

APPENDICES

APPENDIX A

VEHICLE PARAMETER SETS

This appendix contains five data sets corresponding to (1) the empty baseline vehicle with original axle load estimates, (2) the loaded baseline vehicle with original axle load estimates, (3) the empty baseline vehicle with subsequent axle load measurements, referred to here as "New Load Data," (4) a standard 35-foot bus data set (empty), and (5) the empty baseline vehicle data set but containing tire model parameters in place of tire data tables. The tire model was used for all low friction traction/braking maneuvers because corresponding tire data was not available and it also facilitated changes in data sets for the different road friction conditions.

Those parameters having the greatest uncertainty as to actual value and appearing in each of these data sets are identified by an asterisk (*) in data set #5 (sub-appendix A.5). Also, those parameters felt to have the least importance in affecting the simulation results are identified by a (+) in data set #5.



Empty Baseline Vehicle A.1

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CANADIAN ARTIC BUS EMPTY---12'-SINGLE-LANE-CHANGE---100 KPH DEC 16'80 RUNE28

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DPC 16+80 RUN#28 CANADIAN ARTIC DUS EMPTY---12'-SINGLE-LANE-CHANGE---100 KPH

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CANADIAN ARTIC BUS EMPTY---12'-SINGLE-LANE-CHANGE---100 KPH DFC 16'RO RUN#28

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CANADIAN ARTIC DUS EMPTY---12"-SINGLE-LANE-CHANGE---100 KPH DEC 16'80 RUN#28

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CANADIAN ARTIC DUS EMPTY---12'-SINGLE-LANE-CHANGE---100 KPH DEC 16'R0 RUN#28

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CANADIAN ARTIC BUS LOADED--- RAMP STEER INPUT-215.DEG-50-KPH,DEC 16.80 RUN#29

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CANADIAN AHTIC NUS LOADED--- KAMP STEER INPUT-215.DEG-50-KPH,DEC 16'80 RUN#29

THACTOR REAR SUSPENSION AND AXLE FARAMETERS	LEFT SIDE	RIGHT SIDE	
SUSTENSION KEY - O INDICATES SINGLE AXLE, I INDICATES FOUH SPRING, 2 WALKING PI SUSPENSION SPRING RATE (LB/IN/SIDE/AXLE) SUSPENSION VISCOUS DAMPING (LH-SFC/IN/SIDE/AXLE) COULOME FRICTION (LH/SIDE/AXLE)	САМ 1729.00 50.00 0.0	0 1729.00 58.00 0.0	
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THACTOR REAR TIRES AND WHEELS	LEFT SIDE	RIGHT SIDE	
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LONGITUDINAL STIFFNESS (LB/SLIP/TRE) *** NEGATIVE ENTRY INDICATES TABLE ENTERED *** *** ECHO WILL APPEAR ON TAPLE INDEX PAGE ***	-2.00	-2.00	
CAMBER STIFFNESS (LB/DEG/TIRE)	0.0	0*0	
ALIGNING MOBENT (IN-LB/DEG/TIRE)	1512.00	1512.00	
TIRE SPRING RATE (LB/IN/TIRE)	5000.00	5000.00	
TIRE LOADED RADIUS (IN)	20.47	20.47	
FOLAR MOMENT OF INERTIA (IN-LB-SEC##2/WHEEL)	300.00	00°00E	

CICH FHONT INAKES LEFT SIDE TIME LAG (SEC) 0.0200 HISE TIME (SEC) 0.0200 HISE TIME (SEC) 0.0200 HISE TIME (SEC) 0.0200 HISE TIME (SEC) 0.0200 HASE TONOUL (IN-LUZPSIZHNAKE) 0.0200 HARE TONOUL (IN-LUZPSIZHNAKE) 0.0200 HARE PROPORTIONING KEY: 0 ENTRY INDICATES BRAKE PROPORTIONING UPTION NOT IN USE CN VEHICLE TRAIN UTOR HEAR BRAKES 0.01000 UTOR (SEC) 0.0000 ITME LAG (SEC) 0.0500 ITME TORUUE (IN-LEVERITEDESIZE) 0.0000	RIGHT SIDE	0.0200 0.2500 700.0000 0	RIGHT SIDE	0.0500 0.2500 1100.0000
CTUR FHONT MAKES TIME LAG (SEC) HISE TIME (SEC) HISE TIME (SEC) HASE TORQUE (IN-LB/PSI/MAKE) HARE TORQUE (IN-LB/PSI/MAKE) HARE PROPORTIONING KEY: 0 ENTRY INDICATES BRAKE HYSTERESIS OFTION NOT IN HARE PROPORTIONING KEY: 0 ENTRY INDICATES BRAKE HYSTERESIS OFTION NOT IN CTOR HEAR BRAKES CTOR HEAR BRAKES TIME LAG (SEC) HISE TIME (SEC) HARE TORQUE (IN-LB/PSI/MAKE)	LEFT SIDE	0.0200 0.2500 700.0000 USE CN VEHICLE TRAIN OT IN USE ON VEHICLE TRAIN	LEFT SIDE	0.0500 0.2500 1100.0000
	ACTUR FRONT DRAKES	TIME LAG (SEC) HISE TIME (SEC) FRAKE TORQUE (IN-LB/PSI/BHAKE) BHAKE HYSTERESIS OFTION NOT IN (BHAKE HYSTERESIS KEY: 0 ENTRY INDICATES BRAKE PROPORTIONING UPTION NO BHAKE PROPORTIONING KEY: 0 ENTRY INDICATES BRAKE PROPORTIONING UPTION NO	ACTOR REAR BRAKES	TIME LAG (SEC) kise time (Sec) erake torque (In-lb/psi/bhake)

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CANADIAN ARTIC PUS LOADED--- RAMP STEER INPUT-215.DEG-50-KPH,DEC 16.80 RUN129

TRAILER NO. 1 FARAMETERS

			L					
203.40 1938.00 16267.00 93000.00 300000.00 10802.00 58.90 24.000.00 205000.00 20000.00	RIGHT SIDE	0 1742.00 58.00 0.0	7000.00 23.00 75000.00 37.00 76.40 2205.00	RIGHT SIDE	13.22 -1.00	-2.00	0.0 1572.00 5000.00 20.00	2 V • V V
	LEFT SIDE	BEAM 1742.00 58.00 0.0		LEFT SIDE	13.22 -1.00	-2.00	0.0 1572.00 5000.00 300.00	2000
WHELLASE - DISTANCE FHOM KINGPIN TO CENTER OF KEAR SUSPENSION (IN) FASE VEHICLE KINGPIN STATIC LOAD (LB) BASE VEHICLE CURB WEIGHT ON KEAR SUSPENSION (LB) BASE VEHICLE CURB WEIGHT ON KEAR SUSPENSION (LB) SPRUNG MASS CG HEIGHT (IN. ABOVE GHOUND) SPRUNG MASS FITCH ROMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH ROMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH ROMENT OF INERTIA (IN-LB-SEC**2) PAYLOAD WEIGHT (LB) PAYLOAD WEIGHT (LB) PAYLOAD USTANCE AHEAD OF REAR SUSPENSION CENTER(IN) PAYLOAD VEIGHT (IN. ABOVE GROUND) FAYLOAD VEIGHT (IN. ABOVE GROUND) PAYLOAD PITCH MOMENT OF INERTIA(IN-LB-SEC**2) PAYLOAD PITCH MOMENT OF INERTIA(IN-LB-SEC**2) PAYLOAD PITCH MOMENT OF INERTIA(IN-LB-SEC**2)	THAJLER NO. 1 HEAR SUSPENSION AND AXLE PANAMETERS	SUSFENSION KEY - O INDICATES SINGLE AXLE, 1 INDICATES FOUR SPRING, 2 WALKING SUSPENSION SPHING RATE (LB/IN/SIDE/AXLE) SUSFENSION VISCOUS DAMPING (LB-SEC/IN/SIDE/AXLE) COULOME FRICTION (LB/SIDE/AXLE)	AXLE ROLL MOMENT OF INENTIA (IN-LB-SEC**2) ROLL CENTER HEIGHT (IN. ABOVE GROUND) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) ROLL STEFR COEFFICIENT (DEG. STEER/DEG. ROLL) AUXILIARY ROLL STIFFNESS (IN-LB/DEG/AXLE) LATERAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN) TRACK WIDTH (IN) UNSPRUNG WEIGHT (LB)	TRAILER NO. 1 REAR TIRES AND WHEELS	DUAL TIRE SEPARATION (JN) COMNEKING STIFFNESS (LB/DEG/TIRE) **** NEGATIVE ENTRY INDICATES TABLE ENTERED ***	VILL APPEAR ON TAELE INDEX PAGE *** Longitudinal Sitfeness (L6/SLIP/Time) *** NLGATIVE ENTRY INDICATES TAMLE ENTERED ***	CAMBER STIFFIELD AT EARLY AN INCLE INDEA FAGE TO CAMBER STIFFIELS (LUDEG/TIRE) ALIGNING MOFENT (IN-LUJ/DEG/TIRE) TIRE SFRING RATE (LU/IN/TIRE) TIRE LCADED RADIUS (IN) FOR HOMEN OF THE PARTIA (MALHAGE)	FULKIN HUMBINJ UT JIHERIIA (JINTERTORUSELVYZZMINER)

INPUT PAGE NO. - ANNA - MAILES MAN POLICES MAN INTERS - PHASE 4. .

