ3	YAW MOMENT OF IN (IN-LB-SEC**2)	VERTIA OF PAY	LOAD	1421	650.00
PX	HORIZONTAL DISTA SUSPENSION TO PA	ANCE FROM MII	DPOINT OF RE CENTER (IN)	EAR	210.00
PZ	VERTICAL DISTAN(MASS CENTER (IN)	CE FROM GROUI	ND TO PAYLO	AD	68.00
RCH1	ROLL CENTER HEIC SUSPENSION (IN)	SHT, TRACTOR	FRONT		24.00
RCH2	ROLL CENTER HEIC	GHT, TRACTOR	REAR		30.00
RCH3	ROLL CENTER HEIG	GHT, TRAILER	SUSPENSION	(IN	30.00

RSI RSC		COMPLIANCE ROLL STEER	STEER (DEG/I COEFFICIENT,	N) TRACTOR FROM	0.0
RSC	22	SUSPENSION ROLL STEER	COEFFICIENT,	TRACTOR REAR	0.0
RSC	23	ROLL STEER	COEFFICIENT,	TRAILER SUSPI	ENSION 0.10
SY	2	X-AXIS TO HORIZONTAL	TRACTOR FRONT DISTANCE FRO	SUSPENSION (2)	IN) 17.00
SY	3	X-AXIS TO HORIZONTAL	TRACTOR REAR DISTANCE FRO	SUSPENSION (IN M TRAILER BODY	N) 20.00
TI	٩F	X-AXIS TO MAXIMUM RE	TRAILER SUSPE AL TIME FOR S	INSION (IN) SIMULATION (SEG	20.00 2) 4.00
TRI TRI	Al A2	HALF TRACK	, TRACTOR FRO , TRACTOR REA	ONT AXLE (IN) AR AXLE(S) (IN]	38.50
TRA	A3	HALF TRACK	, TRAILER AXL	LE(S) (IN)	36.00 73.33
WI		SPRUNG WEI	GHT OF TRACTO	DR (LBS)	7990.00
W2 WS	1	SPRUNG WEI WEIGHT OF	GHT OF TRAILE TRACTOR FRONT TRACTOR PEAR	ER (LBS) E SUSPENSION (1 SUSPENSION	LBS) 1200.00
N5.	2	(LBS)	IRACIOR REAR	SUSPENSION	2300.00
WS:	3	WEIGHT OF (LBS)	TRAILER SUSPE	ENSION	1500.00
BRAKE	PARAMETER	S: TQ(1,1,1) = 0.050 TQ	(1,1,2) = 0.27	
		TQ(2,1,1) = 0.075 TQ	(2,1,2) = 0.24	5
		TQ(2,2,1 TQ(3,1,1) = 0.075 TQ() = 0.175 TQ((2,2,2) = 0.24 (3,1,2) = 0.30	5 3
		TQ(3,2,1) = 0.175 TQ	(3,2,2) = 0.30	3
TA	BLE 1: TI	ME VS PRESS	URE (PSI)		
	NO 0.0	. OF POINTS 0.	: 2 0		
	0.050	0 0.	0		
IN. Syl	PUT PARAM MBOL	ETER TABLE DESCRIPTIC	FOR BRAKE FOF N	RCE CALCULATIO	N SUBROUTINE INITIAL VALUE
IB	RT	BRAKE TYPE	AXLE	1, LEFT SIDE	NONE
IB	RT	BRAKE TYPE	AXLE	2, LEFI SIDE	NONE
IB	RT	BRAKE TYPE	AXLE	3, LEFT SIDE	NONE
TA	BLE 2: T	IME VS STEE	R ANGLE (DEG)	I	
	N	O. OF POINT	'S: 2		
	0.0 8.000	0.08.	0000		
TA	BLE 3: T R	IME VS STEE IGHT SIDE	R ANGLE (DEG))	
	N	O. OF POINT	S: 2		
	8.000	0 08.	0000		
PA					
	RAMETERS	FOR INCLINE	SURFACE:		
	RAMETERS Gl	FOR INCLINE GRAV	SURFACE: ITY X COMPONE	ENT	0.0
	RAMETERS Gl G2 G3	FOR INCLINE GRAV GRAV GRAV	SURFACE: ITY X COMPONE ITY Y COMPONE ITY Z COMPONE	ENT ENT ENT	0.0 0.0 1.000
TH	RAMETERS G1 G2 G3 ERE WILL	FOR INCLINE GRAV GRAV GRAV BE NO WIND	SURFACE: ITY X COMPONI ITY Y COMPONI ITY Z COMPONI THIS RUN	ENT ENT ENT	0.0 0.0 1.000

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*** END INPUT ***

 DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN)
 195.800
 206.782

 DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN)
 57.300
 65.575

 ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 14842.996
 67451.438

 PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 422206.938
 1849239.000

 YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 422206.938
 1847289.000

EMPTY

LOADED .

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THE STATIC LOADS ON THE TIRES ARE

NUMBER	LOAD	
	10502.242	
	19998.539	
	19999.219	
	NUMBER	NUMBER LOAD 10502.242 19998.539 19999.219

TOTAL 50500.000

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THE TRACTOR TOTAL SPRUNG MASS CENTER IS 44.202 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 92614.000 IN LB SEC**2.

THE TRAILER MASS CENTER IS 209.169 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 2011131.000 IN LB SEC**2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR TRACTOR	FRONT TIRES REAR TIRES	::	FIRESTONE	10X20 10X20	RIB RIB
TRAILER	TIRES	:	FIRESTONE	10X20	RIB

*** BEGIN OUTPUT ***

HSRI TRACTOR-TRAILER HANDLING SIMULATION PAGE NO 1

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2AXLE 140 IN	N. WHEEL BASE TRACTOR-VAN TRAILER RUN# 49	
INPUT PARAMI	ETER TABLE	
SYMBOL	DESCRIPTION INITIA	AL VALUE
KEY(1)	TRACTOR AXLE KEY: 0 FOR SINGLE AXLE	
	1 FOR WALKING BEAM	•
7077 ())	2 FOR 4 ELLIPTIC LEAF	0
$\operatorname{KEY}(2)$	TRAILER AXLE KEY	0
Al	HORIZONTAL DISTANCE FROM TRACTOR CG TO	76.40
	CENTER OF TRACTOR FRONT SUSPENSION (IN)	36.40
A2	HORIZONTAL DISTANCE FROM TRACTOR CG TO	
• •	CENTER OF TRACTOR REAR SUSPENSION (IN)	103.60
AJ	HORIZONTAL DISTANCE FROM TRAILER CG TO	
	STH WHEEL (IN)	212.20
A4	HORIZONTAL DISTANCE FROM TRAILER CG TO	
AT DUA 1	CENTER OF TRAILER SUSPENSION (IN)	195.80
ALPHAI	CDOUND (IN)	10 50
רגעם זג	GROUND (IN) STATIC DISTANCE TRACTOR DEAD AVIE(S) TO	19.50
ALFIAZ	CDOUND (IN)	
כגשתזג	GROUND (IN) SEAMIC DISEANCE EDITED AVIE(C) DO	19.50
ALPRAJ	CROUND (IN)	10 50
NN 1	GROUND (IN) TIDE DESCURE DIST. EUNCTION FOD TDACTOR	19.50
ANI	TIRE PRESSURE DIST. FUNCTION FUR TRACTOR	0 250
2812	TTRED DESCURE DIST. SUNCTION FOR TRACTOR	0.250
AN2	DEAD TIDES	0 250
AN 7	REAR LIRED TIDE DESCUDE DICT EUNCTION FOD TRATIOD	0.250
AND	TIRE PRESSURE DIST. FUNCTION FUR TRAILUR	0 250
88	UNDIZONTAL DIETANCE EDOM ETH WHEEL TO MIDDO	U.200
00	OF TRACTOR READ SUCCESSION (TN)	1N1 00 E0
C 1	UISCOUS DAMDING, JOUNCE ON TRACTOR FRONT	22.50
	SUSPENSION (IR-SEC(IN)	10.00
C 2	VISCOUS DAMPING, DEPOUND ON TRACTOR EDONT	10.00
C2	SUSDENSION (IB_SEC/IN)	20.00
C3	VISCOUS DAMPING. TOUNCE ON TRACTOR READ	20.00
C J	SUSPENSION (IB-SEC/IN)	10.00
C4	VISCOUS DAMPING · DEBOUND ON TRACTOR READ	10.00
Ç1	SUSPENSION (IB-SEC(IN)	20.00
C5	VISCOUS DAMPING, TOUNCE ON TRAILER	20.00
65	SUSPENSION (LB-SEC/IN)	10 00
Cf	VISCOUS DAMPING: REBOUND ON TRAILER	10.00
•••	SUSPENSION (LB-SEC/IN)	20 00
CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	20.00
	(LBS/DEG)	-1.00
CF1	MAXIMUM COULOMB FRICTION, TRACTOR FRONT	1.00
	SUSPENSION (LB)	500.00
CF2	MAXIMUM COULOMB FRICTION. TRACTOR REAR	200.00
	SUSPENSION (LB)	750.00
CF3	MAXIMUM COULOMB FRICTION, TRAILER	
	SUSPENSION (LB)	750,00
CS1	LONGITUDINAL STIFFNESS, TRACTOR FRONT	
	TIRES (LBS)	28000.00
CS2	LONGITUDINAL STIFFNESS, TRACTOR REAR	
	TIRES (LBS)	28000.00
CS3	LONGITUDINAL STIFFNESS, TRAILER TIRES	
	(LBS)	28000.00
D	VERTICAL DISTANCE FROM 5TH WHEEL	
	CONNECTION TO TRACTOR CG (IN)	4.50
DELTAl	STATIC VERTICAL DISTANCE, TRACTOR CG TO	
	TRACTOR FRONT AXLE (IN)	24.50
DELTA3	STATIC VERTICAL DISTANCE, TRAILER CG TO	
	TRAILER AXLE (IN)	37.80
DT2	DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR	
השס	SUSPENSION (IN)	13.00
210	DISTANCE BETWEEN DUAL TIRES, TRAILER	
FAI	BUSTENSIUN (IN) FRICTION REDUCTION DARAMETER ROD TRACTOR	13.00
	FROM TIPES	0.0
FA2	FRICTION REDUCTION DARAMETER FOR TRACTOR	0.0
	REAR TIRES	0 0
FA3	FRICTION REDUCTION PARAMETER FOR TRATIER	0.0
	TIRES	0.0

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IXX	TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA	10770 00
TVV	(IN-LE-SECARZ) TRACTOR SERVICE MASS RETAIL MOMENT OF INFORTA	12//2.00
***	(IN-IB-SEC**2)	67527 00
IZZ	TRACTOR YAW MOMENT OF INERTIA	0/32/.00
	(IN-LB-SEC**2)	67527.00
IXZ	TRACTOR PITCH PLANE CROSS MOMENT	
	(IN-LB-SEC**2)	0.0
ITXX	TRAILER SPRUNG MASS ROLL MOMENT OF INERTIA	
	(IN-LB-SEC**2)	14843.00
ITYY	(IN-LB-SEC**2) MASS PITCH MOMENT OF INER	422207.00
ITZZ	TRAILER YAW MOMENT OF INERTIA	
	(IN-LB-SEC**2)	422207.00
ITXZ	TRAILER PITCH PLANE CROSS MOMENT	
	(IN-LB-SEC**2)	0.0
JAI	ROLL MOMENT OF TRACTOR FRONT AXLE	2720 00
7 . 7	(IN-LD-SECT2) Doli moment of teactor read avis	3/19.00
JAZ	(IN-IB-SEC**2)	4458 00
ר בד.	ROLL MOMENT OF TRAILER AXLE	4430.00
0110	(IN-LB-SEC**2)	4100.00
JS1	POLAR MOMENT OF TRACTOR FRONT WHEELS	
	(IN-LB-SEC**2)	103.00
JS2	POLAR MOMENT OF TRACTOR REAR WHEELS	
	(IN-LB-SEC**2)	231.00
JS3	POLAR MOMENT OF TRAILER WHEELS	
	(IN-LB-SEC**2)	231.00
Kl	SPRING RATE, TRACTOR FRONT SUSPENSION	
	(LB/IN)	1100.00
K2	SPRING RATE, TRACTOR REAR SUSPENSION	
* 2	(LB/IN)	8000.00
K3 KDCI	SPRING RATE, TRAILER SUSPENSION (LB/IN)	8000.00
VDC2	PEND AUXILIARI ROLL STIFFNESS (IN-LB/DEG	0.0
NND2 VDC3	TDATIED ANYTITARY ROLL STIFFNESS (IN-LB/DEG	0.0
KT1	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5300.00
KT2	SPRING RATE, TRACTOR REAR TIRES	5500.00
	(LB/IN)	5300.00
KT3	SPRING RATE, TRAILER TIRES	
	(LB/IN)	5300.00

FIFTH WHEEL SPRING RATE

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ROTATION WH5DFL (DEG) SPRING RATE MC5 (IN-LBS/DEG) 0.0 0.20000E+08

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TRACTOR FRAME ROLL SPRING RATE

	ROTATION TTDFL(DEG) 0.0	SPRING RATE	E TTC(IN-LBS/I D0E+05	DEG)
TRSTF PW	TRAILER FRAME R WEIGHT OF PAYLO	OLL STIFFNESS(AD (LBS)	(IN-LB/DEG)	1500000.00 28430.00
PJl	POLL MOMENT OF (IN-LB-SEC**2)	INERTIA OF PAY	LOAD	49646.00
PJ2	PITCH MOMENT OF (IN-LB-SEC**2)	INERTIA OF PA	AYLOAD	1438368.00
PJ3	YAW MOMENT OF I (IN-LB-SEC**2)	NERTIA OF PAYL	LOAD	1438368.00
PX	HORIZONTAL DIST	ANCE FROM MIDE	POINT OF REAR ENTER (IN)	206.00
PZ	VERTICAL DISTAN	CE FROM GROUND	TO PAYLOAD	68.00
RCH1	ROLL CENTER HEI	GHT, TRACTOR E	FRONT	24.00
RCH2	ROLL CENTER HEI	GHT, TRACTOR F	REAR	24.00
RCH3	SUSPENSION (IN) ROLL CENTER HEI	GHT, TRAILER S	SUSPENSION (II	30.00 N 30.00

1	RS1	COMPLIANCE	STEER (D	EG/IN)		0.0
1	RSC1	ROLL STEER SUSPENSION	COEFFICI	ENT, TR	ACTOR FRONT	0.0
1	RSC2	ROLL STEER SUSPENSION	COEFFICI	ENT, TR	ACTOR REAR	0.10
	RSC3	ROLL STEER	COEFFICI	ENT, TR	AILER SUSPE	NSION 0.10
	SYl	HORIZONTAL X-AXIS TO	DISTANCE TRACTOR F	RONT SU	SPENSION (I	N) 17.00
i	SY2	HORIZONTAL X-AXIS TO	DISTANCE TRACTOR F	FROM T LEAR SUS	RACTOR BODY) 20.00
	SY3	HORIZONTAL X-AXIS TO	DISTANCE TRAILER S	: FROM T SUSPENSI	RAILER BODY ON (IN)	20.00
	TIMF	MAXIMUM RE	AL TIME F	OR SIMU	LATION (SEC) 4.00
	TRA1	HALF TRACK	, TRACTOP	FRONT	AXLE (IN)	38.50
	TRA2	HALF TRACK	, TRACTOR	R REAR A	XLE(S) (IN)	36.00
	TRA3	HALF TRACK	, TRAILER	AXLE(S	S) (IN)	36.00
	VEL	INITIAL VE	LOCITY (E	T/SEC)		73.33
	Wl	SPRUNG WEI	GHT OF TF	ACTOR ((LBS)	8570.00
	W2	SPRUNG WEI	GHT OF TH	RAILER ((LBS)	8500.00
	WSl	WEIGHT OF	TRACTOR H	FRONT SU	JSPENSION (L	.BS) 1200.00
	WS2	WEIGHT OF	TRACTOR H	REAR SUS	SPENSION	00 0050
		(LBS)		UCDENCI		2300.00
	WS 3	(LBS)	TRAILER	DUSPENSI	LUN	1500.00
BRAK	E PARAME:	TERS: TQ(1,1,1 TQ(1,2,1 TQ(2,1,1 TQ(2,2,1 TQ(3,1,1 TQ(3,2,1) = 0.050) = 0.050) = 0.079) = 0.079) = 0.179	<pre>TQ(1,1 TQ(1,2 TQ(2,1) TQ(2,2 TQ(2,2 TQ(3,1) TQ(3,2)</pre>	$\begin{array}{llllllllllllllllllllllllllllllllllll$	
	TABLE 1:	TIME VS PRESS	URE (PSI)			
	_	NO. OF POINTS	: 2			
	0.0	0 0.	.0			
	0.0	0500 0.	U			
	INPUT PAR	RAMETER TABLE	FOR BRAK	E FORCE	CALCULATION	SUBROUTINE
	SYMBOL	DESCRIPTIO)N	AXLE 1.	LEFT SIDE	INITIAL VALUE
	IBRT	BRAKE TYPE	:			NONE
	TEDT	BOAKE TYDE	,	AXLE 2,	LEFT SIDE	NONE
	IDRI	DRAKE IIF		AXLE 3,	LEFT SIDE	NONE
	IBRT	BRAKE TYPE	5			NUNE
	TABLE 2	: TIME VS STER	ER ANGLE	(DEG)		
		NO OF POINT	··· 2			
	0		0			
	8.1	0000 08.	.0000			
	0.					
	TABLE 3	: TIME VS STEP	ER ANGLE	(DEG)		
		RIGHT SIDE				
		NO. OF POINT	rs: 2			
	0.	ο ο.	.0			
	8.	0000 08	.0000			
	PARAMETE	RS FOR INCLINE	SURFACE	:		
	G1	GRAV	/ІТҮ Х СО	MPONENT		0.0
	G 2	GRAV	/ITY Y CO	MPONENT		0.0
	G 3	GRAV	/ITY Z CO	MPONENT		1.000
	THERE WI	LL BE NO WIND	THIS RUN			
THE	ANTILOCK	SYSTEM WILL 1	NOT BE US	ED THIS	RUN	

*** END INPUT ***

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 EMPTY
 LOADED

 DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN)
 195.800
 203.652

 DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN)
 57.300
 65.537

 ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 14842.996
 66429.375

 PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 422206.938
 1862237.000

 YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 422206.938
 1862337.000

THE STATIC LOADS ON THE TIRES ARE AXLE NUMBER LOAD

10504.336
19999.180
19996.484

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TOTAL 50500.000

THE TRACTOR TOTAL SPRUNG MASS CENTER IS 52.523 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 135636.750 IN LB SEC**2.

