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DIESEL BUS PERFORMANCE SIMULATION PROGRAM

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16. Abstract

A diesel bus performance computer simulation program was developed. This program provides information on acceleration, velocity, horsepower, distance traveled, and fuel consumption as a function of time from the originating station. The program was written for diesel engine operation although heat engines other than diesel may be substituted. Fuel economy calculations, using the program, agree well with available measurements on urban buses and may be considered as representative of a baseline urban bus.

Component submodels and vehicle coefficients used in the program have been carefully structured to represent current urban buses.

This report includes a general description of the simulation program and the type of input data it required along with the results obtained by simulating a typical transit bus.

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PREFACE

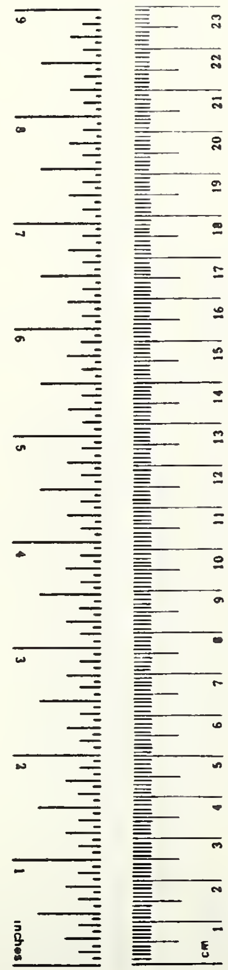
This report presents the technical basis of a diesel bus computer simulation program which was developed at the Transportation Systems Center for the Bus Technology Support Project, Urban Mass Transportation Administration, U.S. Department of Transportation. The computer program simulates the performance and predicts the fuel consumption of diesel-powered urban transit buses for any desired driving cycle. Driving cycles, presented for use in preliminary analyses, represent the upper and lower bounds of national urban bus driving cycles when considered from an energy point of view. The simulation program was developed for the study of the effect of various operating conditions and designs. The program listing is included.

Special mention should be made of the work of R. Hudson of Kentron International, Inc., who was responsible for programming the Diesel Bus Simulation Program.

METRIC CONVERSION FACTORS

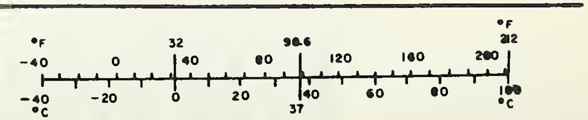
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

To develop propulsion systems for urban buses, it is important to have a bus simulation program which can be used for preliminary trade-off analyses. Since most urban buses are diesel powered, the Bus Simulation Program was written for diesel engine operation, although heat engines other than diesel may be substituted. This simulation may be considered representative of a baseline urban bus.

The modeling technique is similar to that described by N. Beachley and A. Frank[1]. Component submodels and vehicle coefficients have been carefully structured to represent current urban buses. Fuel economy calculations, using the program, agree well with all available urban diesel bus fuel consumption data.

This report is divided into two main sections, Section 2, which presents a description of the computer simulation model, and Section 3, which gives the information necessary to operate the program. A complete listing of the program is included in Section 3.2.

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[1]Beachley, N.H. and Frank, A.A., "Digital Automotive Propulsion Simulator Programs and Description," Vol. II, Department of Electrical and Computer Engineering, University of Wisconsin - Madison, Contract No. DOT-OS-30112, Dec. 1974.

2. DESCRIPTION OF THE COMPUTER SIMULATION MODEL

The Diesel Urban Bus Simulation Program is designed to assess the performance and fuel consumption of buses under various operating conditions and with various power drives. The program will give energy distribution within the power drive of any synthesized vehicle design over specified transient and steady-speed driving patterns.