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CANADIAN ANTIC PUS LOADED--- RAMP STEER INFUT-215.DEG-50-KPH.DEC 16.80 RUN#29

0.1400 0.2500 1600.0000 RIGHT SIDE -1 0.1400 0.2500 1600.0000 LEFT SIDE ***** ANTILOCK KEY: 1 INDICATES ANTILOCK WILL BE USED TIME LAG (SEC) RISE TIME (SEC) DRAKE TORUUE (IN-LD/PSI/BHAKE) TEALLEH NO. 1 REAR BRAKES

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SUMMARY PAGE

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TOANT NEEDEN - CONCOMENTATION CONCOMENTATION - CONCOMENTATIO	14 N-06-930 • CT7 -	1, UEC 16'80 HUNE29	
TRAILER NO. 1 PAYLOAD = 10802.000 LFS.	EMPTY	LOADED	
DISTANCE FROM TRAILER SPRUNG MASS CENTER TO REAR SUSPENSION (IN) DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN) ROLL MOMENT OF INERTIA OF TRAILER SPRUNG MASS (IN-LB-SEC**2) PITCH MOMENT OF INERTIA OF TRAILER SPRUNG MASS (IN-LB-SEC**2) YAK HOMENT OF INERTIA OF THAILER SPRUNG MASS (IN-LB-SEC**2)	24.637 43.300 93000.000 30000.000	38.446 51.885 124579.188 532191.250 519612.000	
TLACTOR PAVIDAD - TAOL - TAOL			
Sill 000 = 10202 = 10202 = 0.001	EMPTY	LOADED	
DISTANCE FROM THACTCR SPRUNG MASS CENTER TO REAH SUSPENSION (IN) DISTANCE FROM TRACTUR SPRUNG MASS CENTER TU GROUND (IN) ROLL MOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC**2) PIICH MOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC**2) YAU HOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC**2)	109.911 39.400 93000.000 744000.000 744000.000	115.311 53.446 139798.500 1317541.000 1305743.000	
THE STATIC LOADS ON THE AXLES ARE: AXLE NUMEER LOAD NS(1,1,1) 13377.6940 NS(1,2,1) 23940.994 NS(2,2,1) 23940.994			
TOTAL 60344.000			
THE INACTOR TOTAL MASS CENTER IS 122.020 INCHES BEHIND THE FRONT AXLE The total Yay moment of inertia is 1397072.000 in-LB-Sec⇔≠2			

THE FIRST TRAILER TOTAL MASS CENTER IS 167.077 INCHES BEHIND THE KINGPIN THE TOTAL YAW MOMENT OF INERTIA IS 534413.563 IN-LB-SEC**2

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CANADIAN ARTIC RUS LOADED--- NAMP STEEN INPUT-215.DEG-50-KPH,DEC 16.00 RUN#29

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MU-Y VS ALFHA TAPLES

NO. OF LUI	UN SUP	. OF VE	LOCITIES		
VELOCITY :	= 73.30 A (DEG)	ET/SEC	LOAD = MU - Y	AL 00.000	
	0.0 1.00 1.00 1.00 1.00 1.2.00		0.0 0.12 0.21 0.38 0.60 0.70		
VELOCITY : ALPH/ 	- 73.30 A (DEG)	FT/SEC	LOAD = MU - Y	6000.00 LB	
	0.0 1.00 4.00 8.00 12.00		0.0 0.19 0.33 0.53 0.64 0.68		
VELOCITY : ALPH	= 73,30 A (DEG)	FT/SEC	LOAD = MU - Y	8000.00 LB	
	0.0 1.00 2.00 4.00 8.00 12.00		0.0 0.08 0.16 0.29 0.58 0.58		
Ацриа	0	•0	1P 0.04	01.0	0.50

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TABLE NO.

1.00	1.00	06-0	0.12	0.17
1.00	1.00	06*0	84.0	0.22

CANADIAN ARTIC PUS LOADED--- HAMP STEER INPUT-215.DEG-50-KPH,DEC 16'80 RUN129

MU-X VS. SLIP TARLES

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	LB		LB		ГB		
	3560.00		6770.00		10210.00		
F VELOCITIES		0.0 0.32 0.64 0.81	/SEC LOAD = MU - X	0.0 16.0 77.0 77.0 5.53	/SEC LOAD = MU - X 	0.0 0.25 0.53 0.70 0.71 0.49	arts
ADS NO. C		0.0 0.04 0.20 0.30 1.00	= 66.00 F1	0.04 0.10 0.20 0.30 1.00	= 66.00 FI	0.0 0.04 0.10 0.20 0.30 1.00	
NO. OF LOA	VELOCITY =		VELOCITY = SLIP 		VELOCITY = SLIP 		

TABLE NO.

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0.40
16.00

WAMMING OUTFUL FIELD WIDTH TOO SMALL. CONDITION OCCURRED DURING A FORMATTED WRITE ON FORTRAN UNIT 7 WHICH IS ATTACHED TO RUN-29. THE WRITE IS SEQUENTIAL AT LINE 1. FOR THIS AND ALL FUTURE OCCURRENCES OF THIS CONDITION, A FLELD OF * S WILL EE WRITTEN.

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CANADIAN ARTIC BUS, EMPTY, B-I-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN #113

SIMULATION OPERATION PARAMETERS:

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TABLE ENTRIES	t of LINES): PO	JEILINE "SIEEN	TIME (S	EC) LEFT W	HEEL (DEG)	RIGHT WHEEL	(DEG)
			0.0 1.5 10.0	0 0	0.0 120.00 120.00	0.0 120.00 120.00	
TREADLE PRESSURE T TABLE ENTRIES	ABLE (NUMBER OF	LINES)		11	IME (SEC)	PRESSURE (PS1)	4
					0.0 3.00 3.25 12.00	0.0 0.0 22.00 22.00	• • •
MAXIMUM SIMULATION TIME INCREMENT OF	I TIME (SEC) Output (sec)						7.50 0.10
ROAD KEY = 0 : FI	AT ROAD.						
OUTPUT PAGE OPTION	KEYS: O DELET	ES PAGES		• • •	•		
SPRUNG MASS POSITION	SPRUNG MASS Velocity	SPRUNG MASS ACCELERATION	TIRE FORCES B PAGES	RAKE SUMMAI PAGES	RY LÂTER Page	AL UNSPRU S PA	ING MASS Iges
1	1	1	1	1	1		1

TEMP PAGES 1

CANADIAN ARTIC BUS, EMPTY, B-I-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN #113

TRACTOR FARAMETERS

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235.00 7008.00 8047.00 39.40 93000.00 744000.00 744000.00	-78.30 27.50 25000.00	LEFT SIDE RIGHT SIDE	508.00 26.00 0.0 0.0	5307.00 17.00 0.06 0.0 40.25 802.00 802.00 15000.00 15000.00 15000.00 100000.00 100000.00	LEFT SIDE RIGHT SIDE	-201.00 -201.00	20000.00 20000.00 0.0 0.0 720.00 720.00 5300.00 5300.00 20.47 20.47
WHEELBASE - DISTANCE FROM FRONT AXLE TO CENTER OF REAR SUSPENSION (IN) BASE VEHICLE CURB WEIGHT ON FRONT SUSPENSION (LB) EASE VEHICLE CUPB WEIGHT ON FRONT SUSPENSION (LB) SPRUNG MASS CG HEIGHT (IN. ABOVE GROUND) SPRUNG MASS CG HEIGHT (IN. ABOVE CROUND) SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS YAW MOMENT OF INERTIA (IN-LB-SEC**2) FAYLOAD WEIGHT (LB)	*** ZEHO ENTRY INDICATES NO PAYLOAD *** *** FIVE PAYLOAD DESCRIPTION PARAMETERS ARE NOT ENTERED *** FIFTH WHEEL LOCATION (IN. AHEAD OF REAR SUSP. CENTER) FIFTH WHEEL HEIGHT ABOVE GROUND (IN) IRACTOR FRAME STIFFNESS (IN-LB/DEG) IRACTOR FRAME TORSIONAL AXIS HEIGHT ABOVE GROUND (IN)	TRÂCTOR FRONT SUSPENSION ÂND ÂXLE PARÂMETERS	SUSPENSION SPRING RATE (LB/IN/SIDE/AXLE) SUSPENSION VISCOUS DAMPING (LB-SEC/IN/SIDE/AXLE) Coulomb Friction (LB/SIDE/AXLE)	AXLE ROLL MOMENT OF INERTIA (IN-LB-SEC+*2) ROLL CENTER HEIGHT (IN. ABOVE GROUND) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) ROLL STERR COLL STIFFNESS (IN-LB/DEG/AXLE) LATERAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN) IRACK WIDTH (IN) UNSFRUNG VEIGHT (LB) STEERING STIFFNESS (IN-LB/DEG) IIE ROD STIFFNESS (IN-LB/DEG)	TRACTOR FRONT TIRES AND WHEELS	CORNERING STIFFNESS (LB/DEG/TIRE) *** CALF LESS THAN - 200. INDICATES TIRE MODEL IS BEING USED *** *** Model Parameters VILL BE Echoed Follouing the Table Echoes ***	LOVGITUDINAL STIFFNESS (LØ/SLIP/TIRE) CAMEER STIFFNESS (LØ/DEG/TIRE) ALIGNING MOMENT (IN-LØ/DEG/TIRE) TIRE SPRING RATE (LØ/IN/TIRE) TIRE LOADED RADIUS (IN) FOLAR MOMENT OF INFPTIA (IN-IN-SFC**2/UNGFT)

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CANADIAN ARTIC BUS, EMPTY, B-1-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN 1113

TRACTOR REAR SUSPENSION AND AXLE PARAMETERS	LEFT SIDE	RIGHT SIDE	
SUSFENSION KEY - 0 INDICATES SINGLE AXLE, 1 INDICATES FOUR SPRING, 2 WALKING BE SUSFENSION SPRING RATE (LB/IN/SIDE/AXLE) Susfension Viscous Damping (LB-Sec/in/Side/AxLe) Coulomb Friction (LB/Side/AxLe)	.AM 880.00 58.00 0.0	0 880.00 58.00 0.0	
AXLE ROLL MOMENT OF INERIJA (IN-LB-SEC**2) ROLL CENTER HEIGHT (IN. ABOVE GROUND) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) AUXILIARY ROLL STIFFNESS (IN-LB/DEG/AXLE) LATEAAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN) TRACK WIDTH (IN) UNSFRUNG WEIGHT (LB)		7000.00 23.00 75000.00 37.00 1466.00	ŧ.
TRACTOR REAR TIRES AND WHEELS	LEFT SIDE	RIGHT SIDE	
DUAL TIRE SEPARATION (IN) Cornering Stiffness (LB/DEG/Tire) *** Calf Less Than -200. Indicates tire model is being used #** *** model parameters will be echoed following the table echoes ***	13.22 -202.00	13.22 -202.00	
LONGITUDINAL STIFFNESS (LB/SLIP/TIRE) CAMBER STIFFNESS (LB/DEG/TIRE) ALIGNING MOMENT (IN-LB/DEG/TIRE) TIRE SPRING RATE (LB/IN/TIRE) TIRE LOADED RADIUS (IN) POLAR MOMENT OF INERTIA (IN-LB-SEC**2/WHEEL)	20000.00 0.0 648.00 5000.00 300.00	2000.00 0.0 648.00 5000.00 20.47 300.00	