THE TRAILER MASS CENTER IS 212.297 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 2021286.000 IN LB SEC**2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR FRONT TIRES : FIRESTONE 10X20 RIB TRACTOR REAR TIRES : FIRESTONE 10X20 RIB TRAILER TIRES : FIRESTONE 10X20 RIB

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145 INCH WHI	EEL BASE 3AXLE TRACTOR, VAN TRAILER RUN# 97	
INPUT PARAM	ETER TABLE	
SYMBOL	DESCRIPTION INITIAL	VALUE
KEY(1)	TRACTOR AXLE KEY: U FOR SINGLE AXLE	
	2 FOR 4 FILIPTIC LEAF	2
KEY(2)	TRAILER AXLE KEY	2
AA1	HORIZONTAL DISTANCE FORM TRACTOR FRONT	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	24.00
AA2	HORIZONTAL DISTANCE FROM TRACTOR REAR	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	24.00
AA4	HORIZONTAL DISTANCE FROM TRACTOR FRONT	1 00
AA5	HORIZONTAL DISTANCE FROM TRACTOR REAR	1.00
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN-	1.00
ААб	VERTICAL DISTANCE FROM AXLE DOWN TO	
	TRACTOR TORQUE ROD (IN)	0.0
AA7	ANGLE BETWEEN TRACTOR TORQUE ROD AND	
	HORIZONTAL (DEG)	0.0
AA8	HORIZONTAL DISTANCE FROM AXLE CENTER	0 0
229	HORIZONTAL DISTANCE FROM TRAILER FRONT	0.0
nn.)	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA10	HORIZONTAL DISTANCE FROM TRAILER REAR	10.00
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA12	HORIZONTAL DISTANCE FROM TRAILER FRONT	
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA13	HORIZONTAL DISTANCE FROM TRAILER REAR	6 25
14	VERTICAL DISTANCE FROM AVIE DOWN TO	0.20
INIT 4	TRAILER TOROUE ROD (IN)	7.00
AA15	ANGLE BETWEEN TRAILER TORQUE ROD AND	
	HORIZONTAL (DEG)	15.01
AA16	HORIZONTAL DISTANCE FROM AXLE CENTER	
	FORWARD TO TRAILER TORQUE ROD (IN)	5.50
AI	HURIZUNTAL DISTANCE FROM TRACTOR CG TO	77 70
A2	HORIZONTAL DISTANCE FROM TRACTOR CG TO	37.70
	CENTER OF TRACTOR REAR SUSPENSION (IN)	107.30
A3	HORIZONTAL DISTANCE FROM TRAILER CG TO	
	5TH WHEEL (IN)	230.50
A4	HORIZONTAL DISTANCE FROM TRAILER CG TO	
וגעמזג	CENTER OF TRAILER SUSPENSION (IN)	179.50
ALPHAI	GROUND (IN)	10 50
ALPHA2	STATIC DISTANCE, TRACTOR REAR AXLE(S) TO	19.50
	GROUND (IN)	19.50
ALPHA3	STATIC DISTANCE, TRAILER AXLE(S) TO	
	GROUND (IN)	19.50
AN1	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
2112	FRONT TIRES	0.250
AN2	FRONT TANDEM TIPES	0 250
AN 3	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	0.250
	REAR TANDEM TIRES	0.250
AN 4	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	
	FRONT TANDEM TIRES	0.250
AN5	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	
88	REAR TANDEM TIRES	0.250
DE	OF TRACTOR REAR SUSPENSION (IN)	18 80
Cl	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT	10.00
	SUSPENSION (LB-SEC/IN)	10.00
C2	VISCOUS DAMPING: REBOUND ON TRACTOR FRONT	-
•	SUSPENSION (LE-SEC/IN)	20.00
C3	VISCOUS DAMPING: JOUNCE ON TRACTOR REAR	10.00
C4	VISCOUS DAMPING. REBOUND ON TRACTOR READ	T0.00
	SUSPENSION (LB-SEC/IN)	20.00
C5	VISCOUS DAMPING: JOUNCE ON TRAILER	
	SUSPENSION (LB-SEC/IN)	10.00
C6	VISCOUS DAMPING: REBOUND ON TRAILER	
	SUBPENDIUN (LB-SEC/IN)	20.00

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(LBS/DEG) -1.00 CF1 MAXIMUK COULOMB FRICTION, TRACTOR FRONT 506.00 CF2 MAXIMUK COULOMB FRICTION, TRACTOR REAR 5000.00 CF3 MAXIMUK COULOMB FRICTION, TRACTOR REAR 5000.00 CF3 MAXIMUK COULOMB FRICTION, TRACTOR REAR 5000.00 CF3 CLONGTUDINAL STIFFNESS, TRACTOR FRONT 70000.00 TANDEM TIRES (LSS) Z8000.00 28000.00 CF3 CLONGTUDINAL STIFFNESS, TRACTOR REAR 28000.00 CF4 LONGTUDINAL STIFFNESS, TRACTOR REAR 28000.00 CF4 CONNECTION TASTIFFNESS, TRALLER FRONT TANDEM TIRES (LSS) 28000.00 CF4 CONNECTION TO TRACTOR CG (IN) 4.50 DEUTA1 STATEC VERTICAL DISTANCE, TRALLER REAR 28000.00 CF4 TANDEM TIRES (LSS) 28000.00 CF5 LONGTUDINAL STIFFNESS, TRACTOR REAR 28000.00 CF6 TATEC VERTICAL DISTANCE, TRALLER REAR 28000.00 CF6 TATEC VERTICAL DISTANCE, TRALLER ACTOR 24.50 DETA1 STATIC VERTICAL DISTANCE, TRALLER CON 7.80 TATACTOR FRONT AXLE (IN)	CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	
SUSPENSION (LB) 500.00 CF2 MAXIMUM COULOME FRICTION, TRACTOR REAR 1500.00 CF3 MAXIMUM COULOME FRICTION, TRACTOR REAR 1500.00 CS1 LONGITUDINAL STIFFNESS, TRACTOR FRONT 28000.00 CS2 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS3 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS4 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS4 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS4 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS5 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS4 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS5 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS5 LONGITUDINAL STIFFNESS, TRACTOR REAR 28000.00 CS5 CONNECTION TO TARCHOR CG (IN) 4.50 DELTAI STATC VERTICAL DISTANCE, FRACTOR CG TO 77.80 CONNECTION TO TARCHOR TARES, TRACTOR REAR 13.00 DT2 DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR 13.00 SUSPENSION (IN) 13.00	CF1	(LBS/DEG) MAXIMUM COULOMB FRICTION, TRACTOR FRONT	-1.00
C12 SUSPENSION (LE) 1500.00 CF3 MAXIMUM COUCHS FRICTION, TRAILER 1500.00 CS1 LONGITUDINAL STIFPHESS, TRACTOR FRONT 28000.00 CS2 LONGITUDINAL STIFPHESS, TRACTOR FRONT 28000.00 CS3 LONGITUDINAL STIFPHESS, TRACTOR FRONT 28000.00 CS4 LONGITUDINAL STIFPHESS, TRACTOR FRONT 28000.00 CS4 LONGITUDINAL STIFPHESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFPHESS, TRALLER FRONT 28000.00 CS4 LONGITUDINAL STIFPHESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFPHESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFPHESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFPHESS, TRALCER FRONT 28000.00 CS6 LONGITUDINAL STIFPHESS, TRALCER FRONT 24000.00 CS5 CONTECTION TO TARACTOR CG (IN) 4.50 DELTA3 STATIC VERTICAL DISTANCE, FRACTOR REAR 37.80 DSEPENSION (IN) 13.00 13.00 CS5 PROTTION REDUCTION PARAMETER FOR TRACTOR 0.0 FA2 FRICTION	CE2	SUSPENSION (LB) MAXIMUM COULOME EPICTION TRACTOR DEAD	500.00
CF3 MAXIMUM COULOWS FRICTION, TWAILER 1500.00 SUSPENSION (LB) 1500.00 CS1 LONGITUDINAL STIFFNESS, TRACTOR FRONT 28000.00 CS2 LONGITUDINAL STIFFNESS, TRACTOR FRONT 28000.00 CS3 LONGITUDINAL STIFFNESS, TRACTOR FRONT 28000.00 CS4 LONGITUDINAL STIFFNESS, TRAILER FRONT 28000.00 CS5 LONGITUDINAL STIFFNESS, TRAILER REAR 28000.00 CS5 LONGITUDINAL STIFFNESS, TRAILER REAR 28000.00 D VERTICAL DISTANCE, FROM STH WHEEL 28000.00 CONNECTION TO TRACTOR GG (IN) 4.50 DELTA1 STATIC VERTICAL DISTANCE, TRACTOR CG TO 77.80 TRALER AXLE (IN) 37.80 78.00 DT2 DISTANCE DETWEND UDLI TIRES, TRACTOR REAR 13.00 SUSPENSION (IN) 13.00 78.11 13.00 FAIL CYENTCAL DISTANCE, TRACTOR TRACTOR 0.0 78.760 FAI CYENTCAL DISTANCE, TRACTOR REAR 0.0 78.760 SUSPENSION (IN) SUSPENSION (IN) 13.00 78.760 FAI CYENCTION REDUCTION PARAMETER FOR TRACTOR 70.0<		SUSPENSION (LB)	1500.00
CS1 LONGITUDINAL STIFFNESS, TRACTOR FRONT 28000.00 CS2 LONGITUDINAL STIFFNESS, TRACTOR FRONT 28000.00 CS3 LONGITUDINAL STIFFNESS, TRALTOR REAR 28000.00 CS4 LONGITUDINAL STIFFNESS, TRALTER FRONT 28000.00 CS4 LONGITUDINAL STIFFNESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFFNESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFFNESS, TRALLER FRONT 28000.00 CS5 LONGITUDINAL STIFFNESS, TRALTER FRONT 4.50 DETA1 STATIC VERTICAL DISTANCE, TRACTOR G TO 4.50 DETA3 STATIC VERTICAL DISTANCE, TRACTOR REAR 31.00 F02 DISTANCE DETWEDN DUAL TIRES, TRACTOR REAR 31.00 F13 PRONT TANDEM TIRES 0.0 0.0 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR 0.0 F24 FRICTION REDUCTION PARAMETER FOR TRALLER 0.0	CF3	MAXIMUM COULOMB FRICTION, TRAILER SUSPENSION (LB)	1500.00
CS2 LONGTUDINAL STIFFNESS, TRACTOR FRONT TANDEM TIRES (LBS) 28000.00 CS3 LONGTUDINAL STIFFNESS, TRACTOR REAR TANDEM TIRES (LBS) 28000.00 CS4 LONGTUDINAL STIFFNESS, TRALTER REAR TANDEM TIRES (LBS) 28000.00 CS5 LONGTUDINAL STIFFNESS, TRALTER REAR TANDEM TIRES (LBS) 28000.00 CS5 LONGTUDINAL STIFFNESS, TRALTER REAR TANDEM TIRES (LBS) 28000.00 D VERTICAL DISTANCE FROM STH WHEEL CONNECTION TO TRACTOR CG (IN) 4.50 DELTAI STATIC VERTICAL DISTANCE, TRALTER REAR SUSPENSION (IN) 37.80 D12 DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR SUSPENSION (IN) 13.00 D3 DISTANCE BETWEEN DUAL TIRES, TRALTER 0.0 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR REAR TANDEM TIRES 0.0 FA2 FRICTION REDUCTION PARAMETER FOR TRALER FRONT TANDEM TIRES 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRALER REAR TANDEM TIRES 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRALER REAR TANDEM TIRES 0.0 IX TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) 97371.00 IX TRACTOR PRONT MAKES PITCH MOMENT OF INERTIA (IN-LB-SEC**2) 97371.00 <	CS1	LONGITUDINAL STIFFNESS, TRACTOR FRONT	28000 00
TANDEM TIRES (LES) TRACTOR REAR 28000.00 CS3 LONGITUDINAL STIFPNESS, TRACTOR REAR 28000.00 CS4 LONGITUDINAL STIFPNESS, TRAILER FRONT 28000.00 CS5 LONGITUDINAL STIFPNESS, TRAILER REAR 28000.00 CS5 LONGITUDINAL STIFPNESS, TRAILER REAR 28000.00 D VERTICAL DISTANCE FROM STH WHEEL 28000.00 CONNECTION TO TRACTOR CG (IN) 4.50 DELTAI STATIC VERTICAL DISTANCE, TRACTOR GG TO 24.50 DELTAI STATIC VERTICAL DISTANCE, TRACTOR REAR 37.80 D12 DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR 33.00 D13 DISTANCE BETWEEN DUAL TIRES, TRACTOR 13.00 FRICTION REDUCTION PARAMETER FOR TRACTOR FRONT TANES 0.0 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR FRONT TANDEM TIRES 0.0 FA3 FRICTION REDUCTION PARAMETER FOR TRALLER 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRALLER 0.0 0.0 IXX TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA 0.0 IXX TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA 0.	CS2	LONGITUDINAL STIFFNESS, TRACTOR FRONT	20000.00
TANDEM TIRES (LBS) 28000.00 C54 LONGITUDINAL STIFNESS, TRAILER FRONT 28000.00 C55 LONGITUDINAL STIFNESS, TRAILER FRANT 28000.00 D VERTICAL DISTANCE FROM STH WHEEL 28000.00 D VERTICAL DISTANCE FROM STH WHEEL 28000.00 DELTAI STATIC VERTICAL DISTANCE, TRAILER REAR 24.50 DELTAI STATIC VERTICAL DISTANCE, TRACTOR G TO 77.80 TRAILER RAILE (IN) 37.80 D12 DISTANCE BETWEEN DUAL TIRES, TRAILER 31.00 D13 DISTANCE BETWEEN DUAL TIRES, TRAILER 0.0 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR 78.00 FRONT TARES 0.0 74.70 75.00 FA2 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA3 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 IXX TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA 0.0 IXX TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA 0.0 </td <td>CS3</td> <td>LONGITUDINAL STIFFNESS, TRACTOR REAR</td> <td>28000.00</td>	CS3	LONGITUDINAL STIFFNESS, TRACTOR REAR	28000.00
TANDEM TIRES (LBS) 28000.00 CS5 LONGITUDINAL STIFFNESS, TRAILER REAR 28000.00 D VERTICAL DISTANCE FROM STH WHEEL 28000.00 CONNECTION TO TRACTOR CG (IN) 4.50 DELTAI STATIC VERTICAL DISTANCE, TRACTOR CG TO 74.50 TRACTOR FRONT AXLE (IN) 37.80 DT2 DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR SUSPENSION (IN) 13.00 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR FA2 FRICTION REDUCTION PARAMETER FOR TRACTOR FA3 FRICTION REDUCTION PARAMETER FOR TRACTOR FA4 FRICTION REDUCTION PARAMETER FOR TRACTOR FA5 FRICTION REDUCTION PARAMETER FOR TRALLER FA6 FRICTION REDUCTION PARAMETER FOR TRALLER FA4 FRICTION REDUCTION PARAMETER FOR TRALLER FA5 FRICTION REDUCTION PARAMETER FOR TRALLER FA4 FRICTION REDUCTION PARAMETER FOR TRALLER FA5 FRICTION REDUCTION PARAMETER FOR TRALLER FA60 TRANDEM TIRES 0.0 IXX TRACTOR WOMENS FOIL MOMENT OF INERTIA (IN-LE-SEC**2) 13630.00 IY	CS4	TANDEM TIRES (LBS) Longitudinal Stiffness, Trailer Front	28000.00
CSSLUNGITUDIANE STIFTADES, TARILER KEARTANDEM THES28000.00DVERTICAL DISTANCE FROM STH WHEELCONNECTION TO TRACTOR CG (IN)4.50DELTAISTATIC VERTICAL DISTANCE, TRACTOR CG TOTRACTOR FRONT AXLE (IN)37.80DT2DISTANCE BETWEEN DUAL TIRES, TRACTOR REARSUSPENSION (IN)13.00FA1FRICTION REDUCTION PARAMETER FOR TRACTORFA2FRICTION REDUCTION PARAMETER FOR TRACTORFA2FRICTION REDUCTION PARAMETER FOR TRACTORFA3FRICTION REDUCTION PARAMETER FOR TRACTORFA4FRICTION REDUCTION PARAMETER FOR TRACTORFA5FRICTION REDUCTION PARAMETER FOR TRALERFA6FRICTION REDUCTION PARAMETER FOR TRALERFA4FRICTION REDUCTION PARAMETER FOR TRALERFA5FRICTION REDUCTION PARAMETER FOR TRALERFA5FRICTION REDUCTION PARAMETER FOR TRALERFA5FRICTION REDUCTION PARAMETER FOR TRALERFA5FRICTION SERUNG MASS PLICH MOMENT OF INERTIA(IN-LE-SEC**2)13630.00IYTRACTOR SFUNG MASS ROLL MOMENT OF INERTIA(IN-LE-SEC**2)0.0IZZTRALER STRUNG MASS PLICH MOMENT OF INERTIA(IN-LE-SEC**2)0.0ITXTRALER SERVEN MASS ROLL MOMENT OF INERTIA(IN-LE-SEC**2)0.0ITY(IN-LE-SEC**2)JA1ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE(IN-LE-SEC**2)0.0JA2ROLL MOMENT OF TRACTOR FRONT TANDEM MALELS(IN-LE-SEC**2)0.0JA3ROLL MOMENT OF TRACTOR FRONT TANDEM	005	TANDEM TIRES (LBS)	28000.00
D VERTICAL DISTANCE FROM STH WHEEL CONNECTION TO TRACTOR CG (IN) 4.50 DELTAI STATIC VERTICAL DISTANCE, TRACTOR CG TO TRALLER AXLE (IN) 24.50 DIZ DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR SUSPENSION (IN) 13.00 DT3 DISTANCE BETWEEN DUAL TIRES, TRALLER SUSPENSION (IN) 13.00 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR FRONT TRES 0.0 FA2 FRICTION REDUCTION PARAMETER FOR TRACTOR REAR TANDEM TIRES 0.0 FA3 FRICTION REDUCTION PARAMETER FOR TRALLER FRONT TANDEM TIRES 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRALLER FRONT TANDEM TIRES 0.0 IXX TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LE-SEC*2) 13630.00 IYY TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LE-SEC*2) 97371.00 IZZ TRACTOR TAW MOMENT OF INERTIA (IN-LE-SEC*2) 97371.00 IZZ TRACTOR FICH PLANE CROSS MOMENT (IN-LE-SEC*2) 759480.00 ITXX TRACTOR FICH PLANE CROSS MOMENT (IN-LE-SEC*2) 759480.00 ITXZ TRACTOR FACTOR FRONT AXLE (IN-LE-SEC*2) 759480.00 ITXZ TRACTOR FRONT OF TRACTOR FRONT AXLE (IN-LE-SEC*2) 3719.00 JA1 ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE (IN-LE-SEC*2)	(5)	TANDEM TIRES (LBS)	28000.00
DELTA1 STATIC VERTICAL DISTANCE, TRACTOR CG TO TRACTOR FRONT AXLE (IN) 24.50 DELTA3 STATIC VERTICAL DISTANCE, TRAILER CG TO TRAILER AXLE (IN) 37.80 DT2 DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR SUSPENSION (IN) 13.00 DT3 DISTANCE BETWEEN DUAL TIRES, TRAILER SUSPENSION (IN) 13.00 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR FRONT TANDEM TIRES 0.0 FA2 FRICTION REDUCTION PARAMETER FOR TRACTOR FRONT TANDEM TIRES 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRALER FRONT TANDEM TIRES 0.0 FA5 FRICTION REDUCTION PARAMETER FOR TRAILER FRONT TANDEM TIRES 0.0 IXX TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LE-SEC**2) 13630.00 IYY TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LE-SEC**2) 97371.00 IZZ TRACTOR PITCH PLANE CROSS MOMENT (IN-LE-SEC**2) 97371.00 IZZ TRACTOR PITCH PLANE CROSS MOMENT (IN-LE-SEC**2) 759480.00 ITXX TRACTOR PITCH PLANE CROSS MOMENT (IN-LE-SEC**2) 759480.00 ITXZ TRACTOR PITCH PLANE CROSS MOMENT (IN-LE-SEC**2) 759480.00 ITXZ TRACTOR PITCH PLANE CROSS MOMENT (IN-LE-SEC**2) 759480.00	D	VERTICAL DISTANCE FROM 5TH WHEEL CONNECTION TO TRACTOR CG (IN)	4.50
DELTA3TARLE OF FRANCE (TABLE (TABLER CALL OF STANCE, TRAILER CG TO TRAILER AXLE (IN)24.30DT2DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR SUSPENSION (IN)13.00DT3DISTANCE BETWEEN DUAL TIRES, TRAILER SUSPENSION (IN)13.00FA1FRICTION REDUCTION PARAMETER, FOR TRACTOR FRONT TANDEM TIRES0.0FA2FRICTION REDUCTION PARAMETER FOR TRACTOR FRONT TANDEM TIRES0.0FA3FRICTION REDUCTION PARAMETER FOR TRAILER FRONT TANDEM TIRES0.0FA4FRICTION REDUCTION PARAMETER FOR TRAILER FRONT TANDEM TIRES0.0FA5FRICTION REDUCTION PARAMETER FOR TRAILER FRONT TANDEM TIRES0.0FA4FRICTION REDUCTION PARAMETER FOR TRAILER FRONT TANDEM TIRES0.0IXXTRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2)13630.00IYYTRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2)97371.00IZZTRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2)97371.00IXXTRACTOR PITCH PLANE CROSS MOMENT (IN-LB-SEC**2)21100.00ITXXTRAILER SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2)759480.00ITXZTRAILER SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2)759480.00ITXZTRAILER SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2)759480.00JA1ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE (IN-LB-SEC**2)759480.00JA2ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE (IN-LB-SEC**2)759480.00JA3ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE (IN-LB-SEC**2)759480.00 </td <td>DELTAL</td> <td>STATIC VERTICAL DISTANCE, TRACTOR CG TO</td> <td>24 50</td>	DELTAL	STATIC VERTICAL DISTANCE, TRACTOR CG TO	24 50
TRAILER AXLE (IN) 37.80 DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR 13.00 DT3 DISTANCE BETWEEN DUAL TIRES, TRAILER 13.00 SUSPENSION (IN) 13.00 FA1 FRICTION REDUCTION PARAMETER FOR TRACTOR 13.00 FA2 FRICTION REDUCTION PARAMETER FOR TRACTOR 0.0 FA3 FRICTION REDUCTION PARAMETER FOR TRACTOR 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA5 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA4 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA5 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 FA5 FRICTION REDUCTION PARAMETER FOR TRAILER 0.0 IXX TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) 97371.00 IXZ TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) 0.0 IXX TRACTOR PITCH PLANE CROSS MOMENT (IN-LB-SEC**2) 0.0 IXX TRACTOR PITCH PLANE CROSS MOMENT (IN-LB-SEC**2) 0.0 IXX TRACTOR PITCH PLANE CROSS MOMENT (IN-LB-SEC**2) <td< td=""><td>DELTA3</td><td>STATIC VERTICAL DISTANCE, TRAILER CG TO</td><td>24.50</td></td<>	DELTA3	STATIC VERTICAL DISTANCE, TRAILER CG TO	24.50
SUSPENSION (IN)13.00DT3DISTANCE BETWEEN DUAL TIRES, TRAILERSUSPENSION (IN)13.00FA1FRICTION REDUCTION PARAMETER FOR TRACTORO.0FA1FRONT TIRESO.0FA2FRICTION REDUCTION PARAMETER FOR TRACTORO.0FA3FRICTION REDUCTION PARAMETER FOR TRACTORFRONT TANDEM TIRESO.0FA4FRICTION REDUCTION PARAMETER FOR TRALERO.0FA5FRICTION REDUCTION PARAMETER FOR TRAILERO.0FX5FRICTION REDUCTION PARAMETER FOR TRAILERO.0IXXTRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA(IN-LB-SEC**2)97371.00IXXTRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA(IN-LB-SEC**2)97371.00IZZTRACTOR PITCH PLANE CROSS MOMENTO.00.0IXXTRALER SPRUNG MASS ROLL MOMENT OF INERTIA(IN-LB-SEC**2)97371.00IXZTRACTOR PITCH PLANE CROSS MOMENT0.00.0IXXTRALER SPRUNG MASS ROLL MOMENT OF INERTIA(IN-LB-SEC**2)97371.00IXXTRALLER SPRUNG MASS PITCH MOMENT OF INERTIA0.0ITXXTRALER SPRUNG MASS PITCH MOMENT OF INERTIA0.0ITXXTRALER SPRUNG MASS PITCH MOMENT OF INERTIA10.0ITXXTRALER SPRUNG MASS PITCH MOMENT OF INERTIA1100.00ITXXTRALER SPRUNG MASS PITCH MOMENT OF INERTIA1100.00ITXXTRALER SPRUNG MASS PITCH MOMENT OF INERTIA1100.00ITXXTRALER SPRUNG TOF TRACTOR FRONT ANDEM AXLE1100.00ITXXTRALER SPRUNG TOF TRACTOR FRONT TANDEM AXLE1000.00 <tr< td=""><td>DT2</td><td>TRAILER AXLE (IN) DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR</td><td>37.80</td></tr<>	DT2	TRAILER AXLE (IN) DISTANCE BETWEEN DUAL TIRES, TRACTOR REAR	37.80
DISTARCE BERWEEN DOAL TIRES, TARLERSUSPENSION (IN)13.00FA1FRICTION REDUCTION PARAMETER FOR TRACTOR0.0FA2FRICTION REDUCTION PARAMETER FOR TRACTOR0.0FA3FRICTION REDUCTION PARAMETER FOR TRACTOR0.0FA4FRICTION REDUCTION PARAMETER FOR TRALLER0.0FA5FRICTION REDUCTION PARAMETER FOR TRALLER0.0FA5FRICTION REDUCTION PARAMETER FOR TRALLER0.0IXXTRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA13630.00IYYTRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA(IN-LB-SEC**2)122TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA97371.00IZZTRACTOR PITCH PLANE CROSS MOMENT0.0IXXTRACTOR PITCH PLANE CROSS MOMENT0.0IXXTRALLER SPRUNG MASS PITCH MOMENT OF INERTIA0.0IXXTRALLER SPRUNG MASS PITCH MOMENT OF INERTIA0.0IXXTRACTOR FRONT GASS PITCH MOMENT OF INERTIA0.0IXXTRACTOR FRONT GASS PITCH MOMENT OF INERTIA0.0IXXTRALLER SPRUNG TOF TRACTOR FRONT AXLE0.0JA1ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE(IN-LB-SEC*2)JA2 </td <td>nm0</td> <td>SUSPENSION (IN)</td> <td>13.00</td>	n m0	SUSPENSION (IN)	13.00
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(IN-LB-SEC**2)103.00JS2POLAR MOMENT OF TRACTOR FRONT TANDEM WHEELS (IN-LB-SEC**2)231.00JS3POLAR MOMENT OF TRACTOR REAR TANDEM WHEELS (IN-LB-SEC**2)231.00JS4POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS (IN-LB-SEC**2)231.00JS5POLAR MOMENT OF TRAILER REAR TANDEM WHEELS (IN-LB-SEC**2)231.00K1SPRING RATE, TRACTOR FRONT SUSPENSION (LB/IN)1300.00K2SPRING RATE, TRACTOR REAR SUSPENSION (LB/IN)10000.00K3SPRING RATE, TRAILER SUSPENSION (LB/IN)16000.00	JSl	POLAR MOMENT OF TRACTOR FRONT WHEELS	4100.00
(IN-LB-SEC**2)231.00JS3POLAR MOMENT OF TRACTOR REAR TANDEM WHEELS (IN-LE-SEC**2)231.00JS4POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS (IN-LB-SEC**2)231.00JS5POLAR MOMENT OF TRAILER REAR TANDEM WHEELS (IN-LB-SEC**2)231.00K1SPRING RATE, TRACTOR FRONT SUSPENSION (LB/IN)1300.00K2SPRING RATE, TRACTOR REAR SUSPENSION (LB/IN)10000.00K3SPRING RATE, TRAILER SUSPENSION (LB/IN)16000.00	J52	(IN-LB-SEC**2) POLAR MOMENT OF TRACTOR FRONT TANDEM WHEELS	103.00
SS3FOLMA HOLAR OF TRAFFOR REAR TANDED231.00JS4POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS (IN-LB-SEC**2)231.00JS5POLAR MOMENT OF TRAILER REAR TANDEM WHEELS (IN-LB-SEC**2)231.00K1SPRING RATE, TRACTOR FRONT SUSPENSION (LB/IN)1300.00K2SPRING RATE, TRACTOR REAR SUSPENSION 	753	(IN-LB-SEC**2) POLAR MOMENT OF TRACTOR REAR TANDEM WHEELS	231.00
JS4 POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS 231.00 JS5 POLAR MOMENT OF TRAILER REAR TANDEM WHEELS 231.00 K1 SPRING RATE, TRACTOR FRONT SUSPENSION 231.00 K2 SPRING RATE, TRACTOR REAR SUSPENSION 1300.00 K3 SPRING RATE, TRAILER SUSPENSION (LB/IN) 10000.00		(IN-LB-SEC**2)	231.00
JS5POLAR MOMENT OF TRAILER REAR TANDEM WHEELS (IN-LB-SEC**2)231.00K1SPRING RATE, TRACTOR FRONT SUSPENSION (LB/IN)1300.00K2SPRING RATE, TRACTOR REAR SUSPENSION (LB/IN)10000.00K3SPRING RATE, TRAILER SUSPENSION (LB/IN)16000.00	JS4	POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS (IN-LB-SEC**2)	231.00
K1SPRING RATE, TRACTOR FRONT SUSPENSION (LB/IN)1300.00K2SPRING RATE, TRACTOR REAR SUSPENSION (LB/IN)10000.00K3SPRING RATE, TRAILER SUSPENSION (LB/IN)16000.00	JS5	POLAR MOMENT OF TRAILER REAR TANDEM WHEELS (IN-LB-SEC**2)	231.00
K2SPRING RATE, TRACTOR REAR SUSPENSION1300.00(LB/IN)10000.00K3SPRING RATE, TRAILER SUSPENSION (LB/IN)16000.00	Kl	SPRING RATE, TRACTOR FRONT SUSPENSION	1300.00
(LB/IN) 10000.00 K3 SPRING RATE, TRAILER SUSPENSION (LB/IN) 16000.00	К2	SPRING RATE, TRACTOR REAR SUSPENSION	1300.00
	КЗ	(LB/IN) Spring rate, trailer suspension (LB/IN)	10000.00 16000.00