2.1 DRIVING CYCLE DEVELOPMENT

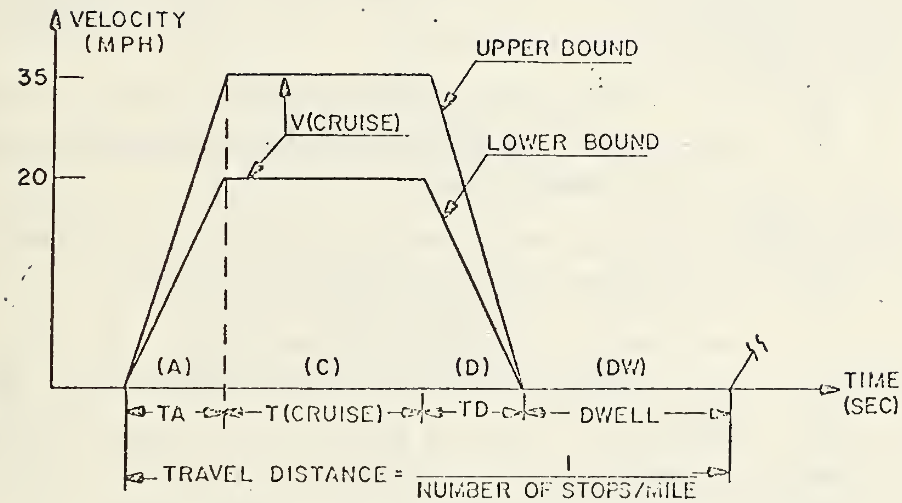
In order for the simulation model to provide useful comparisons of the various types of vehicle propulsion systems, it is necessary to use representative urban bus driving cycles. The cycles selected (see Figure 1) are based on the TRANSBUS and Small Bus specifications (References 2 and 3), work by Renner (Reference 4), and measurements made by TSC in the Boston area.

The simple drive cycles used in this analysis, assumed repetitive over any number of stops, are considered to represent the upper and lower bounds of urban bus driving cycles when considered from an energy point of view. During actual operation, buses are subjected to varying accelerations and cruising velocities within any one driving cycle and to varying numbers of stops per mile. However, in order to determine the performance behavior and the comparisons of different power drive subsystems, the use of simple repetitive drive cycles provides sufficient accuracy.

2.2 VEHICLE SIMULATION MODEL

To simulate the operation of a transit bus over a specified driving cycle for fuel consumption and emissions determinations, it is necessary to:

a) Determine the sequence of engine operating conditions for each moment during the driving cycle.



ITEM	NOMENCLATURE	UPPER BOUND	LOWER BOUND
(A)	ACCELERATION MODE (CONSTANT ACCELERATION)	3.5 mphps	2.0 mphps
(C)	CRUISE MODE (CONSTANT VELOCITY)	35 mph	20 mph
(D)	DECELERATION MODE (CONSTANT DECELERATION)	3.4 mphps	2.5 mphps
(DW)	DWELL TIME AT BUS STOP	20 seconds	10 seconds

FIGURE 1. URBAN TRANSIT BUS DRIVING CYCLE LIMITS

b) Determine from an engine map the instantaneous rate of fuel flow for each moment.

c) Integrate the instantaneous fuel flow and vehicle velocity versus time to obtain the total fuel consumed and total distance traveled.

d) Obtain fuel economy by dividing the total miles traveled by the total number of gallons of fuel consumed; similarly for vehicle emissions.

A generalized computational flow diagram which provides the basis for vehicle simulation is illustrated in Figure 2.

A typical urban bus was selected for modeling. It is a GMC model urban coach, equipped with an 8V-71' engine with N60 fuel injectors, coupled to a Detroit-Allison VH torque converter. The fully loaded vehicle weight, including passengers, driver, and miscellaneous weight is assumed to be 30,000 pounds. A weight breakdown is given in Table 1. Accessories mounted on the engine require up to 40 horsepower, which was subtracted from the total available output. The engine power and torque curves were provided by the Detroit Diesel Engine Division of GMC. Torque converter operating characteristics were provided by GMC's Detroit-Allison Division.

The computer program was developed to simulate all elements of the power drive subsystem for the transit bus operation over the selected driving cycle. The required power at the drive wheel was computed from drive cycle data, vehicle friction, aerodynamic drag, inertial acceleration, and rotational inertias. The corresponding power levels were computed throughout the power drive based on rotational speeds and torques, and component performance characteristics.