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THACTOR FRONT BRAKES	LEFT SIDE	RIGHT SIDE
TIME LAG (SEC) RISE TIME (SEC) URAKE TORQUE (IN-LB/PS1/BRAKE) *** NEGATIVE ENTRY INDICATES TABLE ENTERED ***	0.0200 0.2500 -15.0000	0.0200 0.2500 -15.0000
DRAKE HISTERESIS KEY: O ENTRY INDICATES BRAKE HISTERESIS OPTION NOT IN BRAKE PROPORTIONING KEY: O ENTRY INDICATES BRAKE PROPORTIONING OPTION TRACTOR BEAD DEALES	USE ON VEHICLE TRAIN Ot in Use on Vehicle Train	00
	LEFT SIDE	RIGHT SIDE
TIME LAG (SEC) RISE TIME (SEC) BRAKE TORQUE (IN-LB/PSI/BRAKE) *** NEGATIVE ENTRY INDICATES TABLE ENTERED *☆↓ *** Echo UILL APPEAR ON TABLE INDEX PAGE *☆	0.0500 0.2500 -16.0000	0.0500 0.2500 -16.0000
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CANADIAN ARTIC RUS, EMPTY, B-1-T,22 PS1,50-KPH, MU=0.3, OPEN LOOP, RUN 1113

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TRAILER NO. 1 PARAMETERS

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203.40 1045.00 17160.00 93000.00 300000.00 300000.00	RIGHT SIDE	0 1204.00 58.00 0.0	7000.00 23.00 23.00 75000.00 37.00 76.40 2205.00	RIGHT SIDE	13.22 -203.00	20000.00 1052.00 5000.00 20.00 300.00
	LEFT SIDE	ALKING BEAM 1204.00 58.00 0.0		LEFT SIDE	13.22 -203.00	20000.00 0.0 1052.00 5000.00 20.00 300.00
WHEELBASE - DISTANCE FROM KINGPIN TO CENTER OF REAR SUSPENSION (1N) BASE VEHICLE KINGPIN STATIC LOAD (LB) BASE VEHICLE CURB WEIGHT ON REAR SUSPENSION (LB) PASE VEHICLE CURB WEIGHT (IN. ABOVE GROUND) SPRUNG MASS CG HEIGHT (IN. ABOVE GROUND) SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG WASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG WASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG WASS PAV MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG WASS PAV MOMENT OF INERTIA (IN-LB-SEC**2) *** FIVE PAYLOAD DESCRIPTION PARAMETERS ARE NOT ENTERED ***	IRAILER NO. 1 REAR SUSPENSION AND AXLE PARAMETERS	SUSPENSION KEY - O INDICATES SINGLE AXLE, 1 INDICATES FOUR SPRING, 2 W SUSPENSION SPRING RATE (LD/IN/SIDE/AXLE) SUSPENSION VISCOUS DAMPING (LD-SEC/IN/SIDE/AXLE) COULOMB FRICTION (LD/SIDE/AXLE)	AXLE ROLL MOMENT OF INERTIA (IN-LB-SEC**2) ROLL CENTER HEIGHT (IN. ABOVE GROUND) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) AUXILIARY ROLL STIFFNESS (IN-LB/DEG/AXLE) LATERAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN) TRACK WIDTH (IN) UNSPRUNG WEIGHT (LB)	TRAILER NO. 1 REAR TIRES AND WHEELS	DUAL TIRE SEPARATION (IN) Cornering Stiffness (LD/DEG/TIRE) *** Calf Less THAN -200. Indicates tire model is being used *** *** model parameters will be echoed following the table echoes ***	LONGITUDINAL STIFFNESS (LB/SLIP/TIRE) CAMMER STIFFNESS (LB/DEG/TIRE) ALIGNING MOMENT (IN-LB/DEG/TIRE) TIRE SPRING RATE (LB/IN/TIRE) TIRE LOADED RADIUS (IN) POLAR MOMENT OF INERTIA (IN-LB-SEC**2/WHEEL)

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CANADIAN ARTIC PUS, EMPTY, B-I-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN 1113

TRAILER NO. 1 REAR BRAKES

TIME LAG (SEC) Rise time (SEC)	BRAKE TORQUE (IN-LB/PSI/BRAKE)	*** NEGATIVE ENTRY INDICATES TABLE ENTERED ☆☆ *** Echo Vill Appear on Table Index page ☆☆

ANTILOCK KEY: 1 INDICATES ANTILOCK WILL BE USED

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0.1400 0.2500 -17.0000

0.1400 0.2500 -17.0000

RIGHT SIDE

LEFT SIDE

JUNNING FAGE

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THE FIRST TRAILER TOTAL MASS CENTER IS 191.724 INCHES BEHIND THE KINGPIN THE TOTAL YAW MOMENT OF INERTIA IS 307885.938 IN-LB-SEC**2

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CANADIAN ARTIC BUS, EMPTY, B-1-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN #113

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LOADED	13.285 13.285 93000.000 300000.000 300000.000	LOADED	114.054 39.400 93000.000 744000.000			
EMPTY	13.265 43.300 93000.000 30000.000	EMPTY	114.054 39.400 93000.000 744000.000			
TRAILER NO. 1 PAYLOAD = 0.0 LBS.	DISTANCE FROM TRAILER SPRUNG MASS CENTER TO REAR SUSPENSION (IN) DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN) Roll Moment of Inertia of Trailer Sprung Mass (IN-LB-SEC \approx 2) Pitch Homent of Inertia of Trailer Sprung Mass (IN-LB-SEC \approx 2) YAU MOMENT OF INERTIA OF TRAILER SPRUNG MASS (IN-LB-SEC \approx 2)	TRACTOR FAYLOAD = 0.0 LBS	DISTANCE FROM TRACTOR SPRUNG MASS CENTER TO REAR SUSPENSION (IN) DISTANCE FROM TRACTOR SPRUNG MASS CENTER TO GROUND (IN) ROLL MOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC $^{++2}$) PITCH MOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC $^{++2}$) YAU MOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC $^{++2}$)	THE STATIC LOADS ON THE AXLES ARE: AXLE NUMBER LOAD NS(1,1,1) 6659.816 NS(1,2,1) 9440.184	-> NS(2,2,1) 17159.996 TOTAL 33259.996	THE TRACTOR TOTAL MASS CENTER IS 125.609 INCHES BEHIND THE FRONT ÅXLE The total yaw moment of inertia is 835255.500 in-LB-Sec**2

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CANADIAN ARTIC BUS, EMPTY, B-I-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN #113

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	TABLE NO		-15		TABLE NO		-16		TABLE NO	-17
	TORQUE (IN-LB)		0.0 0.0 100000.00		TORQUE (IN-LB)		0 • 0 0 • 0 200000 • 00		TORQUE (IN-LB)	0.0 0.0 20000.00 220000.00
	PRESSURE (PS1)		0.0 7.00 100.00	•	PRESSURE (PS1)		0.0 7.00 100.00		PRESSURE (PSI)	0.0 1.00 7.00 100.00
PRESSURE VS TORQUE TABLES	NO. OF LINES	m		PRESSURE VS TORQUE TABLES	NO. OF LINES	t u n.		PRESSURE VS TORQUE TABLES	NO. OF LINES	

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CANADIAN ARTIC DUS, EMPTY, B-I-T,22 PSI,50-KPH, MU=0.3, OPEN LOOP, RUN #113

ANTICAME ANTIALDURA, NUMBER, NUM INITED - PHASE 4.

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SEMI-EMPERICAL TIRE MODEL PARAMETERS

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-201.00			- 20 2 • 0 0				-203.00			
TIRE MODEL NO+	D(VAH)/DVELOCITY	00000	0.0 N/A N/A Tire Model NO.	b(VAR)/DVELOCITY	000		N/A N/A TIRE MODEL NO+	D(VAR)/DVELOCITY	0000000 00000022	
	D(VAR)/DLOAD	00000	0 • 0 V V V V V V	D(VAR)/DLOAD			N N N	D(VAR)/DLOAD	0 0 0 0 0 0 C C C 0 0 0 0 0 0 C Z Z	
	INITIAL VALUE	2 415.00 0.30 0.25 0.25 1.70	2500.00 3500.00 40.00	INITIAL VALUE	320.00 0.30	0, 50 0, 50 1,40 2500,00	2500.00	INITIAL VALUE	E 463.00 0.30 0.25 1.80 2500.00 2500.00 1.80 1.80 1.80 0.00 00 00000000	
	VARIABLE DESCRIPTION	NOMJNAL CORNERING STIFFNESS (LB/DEG/TIRE PEAK FRICTION VALUE (PER TIRE) LOCKED WHEEL FRICTION VALUE (PER TIRE) SLIP VALUE AT PEAK FRICTION (PER TIRE) NOMINAL DNEUMATIC TRAIL (IN/TIRE)	LATERAL STIFFNESS (LB/IN/TIRE) NOMINAL VERTICAL LOAD (LB/TIRE) NOMINAL VELOCITY (FT/SEC/TIRE)	VARIABLE DESCRIPTION	NOMINAL CORNERING STIFFNESS (LB/DEG/TIRE FEAK FRICTION VALUE (PER TIRE)	LUCKED WHEEL FAICTION VALUE (FER IINE) SLIP VALUE AT PEAK FRICTION (PER TIRE) Nominal Pneumatic Trail (IN/TIRE) Latrai stiffness (LA/IN/TIRE)	NOMINAL VERTICAL LOAD (LB/TIRE) NOMINAL VELOCITY (FT/SEC/TIRE)	VARIABLE DESCRIPTION	NOMINAL CORNERING STIFFNESS (LB/DEG/TIRE PEAK FRICTION VALUE (PER TIRE) LUCKED WHEEL FRICTION VALUE (PER TIRE) SLIP VALUE AT PEAK FRICTION (PER TIRE) NOMINAL FNEUMATIC TRAIL (IN/TIRE) LATERAL STIFFNESS (LB/IN/TIRE) NOMINAL VERTICAL LOAD (LB/TIRE)	NUMBER OF A DECOMPTION AND A DECOMPTION