KRSl	FRONT AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0	
KRS2	REAR AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0	
KRS3	TRAILER AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0	
AKRS	TRACTOR TR TANDEM AUX ROLL STIFFNESS(IN-LB/	DEG)	0.0
KTl	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5700.00	
KT2	SPRING RATE, TRACTOR FRONT TANDEM TIRES		
	(LB/IN)	5700.00	
КТЗ	SPRING RATE, TRACTOR REAR TANDEM TIRES		
	(LB/IN)	5700.00	
KT4	SPRING RATE, TRAILER FRONT TANDEM TIRES		
	(LB/IN)	5300.00	
KT5	SPRING RATE, TRAILER REAR TANDEM TIRES		
	(LB/IN)	5300.00	

FIFTH WHEEL SPRING RATE

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ROTATION WH5DFL (DEG) 0.0 SPRING RATE MC5 (IN-LBS/DEG) 0.20000E+08

TRACTOR FRAME ROLL SPRING RATE

ROTATION TTDFL(DEG)SPRING RATE TTC(IN-LBS/DEG)0.00.19300E+05

TRSTF	TRAILER FRAME ROLL STIFFNESS(IN-LB/DEG)	1500000.00
PW	WEIGHT OF PAYLOAD (LBS)	49970.00
PJ1	POLL MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	87260.00
PJ2	PITCH MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	2458900.00
PJ3	YAW MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	2458900.00
PX	HORIZONTAL DISTANCE FROM MIDPOINT OF REAR	
	SUSPENSION TO PAYLOAD MASS CENTER (IN)	211.40
PZ	VERTICAL DISTANCE FROM GROUND TO PAYLOAD	
	MASS CENTER (IN)	68.00
RCH1	ROLL CENTER HEIGHT, TRACTOR FRONT	
	SUSPENSION (IN)	24.00
RCH2	BOLL CENTER HEIGHT, TRACTOR REAR	2
	SUSPENSION (IN)	30 00
PCH3	BOLL CENTER HEIGHT TRATLER SUSPENSION (IN	30.00
RCIIJ RCI	COMPLIANCE STEER (DEG/IN)	50.00
PSCI	POLL STEEP COFFETCIENT TRACTOR FRONT	0.0
NUCI	SUSDENSION	0 0
DSC2	DOLL STEED COPPERCIENT TRACTOR DEAD	0.0
NDC2	ROLE SILLA COLIFICIENT, IRACIOR REAR	0.10
PSCA	DOLL STEED COEPERCIENT MEALLED SUCCESSION	0.10
RDCJ EV1	HODIZONTAL DIGTINCE FROM TRAILER SUSPENSION	0.10
511	A NUE TO TRACTOR FROM TRACTOR BODY	17 00
CV2	X-AXIS TO TRACTOR FRONT SUSPENSION (IN)	1/.00
512	HORIZONIAL DISTANCE FROM TRACTOR BODY	
e wo	X-AXIS TO TRACTOR REAR SUSPENSION (IN)	20.00
513	HURIZUNTAL DISTANCE FROM TRAILER BODY	• • • • •
	X-AXIS TO TRAILER SUSPENSION (IN)	20.00
TIMP	MAXIMUM REAL TIME FOR SIMULATION (SEC)	4.00
TRAI	HALF TRACK, TRACTOR FRONT AXLE (IN)	40.25
TRAZ	HALF TRACK, TRACTOR REAR AXLE(S) (IN)	36.00
TRA3	HALF TRACK, TRAILER AXLE(S) (IN)	36.00
VEL	INITIAL VELOCITY (FT/SEC)	73.33
W1	SPRUNG WEIGHT OF TRACTOR (LBS)	9150.00
W2	SPRUNG WEIGHT OF TRAILER (LBS)	12080.00
WS1	WEIGHT OF TRACTOR FRONT SUSPENSION (LBS)	1200.00
WS2	WEIGHT OF TRACTOR FRONT TANDEM	
	SUSPENSION (LBS)	2300.00
WS3	WEIGHT OF TRACTOR REAR TANDEM SUSPENSION	
	(LBS)	2300.00
WS4	WEIGHT OF TRAILER FRONT TANDEM	
	SUSPENSION (LBS)	1500.00
WS 5	WEIGHT OF TRAILER REAR TANDEM SUSPENSION	
	(LBS)	1500.00

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BRAKE PARAMETERS: TQ(1,1,1) = 0.050 TQ(1,1,2) = 0.270TQ(1,2,1) = 0.050 TQ(1,2,2) = 0.270TQ(2,1,1) = 0.075 TQ(2,1,2) = 0.245TQ(2,2,1) = 0.075 TQ(2,2,2) = 0.245TQ(3,1,1) = 0.075 TQ(3,1,2) = 0.245TQ(3,2,1) = 0.075 TQ(3,2,2) = 0.245TQ(4,1,1) = 0.175 TQ(4,1,2) = 0.303TQ(4,2,1) = 0.175 TQ(4,2,2) = 0.303TQ(5,1,1) = 0.175 TQ(5,1,2) = 0.303TQ(5,2,1) = 0.175 TQ(5,2,2) = 0.303TABLE 1: TIME VS PRESSURE (PSI) NO. OF POINTS: 2 0.0 0.0 0.0500 0.0 INPUT PARAMETER TABLE FOR BRAKE FORCE CALCULATION SUBROUTINE SYMBOL DESCRIPTION INITIAL VALUE AXLE 1, LEFT SIDE BRAKE TYPE NONE IBRT AXLE 2, LEFT SIDE NONE BRAKE TYPE TBRT AXLE 3, LEFT SIDE NONE IBRT BRAKE TYPE AXLE 4, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 5, LEFT SIDE NONE IBRT BRAKE TYPE 1 TABLE 2: TIME VS STEER ANGLE (DEG) LEFT SIDE NO. OF POINTS: 2 0.0 0.0 8.0000 08.0000 TABLE 3: TIME VS STEER ANGLE (DEG) RIGHT SIDE NO. OF POINTS: 2 0.0 0.0 8.0000 08.0000 PARAMETERS FOR INCLINE SURFACE: GRAVITY X COMPONENT 0.0 G1 GRAVITY Y COMPONENT 0.0 G2 1.000 GRAVITY Z COMPONENT G3 THERE WILL BE NO WIND THIS RUN THE ANTILOCK SYSTEM WILL NOT BE USED THIS RUN

*** END INPUT ***

LOADED EMPTY DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN) DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN) 179.500 57.300 205.189 65.917 ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) 21099.996 111244.875 759480.000 3246906.000 759480.000 3244020.000

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YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2) THE STATIC LOADS ON THE TIRES ARE

80000.000

LOAD 11997.266 AXLE NUMBER 1 17003.195 2 3 17003.195 16998.172 4 16998.172 5

TOTAL

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THE TRACTOR TOTAL SPRUNG MASS CENTER IS 67.689 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 224224.188 IN LB SEC**2.