The basic computer simulation program is an adaptation of the University of Wisconsin computer program, described in Reference 1. Changes to the program included the subsystem component hardware characteristics and the specific governor-operation of the torque converter. The governor-operation schedule

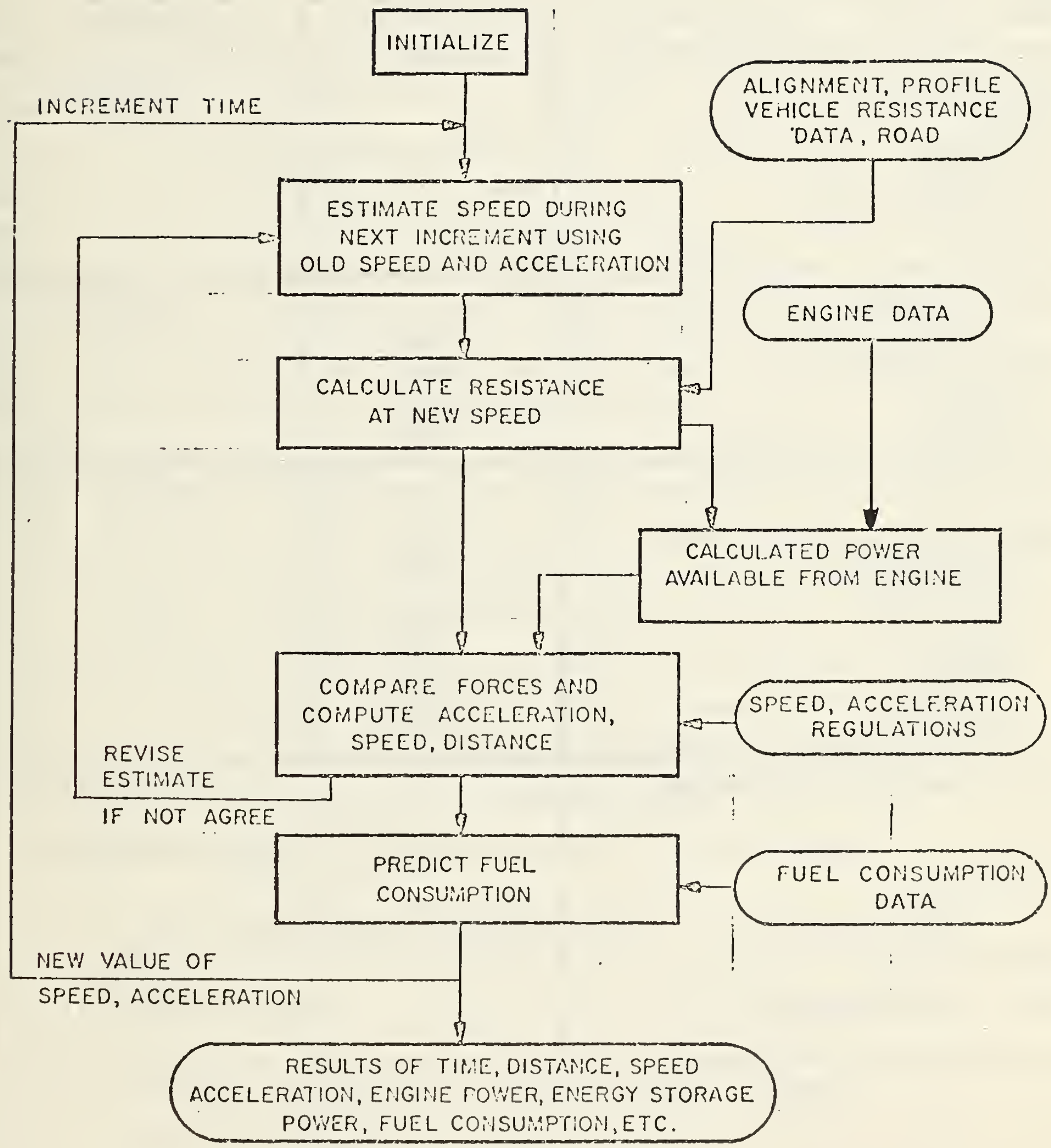


FIGURE 2. TRANSIT BUS VEHICLE COMPUTATIONAL FLOW MODEL

TABLE 1. TYPICAL TRANSIT BUS WEIGHT BREAKDOWN

ITEM	UNIT	SUB-TOTAL
Vehicle Body		10,000 lb
Shell		
Flooring		
Windows		
Interior Trim		
Seats		
Undercarriage		3,660 lb
Suspension	1040	
Wheels, Tires	1360	
Brakes	1120	
Steering	140	
Propulsion		4,215 lb
Rear Axle	1280	
Transmission	500	
Power Plant		
Engine	2000	
Radiator	100	
Exhaust	95	
Battery	95	
Fuel Tank	145	
Weight Empty, Curb Weight		18,275 lb
Payload		9,725 lb
Fuel,Oil		
Passengers, Crew		
Miscellaneous		2,000 lb
Gross Vehicle Weight		30,000 lb

relates the engine rpm with the vehicle velocity. The torque converter characteristics are illustrated in Table 2.