URNING OUTPUT FIELD WIDTH TOO'SMALL. CONDITION OCCURRED DURING A FORMATTED WRITE OM FORTRAN UNIT 7 WHICH IS ATTACHED TO PUN.113. THE URITE IS SEMIENTIAL AT TIME 1. EMD THIS AND ALL FOR THIS OFFICES OF THIS ADDRESS OF THIS ADDRESS OF

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....... STANDARD-35.-BUS,STEP-STEER-RESPONSE,100-KPH, RUN 1112, JAN 14 '81

SIMULATION OPERATION PARAMETERS:

0 91.20 BLE 91.20 RIGHT WHEEL (DEG)	0.0 10.00 10.00 10.00 10.00	ESSURE (PSI)	0.0 4.00 0.10		UNSPRUNG MASS Paces	1
FOLLOVER TAI	0.00 0.00 0.00 0.00	(SEC) PR	.		LÅTERAL Pages	1
IGHT TRUCK) Iegative - Path ((sec) left When	- 25 - 40 - 60 - 40		>		BRÅKE SUMMARY Pages	0
ER O FOR A STHA Angle Table, N Time					TIRE FORCES PAGES	1
TRALLERS - ENT Positive -steer	-	F LINES)	•	LES PAGES	SPRUNG MASS ACCELERATION	1
TION (NUMBER OF (FT/SEC) Er of Lines): S:		CARLE (NUMBER O) S:	/ TIME (SEC) OUTPUT (SEC) AT ROAD.	KEYS: 0 DELET	SPRUNG MASS VELOCITY	1
VEHICLE CONFIGURA INITIAL VELOCITY SIEER TABLE (NUMBI TABLE ENIRLE		TREADLE PRESSURE 1 TABLE ENTRIES	MAXIMUM SIMULATION TIME INCREMENT OF HOAD KEY = 0 : FL	OUTPUT PAGE OPTION	SPRUNG MASS POSITION	1

Standard Bus (Single-Unit), Empty A.4

TEMP PAGES

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ANA STORE AND A STOLEN

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STANDARD-35'-BUS, STEP-STEER-RESPONSE, 100-KPH, RUN #112, JAN 14 '81

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TRUCK PARAMETERS

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WHEELMASE - DISTANCE FROM FRONT AXLE TO CENTER OF REAR SUSPENSION (IN) BASE VEHICLE CURB WEIGHT ON FRONT SUSPENSION (LB) BASE VEHICLE CURB WEIGHT ON REAR SUSPENSION (LB) SPRUNG MASS CG HEIGHT (IN. ABOVE GROUND) SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS YAW MOMENT OF INERTIA (IN-LB-SEC**2) PAYLOAD WEIGHT (LB) *** ZERO ENTRY INDICATES NO PAYLOAD *** *** FIVE PAYLOAD DESCRIPTION PARAMETERS ARE NOT ENTERED ***		235.00 5330.00 14095.00 39.40 120000.00 960000.00 960000.00 0.0
TRUCK FRONT SUSPENSION AND AXLE PARAMETERS	LEFT SIDE	RIGHT SIDE
SUSPENSION SPRING RATE (LB/IN/SIDE/AXLE) SUSPENSION VISCOUS DAMPING (LB-SEC/IN/SIDE/AXLE) COULOMB FRICTION (LB/SIDE/AXLE)	508.00 26.00 0.0	508.00 26.00 0.0
AXLE ROLL MOMENT OF INERTIA (IN-LB-SEC**2) ROLL CENTER HEIGHT (IN. ABOVE GROUND) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) AUXILIARY ROLL STIFFNESS (IN-LB/DEG/AXLE) LATERAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN) TRACK WIDTH (IN) UNSPRUNG WEIGHT (LB) SIEERING GEAR RATIO (DEG STEERING WHEEL/DEG ROAD WHEEL) SIEERING STIFFNESS (IN-LB/DEG) TIE ROD STIFFNESS (IN-LB/DEG) MECHANICAL TRAIL (IN) TORSIONAL WRAP-UP STIFFNESS (IN-LB/IN) LATERAL OFFSET OF STEERING AXIS (IN)	53(8) 75(150(10000)	07.00 17.00 0.06 0.0 40.25 85.60 02.00 38.40 00.00 0.70 00.00 3.00
TRUCK FRONT TIRES AND WHEELS	LEFT SIDE	RIGHT SIDE
CORNERING SIIFFNESS (LB/DEG/TIRE) ### NEGATIVE ENTRY INDICATES TABLE ENTERED ###	-1.00	-1.00
*** ECHO WILL APPEAR ON TABLE INDEX PAGE *** LONGITUDINAL STIFFNESS (LB/SLIP/TIRE) *** NEGATIVE ENTRY INDICATES TABLE ENTERED *** *** ECHO ULL APPEAR ON TABLE INDEX PAGE ***	-2.00	-2.00
CAMBER STIFFNESS (LB/DEG/TIRE) ALIGNING MOMENT (IN-LB/DEG/TIRE) \$\$\$ NEGATIVE ALIGNING MOMENT ENTRY \$\$\$	0.0 -720.00	0.0-720.00
<pre>### ALIGNING MOMENT CURVE FIT PARAMETERS: (0.0 0.0 8.6000 0.0 TIRE SPRING RATE (LB/IN/TIRE) TIRE LOADED RADIUS (IN) POLAR MOMENT OF INERTIA (IN-LB-SEC##2/WHEEL)</pre>) (0.0 0.0 5300.00 20.47 150.00	8.6000 0.0) 5300.00 20.47 150.00

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STANDARD-35'-BUS, STEP-STEER-RESPONSE, 100-KPH, RUN #112, JAN 14'81

RIGHT SIDE	0 880.00	7000.00 23.00 75000.00 37.00 76.40	1466.00 RIGHT SIDE 	13.22 -1.00	-2.00	0.0 648.00 5000.00 20.47 300.00
LEFT SIDE	5 FOUR SPRING, 2 WALKING BEAM 58.00 58.00 0.0		LEFT SIDE	13.22 -1.00	-2.00	0.0 648.00 5000.00 20.417 300.00
TPUCK REAR SUSPENSION AND AXLE PARAMETERS	SUSPENSION KEY - 0 INDICATES SINGLE AXLE, 1 INDICATES SUSPENSION SPRING RATE (LB/IN/SIDE/AXLE) SUSPENSION VISCOUS DAMPING (LB-SEC/IN/SIDE/AXLE) COULOMD FRICTION (LB/SIDE/AXLE)	AXLE ROLL NOMENT OF INERTIA (IN-LB-SECC+2) ROLL CENTER HEIGHT (IN. ABOVE GROUND) ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL) AUXILIARY ROLL STIFFNESS (IN-LB/DEG/AXLE) LATERAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN) UNSPRUNG WEIGHT (LB)	TRUCK REAR TIRES AND WHEELS	DUAL TIRE SEPARATION (IN) COHNERING STIFFNESS (LB/DEG/TIRE) *** NEGATIVE ENTRY INDICATES TABLE ENTERED *** PONCETTION WILL APPEAR ON TABLE INDEX PAGE ***	UUNGIIUUINAL STIFFNESS (LB/SLIP/TIRE) ↔↔ NEGATIVE ENTRY INDICATES TABLE ENTERED ↔↔ ↔↔ ECHO WILL APPEAR ON TABLE INDEX PAGE ↔↔	CAMBER STIFFNESS (LB/DEG/TIRE) ALIGNING MOMENT (IN-LB/DEG/TIRE) TIRE SPRING RATE (LB/IN/TIRE) TIRE LOADED RADIUS (IN) POLAR MOMENT OF INERTIA (IN-LB-SEC**2/WHEEL)

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SUMMARY PAGE

SEANDARD-35'-BUS,STEP-STEER-RESPONSE,100-KPH, RUN #112, JAN 14 '81

TO AT	62.020 39.400 12000.000 96000.000 96000.000
FMDTV	62.020 39.400 120000.000 960000.000
0°0	MASS CENTER TO REAR SUSPENSION (IN) MASS CENTER TO GHOUND (IN) CK SPRUNG MASS (IN-LB-SEC**2) UCK SPRUNG MASS (IN-LB-SEC**2) K SPRUNG MASS (IN-LB-SEC**2)
PAYLOAD =	FROM TRUCK SPRUNG FROM TRUCK SPRUNG IENT OF INEHTIA OF TRU MENT OF INERTIA OF TRU NT OF INERTIA OF TRUCI
TRUCK	DISTANCE DISTANCE Rull Mom Pitch Mo Yau Mome Yau Mome

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AXLES		
LOADS ON THE LOAD	5330.004 14094.996	19425.000
THE STATIC AXLE NUMBER	NS(1,1,1) NS(1,2,1)	TOTAL

THE TRUCK TOTAL MASS CENTER IS 170.519 INCHES BEHIND THE FRONT AXLE The total yay moment of inertia is 1048779.000 in-LB-Sec**2

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- PHASE 4. PHASE 4. PHASE 4.