THE TRAILER MASS CENTER IS 214.274 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 3569055.000 in LB Sec*+2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR	FRONT TIRES	:	FIRESTONE	10X20	RIB
TRACTOR	LEADING TANDEM TIRES	:	FIRESTONE	10X20	RIB
TRACTOR	TRAILING TANDEM TIRES	:	FIRESTONE	10X20	RIB
TRAILER TRAILER	LEADING TANDEM TIRES TRAILING TANDEM TIRES	:	FIRESTONE	10X20 10X20	RIB RIB

*** BEGIN OUTPUT *** ŧ

HSRI TRACTOR-TRAILER HANDLING SIMULATION PAGE NO 1

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165 INCH WH INPUT PARAM	EEL BASE 3AXLE TRACTOR,VAN TRAILER RUN# 145 ETER TABLE	E NO I
SYMBOL KEY(])	DESCRIPTION INITIAL TRACTOR AXLE KEY: 0 FOR SINGLE AXLE	VALUE
	1 FOR WALKING BEAM	_
KEY(2)	2 FOR 4 ELLIPTIC LEAF TRAILER AXLE KEY	2 2
AAl	HORIZONTAL DISTANCE FORM TRACTOR FRONT	
AA2	LEAF-FRAME CONTACT TO AXLE CENTER (IN) HORIZONTAL DISTANCE FROM TRACTOR REAR	24.00
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	24.00
AA4	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	1.00
AA5	HORIZONTAL DISTANCE FROM TRACTOR REAR	1 00
AA6	VERTICAL DISTANCE FROM AXLE DOWN TO	1.00
AA7	TRACTOR TORQUE ROD (IN) ANGLE BETWEEN TRACTOR TOROUE ROD AND	0.0
	HORIZONTAL (DEG)	0.0
AA8	HORIZONTAL DISTANCE FROM AXLE CENTER FORWARD TO TRACTOR TOROUE ROD (IN)	0.0
AA9	HORIZONTAL DISTANCE FROM TRAILER FRONT	
AA10	LEAF-FRAME CONTACT TO AXLE CENTER (IN) HORIZONTAL DISTANCE FROM TRAILER REAR	18.50
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA12	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA13	HORIZONTAL DISTANCE FROM TRAILER REAR	6 25
AAl4	VERTICAL DISTANCE FROM AXLE DOWN TO	0.25
2215	TRAILER TORQUE ROD (IN)	7.00
AA1 2	HORIZONTAL (DEG)	15.01
AA16	HORIZONTAL DISTANCE FROM AXLE CENTER FORWARD TO TRAILER TOROUE ROD (IN)	5.50
Al	HORIZONTAL DISTANCE FROM TRACTOR CG TO	
A2	CENTER OF TRACTOR FRONT SUSPENSION (IN) HORIZONTAL DISTANCE FROM TRACTOR CG TO	57.75
	CENTER OF TRACTOR REAR SUSPENSION (IN)	107.25
A3	STH WHEEL (IN)	230.50
A4	HORIZONTAL DISTANCE FROM TRAILER CG TO	170 50
ALPHA1	STATIC DISTANCE, TRACTOR FRONT AXLE TO	1/9.50
AT DHA 2	GROUND (IN)	19.50
ABFIIAZ	GROUND (IN)	19.50
ALPHA3	STATIC DISTANCE, TRAILER AXLE(S) TO GROUND (IN)	19,50
ANl	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
AN2	FRONT TIRES TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	0.250
2112	FRONT TANDEM TIRES	0.250
ANG	REAR TANDEM TIRES	0.250
AN4	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	0 250
AN5	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	0.200
BB	REAR TANDEM TIRES HORIZONTAL DISTANCE FROM 5TH WHEEL TO MIDPOINT	0.250
	OF TRACTOR REAR SUSPENSION (IN)	24.70
CI	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT SUSPENSION (LB-SEC/IN)	10.00
C2	VISCOUS DAMPING: REBOUND ON TRACTOR FRONT	20 00
C3	VISCOUS DAMPING: JOUNCE ON TRACTOR REAR	20.00
C4	SUSPENSION (LB-SEC/IN) VISCOUS DAMPING: REBOUND ON TRACTOR REAR	10.00
	SUSPENSION (LB-SEC/IN)	20.00
C5	VISCOUS DAMPING: JOUNCE ON TRAILER SUSPENSION (LB-SEC/IN)	10.00
C6	VISCOUS DAMPING: REBOUND ON TRAILER	20.00
	BUBEINGIUN (LD-BLC/IN)	20.00

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CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	
CF1	(LBS/DEG) -1.00 MAXIMUM COULOMB FRICTION, TRACTOR FRONT	
CF2	MAXIMUM COULOMB FRICTION, TRACTOR REAR	
CF3	MAXIMUM COULOMB FRICTION, TRAILER	
CS1	SUSPENSION (LB) 1500.00 LONGITUDINAL STIFFNESS, TRACTOR FRONT	
CS2	TIRES (LBS) 28000.00 LONGITUDINAL STIFFNESS, TRACTOR FRONT	
CS3	TANDEM TIRES (LBS) 28000.00 LONGITUDINAL STIFFNESS, TRACTOR REAR	
CS4	TANDEM TIRES (LBS) 28000.00 LONGITUDINAL STIFFNESS, TRAILER FRONT	
	TANDEM TIPES (IBS) 28000.00	
CS5	LONGITUDINAL STIFFNESS, TRAILER REAR	
D	VERTICAL DISTANCE FROM 5TH WHEEL	
DELTAL	CONNECTION TO TRACTOR CG (IN) 4.50 STATIC VERTICAL DISTANCE, TRACTOR CG TO 4.50	
DELTA3	TRACTOR FRONT AXLE (IN) 24.50 STATIC VERTICAL DISTANCE, TRAILER CG TO	
5000	TRAILER AXLE (IN) 37.80	
DIZ	SUSPENSION (IN) 13.00	
DT3	DISTANCE BETWEEN DUAL TIRES, TRAILER SUSPENSION (IN) 13.00	
FAl	FRICTION REDUCTION PARAMETER FOR TRACTOR	
FA2	FRICTION REDUCTION PARAMETER FOR TRACTOR	
FA3	FRONT TANDEM TIRES 0.0 FRICTION REDUCTION PARAMETER FOR TRACTOR	
FA4	FRICTION REDUCTION PARAMETER FOR TRAILER	
FA5	FRONT TANDEM TIRES 0.0 FRICTION REDUCTION PARAMETER FOR TRAILER	
IXX	REAR TANDEM TIRES 0.0 TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA	
IYY	(IN-LB-SEC**2) 14230.00 TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA	
122	(IN-LB-SEC**2) 102690.00 TRACTOR YAW MOMENT OF INERTIA	
TY7	(IN-LB-SEC**2) 102690.00	
177	(IN-LB-SEC**2) 0.0	
ITXX	TRAILER SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) 21100.00	
ITYY ITZZ	(IN-LB-SEC**2) MASS PITCH MOMENT OF INER 759480.00 TRAILER YAW MOMENT OF INERTIA	
T MV 2	(IN-LB-SEC**2) 759480.00	
1172	(IN-LB-SEC**2) 0.0	
JAl	ROLL MOMENT OF TRACTOR FRONT AXLE (IN-LB-SEC**2) 3719.00	
JA2	ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE	
JA3	ROLL MOMENT OF TRAILER FRONT TANDEM AXLE	
JS1	(IN-LB-SEC**2) 4100.00 POLAR MOMENT OF TRACTOR FRONT WHEELS	
JS2	(IN-LB-SEC**2) 103.00 POLAR MOMENT OF TRACTOR FRONT TANDEM WHEELS	
JS3	(IN-LB-SEC**2) 231.00 POLAR MOMENT OF TRACTOR REAR TANDEM WHEELS	
JS4	(IN-LB-SEC**2) 231.00 POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS	
105	(IN-LB-SEC**2) 231.00	
	(IN-LB-SEC**2) 231.00	
Kl	SPRING RATE, TRACTOR FRONT SUSPENSION (LB/IN) 1300.00	
К2	SPRING RATE, TRACTOR REAR SUSPENSION	
КЗ	SPRING RATE, TRAILER SUSPENSION (LB/IN) 16000.00	

KRS1	FRONT AUXILIARY ROLL STIFFNESS (IN-LB/DEG	0.0	
KRS2	REAR AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0	
KRS3	TRAILER AUXILIARY ROLL STIFFNESS(IN-LB/DEG	0.0	
AKRS	TRACTOR TR TANDEM AUX ROLL STIFFNESS(IN-LB/	DEG)	0.0
KTl	SPRING RATE, TRACTOR FRONT TIRES (LB/IN)	5700.00	
KT2	SPRING RATE, TRACTOR FRONT TANDEM TIRES		
	(LB/IN)	5700.00	
KT 3	SPRING RATE, TRACTOR REAR TANDEM TIRES		
	(LB/IN)	5700.00	
KT4	SPRING RATE, TRAILER FRONT TANDEM TIRES		
	(LB/IN)	5300.00	
KT5	SPRING RATE, TRAILER REAR TANDEM TIRES		
	(LB/IN)	5300.00	

FIFTH WHEEL SPRING RATE

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ROTATION WH5DFL (DEG) SPRING RATE MC5 (IN-LBS/DEG) 0.0 0.20000E+08

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TRACTOR FRAME ROLL SPRING RATE

	ROTATION TTDFL(DEG) SPRING RATE TTC(IN-LBS/DEG) 0.0 0.17000E+05	
TRSTF PW	TRAILER FRAME ROLL STIFFNESS(IN-LB/DEG) 1500000. WEIGHT OF PAYLOAD (LBS) 49586.	00
PJ1	POLL MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2) 86590.	00
PJ2	PITCH MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2) 2472220.	00
PJ3	YAW MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2) 2472220.	00
PX	HORIZONTAL DISTANCE FROM MIDPOINT OF REAR SUSPENSION TO PAYLOAD MASS CENTER (IN) 209.	80
PZ	VERTICAL DISTANCE FROM GROUND TO PAYLOAD MASS CENTER (IN) 68.	00
RCH1	ROLL CENTER HEIGHT, TRACTOR FRONT	00
RCH2	ROLL CENTER HEIGHT, TRACTOR REAR	00
RCH3	ROLL CENTER HEIGHT, TRAILER SUSPENSION (IN 30.	00
RSC1	ROLL STEER COEFFICIENT, TRACTOR FRONT	0
RSC2	ROLL STEER COEFFICIENT, TRACTOR REAR	
RSC3	ROLL STEER COEFFICIENT, TRAILER SUSPENSION 0.	10
511	X-AXIS TO TRACTOR FRONT SUSPENSION (IN) 17.	00
512	X-AXIS TO TRACTOR REAR SUSPENSION (IN) 20.	00
513	X-AXIS TO TRAILER SUSPENSION (IN) 20.	00
TIMF TRA1 TRA2 TRA3	MAXIMUM REAL TIME FOR SIMULATION (SEC)0.HALF TRACK, TRACTOR FRONT AXLE (IN)40.HALF TRACK, TRACTOR REAR AXLE(S) (IN)36.HALF TRACK, TRAILER AXLE(S) (IN)36.	10 25 00 00
VEL Wl W2	INITIAL VELOCITY (FT/SEC)73.SPRUNG WEIGHT OF TRACTOR (LBS)9550.SPRUNG WEIGHT OF TRAILER (LBS)12080.	33 00 00
WS1 WS2	WEIGHT OF TRACTOR FRONT SUSPENSION (LBS) 1200. WEIGHT OF TRACTOR FRONT TANDEM SUSPENSION (LBS) 2300	00
WS3	WEIGHT OF TRACTOR REAR TANDEM SUSPENSION (LBS) 2300.	00
WS4	WEIGHT OF TRAILER FRONT TANDEM SUSPENSION (LBS) 1500.	00
WS5	WEIGHT OF TRAILER REAR TANDEM SUSPENSION (LBS) 1500.	00

BRAKE PARAMETERS: TQ(1,1,1) = 0.050 TQ(1,1,2) = 0.270TQ(1,2,1) = 0.050 TQ(1,2,2) = 0.270TQ(2,1,1) = 0.075 TQ(2,1,2) = 0.245TQ(2,2,1) = 0.075 TQ(2,2,2) = 0.245TQ(3,1,1) = 0.075 TQ(3,1,2) = 0.245TQ(3,2,1) = 0.075 TQ(3,2,2) = 0.245TQ(4,1,1) = 0.175 TQ(4,1,2) = 0.303TQ(4,2,1) = 0.175 TQ(4,2,2) = 0.303TQ(5,1,1) = 0.175 TQ(5,1,2) = 0.303TQ(5,2,1) = 0.175 TQ(5,2,2) = 0.303TABLE 1: TIME VS PRESSURE (PSI) NO. OF POINTS: 2 0.0 0.0 0.0500 0.0 INPUT PARAMETER TABLE FOR BRAKE FORCE CALCULATION SUBROUTINE SYMBOL DESCRIPTION INITIAL VALUE AXLE 1, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 2, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 3, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 4, LEFT SIDE BRAKE TYPE TBRT NONE AXLE 5, LEFT SIDE IBRT BRAKE TYPE NONE TABLE 2: TIME VS STEER ANGLE (DEG) LEFT SIDE NO. OF POINTS: 2 0.0 0.0 8.0000 08.0000 TABLE 3: TIME VS STEER ANGLE (DEG) RIGHT SIDE NO. OF POINTS: 2 0.0 0.0 $\overline{}$ 8.0000 08.0000 PARAMETERS FOR INCLINE SURFACE: G1 GRAVITY X COMPONENT 0.0 G 2 GRAVITY Y COMPONENT 0.0 G3 GRAVITY Z COMPONENT 1.000 THERE WILL BE NO WIND THIS RUN THE ANTILOCK SYSTEM WILL NOT BE USED THIS RUN *** END INPUT ***

 EMPTY
 LOADED

 DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN)
 179.500
 203.8€

 DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN)
 57.300
 65.904

 ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 21099.996
 110570.500

 PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 759480.000
 3257679.00

 YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)
 759480.000
 3254798.00

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THE STATIC LOADS ON THE TIRES ARE AXLE NUMBER LOAD

1	11997.523
2	17007.320
3	17007.320
4	17001.918
5	17001.918

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TOTAL 80016.000

THE TRACTOR TOTAL SPRUNG MASS CENTER IS 85.375 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 239847.063 IN LB SEC**2.

THE TRAILER MASS CENTER IS 215.594 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 3575726.000 in LB Sec**2

TIME INCREMENT TO BE PRINTED OUT IS 0.10

TRACTOR	FRONT TIRES	:	FIRESTONE	10X20	RIB
TRACTOR	LEADING TANDEM TIRES	:	FIRESTONE	10X20	RIB
TRACTOR	TRAILING TANDEM TIRES	:	FIRESTONE	10X20	RIB
TRAILER	LEADING TANDEM TIRES	::	FIRESTONE	10X20	RIB
TRAILER	TRAILING TANDEM TIRES		FIRESTONE	10X20	RIB

*** BEGIN OUTPUT ***

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200 INCH WH	EEL BASE 3AXLE TRACTOR,VAN TRAILER RUN # 193	
INPUT PARAM	ETER TABLE	
SYMBOL	DESCRIPTION INITIAL	VALUE
KEY(1)	I FOR WALKING REAM	
	2 FOR 4 ELLIPTIC LEAF	2
KEY(2)	TRAILER AXLE KEY	2
AA1	HORIZONTAL DISTANCE FORM TRACTOR FRONT	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	24.00
AA2	HORIZONTAL DISTANCE FROM TRACTOR REAR	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	24.00
AA4	HORIZONTAL DISTANCE FROM TRACTOR FRONT	1 00
AA 5	HORIZONTAL DISTANCE FROM TRACTOR REAR	1.00
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	1.00
ААб	VERTICAL DISTANCE FROM AXLE DOWN TO	
	TRACTOR TORQUE ROD (IN)	0.0
AA7	ANGLE BETWEEN TRACTOR TORQUE ROD AND	
	HORIZONTAL (DEG)	0.0
AA8	HORIZONTAL DISTANCE FROM AXLE CENTER	• •
PAA	HORTZONTAL DISTANCE FROM TRATIER FROMT	0.0
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA10	HORIZONTAL DISTANCE FROM TRAILER REAR	
	LEAF-FRAME CONTACT TO AXLE CENTER (IN)	18.50
AA12	HORIZONTAL DISTANCE FROM TRAILER FRONT	
	LEAF-FRAME CONTACT TO LOAD LEVELER PIN (IN	6.25
AA13	HORIZONTAL DISTANCE FROM TRAILER REAR	6 75
AA14	VERTICAL DISTANCE FROM AXLE DOWN TO	0.25
	TRAILER TOROUE ROD (IN)	7.00
AA15	ANGLE BETWEEN TRAILER TORQUE ROD AND	
	HORIZONTAL (DEG)	15.01
AA16	HORIZONTAL DISTANCE FROM AXLE CENTER	
• •	FORWARD TO TRAILER TORQUE ROD (IN)	5.50
AI	CENTER OF TRACTOR FROM TRACTOR CG TO	60 00
A2	HORIZONTAL DISTANCE FROM TRACTOR CG TO	60.00
	CENTER OF TRACTOR REAR SUSPENSION (IN)	140.00
A3	HORIZONTAL DISTANCE FROM TRAILER CG TO	
	5TH WHEEL (IN)	230.50
A4	HORIZONTAL DISTANCE FROM TRAILER CG TO	
וגעסזג	CENTER OF TRAILER SUSPENSION (IN)	1/9.50
AUFIAL	GROUND (IN)	19 50
ALPHA2	STATIC DISTANCE, TRACTOR REAR AXLE(S) TO	19.50
	GROUND (IN)	19.50
ALPHA3	STATIC DISTANCE, TRAILER AXLE(S) TO	
	GROUND (IN)	19.50
ANI	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	
AN2	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	0.250
	FRONT TANDEM TIRES	0.250
AN 3	TIRE PRESSURE DIST. FUNCTION FOR TRACTOR	0.200
	REAR TANDEM TIRES	0.250
AN4	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	
ANE	FRONT TANDEM TIRES	0.250
AND	TIRE PRESSURE DIST. FUNCTION FOR TRAILOR	0 250
BB	HORIZONTAL DISTANCE FROM 5TH WHEEL TO MIDPOINT	0.250
	OF TRACTOR REAR SUSPENSION (IN)	24.40
C1	VISCOUS DAMPING: JOUNCE ON TRACTOR FRONT	
	SUSPENSION (LB-SEC/IN)	10.00
C2	VISCOUS DAMPING: REBOUND ON TRACTOR FRONT	
C 2	SUSPENSION (LE-SEC/IN)	20.00
.	SUSPENSION (LB+SEC/IN)	10 00
C4	VISCOUS DAMPING: REBOUND ON TRACTOR REAR	T0.00
	SUSPENSION (LB-SEC/IN)	20.00
C5	VISCOUS DAMPING: JOUNCE ON TRAILER	
<u> </u>	SUSPENSION (LB-SEC/IN)	10.00
CD	VISCOUS DAMPING: REBOUND ON TRAILER	20.00
	COLIDIOI (TD-DRC/IN)	20.00