A simulation information flow diagram of the vehicle power model is illustrated in Figure 3. The nomenclature shown in the flow diagram is defined in the computer program discussion given in part II Section 3.2 of this report. Basic to the simulation model is the breakout of the vehicle mass. It can be shown that the kinetic energy of a moving body is made up of two components, one due to translation of the center of mass and one from rotation about the center of mass. A bus generally experiences only translation; however, an integral part of the vehicle, the power drive, consists of components which rotate as a function of the translational motion. Since the propulsion system must supply the power to produce the translational as well as the rotational energy, it is convenient to convert the kinetic energy of rotation to an equivalent kinetic energy of translation. This yields an equivalent mass (M_{EQ}) that must be added to the accelerated mass (M) of the vehicle. For preliminary calculations, an equivalent mass value of 10 percent can be used. However, in the computer the actual values of the equivalent mass are computed at every time interval.

The derivation of the equivalency is as follows:

$$\text{(KE) (EQUIVALENT) TRANSLATION} = \text{(KE) ROTATION}$$

$$\frac{1}{2}\,(MV^2)EQ = \frac{1}{2}\,I_R\,\omega_{WH}{}^2$$

$$(M_{EQ})\,(R_{WH}\omega_{WH})^2 = I_R\omega_{WH}{}^2$$

or

$$M_{EQ} = I_R/R_{WH}{}^2.$$

Where I_R is the sum of the inertias of rotating members referred to the drive wheel side, F_{WH} is the drive wheel radius, and ω is the rotational speed.

TABLE 2. TORQUE CONVERTER CHARACTERISTICS

SR SPEED RATIO	TQR TORQUE RATIO	$\frac{1}{K^2} \times 10^{-4}$
0.000	3.820	2.5690
0.100	3.430	2.3760
0.200	2.950	2.1400
0.300	2.430	1.8210
0.400	2.010	1.5230
0.500	1.650	1.3200
0.600	1.300	1.1210
0.610	1.260	1.1000
0.620	1.230	1.0780
0.630	1.190	1.0500
0.640	1.150	1.0300
0.650	1.120	1.0150
0.660	1.080	0.9900
0.670	1.040	0.9750
0.680	1.010	0.9500
0.690	0.970	0.9200
0.700	0.930	0.8838
0.710	0.900	0.8300
0.720	0.860	0.7800
0.730	0.820	0.7600

SR = SPEED RATIO = $\frac{\text{OUTPUT SPEED}}{\text{INPUT SPEED}}$

TQR = TORQUE AMPLIFICATION RATIO = $\frac{\text{OUTPUT TORQUE}}{\text{INPUT TORQUE}}$

$\frac{1}{K^2}$ defined as the reciprocal of the input capacity factor, is given by:

$$\frac{1}{K^2} = \frac{\text{INPUT TORQUE}}{(\text{INPUT SPEED})^2}$$

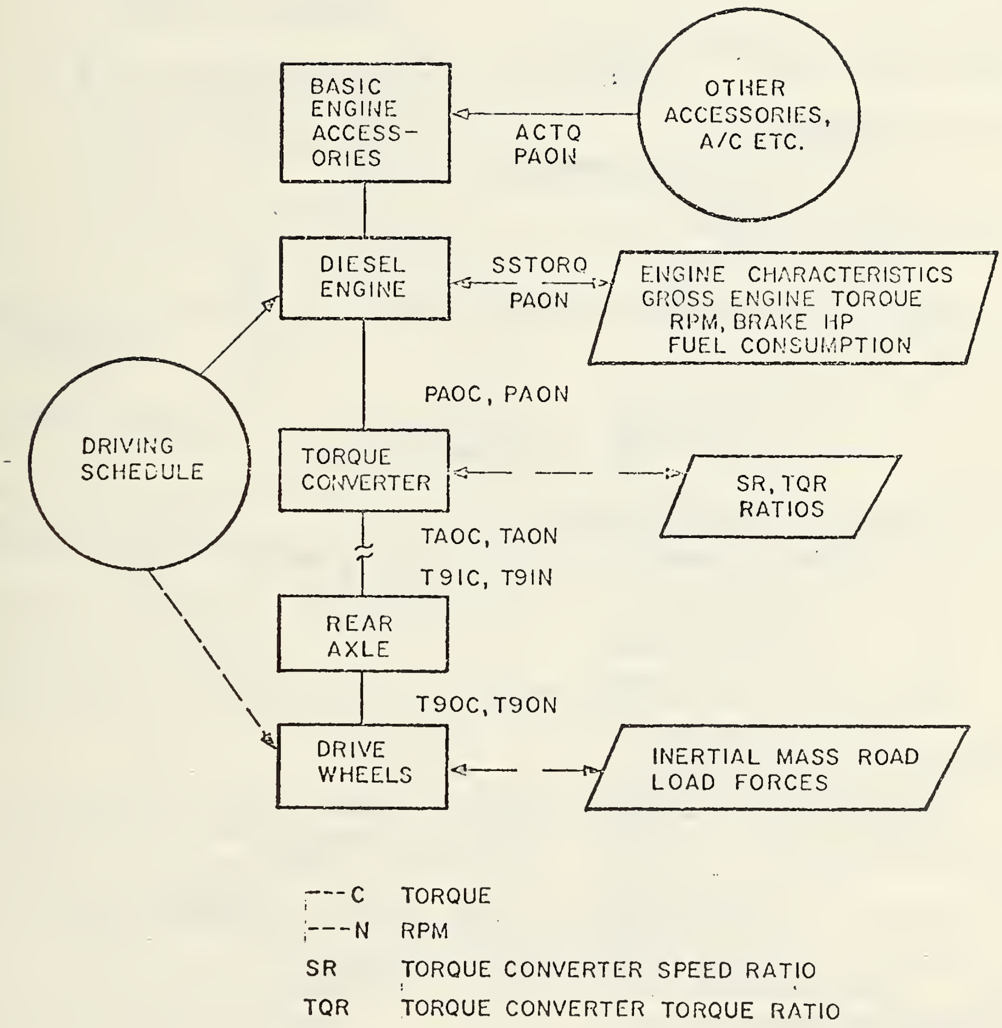


FIGURE 3. INFORMATION FLOW IN VEHICLE POWER DRIVE MODEL

2.3 POWER DRIVE COMPONENTS CHARACTERIZATION

The mechanical component arrangement shown in Figure 4 consists of:

Drive Wheel Speed of Rotation

Rotational speed (T9ON) of drive wheels in terms of vehicle velocity (mph):

$T9ON = [(5280/60)/(2\pi R_{WH})]V$

Drive Wheel Torque:

$T90C = F_T \cdot R_{WH}$,

where R_{WH} = drive wheel rolling radius in feet

F_T = road load

= inertial load + aerodynamic load + road resistance load.

Drive Shaft Speed and Torque

Drive shaft speed = T91N = (RAR) (T90N)

Drive shaft torque = T91C = T90C/(RAR) (η_{RA}),

where RAR = rear axle ratio

η_{RA} = rear axle efficiency.

Input to Transmission

Shaft speed = TA0N = (TRGR) (T91N)

Shaft torque - TA0C = T91C/(TRGR) (η_{TR}),

where TRGR is the transmission gear ratio (variable) and TR ηTR the transmission efficiency,

Torque Converter

Input speed = PA0N = (SR) (TA0N)

Input torque = PA0C = (TQR) (TA0C)

where SR is the torque converter speed ratio and TQR is the torque ratio,

The torque PA0C is referred to the engine flywheel, which is the energy storage device. The flywheel absorbs transients in the engine rotational speeds as the velocity of the bus varies throughout the driving cycle.