STANDARD-35'-BUS, STEP-STEER-RESPONSE, 100-KPH, RUN #112, JAN 14 'B1

MU-Y VS ALPHA TABLES

VELOCITY = 73.30 FT/SEC ALPHA (DEG)	LOAD = MU - Y 	4000.00 LB		
0.0 1.00 1.00 1.00 1.2.00	0.0 0.12 0.21 0.38 0.38 0.70			•
VELOCITY = 73.30 FT/SEC ALPHA (DEG) 	U. /4 LOAD = MU - Y	6000.00 LB	•	
0.0 1.00 2.00 4.00 12.00 16.00	0.0 0.10 0.19 0.33 0.53 0.64			
VELOCITY = 73.30 FT/SEC ALPHA (DEG)	ĹОАD = МU - Y	8000°00 FB	· · · · · ·	
0.0 1.00 2.00 4.00 12.00 16.00	0.0 0.08 0.16 0.29 0.59 0.58			
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STANDARD-35'-BUS,STEP-STEER-RESPONSE,100-KPH, RUN #112, JAN 14 '81

MU-X VS. SLIP TABLES

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NO. OF LOA	DS NO. OF VEI	LOCITIES		
3 1.12 VELOCITY = 	1 66.00 FI/SEC	LOAD = MU - X	3560.00 LB	
	0.0 0.04 0.10 0.20 0.30 1.00	0.0 0.32 0.64 0.81 0.81 0.58		
VELOCITY = SLIP 	66.00 FI/SEC	LOAD = MU - X	6770.00 LB	
	0.0 0.04 0.10 0.20 0.30 1.00	0.0 0.31 0.60 77 0.77 0.53		· · ·
VELOCITY = SLIP 	66.00 FT/SEC	LOAD = MU - X	10210.00 LB	
	0.0 0.04 0.10 0.20 0.30 1.00	0.0 0.25 0.53 0.70 0.71		
JULL-OFF TABLE				
АЦРНА	0.0	LP 0.04	0.10	0.50
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INPUT PAGE NO. HOMILANA BRAKING AND HANDLING SIMULATION OF TRUCKS, TRACTOR-SEMITRAILERS, DOUFLES, AND TRIPLES - PHASE 4.

CANADIAN ARTIC BUS EMPTY,100 KPH, BRAKING-IN-A-TURN-, 44-PSI, 50--DEG, RUN #55, JAN-05

SINULATION OPERATION PARAMETERS:

VEHICLE CONFIGURATI INITIAL VELOCITY (F STRER TABLE (NUMBER TABLE ENTRIES:	ON (NUMBER OF "L'SEC) OF LINES): P	TRAILERS – ENTE OSITIVE –STEER	R O FOR A STRI Angle table, n Time	.IGHT TRUCK) Egative – Path (SEC) left wh	FOLLOWER Follower	1 91.10 TABLE 3 RIGHT WHEEL (DEG)	
			27	0.000	0.0 50.00 50.00	0.0 50.00 50.00	
TREADLE PRESSURE TA TABLE BNTRIES:	BLE (NUMBER CF	LINES)		TIN	E (SEC)	4 Pressure (PSI)	
					0.0 3.00 3.25 12.00	0.0 0.0 0.0 0.0 0.0 0.0	
MAXINUM SIMULATION TIME INCREMENT OF O	TIME (SEC) UTPUT (SEC)					7.50	
ROAD KEY = 0 : FLA	T ROAD.						
OUTPUT PAGE OPTION	KEYS: O DELET	ES PAGES					
SPRUNG MASS POSITION	SPRUNG MASS VELOCITY	SPRUNG MASS ACCELERATION	TIRE FORCES PAGES	ERAKE SUMMARY Pages	LATERA	L UNSPRUNG EAS: PAGES	TEL
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A.5 Empty Baseline Vehicle with Tire Model

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CANADIAN ARTIC BUS EMPTY, 100 KPH, BRAKING-IN-A-TURN-, 44-PSI, 50--DEG, RUN\$55, JAN-05

TRACTOR PARAMETERS

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WHEELBASE - DISTANCE FROM FRONT AXLE TO CENTER OF REAR SUSPENSION (IN) BASE VEHICLE CURB WEIGHT ON FRONT SUSPENSION (LB) EASE VEHICLE CURB WEIGHT ON BEAR SUSPENSION (LB) SPRUNG MASS CG HEIGHT (IN. ABOVE GROUND) SPRUNG MASS ROLL MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS YAW MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS YAW MOMENT OF INERTIA (IN-LB-SEC**2) FAYLOAD WEIGHT (LB) *** ZERO ENTRY INDICATES NO PAYLOAD *** *** FIVE PAYLOAD DESCRIPTION EARAMETERS ARE NOT ENTERED ***	-	$\begin{array}{c} 235.00 \\ 6820.00 \\ 8315.00 \\ 39.40 \\ 93000.00 \\ \times \\ 744000.00 \\ \times \\ 744000.00 \\ 0.0 \end{array}$				
FIPTH WHEEL LOCATION (IN. AHEAT OF REAR SUSP. CENTER)		~78,30				
FIPTH WHEEL HEIGHT ABOVE GROUND (IN)		27.50				
TRACTOR FRAME STIPPNESS (IN-LB/DEG)		250000.00 × +				
TRACTOR FRAME TORSIONAL AXIS HEIGHT ABOVE GROUND (IN)		39.40				
TRACTCR FRONT SUSPENSION AND AXLE PARAMETERS	LEFT SIDE	RIGHT SIDE				
SUSPENSION SPRING RATE (LE/IN/SICE/AXLE)	508.00	508.00				
SUSPENSION VISCOUS DAMEING (LB-SEC/IN/SIDE/AXLE)	26.00	26.00 × +				
COULOND FRICTION (LB/SICE/AXLE)	0.0	0.0				
AXLE ROLL MOMENT OF INERTIA (IN-IB-SEC ++2)	53	07.00 +				
ROLL CENTER HEIGHT (IN. ABOVE GROUND)		17.00				
ROLL STEER COEFFICIENT (DEG. STEER/DEG. ROLL)		17.00 0.06 × + 0.0				
AUXILIARY ROLL STIFFNESS (IN-LE/CEG/AXIE)		0.0				
LATERAL DISTANCE BETWEEN SUSPENSION SPRINGS (IN)		40.25				
TRACK WIDTH (IN)		85.60				
UNSPRUNG WEIGHT (LB)	6	02.00				
STEERING GEAR RATIO (DEG STEERING WHEEL/DEG ROAD WHEEL)		38.40				
STEERING STIFFNESS (IN-LB/DEG)	75	00.00 *				
TIE ROD STIFFNESS (IN-LB/DEG)	150	00.00 🗡				
MPCHANICAL TRAIL (IN)		0.70 🛨				
TORSIONAL WRAP-UP STIFFNESS (IN-IB/IN)	10000	00.00 ×				
IATERAL OPPSET OF STEERING AXIS (IN)		3.00 ×				
TRACTOR PRONT TIRES AND WHEEIS	LEFT SIDE	RIGHT SIDE				
		201 00				
CORNERING STIFFNESS (LB/DEG/TIRE)	-201.00	-201.00				
*** CALF LESS THAN -200. INTICATES TIRE MODEL IS BEING USET *** *** MODEL PARAMETERS WILL BE ECHOED FOLLOWING THE TABLE ECHOES ***						
LONGITUDINAL STIFFNESS (LB/SLIP/TIRE)	20000.00	20000.00				
CAMBER STIPPNESS (LB/DEG/TIRE)	0.0	0.0 * *				
ALIGNING MOHENT (IN-LE/DEG/TIRE)	720.00	720.00				
TIRE SPRING RATE (LB/IN/TIRE)	5300.00	5300.00				
TIRE LOADED RADIUS (IN)	20.47	20.47				
PATAR MANDOM AT TURBOITS ITO TO STATES CONSTITUTE						

INPUT PAGE NO. чантана маллим ами намиция simulation of Trucks, Tbactor-semitrallers, Doubles, And Triples - Phase 4.

CANADIAN ARTIC BUS EMPTY,100 KPH,BRAKING-IN-A-TURN-,44-PSI,50--DEG,RUN#55,JAN-05

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TRACTOR REAR SUSPENSION AND AXLE PARAMETERS	LEFT SIDE	RIGHT SIDE	
SUSPENSION KEY - O INDICATES SINGLE AXLE, 1 INDICATES FOUR SPRING, 2 WALKING BE SUSPENSION SPRING RATE (LB/IN/SICE/AXLE) SUSPENSION VISCOUS DAMFING (LB-SFC/IN/SIDE/AXLE) COULOM B FRICTION (LB/SIDE/AXLE)	A H 880.00 58.00	0 680.00 58.00	+ *
AXLE ROLL MOMENT OF INEFTIA (IN-LE-SEC**2) Roll Center Height (IN. Adove Grcund) Roll Steer Coefficient (deg. Steer/deg. Roll) Auxiliant Roll Stipphess (IN-Le/Eg/Axle) IATERAL DISTANCE BETWFEN SUSPENSION SPRINGS (IN) TRACK WIDTH (IN)	0.0	7000.00 + 0.0 23.00 + 75000.00 *	+ <
UNSPRUNG WEIGHT (LB) TRACTOR RPAR TIRES AND UNDERS		1466.00 15.40	
	LEFT SIDE	RIGHT SIDE	
DUAL TIRE SEPARATION (IN) Cornering Stiffness (le/deg/tire) *** Calf less than -200. indicates tire model is being used *** *** model parameters will be echoed following the table echoes ***	13.22	13.22-202.00	
LONGITUDINAL STIFPNESS (LB/SLIP/TIRE) CAMBER STIFPNESS (LB/DEG/TIRE) ALIGNING MOMENT (IN-LB/DEG/TIRE) TIRE SPNING BATE (LE/IN/TIRE) TIRE LOADED RADIUS (IN) FOLAR MOMENT OF INBRTIA (IN-IB-SEC++2/WHEEL)	20000.00 0.0 648.00 5000.00 20.47 300.00	20000,00 648.00 5000.00 20047 300.00 +	NI.