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CALF1	LATERAL STIFFNESS, TRACTOR FRONT TIRES	
CF1	(LBS/DEG) MAXIMUM COULOMB FRICTION, TRACTOR FRONT	-1.00
CF2	SUSPENSION (LB) MAXIMUM COULOMB FRICTION, TRACTOR REAR	500.00
CF3	MAXIMUM COULOMB FRICTION, TRAILER	1500.00
CS1	SUSPENSION (LB) LONGITUDINAL STIFFNESS, TRACTOR FRONT	1500.00
CS2	TIRES (LBS) LONGITUDINAL STIFFNESS, TRACTOR FRONT	28000.00
CS3	TANDEM TIRES (LBS) LONGITUDINAL STIFFNESS, TRACTOR REAR	28000.00
CS4	TANDEM TIRES (LBS) LONGITUDINAL STIFFNESS, TRAILER FRONT	28000.00
CS5	TANDEM TIRES (LBS) LONGITUDINAL STIFFNESS, TRAILER REAR	28000.00
D	TANDEM TIRES (LBS) VERTICAL DISTANCE FROM 5TH WHEEL	28000.00
DELTAl	CONNECTION TO TRACTOR CG (IN) STATIC VERTICAL DISTANCE, TRACTOR CG TO	4.50
	TRACTOR FRONT AXLE (IN)	24.50
	TRAILER AXLE (IN)	37.80
DT2	SUSPENSION (IN)	13.00
DT3	DISTANCE BETWEEN DUAL TIRES, TRAILER SUSPENSION (IN)	13.00
FAl	FRICTION REDUCTION PARAMETER FOR TRACTOR	0.0
FA2	FRICTION REDUCTION PARAMETER FOR TRACTOR	0.0
FA3	FRICTION REDUCTION PARAMETER FOR TRACTOR	0.0
FA4	FRICTION REDUCTION PARAMETER FOR TRAILER	0.0
FA5	FRONT TANDEM TIRES FRICTION REDUCTION PARAMETER FOR TRAILER	0.0
IXX	TRACTOR SPRUNG MASS ROLL MOMENT OF INERTIA	0.0
IYY	(IN-LB-SEC**2) TRACTOR SPRUNG MASS PITCH MOMENT OF INERTIA	15200.00
IZZ	(IN-LB-SEC**2) TRACTOR YAW MOMENT OF INERTIA	1532/0.00
IXZ	(IN-LB-SEC**2) TRACTOR PITCH PLANE CROSS MOMENT	1532/0.00
ITXX	(IN-LB-SEC**2) TRAILER SPRUNG MASS ROLL MOMENT OF INERTIA	0.0
ITYY	(IN-LB-SEC**2) (IN-LB-SEC**2) MASS PITCH MOMENT OF INER	21100.00 759480.00
ITZZ	TRAILER YAW MOMENT OF INERTIA (IN-LB-SEC**2)	759480.00
ITXZ	TRAILER PITCH PLANE CROSS MOMENT	0 - 0
JAl	ROLL MOMENT OF TRACTOR FRONT AXLE	3719 00
JA2	(IN-LD-SEC-2) ROLL MOMENT OF TRACTOR FRONT TANDEM AXLE	3/19.00
5AL	(IN-LB-SECA-2) ROLL MOMENT OF TRAILER FRONT TANDEM AXLE	4458.00
JS1	POLAR MOMENT OF TRACTOR FRONT WHEELS	4100.00
JS2	(IN-LB-SEC**2) POLAR MOMENT OF TRACTOR FRONT TANDEM WHEELS	103.00
JS3	(IN-LB-SEC**2) POLAR MOMENT OF TRACTOR REAR TANDEM WHEELS	231.00
JS4	(IN-LB-SEC**2) POLAR MOMENT OF TRAILER FRONT TANDEM WHEELS	231.00
JS5	(IN-LB-SEC**2) POLAR MOMENT OF TRAILER REAR TANDEM WHEELS	231.00
Kl	(IN-LB-SEC**2) Spring rate, tractor front suspension	231.00
К2	(LE/IN) SPRING RATE, TRACTOR REAR SUSPENSION	1300.00
КЗ	(LB/IN) Spring rate, trailer suspension (LB/IN)	10000.00 16000.00

KRS1 KRS2 KRS3	FRONT AUXILIARY ROLL STIFFNESS (IN-LB/D REAR AUXILIARY ROLL STIFFNESS (IN-LB/D TRAILER AUXILIARY ROLL STIFFNESS (IN-LB/D	EG 0.0 EG 0.0	
AKRS	TRACTOR TR TANDEM AUX ROLL STIFFNESS(IN- SPRING BATE, TRACTOR FRONT TIRES (LB/IN)	LB/DEG) 0.0)
KT2	SPRING RATE, TRACTOR FRONT TANDEM TIRES	5700-00	
КТЗ	SPRING RATE, TRACTOR REAR TANDEM TIRES	5700.00	
KT4	SPRING RATE, TRAILER FRONT TANDEM TIRES	5300.00	
КТ5	SPRING RATE, TRAILER REAR TANDEM TIRES	5300.00	
KT5	SPRING RATE, TRAILER REAR TANDEM TIRES (LB/IN)	5300.00	

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FIFTH WHEEL SPRING RATE

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ROTATION WH5DFL (DEG)SPRING RATE MC5 (IN-LBS/DEG)0.00.20000E+08

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TRACTOR FRAME ROLL SPRING RATE

	ROTATION TTDFL(DEG) SPRING RATE TTC(IN-LBS/DI 0.0 0.14000E+05	EG)
TRSTF	TRAILER FRAME ROLL STIFFNESS(IN-LB/DEG)	1500000.00
PW	WEIGHT OF PAYLOAD (LBS)	48920.00
PJl	POLL MOMENT OF INERTIA OF PAYLOAD (IN-LB-SEC**2)	85427.00
PJ2	PITCH MOMENT OF INERTIA OF PAYLOAD	
	(IN-LB-SEC**2)	2493130.00
PJ3	YAW MOMENT OF INERTIA OF PAYLOAD	
-	(IN-LB-SEC**2)	2493130.00
PX	HORIZONTAL DISTANCE FROM MIDPOINT OF REAR	207.10
77	SUSPENSION TO PAYLOAD MASS CENTER (IN) NEDTICAL DISTANCE EDOM CROUND TO DAVLOAD	207.10
P2	WASS CENTED (IN)	68 00
DCH1	PARS CENTER (IN) Pail center height tractor front	00.00
KCHI	SUSPENSION (IN)	24.00
RCH2	BOLL CENTER HEIGHT, TRACTOR REAR	2
	SUSPENSION (IN)	30.00
RCH3	ROLL CENTER HEIGHT, TRAILER SUSPENSION (IN	30.00
RS1	COMPLIANCE STEER (DEG/IN)	0.0
RSC1	ROLL STEER COEFFICIENT, TRACTOR FRONT	
	SUSPENSION	0.0
RSC2	ROLL STEER COEFFICIENT, TRACTOR REAR	
	SUSPENSION	0.10
RSC3	ROLL STEER COEFFICIENT, TRAILER SUSPENSION	0.10
SYI	HORIZONTAL DISTANCE FROM TRACTOR BODY	
67.0	X-AXIS TO TRACTOR FRONT SUSPENSION (IN)	17.00
512	HURIZUNIAL DISTANCE FRUM TRACTOR BUDY	20.00
SV3	HORIZONTAL DISTANCE FROM TRALLED BODY	20.00
010	X-AXIS TO TRAILER SUSPENSION (IN)	20.00
TIMF	MAXIMUM REAL TIME FOR SIMULATION (SEC)	4.00
TRA1	HALF TRACK, TRACTOR FRONT AXLE (IN)	40.25
TRA2	HALF TRACK, TRACTOR REAR AXLE(S) (IN)	36.00
TRA 3	HALF TRACK, TRAILER AXLE(S) (IN)	36.00
VEL	INITIAL VELOCITY (FT/SEC)	73.33
W1	SPRUNG WEIGHT OF TRACTOR (LBS)	10200.00
W2	SPRUNG WEIGHT OF TRAILER (LBS)	12080.00
WS1	WEIGHT OF TRACTOR FRONT SUSPENSION (LBS)	1200.00
WS2	WEIGHT OF TRACTOR FRONT TANDEM	
WC 2	SUSPENSION (LBS) WEICHT OF TRACTOR REAR TANDEM SUCREMICION	2300.00
w53	(IBS)	2300 00
WS4	WEIGHT OF TRAILER FRONT TANDEM	2300.00
	SUSPENSION (LBS)	1500.00
WS5	WEIGHT OF TRAILER REAR TANDEM SUSPENSION	
	(LBS)	1500.00

BRAKE PARAMETERS: TQ(1,1,1) = 0.050 TQ(1,1,2) = 0.270TQ(1,2,1) = 0.050 TQ(1,2,2) = 0.270TQ(2,1,1) = 0.075 TQ(2,1,2) = 0.245TQ(2,2,1) = 0.075 TQ(2,2,2) = 0.245TQ(3,1,1) = 0.075 TQ(3,1,2) = 0.245TQ(3,2,1) = 0.075 TQ(3,2,2) = 0.245TQ(4,1,1) = 0.175 TQ(4,1,2) = 0.303TQ(4,2,1) = 0.175 TQ(4,2,2) = 0.303TQ(5,1,1) = 0.175 TQ(5,1,2) = 0.303TQ(5,2,1) = 0.175 TQ(5,2,2) = 0.303TABLE 1: TIME VS PRESSURE (PSI) NO. OF POINTS: 2 0.0 0.0 0.0500 0.0 INPUT PARAMETER TABLE FOR BRAKE FORCE CALCULATION SUBROUTINE SYMBOL DESCRIPTION INITIAL VALUE AXLE 1, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 2, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 3, LEFT SIDE IBRT BRAKE TYPE NONE AXLE 4, LEFT SIDE NONE IBRT BRAKE TYPE AXLE 5, LEFT SIDE IBRT BRAKE TYPE NONE TABLE 2: TIME VS STEER ANGLE (DEG) LEFT SIDE NO. OF POINTS: 2 0.0 0.0 8.0000 08.0000 TABLE 3: TIME VS STEER ANGLE (DEG) RIGHT SIDE NO. OF POINTS: 2 0.0 0.0 8.0000 08.0000 PARAMETERS FOR INCLINE SURFACE: GRAVITY X COMPONENT GRAVITY Y COMPONENT 0.0 G] G2 0.0 GRAVITY Z COMPONENT 1.000 G3 THERE WILL BE NO WIND THIS RUN THE ANTILOCK SYSTEM WILL NOT BE USED THIS RUN *** END INPUT ***

DISTANCE FROM TRAILER SPRUNG MASS CENTER TO TRAILER REAR AXLE CENTERLINE (IN)EMPTYLOADEDDISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN)57.30065.881ROLL MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)21099.996109399.813PITCH MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)759480.0003274597.000YAW MOMENT OF TRAILER SPRUNG MASS (IN-LB-SEC**2)759480.0003271724.000

: FIRESTONE 10X20 RIB

THE TRACTOR TOTAL SPRUNG MASS CENTER IS 95.750 INCHES BEHIND THE FRONT AXLE, THE TOTAL YAW MOMENT OF INERTIA IS 365106.750 IN LB SEC**2.

THE TRAILER MASS CENTER IS 217.818 INCHES BEHIND THE FIFTH WHEEL, THE TOTAL YAW MOMENT OF INERTIA IS 3585798.000 IN LB SEC**2

TRACTOR LEADING TANDEM TIRES : FIRESTONE 10X20 RIB TRACTOR TRAILING TANDEM TIRES : FIRESTONE 10X20 RIB

TRAILER LEADING TANDEM TIRES : FIRESTONE 10X20 RIB TRAILER TRAILING TANDEM TIRES : FIRESTONE 10X20 RIB .

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THE STATIC LOADS ON THE TIRES ARE

LOAD 11999.914

16999.664

16999.664 17000.379

17000.379

80000.000

TIME INCREMENT TO BE PRINTED OUT IS 0.10 TRACTOR FRONT TIRES

*** BEGIN OUTPUT ***

AXLE NUMBER

1

2

3 4 5

TOTAL

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1

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TIRE DATA

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(TRANSPORT 1) FIRESTONE, 10.00X20 RIB

0.25 0.000 05		AN FA	PRESSU FRICTI ALIGNI	JRE ION ING	DISTRI REDUCT TORQUE	BUTION FUN ION PARAMN TABLE	NCTION ETER
2000.0	05						
0.0							
3.0	43.54						
7.0	61.00						
10.0	39.0						
4000.0	05						
0.0	0.0						
1.0	343 0						
7.0	194.0						
10.0	158.0						
6000.0	05						
0.0	0.0						
1.0	130.0						
7.0	373.0						
10.0	329.0						
8000.0	05						
0.0	0.0						
1.0	1/9.0						
7.0	562.0						
10.0	473.0						
9000.0	05						
0.0	0.0						
1.0	200.0						
7.0	4J2.0 650.0						
10.0	565.0						
06				COF	RNERING	STIFFNESS	5 TABLE
0.0	0	.0			1.0		10.0
2000.0	39	90.0)		1.0		10.0
4000.0	74	40.()		1.0		10.0
8000.0		0.00)		1.0		10.0
9000.0	82	25.0)		1.0		10.0
06			M	1UZE	RO TABI	LE	
0.0	1.0						
4000.0	0.94						
6000.0	0.88						
8000.0	0.85						

9000.0 0.81

(TRANSPORT 1) FIRESTONE, 10.00X22 RIB

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0.25	AN PRESSURE DISTRIBUTION FUNCTION	
0.002	FA FRICTION REDUCTION PARAMETER	
05	ALIGNING TORQUE TABLE	
1375.0	05	
0.00	0.0	
2.0	26.70	
4.0	31.80	
8.0	21.00	
16.0	5.50	
2890.0	05	
0.0	0.0	
2.0	90.20	
4.0	114.0	
8.0	85.5	
16.0	37.0	
5780.0	05	
0.0	0.0	
2.0	209.6	
4.0	301.8	
8.0	260.0	
16.0	110.0	
7500.0	05	
0.0	0.0	
2.0	282.50	
4.0	419.5	
8.0	414.0	
16.0	270.0	
9000.0	05	
0.0	0.0	
2.0	345.4	
4.0	533.1	
8.0	488.0	
16.0	380.0	
06	CORNERING STIFFNESS TABLE	
0.0	0.0 0.0 8.0	}
3000.0	550.0 0.0 8.0)
4500.0	655.0 0.0 8.0	، ۱
6000.0	705.0 0.0 8.0	,)
7500.0	730.0 0.0 8.0	, }
9000.0	780.0 0.0 8.0	۱
06	MUZERO TABLE	'
0.0	3.00	
3000.0	0.93	
4500.0	0.90	
6000.0	0.83	
7500.0	0.79	
9000.0	0.74	

(FLEETMASTER SUPERLUG)

UNIROYAL 10.00X20 LUG

0.25		AN	PRESS	URE	DIST	RIBUT	ION FI	NCTION
0.000		ΓA.	FRICT	ION	RED	PARAM	ETER	
04		ALI(GNING	TOF	QUE	TABLE		
2000.0	05							
0.00	0.0							
2.0	40.0							
4.0	49.0							
8.0	50.0							
16.0	16.0							
4000.0	05							
0.0	0.0							
2.0	102.0							
4.0	143.0							
8 0	162 0							
16 0	66 0							
6000 0	00.0							
0000.0	0 0							
2 0	165 0							
2.0	248 0							
4.0	240.0							
16 0	300.0							
10.0	14/.0							
0000.0	05							
0.0								
2.0	231.0							
4.0	361.0							
8.0	466.0							
16.0	257.0					m 1 D r	-	
05	00	ANER.	ING S	LTEE	NESS	TABL	E	
0.0	0.	.0			0.5			10.0
2000.0	20				0.5			10.0
4000.0	4	50.0			0.5			10.0
6000.0	5.	50.0			0.5			10.0
8000.0	59	10.0		_	0.5			10.0
05	MUZ	CERO	TABL	Ľ				
0.0	0.95							
2000.0	0.95							
4000.0								
	0.85							
8000.0	0.82							
APPENDIX III

DETAILED DATA FROM FULL-SCALE TESTS

This appendix contains test data obtained from trapezoidal steer experiments conducted on tractor-semitrailer vehicles. The tests were done at a forward speed of approximately 43 mph, in the fully loaded condition. The three tractor-semitrailer combinations for which test data are presented are listed below:

- 1) International Harvester tractor/Fruehauf van trailer,
- 2) International Harvester tractor/Trailmobile flat-bed trailer, and
- 3) Ford tractor/Trailmobile flat-bed trailer.

Each of the vehicles was tested under the following four test configurations:

- 1) baseline
- 2) frame stiffener attached to tractor frame
- auxiliary front roll stiffener (sway bar) attached to tractor front axle, and
- the condition in which both tractor frame stiffener and sway bar were used (also called the "modified" condition).

First, plots of steady-state lateral acceleration of the tractor as a function of steering-wheel angle are presented. These plots are followed by another set of plots which display the tractor steady-state yaw rate response as a function of the steering-wheel angle.

Next, the data are presented in the handling diagram format by using the $[(Lr/V - \delta_{FW}), a_y]$ coordinate system. The front-wheel angle, δ_{FW} , were estimated by using an "apparent" or "effective" steering ratio of 73 for the International Harvester tractor and 100 for the Ford tractor.

Lateral Acceleration vs. Steering-Wheel Angle

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IHC-VAN TRAILER MODIFIED









IHC-FLAT BED TRAILER MODIFIED

71

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FORD-FLAT BED TRAILER BASELINE







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Yaw Rate vs. Steering-Wheel Angle



IHC-VAN TRAILER BASELINE





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Handling Diagrams

(Lr/V - $\delta)$ vs. Tractor Lateral Acceleration, $a_{\rm y}$









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APPENDIX IV

ANALYSIS OF TRACTOR-SEMITRAILER YAW RESPONSE

Linear analysis techniques have been used for the purpose of studying the steady turning behavior of passenger cars and articulated vehicles at low levels of lateral acceleration. Such maneuvers result in small levels of slip angle and side-to-side load transfer such that the assumption of linear tire characteristics (particularly, the cornering force versus slip angle relationship) is warranted.

Because of their relatively high ratio of c.g. height to track width, commercial vehicles possess a low rollover threshold (usually in the range of 0.45 to 0.65 g of lateral acceleration) and they experience large amounts of side-to-side load transfer, even at moderate levels of lateral acceleration. Since the cornering force produced at an axle is influenced by the amount of load transfer that takes place at that axle, as well as the magnitude of the slip angle, the steady turning behavior of commercial vehicles is very sensitive to the severity of the maneuver and to the roll moment distribution among the axles.

In this appendix, a simplified analysis of the steady turning behavior of tractor-trailer vehicles based on a quasi-linear yaw model (a model in which all geometric nonlinearities are neglected, but tire nonlinearities are retained) is used as an aid in understanding the phenomenon of yaw divergence of tractor-trailer combinations.

This analysis is developed in a number of steps which, together, form the basis for an understanding of the tractor-trailer yaw response characteristics within which tractor yaw stability is singled out as the primary issue. The discussion begins with a simplified analysis of the linear tractor-semitrailer. This analysis concludes with expressions describing the tractor's steady-state yaw response to front-wheel steer angle as well as the trailer's response to articulation angle.

Two basic types of tractor-semitrailer yaw divergency are identified. From this review, we see that all truly unstable yaw behaviors of tractorsemitrailers require that the tractor itself be operating in a yaw-unstable

mode. Thus, all subsequent presentations of system stability are confined to displays of the tractor's operating state.