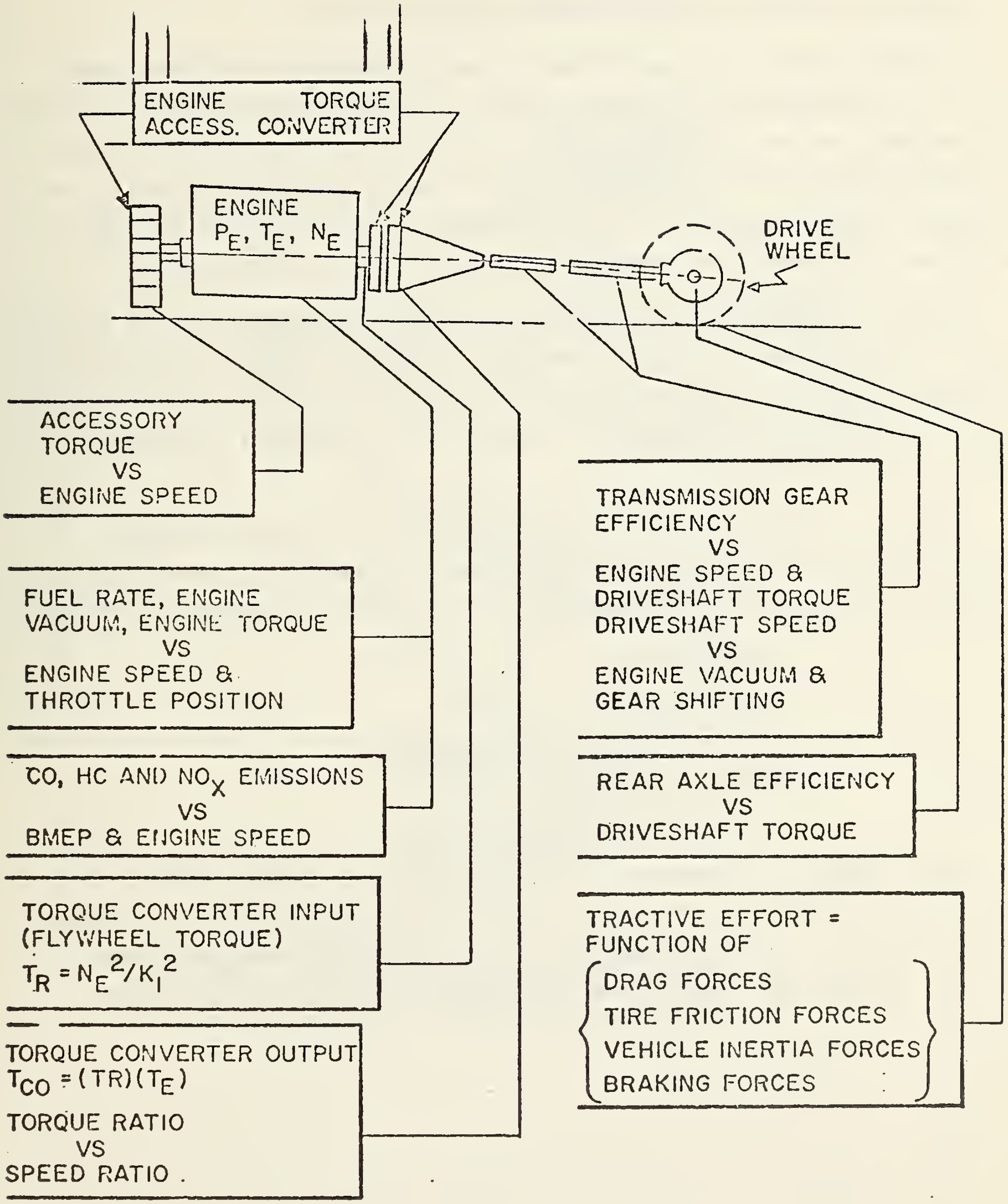


FIGURE 4. MOTOR VEHICLE POWER DRIVE SYSTEM

2.4 DIESEL URBAN BUS PERFORMANCE CALCULATIONS

A large number of performance calculations have been made using the simulation program. They correlate well when compared with actual urban bus data. Only in a few cases, however, are the data sufficiently characterized to make highly accurate comparisons. Well-measured bus performance and fuel consumption data over accurately determined driving cycles are needed.

Figure 5 shows the variation of fuel consumption with variation in the number of stops per mile for the lower bound driving cycle of Figure 1. Included in this figure are data points from high-confidence measurements, taken from equivalent driving cycles.

Figure 6 gives a plot of data obtained in fuel economy tests of a Flexible (ROHR) Transit Bus, driven on a test track, following Driving Cycle B (Reference 6) which is characterized by:

acceleration - 3.0 mph/sec
cruise speed - 30 mph
deceleration - 3.4 mph/sec
dwell time - 16 sec

Also shown in Figure 6 is a set of fuel economy points calculated by the Diesel Urban Bus Simulation Program for the same driving cycle. The correlation of the calculated values with the test values is considered to be quite good, within a few percent.