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RIGHT SIDE	0.0200 * 0.2500 * - 15.0000 * - 15.0000 *	0.0500 × × 0.2500 × × -16.0000 ×	
LTFT SIDE	0.0200 0.2500 -15.0000 Vehicle train Use on Vehicle train Use on Vehicle train	0.0500 0.2500 -16.0000	
	CPTION NOT IN USE ON		
	BLE ENTERED *** NDEX PAGE *** ES BRAKE HYSTERESIS CATES ERAKE PROPORTI	*** GIRINI AL	
CR FRONT BRAKES	TIME LAG (SEC) RISE TIME (SEC) BRAKE TORQUE (IN-LB/PSI/BRAKE) *** NEGATIVE ENTEY INDICATES TAE *** Echo Will Appear on Table IN erake hysteresis key: O entry incicate erake proportioning key: O entry incicate or readed brakes	TIME LAG (SEC) RISE TIME (SEC) BRAKE TORQUE (IN-LB/PSI/ERAKE) *** NEGATIVE ENTRY INDICATES TAB *** ECHO WILL APFEAR ON TAPIFIN	
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INPUT PAGE NO. HSRI/NVMA BRAKING AND HANDLING SIMULATION CF TRUCKS, TRACTOR-SEMITRAILERS, DCUBLES, AND TRIPLES - PHASE 4.

CANADIAN ARTIC BUS EMPTY,100 KPH,BFAKING-IN-A-TURN-,44-PSI,50--DEG,RUN#55,JAN-05

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TRAILER NO. 1 PARAMETERS

203.40 1938.00 16267.00 43.30 93000.00 300000.00 *	RIGHT SILE	0 1204.00 58.00 X + 0.0	7000.00 + 23.00 + 75000.00 * 37.00 75.00	RIGHT SIDE	13.22 -203.00	20000.00 * 0.0 * 1052.00 * 200.00 +
ON (IN) ***	LEFT SIDE	PRING, 2 WALKING BEAM 1204.00 58.00 0.0		LEFT SIDE	13.22 ISED *** ECHOES ***	20000.00 0.0 1052.00 5000.00 20.00
WHEELBASE - DISTANCE FROM KINGPIN TO CENTER OF REAR SUSPENSI BASE VEHICLE KINGPIN STATIC LOAF (1B) BASE VEHICLE CURB WEIGHT ON REAR SUSPENSION (1B) SPRUNG MASS CG HEIGHT (IN. ABOVE GROUND) SPRUNG MASS ROLL MCHENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS PITCH MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS TAW MOMENT OF INERTIA (IN-LB-SEC**2) SPRUNG MASS YAW MOMENT OF INERTIA (IN-LB-SEC**2) PAYLOAD WEIGHT (LE) *** ZERO ENTRY INDICATES NO PAILOAD *** *** FIVE PAYLOAD DESCRIPTICN FARAMETERS ARB NOT BNTERED	TRAILER NO. 1 REAR SUSPENSICN AND AILE PARAMETERS	SUSPENSION KET ~ 0 INDICATES SINGLE AXLE, 1 INDICATES FOUR S SUSPENSION SPRING RATE (LB/IN/SIDE/AXLE) SUSPENSION VISCOUS DAMEING (LB-SEC/IN/SIDE/AXLE) COULOMB FRICTION (LB/SIDE/AXLE)	AXLE ROLL MOMENT OF INEFTIA (IN-LE-SPC++2) ROLL CENTER HEIGHT (IN. ABOVE GRCUND) ROLL STRER COEFFICIENT (DEG. STEER/DEG. ROLL) AUTILIANT ROLL STIFFNESS (IN-LB/DEG/AXLE) LATERAL DISTANCE DETWEEN SUSPENSION SPRINGS (IN) TRACK WIDTH (IN) UNSPRUNG WEIGHT (LB)	TRAILER NO. 1 REAR TIRES AND WHEELS	DUAL TIRE SEPARATION (IN) Cornering Stiffness (le/deg/tirf) *** Calf less than -200. Indicates tire model is bring (*** model parameters will be echoed following the table	LONGITUDINAL STIFFNESS (LB/SLIE/TIRE) CAMBER STIFFNESS (LB/DEG/TIRE) ALIGNING MOMENT (IN-LB/DEG/TIRE) TIRE SPRING RATE (LB/IN/TIRE) TIRE LOADED RADIUS (IN) POLAR MOMENT OF INERTIA (IN-LB-SEC**2/WHEEL)

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INPUT PAGE NO.
AND TRIPLES - PHASE 4.
DCUBLES,
TEACTOR-SEMITRAILERS,
F TRUCKS,
SIMULATICN CI
HANDLING
AND
HSHL/HVAA BRAKING

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CANADIAN ARTIC BUS EMPTY,100 KPH, BRAKING-IN-A-TURN-,444-PSI,50--DEG,RUNE55,JAN-05

TRAILER NO. 1 REAR BRAKES	LEFT SIDE	RIGHT SIDE	
TIME LAG (SEC) RISE TIME (SEC) BRAKF TORQUE (IN-LB/PSI/BRAKE) *** NEGATIVE ENTRY INLICATES TABLE ENTERED *** *** ECHO WILL APEEAR ON TAELF INLEX PAGE ***	0.1400 0.2500 -17.0000	0.1400 ¥ 0.2500 ¥ 11.0000 ¥	+ + * * *
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SUBBARY PAGE

CANADIAN ARTIC BUS EMPTY,100 KPN,BFAKING-IN-A-TURN-,44-PSI,50--DEG,RUN#55,JAN-Q5 LOADED LOADED 43.300 300000.000 109.911 39.400 9 3000 . 000 8 93000.00056 744000-000 24.637 300000.000 744000.000 93000.000 300000.00006 24.637 43.300 300000.000 93000.00059 744000-000 39.400 109.911 744000.000 EMETY LAFTY 29.106 INCHES BEHIND THE FRONT AXLE DISTANCE FROM TRAILER SPRUNG MASS CENTER TC FEAR SUSPENSION (IN) DISTANCE FROM TRAILER SPRUNG MASS CENTER TO GROUND (IN) ROLL MOMENT OF INBRTIA OF TRAILER SPRUNG MASS (IN-LB-SEC**2) PITCH NOMENT OF INBRTIA OF TRAILER SFRUNG MASS (IN-LB-SEC**2) DISTANCE FROM TRACTOR SPRUNG MASS CENTER TO REAR SUSPENSION (IN) PITCH MOMENT OF INERTIA OF THACTOR SPRUNG MASS (IN-IB-SEC**2) DISTANCE FROM TRACTOR SPRUNG MASS CENTER TO GROUND (IN) ROLL MOMENT OF INERTIA OF TRACTOR SPRUNG MASS (IN-LB-SEC+*2) 834064.500 IN-LB-SBC++2 YAW MOMENT OF INERTIA OF TRAILEE SEGUNG MASS (IN-LB-SEC**2) YAW MOMENT OF INERTIA OF TRACTCE SPBUNG MASS (IN-LB-SEC++2) LBS. LBS 0.0 0.0 THE TRACTOR TOTAL MASS CENTER IS THE TOTAL YAW MOMENT OF INERTIA IS THE STATIC LOADS ON THE AXLES ABE: # PAYLOAD PAYLOAD = 966°68888 6174.277 10898.723 16266.996 LOAD TRAILER NO. AXLE NUMBER NS (1, 1, 1) NS (1, 2, 1) NS (2, 2, 1) TRACTOR TOTAL 102 2 Ć

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CANADIAN ARTIC BUS EMPTY,100 KPH, BFAKING-IN-A-TURN-,44-PSI,50--DEG,RUN#55, JAN-05

TABLE NO	-15 *	TABLE NO	- 16	TABLE NO	-17 *
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HSRI/MYMA BRAKING AND HANDLING SIMULATION OF TRUCKS, TRACTOR-SEMITRAILERS, DOUBLES, AND TRIPLES - PHASE 4.

CANADIAN ARTIC BUS EMPTY,100 KPH, BEAKING-IN-A-TURN-,44-PSI,50--DEG,RUN#55,JAN-05

SEMI-EMPERICAL TIRE MODEL PARAMETERS

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		•	TIRE MODEL NO20	201.00
ARLABLE DESCRIPTION	INTTIAL VALUE	D (VAR) / DLOAD	D (VAR) /DVELOCITY	
DMINAL CORNERING STIFFNESS (LB/DEG/TIRE	415.00	0-0	0.0	
SAK FRICTION VALUE (PEB TIRE)	0.60	0.0	0.0	
JCKED WHEEL FRICTICN VALUE (PER TIRE)	0.40	0-0	0.0	
LIP VALUE AT PEAK PRICTION (PER TIRE)	0.30	0.0	0.0	
DMINAL PNEUMATIC TRAIL (IN/TIRE)	1. 70	0.0	0.0	
ATERAL STITTNESS (LB/IN/TIRE)	2500.00	0.0	0.0	
DMINAL VERTICAL LCAD (LB/TIRE)	3500.00	N/N	A/A	
DMINAL VELOCITY (FT/SEC/TIRE)	40.00	N/N	N/N	
			TIRE NODEL NO202	02.00
RIABLE DESCRIPTION	INITIAL VALUE	D (VAR) / DLOAD	D (VAR) /DVELOCITY	

A GIU/DAU/A 1/ SSANJAIUS DNIGAN GUJ IENIM	00 065	6	6	
THE DEPOSITE THE STATE OF THE DEPOSITE STATE				
AN FALCTION VALUE (FEB TIME)	0.00		0-0	•
CKED WHEEL FRICTION VALUE (PER TIRE)	0.40	0.0	0.0	
IP VALUE AT PEAK PRICTION (PEE TIRF)	0. 30	0.0	0.0	
MINAL PNEUMATIC TRAIL (IN/TIRE)	1.40	0.0	0.0	
TERAL STIFFNESS (LO/IN/TIRE)	2500.00	0.0	0.0	
MINAL VERTICAL LOAD (IB/TIRE)	2500.00	N/A	N/N	
MINAL VELOCITY (F1/SEC/TIRE)	40.00	N/A	N/A	
			TIRE MODEL NO20	00.503
RIABLE DESCRIPTION	INITIAL VALUE	D (VAR) / ELOAD	D (VAR) /DVELOCITY	1 6 6 1
		88589933333333		
MINAL CORNERING STIFFNESS (LD/DEG/TIRE	463.00	0-0	0*0	
AK FRICTION VALUE (PER TIRE)	0.60	0.0	0*0	
CKED WIEEL FRICTION VALUE (PEB TIRE)	0.40	0-0	0.0	
IP VALUE AT PEAK FRICTION (PER TIRE)	0.30	0.0	0.0	
DMINAL PNEUMATIC TRAIL (IN/TIRE)	1.80	0.0	0.0	
VTERAL STIFFNESS (LB/IN/TIRE)	2500.00	0.0	0.0	
DMINAL VERTICAL LOAD (LB/TIRE)	4000.00	N	N/A	
DMINAL VELOCITY (FT/SEC/TIRE)	40.00	N/N	N/A	

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APPENDIX B

TIME HISTORY PLOTS AND SIMULATION RUN DESCRIPTIONS

This appendix contains time history plots for each of the simulated vehicle maneuvers. Each set of plots, corresponding to a specific maneuver (ramp-step, pulse-steer, etc.), is separated by a table which describes the particular runs which follow. Each simulation run is identified by a Run # and further described with regard to loading condition, speed, maneuvering type, and whether or not the articulation controller and retarder were in use.