A generally useful diagram for presenting steady-state yaw response characteristics is then introduced. Called the "handling diagram," this presentation scheme is expanded to permit inclusion of the rollover threshold and to describe a yaw stability boundary for broad application of the diagram to the stability investigations of this study.

In successive steps, then, the treatment of the vehicle system with a nonlinear representation of the tire permits the definition of three basic forms of tractor yaw behavior vis-a-vis the handling diagram. Next, the addition of tandem axles as another mechanism influencing yaw response is covered, revealing a specific treatment of the handling diagram needed for representing the tandem-axle tractor. The last two sections develop the basis for evaluating the yaw behavior of the tandemaxle tractor with (a) a linear tire representation (for which a single curve on the handling diagram constitutes a complete description of the vehicle's steady-turning response) and (b) a nonlinear tire representation (for which a family of curves, one for each operating velocity, is needed to describe vehicle response).

IV.1 <u>Simplified Analysis of the Steady-Turning Behavior of a Two-Axle</u> <u>Tractor/Single-Axle Trailer Combination</u>

A plan view of the tractor-trailer combination, whose steady-turning behavior is to be analyzed, is shown in Figure IV.1. Simplifying assumptions made in the analysis are as follows:

- All motions of the vehicle take place in the horizontal plane
- 2) The steer angle, δ , and the articulation angle, Γ , are small so that sin $\delta \simeq \delta$, cos $\delta \simeq 1.0$ and sin $\Gamma \simeq \Gamma$, cos $\Gamma \simeq 1.0$
- 3) The slip angles, α_i (i=1,2,3) at the tire-road interface are small, so that sin $\alpha_i \approx \alpha_i$ and cos $\alpha_i \approx 1.0$, although the lateral force can be made a nonlinear function of the slip angle

Table IV.1. List of Symbols Used in the Analysis

- NOTE: A double subscript notation has been used when referring to the axles of the articulated vehicle. The first subscript stands for the unit number (1 = tractor, 2 = semitrailer) and the second subscript stands for the axle number of that unit. For example, axle "21" refers to the first axle on the semitrailer.
- V forward velocity of the tractor (in/sec)
- v; lateral velocity at the mass center of the ith unit (in/sec)
- r; yaw rate of the ith unit (rad/sec)
- r articulation angle of the tractor with respect to the trailer (rad)
- δ steer angle at the front wheels of the tractor (rad)
- m, mass of the ith unit (lb·sec²/in)
- I, yaw moment of inertia of the ith unit (lb·in·sec²)
- C_{ij} sum of the cornering stiffnesses of all tires mounted on axle ij (lb/rad)
- F_{ii} lateral force at axle ij (lb)
- α_{ii} sideslip angle at axle ij (rad)
- X_{ij} longitudinal distance of axle ij from the mass center of the ith unit (in)
- $X_{1\Delta}$ distance of tractor fifth wheel from mass center of tractor (in)
- $X_{2\Delta}$ distance of tractor fifth wheel from mass center of semitrailer (in)
- a_v lateral acceleration of the vehicle during a steady turn (in/sec²)

- 4) Forward velocity of the vehicle is a constant
- 5) The radius of turn is large in comparison to the wheelbases of the tractor and trailer
- 6) The drive thrust needed to maintain a constant velocity is small and hence its influence on the cornering force characteristics at the drive axle is negligible
- The influence of aligning torques and dual tire effects are negligible.

From Figure IV.1 we see that, under steady turning conditions, the slip angles α_{11} , α_{12} , $\overline{\alpha}_{21}$ can be expressed as:

$$\alpha_{11} = \frac{(v_1 + x_{11}r)}{V} - \delta$$
 (1)

$$\alpha_{12} = \frac{(v_1 - x_{12}r)}{V}$$
(2)

$$\alpha_{21} = \frac{(v_1 - (x_{1A} + X_{2A} + x_{21})r)}{U} + r$$
(3)

$$\alpha_{12} - \alpha_{11} = \delta - L/R \tag{4}$$

$$\alpha_{21} - \alpha_{12} = \Gamma - L_T / R$$
 (5)

where L = $(x_{11} + x_{12})$ wheelbase of tractor and L_T = $(x_{1A}+x_{2A}+x_{21}-x_{12})$ wheelbase of trailer

Free-body diagrams of the tractor and trailer are shown in Figure IV.2. Upon applying Newton's laws and eliminating the constraint force at the fifth wheel, we obtain the set of governing nonlinear differential equations of motion.

$$-m_{2}(x_{1A}+x_{2A})\dot{r}_{1} + (m_{1}+m_{2})(vr_{1}+\dot{v}_{1}) - m_{2}x_{2A}\ddot{\Gamma} = F_{y11}+F_{y12}+F_{y21}$$
(6)



Figure IV.1





$$\begin{bmatrix}I_{1}+I_{2}+m_{2}(x_{1A}+x_{2A})^{2}\end{bmatrix}\dot{r}_{1} - m_{2}(x_{1A}+x_{2A})(\forall r_{1} + \dot{v}_{1}) + \begin{bmatrix}I_{2}+m_{2}(x_{2A}+x_{1A})x_{2A}\end{bmatrix}\ddot{r}$$

= $x_{11}F_{y11} - x_{12}F_{y12} - (x_{1A}+x_{2A}+x_{21})F_{y21}$ (7)

$$[I_{2}+m_{2}x_{2A}(x_{1A}+x_{2A})]\dot{\mathbf{r}}_{1} - m_{2}x_{2A}(\dot{\mathbf{v}}_{1} + \mathbf{V}\mathbf{r}_{1}) + (I_{2}+m_{2}x_{2A}^{2})\dot{\mathbf{r}} = -(x_{2A}+x_{21})F_{y21}$$
(8)

In the steady state \dot{v}_1 , \dot{r}_1 , \dot{r} , and \ddot{r} are zero and (6), (7), and (8) reduce to equations of equilibrium, which can be solved for the steady-state cornering forces \overline{F}_{y11} , \overline{F}_{y12} , and \overline{F}_{y21} :

$$\overline{F}_{y|1} = \left[\frac{m_1 x_{11}}{(x_{11} + x_{12})} + \frac{m_2 x_{21} (x_{11} + x_{1A})}{(x_{11} + x_{12}) (x_{2A} + x_{21})}\right] \vee r$$
(9)

$$\overline{F}_{y12} = \left[\frac{m_2 x_{12}}{(x_{11} + x_{12})} + \frac{m_2 x_{21} (x_{12} - x_{1A})}{(x_{11} + x_{12}) (x_{2A} + x_{21})} \right] Vr$$
(10)

$$\overline{F}_{y21} = \frac{m_2^{x} 2A}{x_{2A}^{+} x_{21}} \cdot Vr$$
(11)

Since the connection at the fifth wheel is a pin joint, permitting the trailer to pitch with respect to the tractor, the vertical loads carried by each axle can be expressed as:

$$\overline{F}_{z11} = \frac{m_1 g x_{11}}{(x_{11} + x_{12})} + \frac{m_2 g x_{21}(x_{11} + x_{1A})}{(x_{11} + x_{12})(x_{2A} + x_{21})}$$
(12)

$$\overline{F}_{z12} = \frac{m_2 g x_{12}}{(x_{11} + x_{12})} + \frac{m_2 g x_{21}(x_{12} - x_{1A})}{(x_{11} + x_{12})(x_{2A} + x_{21})}$$
(13)

$$\overline{F}_{z21} = \frac{m_2 g x_{2A}}{(x_{2A} + x_{21})}$$
(14)

Substituting (12), (13), and (14) in (9), (10), and (11), respectively, we find

$$\frac{\overline{F}_{y11}}{\overline{F}_{z11}} = \frac{\overline{F}_{y12}}{\overline{F}_{z12}} = \frac{\overline{F}_{y21}}{\overline{F}_{z21}} = \frac{Vr}{g}$$
(15)

IV.1.1 <u>Linear Tire Characteristics</u>. For the case where the tire characteristics can be assumed to be linear, the cornering forces can be expressed as:

$$F_{y11} = -C_{\alpha 11}^{\alpha} = -C_{\alpha 11}^{\alpha} \left(\frac{(v_1 + x_{11}^{r})}{V} - \delta \right)$$

$$F_{y12} = -C_{\alpha 12}^{\alpha} = -C_{\alpha 12}^{\alpha} \frac{(v_1 - x_{12}^{r})}{V}$$

$$F_{y21} = -C_{\alpha 21}^{\alpha} = -C_{\alpha 21}^{\alpha} \left[\frac{(v_1 - (x_{14}^{+} + x_{24}^{+} + x_{21}^{+})r)}{V} + r \right]$$
(16)

Substituting the expressions for F_{y11} , F_{y12} , F_{y21} in (9), (10), and (11), respectively, we get:

$$\frac{(v_{i}+x_{j})r}{V} - \delta = \frac{-\overline{F}_{z}}{C_{\alpha j}} \frac{Vr}{g}$$
(17)

$$\frac{(v_1 - x_{12}r)}{V} = \frac{-\overline{F}_{z12}}{C_{\alpha 12}} \frac{Vr}{g}$$
(18)

$$\frac{v_{1} + (x_{1A} + x_{2A} + x_{21})r}{V} + = \frac{-\overline{F}_{221}}{C_{\alpha 21}} \frac{Vr}{g}$$
(19)

Equations (17) and (18) imply that:

•

$$\delta - \frac{(x_{11} + x_{12})r}{V} = \left(\frac{\overline{F}_{z11}}{C_{\alpha 11}} - \frac{\overline{F}_{z12}}{C_{\alpha 12}}\right) \frac{Vr}{g}$$
(20)

Equations (18) and (19) imply that:

$$\Gamma - \frac{(x_{1A} + x_{2A} + x_{21} - x_{12})r}{V} = \left(\frac{\overline{F}_{z12}}{C_{\alpha 12}} - \frac{\overline{F}_{z21}}{C_{\alpha 21}}\right) \frac{Vr}{g}$$
(21)

Equations (20) and (21) can be written in the form,

$$\delta = \frac{L}{R} + U \cdot \frac{Vr}{g}$$
(22)

$$\Gamma = \frac{L_{T}}{R} + U_{T} \cdot \frac{V_{r}}{g}$$
(23)

where

U is the under- or oversteer gradient for the tractor, rad/g $U_{\rm T}$ is the under- or oversteer gradient for the trailer, rad/g

IV.2 Basic Modes of Tractor-Semitrailer Limit Yaw Response [1]

Since the articulation angle is a measure of the difference in the yaw orientation of the tractor and trailer units, it is influenced by the directional behavior of the tractor as well as the trailer and serves as a good indicator of the steady turning behavior of the system as a whole. We can therefore examine the steady-state articulation angle gain, Γ/δ _{ss}, to inventory the limiting yaw response modes of behavior.

Dividing Equation (23) by (22) we get

$$\frac{\Gamma}{\delta}\Big|_{ss} = \frac{L_T/R + U_T \cdot V^2/Rg}{L/R + U \cdot V^2/Rg} = \frac{L_T + U_T \cdot V^2/g}{L + U \cdot V^2/g}$$
(24)

On examining (24) we find that, depending on the signs and magnitudes of U and U_T , five types of directional behavior are possible. Each of the cases is discussed below.

(1) U > 0 and $U_T > 0$

In this case the tractor and the trailer are both understeer. The articulation angle gain is finite and positive for all values of forward

velocity, V, and the vehicle therefore does not exhibit any directional instability. A plot of the articulation angle gain, as a function of the forward velocity, V, is shown in Figure IV.3.





(2) U > 0, $U_T < 0$

In this case, the tractor is understeer, but the trailer is oversteer. We find that the articulation angle gain remains finite for all values of forward velocity, V, as shown in Figure IV.4.



Figure IV.4

(3) $U < 0, U_T > 0$

In this case the tractor is oversteer while the trailer is understeer. When the tractor is oversteer, we find that the denominator in Equation (24) approaches zero as the velocity reaches the critical velocity, V_c , such that the articulation angle gain approaches infinity as shown in Figure IV.5. A divergent increase in the articulation angle causes the vehicle to fold up on the inside of the turn, creating a "tractor jackknife" type of instability.



Figure IV.5

(4) $U < 0, U_T < 0$ and

$$\frac{|U_{T}|}{L_{T}} < \frac{|U|}{L}$$
(25)

When the tractor and the trailer are both oversteer and the inequality (25) is satisfied, a steady turning behavior similar to that of Case (3) will be exhibited by the vehicle, and as shown in Figure IV.6, for velocities V \geq V_c "tractor jackknifing" occurs.



Figure IV.6

(5)
$$U < 0, U_T < 0$$
 and

 $\frac{|U_{T}|}{L_{T}} > \frac{|U|}{L}$ (26)

The tractor and trailer are oversteer in this case as well, but since the inequality (26) is satisfied, the articulation angle gain changes sign at $V_{\rm CT}$. As the forward velocity approaches the critical velocity, $V_{\rm C}$, the articulation angle gain approaches $-\infty$ and the vehicle is said to exhibit "trailer swing" type of directional instability, although, in practical terms, both vehicle elements are slewing in yaw, with the trailer's slew rate exceeding that of the tractor.



Figure IV.7

In summary, upon examining the five cases, we find that the steady turning behavior of the tractor ultimately determines the stability of the vehicle; i.e., the tractor must be operating with an oversteer response and the forward velocity must be in excess of the critical velocity, V_c , if a divergent type instability is to occur. The steady turning behavior of the trailer is of secondary importance in that it only determines the nature of the instability (i.e., whether the instability finally produces an articulation angle which is of the sort of "trailer swing" or "tractor jackknife).

Since an examination of the steady turning behavior of the tractor provides us with all the information needed to determine the static stability of a tractor-trailer combination, all further discussion will be limited to the steady turning performance of the tractor.

IV.3 The Handling Diagram

Given Equations (22) and (23), there is need for a generally useful means of presenting the basic features of vehicle yaw response. A particular presentation which will be used throughout this report is called the "handling diagram," first proposed by Pacejka [2] and found to be especially useful in this study for examining a vehicle's yaw stability while also locating the rollover threshold.

In Figure IV.8, the quantity $(L/R-\delta)$ is plotted against the lateral acceleration (V^2/R) to produce the handling diagrams which define each of three commonly-cited characteristics, namely,

- 1) U > 0 (understeer)
- 2) U = 0 (neutral steer) (27)
- 3) U < 0 (oversteer)

Lines of constant velocity and constant path radius are superimposed on these diagrams using L/R as the abscissa. The lateral acceleration level corresponding to the rollover threshold is also marked. We see that the steer angle, δ , needed to execute a turn of given radius and velocity can be read directly off the handling diagram.



Figure IV.8

t

For an understeer vehicle, the steer angle needed to execute a turn of constant radius increases with increasing velocity, and the yaw rate gain, r/δ)_{ss}, remains finite for all forward velocities. The understeer vehicle, therefore, cannot exhibit a yaw divergence type of directional instability; its steady turning performance is limited only by the possibility of a rollover. Hence, we find the vehicle to be stable for all maneuvers which result in lateral acceleration levels which are lower than the rollover threshold.

In the case of the neutral steer vehicle, the steer angle needed to negotiate a turn of fixed radius is independent of forward velocity and is determined only by the radius of the turn. For this vehicle, the yaw rate gain remains finite for all forward velocities and the steady turning performance is limited only by the possibility of a rollover.

For an oversteer vehicle, the steer angle decreases with increasing velocity. As the velocity approaches the "critical velocity," V_c , the δ level needed for any turn diminishes toward zero and the yaw rate gain goes to infinity. The vehicle therefore is said to be statically unstable or "yaw divergent" for all $V \ge V_c$. For single unit vehicles, such as passenger cars, this divergent type of directional instability results in a spinout. For tractor-trailer vehicles, depending on the distribution of cornering stiffness, two types of divergent behavior are possible: (1) tractor jackknife - an unstable response which results in an exponential growth of the articulation angle with the vehicle "folding up" into the inside of the turn and (2) trailer swing - an instability which results in the trailer swinging out of the turn and the vehicle folding up to the outside of the turn. Either of these unstable phenomena can ultimately result in a roll over.

It should be noted that oscillatory-type directional instabilities are at least <u>theoretically</u> possible for tractor-trailer vehicles. Such instabilities are due to dynamic interactions and are not revealed by a static analysis. A perturbation analysis reveals the possibility of oscillatory- and divergent-type instabilities. Since the oscillatory modes of typical commercial tractor-trailer vehicles are well damped, the only type of <u>directional instability</u> that can possibly be exhibited by a practical commercial tractor-trailer vehicle is the monotonically divergent type. The rest of this appendix, therefore, would deal only with this divergent type of directional instability.

IV.4 <u>Features of the Handling Diagram Describing the Response of the</u> <u>Nonlinear Tractor</u>

During a steady turn, the slip angle established at an axle is, in general, a nonlinear function of (1) the lateral force that is generated at the axle and (2) the amount of side-to-side load transfer that takes place at that axle, i.e.,

$$\alpha_i = f_i(F_{y_i}, \text{ load transfer at axle i}) \text{ i=1,2,3}$$
 (28)

From Equation (15) we know that, for the case of a two-axle tractor coupled to a single-axle trailer, the steady-state lateral force generated at an axle is directly proportional to the lateral acceleration of the turn. Therefore, rewriting Equation (15) we get

$$F_{y_{i}} = F_{z_{i}} a_{y}$$
 i=1,2,3 (29)

The load transfer that takes place at an axle is also a function of the lateral acceleration of the turn and is influenced by such suspension properties as roll center height and roll stiffness.

Therefore, Equation (28) can be rewritten to show α_i simply as a function of lateral acceleration,

$$\alpha_i = f_i(a_v) \tag{30}$$

In other words, the slip angle at each axle is uniquely determined by the severity of the turn and, in general, is a nonlinear function of the lateral acceleration of the turn. Hence, a handling diagram constructed using $((\alpha_1 - \alpha_2), a_y)$ or $((L/R-\delta), a_y)$ as coordinates constitutes a unique curve which is independent of forward velocity, and can be used for studying the nonlinear steady turning behavior and stability over a range of forward velocities and turn radii.

Depending upon the cornering force properties of the tires mounted on the tractor front and rear axles and the amount of load transfer that takes place at each axle, any of three generic types of nonlinear steady turning behavior can commonly be expected, namely,

1) The tractor is understeer at low levels of lateral acceleration and is progressively more understeer as the lateral acceleration of the turn is increased.

Two handling diagrams which are representative of this type of behavior are shown in Figure IV.9. A vehicle whose steady turning behavior is described by either of these handling diagrams will not exhibit a divergent type of directional instability. In the case of handling curve (a), as the severity of the turn is increased, the vehicle arrives at a limit condition only by exceeding the rollover threshold. The handling diagram (b) results for the case of a vehicle whose front-tire cornering forces saturate at a lateral acceleration level "A" which is below the rollover threshold. The steady turning performance of such a vehicle is therefore limited by the characteristics of the front tires such that the vehicle "plows out" of the turn.

2) The tractor is understeer at low levels of lateral acceleration but suffers a transition to oversteer at higher levels of lateral acceleration.