Run #	Calculation #	Loading Condition	Speed (KPH)	Maneuver	Articulation Controller
1.1	11	E	100	40° step	Yes
1.2	12	Е	100	85° "	Yes
1.3	13	Е	100	135° "	Yes
1.4	30	E	50	120° "	Yes
1.5	36	Е	50	220° "	Yes
		file our e-drei die bassilité de lan our admissiliteres ann			
1.6	8	L	100	85° "	Yes
1.7	9	L	100	175° "	Yes
1.8	10	L	100	270° "	Yes
1.9	29	L	50	215° "	Yes
1.10	35	L	50	300° "	Yes
1.11	7	L	100	85° "	No
1.12*	112	Е	100	40° "	N/A

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Table 1. Ramp/Step Input

*Standard 35-foot Bus











CANADIAN ARTICULATED BUS, STEP STEER MANEUVERS, EMPTY, 100 KPH,

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CANADIAN ARTICULATED BUS, STEP STEER MANEUVERS, LOADED, 100 KPH,



CANADIAN BUS, STEP STEER MANEUVERS, 100 KPH, LOADED,








CANADIAN ARTICULATED BUS, STEP STEER MANEUVERS, LOADED, 100 KPH,













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Run #	Calculation #	Loading Condition	Speed (KPH)	Maneuver	Articulation Controller
2.1	33	E	100	120° Pulse Steer	Yes
2.2	34	E	50	11	Yes
2.3	31	L	100	11	Yes
2.4	32	L	50	11	Yes
2.5	110	E	100	u	No
2.6*	111	E	100	11	Yes

Table 2. Pulse-Steer Input

*Same as Run #2.1, with new load data

























CANADIAN ARTIC BUS, EMPTY, PULSE STEER, INFLUENCE OF CONTROLLER, 100 KPH

















Maneuver
Lane-Change
Twelve-Foot
Table 3.

Run #	Calculation #	Loading Condition	Speed (KPH)	Maneuver	Articulation Controller	Comments
3.1	25	ш	100	Lane Change Dist. = 125'	Yes	τ=0.25, Prev.=1.75
3.2	24	ш	100	150'	Yes	r=0.25, Prev.=1.50
3.3	26	ш	100	150'	Yes	$\tau = 0.25$, Prev.=1.75
3.4	28	ш	100	150'	Yes	$\tau = 0.25$, Prev.=2.0
3.5	27	ш	100	175'	Yes	_τ =0.25, Prev.=1.75
3.6	21	<u> </u>	100	125'	Yes	τ=0.25, Prev.=].75
3.7	20	Ţ	100	150'	Yes	τ=0.25, Prev.=1.5
3.8	22	Г	100	150'	Yes	$\tau = 0.25$, Prev.=1.75
3.9	19		100	150'	Yes	_τ =0.25, Prev.=2.0
3.10	23		100	175'	Yes	_T =0.25, Prev.=1.75
































CANADIAN ARTIC BUS, LOADED, INFLUENCE OF PREV INTERVAL, 12' LANE CHANGE,















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Run #	Calculation #	Loading Condition	Articulation Controller	Drive Torque in-1b
4.1	37	E	Yes	20,000
4.2	38	Ε	Yes	40,000
4.3	39	E	Yes	60,000
4.4	40	Е	Yes	80,000
4.5	41	L	Yes	28,800
4.6	42	L	Yes	57,600
4.7	43	L	Yes	86,400
4.8	44	L	Yes	115,200
4.9*	109	E	No	40,000
4.10**	114	E	No	80,000

Table 4. Cornering with Acceleration on a Low Friction Surface Speed = 10 ft/sec, Maneuver = 1460° Steer Input

*Same as #4.2 without controller

**Same as #4.4 without controller














































Run #	Calculation #	Loading Condition	Speed (KPH)	Brake Pressure (psi)	Retarder	Comments
5.1	46	E	100	20	Yes	μ _p =0.3
5.2	47	Ε	100	40	Yes	μ _p =0.6
5.3	48	E	100	20	No	μ _p =0.3
5.4	51	E	50	7	Yes	μ _p =0.1 μ ₌ =0.08, s ₌ =0.1
5.5	49	L	100	30	Yes	μ _p =0.3
5.6	50	L	100	60	Yes	μ _p =0.6

Table 5. Straight-Line Braking

ts		·							,		: #6.2 w Load	:#6.4 :Cont.	.#6.4 rrn
Commen	μ _n =0.6	г µ _n =0.3	μ _n =0.3	μ _n =0.6	μ _p =0.3	μ _n =0.6	μ _n =0.3	μ _n =0.3	μ _n =0.6	ь µ _p =0.3	Same as with Ne Data	Same as without	Same as Left tu
Brake Pressure (psi)	44	22	25	63	33	44	22	25	63	33	22	63	63
<u>O</u> pen- or <u>C</u> losed- Loop	0	0	0	0	0	C	C	C	C	S	0	0	0
Retarder	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Artic. Controller	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N	No	Yes
	Inp.	=	=	=	=						=	=	=
Iver	teer	=	=	=	=						=	=	=
Maneı	50° 5	120°	120°	85°	160°						120°	85°	.85°
Speed (KPH)	100	50	50	100	50	100	50	50	100	50	50	100	- 100
Loading Condition	ш	ш	ليا			Ш	L.J.	ш			ш		
Calculation #	55	52	54	56	53	63	60	61	64	62	113	107	108
Run #	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	6.10	6.11	6.12	6.13

Table 6. Braking in a Turn

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APPENDIX C

LINEAR ANALYSIS OF DIRECTIONAL RESPONSE CHARACTERISTICS

A broad understanding of the <u>directional</u> qualities of the articulated bus can be gained by conducting a linear yaw plane analysis of its directional response characteristics. In this appendix, eigenvalues of the articulated bus are utilized to establish the extent to which the directional qualities of the bus (at highway speeds) are affected by changes in the following design parameters and operating conditions:

- 1) Loading condition
- 2) Forward velocity
- 3) Tire properties
- 4) Location of trailer c.g.
- 5) Fifth wheel damping

In the discussion that follows, a brief description of the yaw plane model and eigenvalues is first given, following which the results of the calculations are presented.

Linear Yaw Plane Model

A linear yaw plane model which was developed by HSRI as part of an earlier study on double tankers [] was used for conducting the eigenvalue calculations. In the model, all motions are assumed to take place on a horizontal plane. Moreover, the cornering forces and aligning moments generated at the tire/road interfaces are assumed to be linear functions of the sideslip angles at the tires. Steering system dynamics are left out of the model and the steering input is assumed to be given directly to the front wheels. The only degrees of freedom permitted in the model are therefore: (1) the sideslip velocity of the tractor, (2) yaw rate of the tractor, and (3) articulation of each of the trailing units. It was not possible to represent the articulation controller in the linear model due to the fact that, even for small articulation angles, the yaw moment produced by the controller is a highly nonlinar function of the articulation angle. The influence of the damping moment produced by the controller was studied separately by representing the controller as a viscous torsional damper whose damping moment is directly proportional to the rate of change of the articulation angle.

Eigenvalues

The two-unit articulated bus, as represented in the linear model, has a set of four complex eigenvalues and a corresponding set of four complex eigenvectors. The eigenvalues for a fully loaded bus, traveling at 100 KPH, are shown in Figure C.1. The pair of lightly damped eigenvalues marked A_1 correspond to the yaw motion of the rear unit (trailer) and the pair of heavily damped eigenvalues marked ${\rm A}_2$ correspond to the front unit (or tractor). Expressions for the damping ratio and settling time for equivalent second-order systems are also included in Figure C.l. From these expressions it is obvious that the closer a pair of eigenvalues is to the imaginary axis, the less damped is the corresponding natural mode of oscillation. The time taken for a disturbance to settle down is also inversely proportional to distance of the rest from the imaginary axis. Hence, the influence of changes in operating conditions or design parameters on the directional response characteristics of a vehicle can be determined by studying the location of the eigenvalues in the complex plane.

Since the eigenvalues lying in the lower half of the complex plane are just a mirror image of the roots lying in the top half plane, we shall in all future references to eigenvalues show only the roots lying in the top half of the complex plane.

Influence of Loading Condition

The eigenvalues of the articulated bus for four different loading conditions, ranging from fully loaded to empty, are shown in Figure C.2. For each loading condition, the eigenvalues are shown for two







Figure C.2. Influence of speed and load distributions on the eigenvalues of the articulated bus.

forward speeds, namely, 50 and 100 KPH. It is interesting to note that changes in the loading condition do not have a significant impact on the lightly damped trailer oscillation mode. At 100 KPH, the eigenvalue corresponding to the trailer oscillation mode has an observed natural frequency of about 3 rad/sec (1/2 Hz) and a damping ratio of approximately 0.3 for all the four loading conditions. On the other hand, loading condition has a significant effect on the eigenvalues which correspond to the motion of the tractor. When the lead unit is empty, the eigenvalues of the tractor are characterized by a pair of real roots. When the lead unit is empty and the trailing unit is loaded, one of the real roots tends to cross over to the right half of the complex plane, resulting in a yaw divergence type instability at speeds exceeding 130 KPH.

Influence of Speed

In Figure C.2 we note that increasing the speed from 50 to 100 KPH results in the translation of all of the eigenvalues towards the right. The damping ratios of the roots decreases and the time needed for a disturbance to settle down increases. For example, the damping ratio of the trailer oscillation mode is reduced from 0.6 to 0.3 by an increase in the speed from 50 to 100 KPH.

Tire Properties

In this section we shall discuss the effects of reducing the cornering stiffness levels of the tires on each of the three axles of the articulated bus. The calculations were performed for a forward velocity of 100 KPH.

The influence of reducing the cornering stiffness of the tires on the tractor front axle is illustrated in Figure C.3 for the fully loaded bus. As the cornering stiffness is reduced, the observed natural frequency of the pair of eigenvalues which correspond to the tractor motion is increased and the damping ratio is reduced. Reducing the cornering stiffness of the tires on the front axle from 1220 lb/deg to 800 lb/deg reduces the damping ratio from 0.9 to 0.65. It

CANADIAN	ART	ICUL	ATE	D	BVS	
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is interesting to note that changing the cornering stiffness of the tires on the tractor front axle has a negligible effect on the eigenvalue of the trailer oscillation mode. This is due to the fact that there is very little participation of the tractor motion in the trailer oscillation mode.

The influence of reducing the cornering stiffness of the tires on the mid axle is portrayed in Figure C.4. As the cornering stiffness of the tires on the mid axle is reduced, the complex eigenvalues which correspond to the tractor move toward the real axis and split into a pair of real eigenvalues. When the cornering stiffness of the tires is reduced below 1600 lb/deg, one real root crosses over to the right half plane, resulting in a yaw divergence type instability at 100 KPH. The eigenvalue corresponding to the trailer oscillation mode can be seen to once again remain unaffected by a change in the cornering properties of the tractor tires.

The effect of changing the cornering stiffness of the tires on the trailer axle is illustrated in Figure C.5. It can be observed that the eigenvalue corresponding to the tractor motion is unaffected by changes in the cornering stiffness properties of the trailer tires. The eigenvalue corresponding to the trailer oscillation mode shows a decrease in the observed natural frequency and a decrease in the damping ratio as well. When the cornering stiffness of the trailer rear-axle tires is reduced from 2396 lb/deg to 1200 lb/deg (a 50 percent reduction), the damping ratio is reduced from 0.303 to 0.206 (a reduction of 32 percent).

Changes in the cornering stiffness of the tires on the tractor front axle, mid axle, and the trailer axle of an empty bus are illlustrated in Figures C.6, C.7, and C.8, respectively. The comments made in connection with discussing the fully loaded vehicle (Figs. C.3-C.5) hold true for these figures as well.

From these figures it can be concluded that (1) a variation of 10 to 20 percent in the cornering properties of the tires should not make a significant difference in the high-speed transient response characteristics of the vehicle and (2) the damping ratio and natural frequency of the lightly damped trailer oscillation mode is primarily determined by the cornering stiffness of the trailer tires.



Figure C.4. Influence of reducing the cornering stiffness of the tires on the mid axle.





ARTICULATED

BUS

CANADIAN





Figure C.7. Influence of reducing the cornering stiffness of the tires on the mid axle - empty bus.

CANADIAN ARTICULATED BUS

<u>EMPTY 100 KPH</u>



Figure C.8. Influence of reducing the cornering stiffness of the tires on the trailer axle.

Location of Trailer c.g.

In the baseline configuration, the c.g. of the trailer (when empty) is very close to the trailer axle. The vertical load carried by the fifth wheel is therefore very small—around 1900 lbs. We shall in this section discuss the effect of moving the trailer c.g. further back and closer to the trailer axle. Figure C.9 shows the eigenvalues of the empty articulated bus traveling at 100 KPH for three positions of the trailer c.g.—21.7 in., 12 in., and 0 in. ahead of the trailer axle. It can be seen that the location of the trailer c.g. has a significant impact on the damping ratio of the trailer oscillation mode. When the trailer c.g. is moved back by 21.7 in. (to a point which is exactly above the trailer axle), the damping ratio is reduced from 0.305 to 0.177—a reduction of 42 percent. The observed natural frequency is also reduced from about 3 rad/sec to 2.5 rad/sec.

Fifth Wheel Damping

For small articulation angles, the resisting moment produced by the articulation angle controller is composed of a damping moment which is dependent on angular velocity and a moment which is dependent on the angular displacement. The influence of the damping moment on the directional behavior of the vehicle was studied by incorporating a linear viscous damper at the fifth wheel of the linear model. Results of the eigenvalue calculations for various levels of damping varying from 0 to 2000 in-lb-sec/deg are shown in Figure 10 for an empty vehicle traveling at 100 KPH.

The presence of the damping element increases the damping ratio of the trailer oscillation mode to a small extent. The presence of a viscous damper of 2000 in-lb-sec/deg merely increases the damping ratio from 0.305 to 0.377 (an increase of 23 percent), thereby suggesting that the damping moment produced by the controller is not powerful enough to radically increase the damping ratio of the trailer oscillation mode.



Figure C.9. Influence of shifting the c.g. of the trailer.

	CANADIAN	ARTICULATED BUS		
	<u>EMPTY</u>	<u>100 крн</u>		
	X DAI	HPIN4 = 0.0		
	0	= 500 in lb. sec/deg		
	•	= 1000 in lb.sc/deg		
	P	= 1500 in eb. see / deg		
	۵	= 2000 in lb sec/deg		
		Ag.0×F=0.305	- 3.0 M	,
		£= 0·377		•
			- 2.5 3	
			- 2.0 F	
			NARY	
			15 15 H	
			- 1:0	
			- 0.5	
- 3.	0 -2.5	4-2.0 -1.5 -1.0 -0.5]	
		REAL AXIS - 5Wn		

Figure C.10. Influence of fifth wheel damping.

APPENDIX D

SIMPLIFIED BRAKING ANALYSIS

The equations of "steady" motion for an articulated vehicle making a nearly constant deceleration stop are given in Equations (1) through (4) using the symbols illustrated in Figure D.1 and defined in Table D.1.

Tractor Plus	$A(W_1 + W_2) = F_{X_1} + F_{X_2} + F_{X_2}$	(1)
Irailer		
Acceleration	$W_{7} + W_{6} = F_{-} + F_{-} + F_{-}$	(2)

$$W_1 + W_2 = F_{z_1} + F_{z_2} + F_{z_3}$$
 (2)

(3)

Trailer: $0 = F_{x_3}h_f + F_{z_3}(a_2+b_2) - W_2a_2 + AW_2(h_2-h_f)$ Pitch Moments about the Fifth Wheel

Tractor:
$$0 = (F_{x_1} + F_{x_2})h_f + F_{z_2}(b_1 - b_f) + W_1b_f - F_{z_1}(a_1 + b_f)$$

Pitch Moments
about the
Fifth Wheel
$$-AW_1(h_f - h_1)$$
(4)

The following calculation procedure, employing Equations (1) through (4), was used to determine operating conditions that will result in wheel lock:

1. Select a treadle pressure (based on a reasonable guess).

2. Look up the brake torques, T_i , using Figure 2.4.

3. Calculate the longitudinal forces, F_{x_i} , at each axle, i.e.,

$$F_{x_i} = \frac{2T_i}{20''}$$
 where

20" ≈ tire rolling radius

2 = multiplying factor for 2 brakes on an axle.


Figure D.1. Illustration of symbols. (For the bus, $b_f > b_1$ and tandem axles are replaced by single axles.)

Table D.1. Definition of Symbols

А	Deceleration of the vehicle in g's
al	Front axle to c.g. of the tractor
^a 2	Fifth wheel to c.g. of the trailer
b ₁	c.g. of tractor to center of tractor rear suspension
^b 2	c.g. of trailer to center of trailer rear suspension
^b f	c.g. of tractor to fifth wheel
F _{x1}	Brake force produced by the front tires
F _{x2}	Brake force produced by the tires on the tractor rear suspension
F _{X3}	Brake force produced by the tires on the trailer suspension
F_{z_1}	Vertical load on the front tires
F _z	Vertical load on the tires on the tractor rear suspension
Fza	Vertical load on the tires on the trailer suspension
hı	Height of the tractor c.g.
h ₂	Height of the trailer c.g.
h _f	Height of the fifth wheel
W	Weight of the tractor
W ₂	Weight of the trailer

Note:

For the bus

"tractor" ≡ "leading unit" "trailer" ≡ "trailing unit"

- 4. Calculate deceleration, A, using Equation (1).
- 5. Compute vertical loads, F_{z_i} , at each axle. (Solve Equation (3) for F_{z_3} . Then solve (2) and (4) simultaneously for F_{z_2} and F_{z_1} .)
- 6. Compute friction utilizations, K_i , where $K_i = F_x / F_z$. (This assumes that the friction level is large enough to provide these utilizations.)
- 7. Choose μ slightly less than the largest K_i but greater than the other K_i values. The axle corresponding to the largest K_i is expected to lock up for this value of μ .

The results given in Section 2.5 are based on the above procedure using the parametric values listed in Table D.2.

 Table D.2

 Empty
 Full

 121.6
 122

al	121.6	122	inches
^a 2	181.7	167.9	11
b _l	113.4	113	
^b 2	21.7	35.5	II
^b f	191.7	191.3	н
h _l	39.4	53.5	н
h ₂	43.3	51.9	11
h _f	27.5	27.5	11
۳ ^۱	14,135	31,337	lbs
W ₂	18,205	29,007	п
[₩] 1 ^{+₩} 2	32,340	60,344	н