A handling diagram which is representative of this type of steady turning behavior is shown in Figure IV.10. Since the vehicle changes to an oversteer behavior as the lateral acceleration level is increased, it is possible for the steady turning performance to be limited by the onset of directional instability at acceleration levels which are lower than the rollover threshold. For a vehicle exhibiting nonlinear handling



Figure IV.9



Figure IV.10

behavior, the criterion for the directional stability of a steady turn is given by the inequality

$$\frac{\partial(\delta)}{\partial a_y} > 0$$
 (31)

(Note: The above condition can be derived from the linear differential equations which describe the motion of the tractor-semitrailer for small perturbations about a steady state.) The inequality (31) can also be written as

$$\frac{\partial (L/R - \delta)}{\partial a_{y}} < L/V^{2}$$

or

$$\frac{\partial(a_y)}{\partial(L/R - \delta)} > V^2/L$$
(32)

When the stability condition is expressed in the form of the inequality (32), the left-hand side corresponds to the slope of the handling diagram and the right-hand side corresponds to the slope of the constant velocity line (which is superimposed on the handling diagram, using $(L/R, a_y)$ coordinates). Therefore, the condition for directional stability can also be stated as follows:

A two-axle tractor/single-axle trailer combination traveling with a forward velocity, V, is directionally stable (does not exhibit yaw divergence) at lateral acceleration levels for which the local slope of the handling diagram is steeper than the slope of the constant velocity line that corresponds to velocity, V.

Therefore, for each forward velocity, V_i , we can use the handling diagram to determine the "critical lateral acceleration" level, a_{y_i} , above which the vehicle exhibits yaw divergence. Upon connecting these critical acceleration points which are marked off on the constant velocity lines we can obtain a stability boundary in the (L/R, a_y) coordinate system, the construction of which is shown in Figure IV.10. It can be

seen that, for velocities less than V_R , the steady turning performance is limited by rollover. For velocities greater than V_R , the vehicle is yaw-stable only within that steady-state operating space lying beneath the line AB (which comprises an envelope of critical acceleration rates).

3) <u>The tractor is oversteer at low levels of lateral acceleration</u> and is increasingly oversteer as the lateral acceleration level of the turn is increased.

As shown in Figure IV.lla and IV.llb, two kinds of limit behaviors are possible and directional instability can occur in both cases. The criteria for directional stability is once again the satisfaction of the condition expressed in Equation (32).

A vehicle which exhibits a handling character which is similar to that shown in Figure IV.11a, is directionally stable for all velocities less than V_R , and its steady turning performance for such velocities is limited only by the occurrence of rollover at lateral acceleration levels which exceed the rollover threshold. For velocities greater than V_R , the steady turning performance is limited by the onset of yaw divergence and the "directional stability boundary" A-B can be constructed in a manner similar to that shown in Figure IV.10.

In the case of the handling behavior shown in Figure IV.11b, the cornering force generated at the tractor rear axle saturates at a lateral acceleration level C' which is below the rollover threshold and the steady turning performance is, at all forward velocities, limited by the occurrence of directional instability. (Note: the analysis is not valid for a maneuver in which the forward velocity is very small and lateral accelerations high. In such maneuvers, the front-wheel angles and articulation angles tend to be large and the geometric linearity assumptions made in this analysis lead to considerable errors.)



Figure IV.lla



Figure IV.11b

IV.5 Influence of Tandem Axles on the Steady Turning Behavior of Tractor-Semitrailers

In this section, the steady turning behavior of a tractor-trailer combination consisting of a single-axle trailer and a three-axle tractor (a tractor which has a single front axle and tandem rear axles) is analyzed in order to illustrate the influence of tandem axles on steady turning behavior. A plan view of the vehicle is shown in Figure IV.12. The simplifying assumptions made in analyzing the steady turning behavior of the two-axle tractor/single-axle trailer are used in this analysis as well.

The kinematic relationshipsbetween the slip angles and the motion variables are as follows:

$$\alpha_{11} = \frac{(v_1 + x_{11}r)}{V} - \delta$$
 (33)

$$\alpha_{12} = \frac{(v_1 - x_{12}r)}{V}$$
(34)

$$\alpha_{13} = \frac{(v_1 - x_{13}r)}{V}$$
(35)

$$\alpha_{21} = \frac{v_1 - (x_{1A} + x_{2A} + x_{21})r}{V} + r$$
(36)

also

$$\begin{array}{c} \alpha_{12} - \alpha_{13} = \frac{\Delta}{R} \\ \left[\alpha_{11} - \frac{(\alpha_{12}^{+}\alpha_{13})}{2} \right] \\ = \frac{\left[x_{11} + \frac{(x_{12}^{+}x_{13})}{2} \right]^{r}}{V} - \delta \\ = \frac{L}{R} - \delta \end{array}$$
(37)

and

.

$$\left[\frac{\alpha_{12} + \alpha_{13}}{2} - \alpha_{21}\right] = \frac{L_T}{R} - \Gamma$$
(39)



Figure IV.12

where

- R is the turn radius = V/r
- △ is the longitudinal distance between the tandem axles, also called the tandem spread
- L is defined as the tractor wheelbase, which is the longitudinal distance from the tractor front axle to the midpoint of the tandem suspension
- L_T is defined as the trailer wheelbase, which is the longitudinal distance from the midpoint of the tractor tandem axles to the trailer axle.

The differential equations of motion are similar to those of the two-axle tractor/single-axle trailer combination except for the addition of a third lateral tire force at the third axle of the tractor. The differential equations are therefore:

$$-m_{2}(x_{1A}+x_{2A})\dot{r}_{1} + (m_{1}+m_{2})(Vr_{1} + \dot{v}_{1}) - m_{2}x_{2A}\ddot{r} = F_{y11}+F_{y12}+F_{y13}+F_{y21}$$
(40)

$$\begin{bmatrix} I_{1}+I_{2}+m_{2}(x_{1A}+x_{2A})^{2} \end{bmatrix} \dot{r}_{1} - m_{2}(x_{1A}+x_{2A}) \begin{bmatrix} \forall r_{1} + \dot{v}_{1} \end{bmatrix} + (I_{2}+m_{2}(x_{2A}+x_{1A})x_{2A})^{T}$$

= $x_{11}F_{y11} - x_{12}F_{y12} - x_{13}F_{y13} - (x_{1A}+x_{2A}+x_{21})F_{y21}$
(41)

$$[I_{2}^{+m}2^{x}2A^{(x_{1}A^{+}x_{2}A^{)}]\dot{r}_{1} - m_{2}^{x}2A^{(\dot{v}_{1} + Vr_{1})} + [I_{2}^{+m}2^{x}2A^{]\ddot{r}} = -(x_{2}A^{+}x_{2})F_{y21}$$
(42)

In the steady state \dot{v} , \dot{r}_{1} , \dot{r} , \ddot{r} are zero and the differential equations reduce to a set of equilibrium equations:

$$(m_1+m_2)a_{y1} = F_{y11} + F_{y12} + F_{y13} + F_{y21}$$
 (43)

$$-m_{2}(x_{1A}+x_{2A})a_{y1} = x_{11}F_{y11} - x_{12}F_{y12} - x_{13}F_{y13} - (x_{1A}+x_{2A}+x_{21})F_{y21}$$
(44)

$$-m_2 x_{2A} a_{y1} = -(x_{2A} + x_{21}) F_{y21}$$
(45)

Equation (45) can be solved for F_{y21} as an explicit function of a_{y1} and upon substituting in (43) and (44), we would be left with three unknown quantities, F_{y11} , F_{y12} , and F_{y13} , and two equations (43) and (44). Therefore, unlike the case of the two-axle tractor (see Equation (15)), it is not possible to solve for the lateral forces (and eventually the slip angles) at the tractor axles as explicit functions of the lateral acceleration of the steady turn alone. The situation is analogous to a statically indeterminate beam supported at three points, where the load carried by each support is not only a function of the load acting on the beam, but also of other classic properties such as stiffness of the support, the rigidity of the beam in bending, etc.

The influence of tandem axles on steady turning response in both the linear and nonlinear regime of operation is discussed in the next two sections.

IV.6 Handling Diagram for the Tandem-Axle Tractor with Linear Tires

For maneuvers which result in low levels of lateral acceleration, the tire forces are linear functions of the slip angles. Therefore, for a steady turn:

$$F_{y11} = -C_{\alpha 11}^{\alpha} = -C_{\alpha 11} \left[\frac{(v_1 + x_{11}^r)}{V} - \delta \right]$$
(46)

$$F_{y12} = -C_{\alpha 12}^{\alpha} = -C_{\alpha 12} \frac{(v_1 - x_{12}^{r})}{V}$$
(47)

$$F_{y13} = -C_{13} = -C_{13} \frac{(v_1 - x_{13}r)}{V}$$
 (48)

$$F_{y21} = -C_{\alpha 21}^{\alpha} = -C_{\alpha 21} \left[\frac{(v_1 - (x_{1A} + x_{2A} + x_{21})r)}{V} + r \right]$$
(49)

Substituting for the tire forces, F_{ij} , in terms of the slip angles, α_{ij} , in Equations (43), (44), and (45) and using the kinematic relationship (37), we can solve for the slip angles, α_{ij} , in terms of the motion variables V and γ . Upon carrying out the algebra, we get

$$\alpha_{11} = -m_{1}(C_{\alpha 12}x_{12} + C_{\alpha 13}x_{13})Vr - \frac{m_{2}x_{21}}{(x_{2A}+x_{21})} [C_{\alpha 12}(x_{12}-x_{1A}) + C_{\alpha 13}(x_{13}-x_{1A})]Vr - C_{\alpha 12} \cdot C_{\alpha 13} \frac{(x_{13}-x_{12})^{2}}{R} - \frac{C_{\alpha 11}[C_{\alpha 12}(x_{11}+x_{12}) + C_{\alpha 13}(x_{11}+x_{13})]}{(50)}$$

$${}^{\alpha_{12}} = -\frac{x_{11}m_{1}V_{1}}{C_{\alpha_{12}}(x_{11}+x_{12})} + C_{\alpha_{13}}\frac{(x_{13}-x_{12})(x_{11}+x_{13})}{R} + C_{\alpha_{13}}\frac{(x_{13}-x_{12})(x_{11}+x_{13})}{R}$$
(51)

$$\alpha_{13} = \underbrace{\left[-x_{11}m_{1}\forall \mathbf{r} - \frac{(x_{11}+x_{1A})m_{2}x_{21}\forall \mathbf{r}}{(x_{2A}+x_{21})} - \frac{C_{\alpha 12}(x_{13}-x_{12})(x_{11}+x_{12})}{R} \right]}_{\left[C_{\alpha 12}(x_{11}+x_{12}) + C_{\alpha 13}(x_{11}+x_{13})\right]}$$
(52)

$$\alpha_{21} = \frac{m_2 x_{2A} V r}{(x_{2A} + x_{21}) C_{\alpha 21}}$$
(53)

We find that the slip angles at the tractor tires are not only influenced by the lateral acceleration of the turn (a_y) , but also by the turn radius (R). The slip angles α_{11} , α_{12} , and α_{13} are related to the steer input by Equation (38), hence

$$\frac{L}{R} - \delta = \left[\alpha_{11} - \frac{\alpha_{12} + \alpha_{13}}{2}\right]$$

$$= \left[\left[x_{11}c_{11} - x_{12}c_{12} - x_{13}c_{13} \right]m_{1} + \left[(x_{1A} + x_{11})c_{11} - (x_{12} - x_{1A})c_{12} - (x_{13} - x_{1A})c_{13} \right] \frac{m_{2}x_{21}}{(x_{2A} + x_{21})} \right] \forall r + \frac{(x_{13} - x_{12})}{R} \left[c_{11}c_{12} \frac{(x_{11} + x_{12})}{2} - c_{11}c_{13} \frac{(x_{11} + x_{13})}{2} - c_{12}c_{13}(x_{13} - x_{12}) \right] - c_{11}\left[c_{12}(x_{11} + x_{12}) + c_{13}(x_{11} + x_{13}) \right]$$

$$(54)$$

which is of the form

$$\delta = \frac{L}{R} + U V r + \frac{B}{R}$$
 (55)

where U and B are defined in Equation (54) and are quantities which depend on tire cornering stiffness, $C_{i,i}$, and other vehicle parameters.

For steady turning maneuvers which are within the linear regime, the cornering stiffnesses, C_{ij} , are constant and hence U and B are also constant. Therefore, for linear operation, Equation (55) can be rewritten as

$$s = \frac{L_e}{R} + U \cdot V r$$
 (56)

where $L_e = (L+B)$ and is called the effective wheelbase

U = the under- or oversteer gradient.

A handling diagram similar to that shown in Figure IV.13 can therefore be constructed using $(L_e/R - \delta)$ and Vr as the abscissa and the ordinate, respectively.



Figure IV.13

The discussion in Section IV.3 with regard to criterion for yaw divergence and rollover apply for the linear model of the three-axle tractor/single-axle trailer combination as well. The only difference being the effective wheelbase, L_e , is to be used in place of the tractor's actual wheelbase, L.

IV.7 Handling Diagram for the Tandem-Axle Tractor with Nonlinear Tires

For maneuvers which result in high levels of lateral acceleration and side-to-side load transfer, the lateral force generated by the tires is a nonlinear function of slip angle. Under such conditions, Equations (37), (43), (44), and (45) become a set of nonlinear algebraic equations in slip angles α_{11} , α_{12} , α_{13} , and α_{21} and cannot be solved except by numerical means. The solution of these equations would be of the general form

$$\alpha_{i,i} = \phi_{i,i}(a_v, 1/R)$$
(57)

since

$$a_v = V^2/R$$
.

The above equation can also be written as

$$\alpha_{ij} = \phi'_{ij}(a_y, 1/V^2)$$
(58)

but since

$$L/R - \delta = \alpha_{11} - \frac{\alpha_{12} + \alpha_{13}}{2}$$

then we see

$$L/R - \delta = \psi_{i,i}(a_v, 1/V^2)$$
 (59)

Hence, if a handling diagram relating $(L/R - \delta)$ with a_y were to be constructed, it would be sensitive to forward velocity, V. Unlike the case of a two-axle tractor/single-axle trailer combination, the treatment of a tractor with a tandem rear axle requires a family of handling diagrams, one for each forward velocity. Two such handling curves are shown in Figure IV.14 for forward speeds of 25 and 50 mph.





Since a unique handling diagram (valid for a range of forward velocities) can be constructed for a two-axle tractor/single-axle trailer combination, it is possible to make inferences about the under- or oversteer character and directional stability of the vehicle over an entire range of operating speeds and lateral acceleration levels by inspecting the results of steady turning experiments or simulations conducted at any single selected forward velocity. The existence of a family of handling curves for a three-axle tractor/single-axle trailer
combination places a much greater burden for the gathering of data over a range of speeds in order to define vehicle response over the full operating range.

References

- Fancher, P.S., Mallikarjunarao, C., Nisonger, R.L., <u>Simulation of</u> the Directional Response Characteristics of Tractor-Semitrailer <u>Vehicles</u>. Final Report, MVMA Project #1.39, March 1979.
- Pacejka, H.B., <u>Simplified Analysis of Steady-State Turning Behavior</u> of Motor Vehicles. Vehicle System Dynamics, 2 (1973), pp. 161-204.

APPENDIX V

DETAILED RESULTS OF COMPUTERIZED PARAMETRIC SENSITIVITY STUDY

Results from the parametric sensitivity study (performed using the Phase II tractor-semitrailer model) are displayed here in the handling diagram format. Parameter values used in conducting the simulations are given in Appendix II.

First, handling diagrams are presented describing the sensitivity of vehicle response to roll stiffness distribution. This set of simulations was conducted using a ramp-type steer input, at a rate of 1.5 deg/sec. Note that the symbol, KRS1, which appears on the diagrams represents the value of auxiliary roll stiffness of the roll stabilizer on the tractor front axle (in-1b/deg). Each of the plots in this series describes the variation in handling curves which derives when KRS1 is varied, while the tractor frame stiffness parameter, TTC, is held fixed at the indicated value.

Next, the results from the parametric sensitivity study conducted on five typical tractor-semitrailer configurations are given. The matrix showing the parametric variation scheme is reproduced here in Figure V.1. The handling diagrams for each of the five basic vehicles are arranged in the same sequence as that shown from left to right along the bottom row of this figure, but are labeled using a continuous sequence of configuration numbers, from 1 to 240. The symbol, PZ, which appears in these diagrams corresponds to the height of the center of gravity of the payload above the ground (in). A ramp-type steer input of one deg/sec was used for this set of 240 runs.



Figure V.1

Handling diagrams showing sensitivity to changes in tractor auxiliary front roll stiffness and frame torsional stiffness.



IHC-VAN TRAILER, RIB TIRES, FRAME 20000 IN.LB/DEG





IHC-VAN TRAILER, RIB TIRES, FRAME 60000 IN.LB/DEG













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Handling diagrams for showing sensitivity to variation in operating conditions and design variables.

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140 IN.WHEEL BASE TRACTOR, LUG TIRES, RUN # 91,92493






































































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APPENDIX VI

DETAILED MEASURES OF RIDE RESPONSE

This appendix contains a detailed discussion of the ride response of the various vehicle combinations tested, as well as a complete set of power spectral density plots for all tests. Section VI.1 contains a vehicle-by-vehicle discussion of dominant ride modes and the effects of surface and speed on the operator's vibrational environment. Additional power spectra are presented in VI.2 covering all other vehicle configurations and test conditions.

Test surfaces are referenced by site number. The site numbers are as follows:

- I-94 East, Mile Markers 181-182 smooth bituminous expressway
- I-94 West, Mile Markers 75-74 pockmarked concrete
- 3) US 23 South, Mile Markers 47-46 aging concrete
- 4) M-14 East, east of US 23 new concrete
- 5) Huron Parkway, Glacier Way to Geddes aging urban street

VI.1 Dominant Modes and Effects of Surface and Speed

In the following sections, cab vibrations are characterized by the power spectral densities of vertical and longitudinal vibrations of the operator's seat. These measures are augmented by power spectra and phase relationships of the three frame-mounted accelerometer signals to deduce the modes of vibration that account for vibrations of the seat. These pieces of information provide a description of the vehicle's ride response in terms of the dominant ride modes and the vibrational environment of the operator. Each vehicle is treated separately with a discussion of the ride modes followed by a summary of the effects of differing surfaces and speeds on the cab vibrations.

VI.1.1 Cab-Over-Engine Tractor, Bobtail. Dominant modes were identified by examining the power spectral densities and phase relationships between the three frame-mounted accelerometer signals. Peaks in the spectral density occur at frequencies where a resonance occurs or a large driving force is present. By examining the phase relationships and the relative amplitudes at the three frame locations, the mode shape can be estimated. PSD's from the frame-located accelerometers are shown in Figure VI.1 for the bobtail COE tractor traveling over site number 1 (smooth bituminous section of I-94) at 55 mph. Phase angles of the midframe and rear frame signals relative to the front location are shown in Figure VI.2. All three locations show significant peaks at approximately 7.5, 15, and 22.5 Hz. These peaks correspond to the first-, second- and third-order wheel rotation. Tire radial force variations are a major vibratory input on this surface which has only small irregularities exciting the suspension. Two other peaks appear below 7.5 Hz at 3.0-3.5 and 5.0-5.5 Hz, the magnitudes of these peaks vary from location to location, providing an initial indication of mode shape. The 3.0-3.5 Hz mode has nearly constant amplitude from front to rear with the center and rear signals lagging the front signal by less than 90°. This is a "bouncing" mode and the phase lag is due to the spacing between the front and rear axles which causes disturbances to be encountered by the rear axle at a time delay relative to the front axle, thus slightly distorting the mode shape. At 5.0-5.5 Hz the power content increases from front to rear and both the center and rear signals are approximately 180° out of phase with the front. This frequency corresponds to a "pitching" motion with the node located between the front axle and the frame midpoint. Higher frequency components cannot be clearly attributed to any particular source, but in all likelihood power found in the 10-14 Hz range can be attributed to unsprung mass motions, axle hop, etc. Higher frequency motions are due to various component resonances, viz., exhaust stacks, fuel tanks, etc.



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Figure VI.2. Phase relationships, bobtail COE tractor over site #1 at 55 mph.



Figure VI.2 (Cont.)

Figure VI.1 also shows PSD's of the vertical and fore/aft accelerations on the seat and vertical acceleration at the seat base. Figure VI.2 shows the corresponding phase relationships between the seat base and front frame accelerations, and seat base and seat vertical accelerations. From these it can be seen that the cab has a natural frequency on its mounts of approximately 13 Hz and the natural frequency of the seat suspension is in the neighborhood of 5 Hz.

Effects of Surface and Speed on Cab Vibrations:

Given the dominant modes of a vehicle's ride motions, the vibrations experienced by the operator are primarily dependent on the inputs from the road surface and inputs dependent on the vehicle's forward speed. For the very smooth bituminous surface of Site #1, the input from the surface irregularities compared to that of the tire-wheel systems is small, this fact is illustrated in the spectral densities of the vertical and fore/aft accelerations at the seat, shown in Figures VI.1 and VI.3. These are the responses at the seat of the COE tractor at 55 and 45 mph on Site #1. The dominant peaks appearing in each of these PSD's are directly related to first-, second-, and third-order wheel rotation. At 55 mph, the frequencies are 7.5, 15 and 22.5 Hz; at 45 mph the tire-wheel components appear at 6.25, 12.5, and 18.5 Hz. Another significant contribution to the seat vertical spectra comes from the bounce mode previously identified at 3.0 Hz. The pitch mode contribution to both vertical and fore/aft motions occurs at 5.5 Hz. At 45 mph a peak appears at 8 Hz. From the phase information, the peak at 8 Hz appears to be a pitching mode, but at this frequency it is more likely a frame beaming mode. Insufficient information is available, however, to provide a conclusive identification.

On Site #2, the tire-wheel harmonics are not as dominant, but still present and significant, in the seat vertical spectra (Figures VI.4 and VI.5). In this case, the dominant peak in the seat vertical spectrum occurs at 2.5 Hz and corresponds to the vehicle's bounce mode. This frequency is slightly lower than that at which the bounce mode was observed on the smooth surface. The apparent reduction in the frequency of a natural mode can be explained by an effective "softening" of the



Figure VI.3. PSD's at seat, bobtail COE tractor over site #1 at 45 mph.







Figure IV.5. PSD's at seat, bobtail COE tractor over site #2 at 45 mph.

suspension due to larger deflections causing the springs to "break through" the coulomb friction in the leaf springs. The seat fore/aft acceleration is still dominated by the tire-wheel rotational frequencies at 45 and 55 mph with some contribution coming from 7-8 Hz at 45 mph. Once again, the phase relationships show signals at the midpoint and rear of the frame about 180° out of phase with the front at this frequency.

The previously described trends are the same for Sites #3 and 4 (Figures VI.6-9), with vertical vibrations dominated by the bounce resonance and by tire inputs. The bounce mode contribution contains less power than in the case of Site #2.

The fore/aft spectra have significant power at 5 Hz (pitch mode) and at the tire-wheel rotational frequencies. At 45 mph the natural mode appearing at 7.5-8 Hz becomes distinct from the tire-wheel input excitation that was seen to coincide with this mode at 55 mph.

Site #5 (Huron Parkway) was run at 35 mph resulting in a tire rotational frequency of approximately 5 Hz which is near the vehicle's pitch frequency. This frequency is a major contributor to both vertical and longitudinal power content as shown in Figure VI.10. The vertical spectra also contains peaks at 2.5 and 7.5 Hz, corresponding, respectively, to bounce and pitching motions. Longitudinal vibrations are dominated by the 5 Hz pitch/tire rotational mode and the 7.5 Hz pitching mode.

VI.1.2 <u>Cab-Over-Engine Tractor - Loaded</u>. The loaded COE tractor demonstrates three dominant ride modes in addition to the tire-wheel related responses. One bouncing and two pitching modes are seen as the dominant ride responses.

Bounce appears at 2.5-3 Hz with decreasing magnitude from front to rear indicating a node rear of the tractor. Pitching modes occur with frequencies of 3.5 Hz and 4.5 Hz. In both cases, the node is located between the front axle and the frame midpoint. The interaction of these pitching modes with the trailer cannot be determined because the trailer was not instrumented. Spectral densities and phase relationships for the loaded cab-over-engine tractor at 55 mph on Site #1 are presented in Figures VI.11 and VI.12.



Figure VI.6. PSD's at seat, bobtail COE tractor over site #3 at 55 mph.



Figure VI.7. PSD's at seat, bobtail COE tractor over site #3 at 45 mph.



Figure VI.8. PSD's at seat, bobtail COE tractor over site #4 at 55 mph.



Figure VI.9. PSD's at seat, bobtail COE tractor over site #4 at 45 mph.



Figure VI.10. PSD's at seat, bobtail COE tractor over site #5 at 35 mph.



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Figure VI.12. Phase relationships, loaded COE tractor over site #1 at 55 mph.



Figure VI.12 (Cont.)

As with the bobtail COE unit, the loaded unit traveling over the smooth bituminous roadway of Site #1 has major contributions to both vertical and fore/aft seat acceleration spectra (Figures VI.11 and 13) corresponding to the primary tire rotational frequency, but the second- and third-order tire rotational frequencies are less dominant in the loaded condition than in the bobtail condition. Additional power in the seat vertical motion comes from the bounce mode and both pitching modes at 2.5-3, 3.5, and 4.5 Hz, respectively. Reducing speed from 55 to 45 mph does not cause the peak at 7.5 Hz, observed in the bobtail configuration, to appear. The fore/aft acceleration of the seat is dominated by the two pitching modes at 3.5 and 4.5 Hz in addition to the tire rotational contribution.

The irregularities of Site #2 provide sufficient input to the suspension of the vehicle to cause the power contained at frequencies relating to ride motions to outweigh the tire-wheel inputs. The dominant peak of the vertical seat spectra (Figures VI.14 and 15) occurs at 2 Hz, as seen with the bobtail unit. The bounce frequency is slightly lower on this rougher surface than on the smooth surface of Site #1.

The pitching modes and tire-wheel inputs also contribute to the seat vertical motions. The seat fore/aft spectra shows major contributions from the two pitch modes (3.5 and 4.5 Hz), the wheel rotations, and, at 55 mph, a contribution from the 2 Hz bounce mode. Power levels are higher for all the modes at 55 than at 45 mph.

While visually appearing less irregular than Site #2, vibrations encountered traveling over Sites #3 and #4 show considerably more power in both fore/aft and vertical seat motions, corresponding to the vehicle ride modes (Figures VI.16-19). On these sites, reducing speed from 55 to 45 mph results in decreased power contained in the bouncing mode with little change in the power content due to pitching motions.





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On the urban road, Site #5, peaks corresponding to the bounce and both pitch modes appear in both vertical and longitudinal seat spectra (Figure VI.20) with the dominant peak on both directions attributable to the tractor bounce mode. The level of vibrational power on this surface is comparable with those encountered on Sites #3 and #4.

VI.1.3 <u>Conventional Tractor - Bobtail</u>. The dominant natural ride modes of the bobtail conventional tractor are a bounce mode at 3-3.5 Hz and a pitch mode at 5.5 Hz. The spectral densities and phase relationships are shown in Figures VI.21 and VI.22. The frequencies and mode shapes are very similar to the COE tractor in the bobtail condition with the bounce mode showing a slight phase lag between front and rear accelerations and the pitch node occurring between the front axle and frame midpoint.

Seat vibrations of the conventional tractor traveling over Site #1 in the bobtail condition are totally dominated by the tire force inputs. Power present at these frequencies is orders-of-magnitude above the peaks corresponding to the pitch and bounce ride motions (Figures VI.21 and 23).

On the rougher surface of Site #2, the ride motions contribute more significant levels of power to the vibration environment of the operator. Bounce and pitch modes, at 2.5 Hz and 5.5 Hz, respectively, contribute approximately equal levels of power to the seat vertical vibration as that deriving from the tire-wheel rotation influence (Figures VI.24 and 25) at 55 mph. Also at 55 mph, the fore/aft vibration of the seat is excited primarily by the pitch mode and secondarily by the bounce and tire-wheel resonances. At 45 mph the power associated with the bounce and pitch modes decrease significantly in the seat vertical spectrum and tire rotational forces again become dominant. In the longitudinal direction, the major peak in the spectrum for the 45-mph test occurs at the first-order tire rotational frequency that is very near the pitch natural frequency and thus excites that mode.





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Figure VI.22. Phase relationships, bobtail conventional tractor over site #1 at 55 mph.


Figure VI.22 (Cont.) 279







Responses on Sites #3 and #4 are very similar to those observed on Site #2 with bounce and pitch motions controlling the seat vertical spectra and pitch controlling the longitudinal vibrations at 55 mph. With the speed reduced to 45 mph, the bounce mode power decreases and tire-wheel rotational force variation input becomes a major contributor to both vertical and fore/aft accelerations. The spectra are shown in Figures VI.26-29.

On Site #5 vertical and longitudinal vibrations (Figure VI.30) are attributable, in large part, to the pitching motion of the vehicle, the natural frequency of which occurs very near to the tire rotational frequency.

IV.1.4 <u>Conventional Tractor - Loaded</u>. As with the COE unit, the loaded conventional tractor has three dmoninant ride modes: a bounce and two pitch modes. The "bounce" mode natural frequency is approximately 3 Hz with its node located aft of the tractor. The two pitch modes, at 3.5 and 5.5 Hz, have differing node shapes. The lower frequency mode has a node between the frame midpoint and the rear axle while the 5.5 Hz mode has its node between the front axle and the midpoint. Spectra and phase information are contained in Figures VI.31 and VI.32.

On the smooth surface at Site #1 the loaded conventional tractor's response at the driver's seat (Figures VI.31 and 33) is dominated by the vehicle's pitch mode, at 3.5 and 5.5 Hz, and the tire rotational frequencies. At 55 mph, the ride motions and response to tire rotation are of approximately equal magnitudes, while at 45 mph the tire-wheel contribution dominates.

On the rougher surface of Site #2, the bounce mode appears more strongly in the seat vertical spectrum at 55 mph, with a decreased influence at 45 mph at which the pitch modes and tire inputs become dominant (see Figures VI.34 and 35). The fore/aft vibration at both speeds is mainly attributable to pitch modes and tire inputs with comparable power levels for both speeds.



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Figure VI.32. Phase relationships, loaded conventional tractor over site #1 at 55 mph. 292



Figure VI.32 (Cont.)



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On Sites #3 and 4 the situation is similar with bounce, pitch and tire rotational frequencies contributing to seat vertical motions at 55 mph; the bounce mode becoming less significant at 45 mph. Fore/ aft vibration is again dominated by the pitch resonances and the tire rotational disturbance (Figures VI.36-39).

The 3.5 Hz pitch mode and the 5 Hz pitch mode coupled with the tire rotational input dominate the vertical seat vibration on Site #5 (Figure VI.40). The coinciding pitch and tire rotational frequency at 5 Hz completely dominates the seat longitudinal vibration.



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Figure VI.36. PS)'s at seat, Toader' contentional tractor over site #4 at 55 mph. 300



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VI.2 Additional Ride Response Data

This section contains power spectra information not presented in Section VI.1. All test vehicles and sites are covered. The data are arranged by vehicle configuration, i.e., bobtail COE tractor, loaded COE tractor, bobtail conventional tractor, and loaded conventional tractor. Test sites are numbered according to the site designations presented at the beginning of Appendix VI.







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Figure VI.2.1 (Cont.)



Figure VI.2.1 (Cont.)



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Figure VI.2.1 (Cont.)





Figure VI.2.1 (Cont.)



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01 Site #2 -55 MPH SPECTRAL DENSIT lŰ FRAME-REAR 10-3 1055 10 10 0 5 15 Z FREQUENCY (H2) 10 SEAT BASE DENSIT 15 3H/257 SPECTRAL - 10-3 105 10 15 20 0 FREQUENCY (HZ) Figure VI.2.2 (Cont.)



















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Figure VI.2.2 (Cont.)















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APPENDIX VII

APPROXIMATE ANALYSIS OF TIRE SIDE FORCES ARISING DURING A TRANSIENT MANEUVER

In this appendix, a simplified analysis is derived for identifying the terms which make up the expression for tire side forces prevailing at each of the three nominal axle positions of a tractorsemitrailer. The purpose of the analysis is to permit an assessment of the extent to which the mere presence of a non-steady turning condition could influence the tractor's yaw stability at a given operating point.

In particular, the analysis aided in identifying the mechanisms by which tractor-trailers appear more stable in the ramp-steer transient maneuver than in a steady-state turn. While previous discussion, in Section 6.2, showed that a lagging trailer response in the transient turn promotes tractor yaw stability indirectly through a roll mechanism, the presently derived expressions further indicate two contributions to tractor tire side force which work in opposing directions to influence tractor stability directly through a yaw plane mechanism.

A plan view of a two-axle tractor/single-axle trailer combination, along with the free-body diagrams (in the yaw plane) of the tractor and semitrailer units, is shown in Figure VII.1. If the assumption of small steering-wheel angles and articulation angles is valid, and, if there are no accelerating or braking forces present in the longitudinal direction, simple equations relating the tire side forces to the yaw angular acceleration and lateral acceleration of the tractor and trailer units can be derived from an inspection of the freebody diagrams. The equations are as follows:

Lateral force equilibrium of the tractor

 $F_1 + F_2 - F_f = m_1 a_{y1}$ (1)





 $\frac{\text{NOTE}:}{ay_2 = \dot{v}_1 + ur_1}$ $\frac{ay_2 = \dot{v}_1 + ur_1 - X_{1A}\dot{r}_1 - X_{2A}\dot{r}_2$

Figure VII.1

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Yaw moment equilibrium of the tractor

$$F_{1}X_{11} - F_{2}X_{12} + F_{f}X_{1A} = I_{1}r_{1}$$
 (2)

Lateral force equilibrium of the trailer

$$F_{f} + F_{3} = m_{2} a_{v2}$$
 (3)

Moment equilibrium of the trailer

$$F_{f}X_{2A} - F_{3}X_{21} = I_{2}\dot{r}_{2}$$
(4)

Upon eliminating the lateral force at the fifth wheel, F_f from Equations (1) - (4), the tire side forces, F_1 , F_2 , and F_3 can be expressed in terms of \dot{r}_1 , \dot{r}_2 , a_{y1} , and a_{y2} and are of the form:

$$F_{1} = \frac{X_{12}m_{1}a_{y1}}{(X_{11}+X_{12})} + \frac{(I_{2}\dot{r}_{2} + m_{2}X_{21}a_{y2})(X_{12}-X_{1A})}{(X_{2A}+X_{21})(X_{11}+X_{12})} + \frac{I_{1}\dot{r}_{1}}{(X_{11}+X_{12})}$$
(5)

$$F_{2} = \frac{X_{11}m_{1}a_{y1}}{(X_{11}+X_{12})} + \frac{(I_{2}\dot{r}_{2} + m_{2}X_{21}a_{y2})(X_{11}+X_{1A})}{(X_{2A}+X_{21})(X_{11}+X_{12})} - \frac{I_{1}\dot{r}_{1}}{(X_{11}+X_{12})}$$
(6)

$$F_{3} = \frac{m_{2}X_{2A}a_{y2} - I_{2}\dot{r}_{2}}{(X_{2A}+X_{21})}$$
(7)

When the fifth wheel is located directly over the tractor rear axle, $X_{1A} = X_{12}$, and Equations (5), (6), and (7) reduce to a simpler form:

$$F_{1} = \frac{X_{12}m_{1}a_{y1}}{L} + \frac{I_{1}\dot{r}_{1}}{L}$$
(8)

$$F_{2} = \frac{X_{11}m_{1}a_{y1}}{L} + \frac{m_{2}X_{21}}{L_{T}}a_{y2} + \frac{I_{2}\dot{r}_{2}}{L_{T}} - \frac{I_{1}\dot{r}_{1}}{L}$$
(9)

$$F_{3} = \frac{m_{2} \chi_{2A} a_{y2}}{L_{T}} - \frac{I_{2} \dot{r}_{2}}{L_{T}}$$
(10)

If we compare these instantaneous tire forces, F_i , to the forces F_i)_{ss} during a steady turn of lateral acceleration, a_{yl} , we find

$$F_{1}-F_{1}\bigg)_{ss} = \frac{I_{1}\dot{r}_{1}}{L}$$
(11)

$$F_{2}-F_{2}\Big|_{ss} = \frac{I_{2}\dot{r}_{2}}{L_{T}} - \frac{I_{1}\dot{r}_{1}}{L_{T}} - \frac{m_{2}X_{21}}{L_{T}}(a_{y1}-a_{y2})$$
(12)
$$F_{3}-F_{3}\Big|_{ss} = \frac{-I_{2}\dot{r}_{2}}{L_{T}}$$

The factors which contribute to the deviation of the yaw response of the tractor during ramp-steer-type transient maneuvers from the steady turning behavior can be explained with the aid of Equations (11) and (12).

During the ramp-steer transient maneuver, the lateral acceleration of the trailer lags behind the lateral acceleration of the tractor and the yaw rates r_1 and r_2 increase with time. From Equation (12) we find that a lag in the trailer acceleration will lower the side force, F_2 , and therefore will provide a stabilizing effect on the tractor. The tractor yaw angular acceleration term $(I_1\dot{r}_1)$ causes an increase in F_1 and a decrease in F_2 , and therefore also has a stabilizing effect. The trailer angular acceleration term $(I_2\dot{r}_2)$, on the other hand, tends to increase F_2 and hence has a destabilizing effect. For typical tractor-trailer vehicles, the influence of trailer

lag dominates and the result is the contribution of a net stabilizing effect (during ramp-steer-type maneuvers) for those tractors which have a tendency to exhibit yaw divergence.