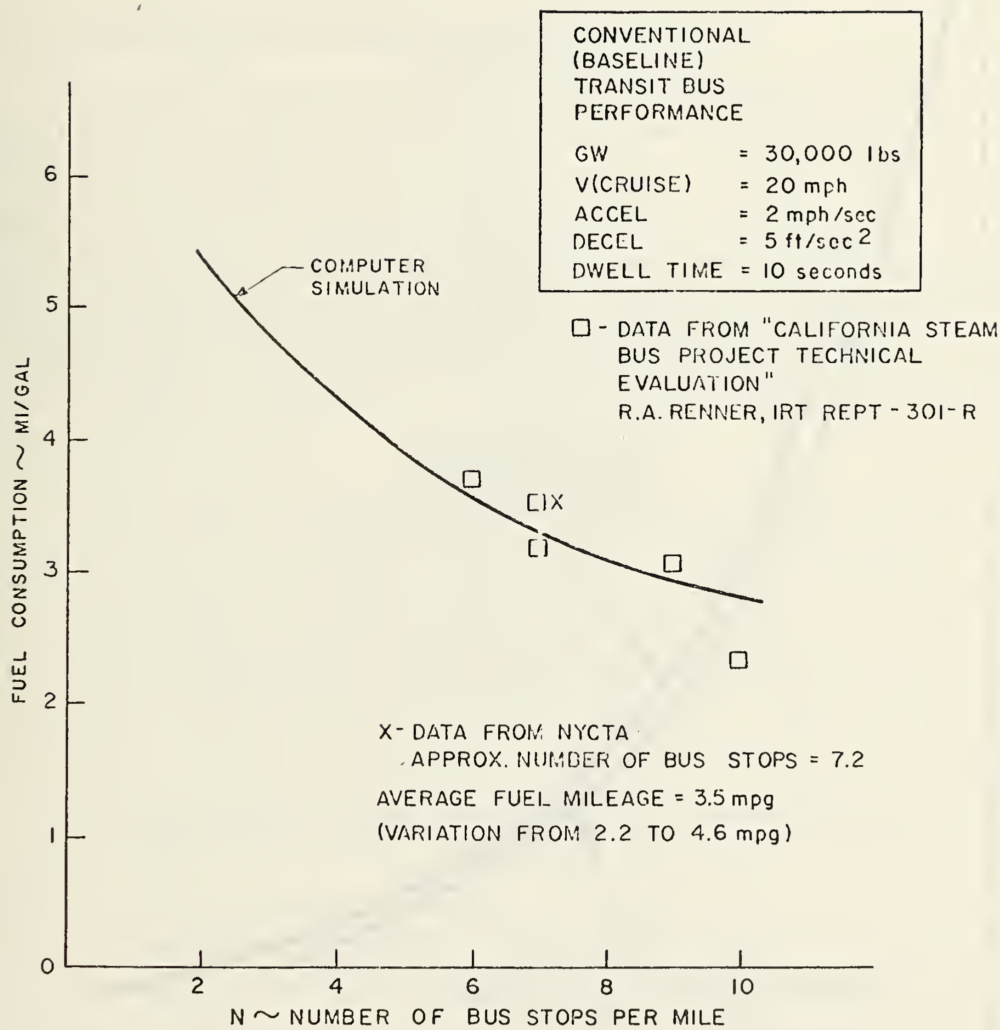


FIGURE 5. TRANSIT BUS PERFORMANCE

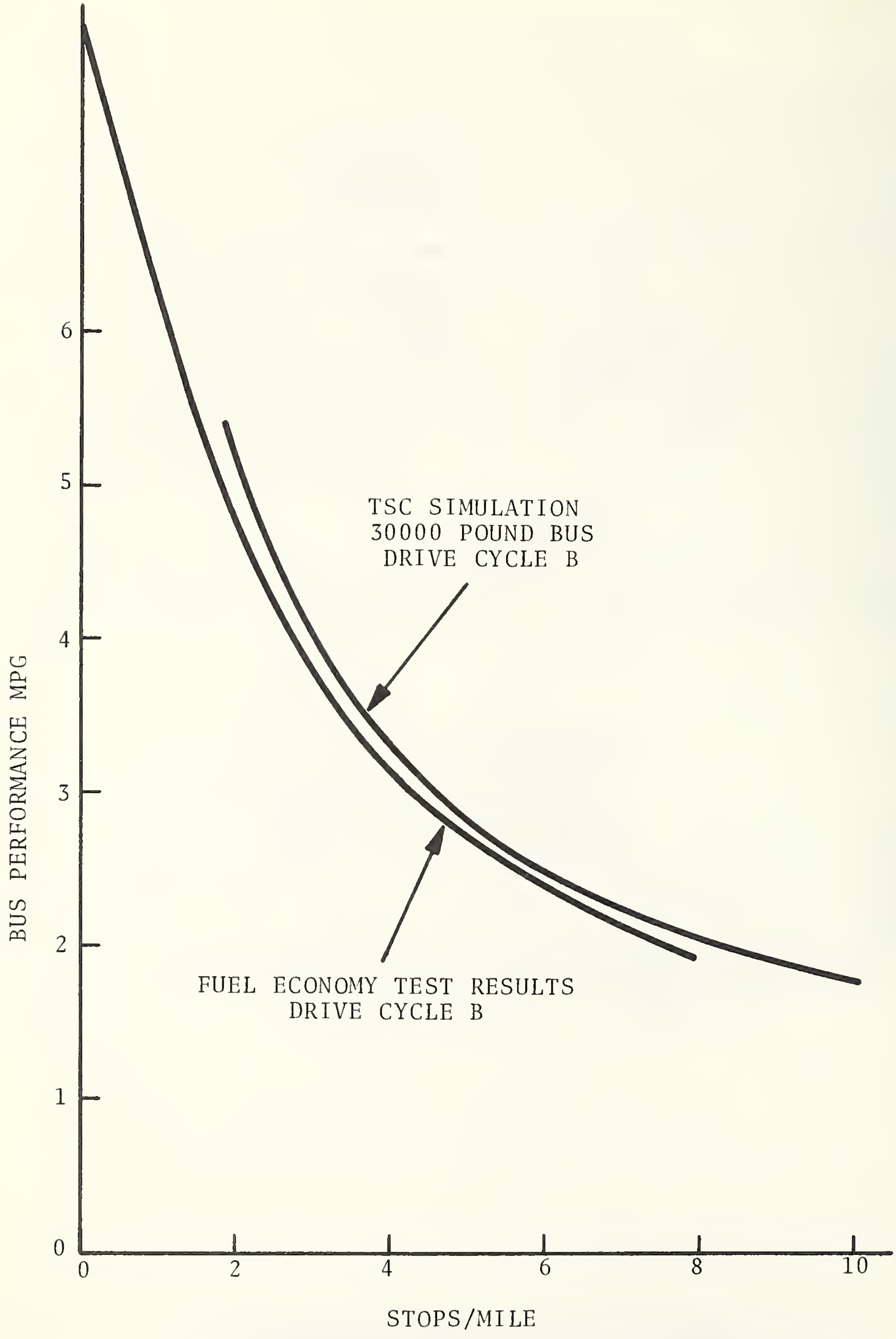


FIGURE 6. FLEXIBLE 870 BUS PERFORMANCE TEST RESULTS - DRIVING CYCLE B

3. MODEL OPERATION

3.1 DESCRIPTION OF COMPUTER SIMULATION MODEL

The diesel bus performance simulation model predicts the performance of vehicles with various power plants over any desired set of segments of a driving cycle. Each driving cycle segment has a specified length and grade, a dwell time or vehicle idling time (to simulate passenger loading and unloading), and a desired vehicle cruise speed. Actual vehicle performance is determined by solving Newton's equations of motion at regular time intervals subject to the constraints of engine and vehicle characteristics.

Output data include torque and horsepower, at the engine and at the tires' interfaces with the road; velocity and acceleration during each time period; engine speed; and fuel consumption. These data can be plotted as well as printed, permitting quick cross-comparisons among variables. Characteristics of the power plant and drive train are modeled in a series of subroutines; fuel consumption rate is calculated in another subroutine.

The simulation program receives input data, transmits output data, and initializes appropriate variables at the beginning of each driving cycle segment. It also includes all routing logic for determining whether the vehicle should be accelerating, decelerating, or cruising. A vehicle dynamics subroutine contains an integration algorithm to solve the equations of motion. A subroutine is provided to calculate fuel consumption when the vehicle is moving, and when it is stationary. A print subroutine handles output printing, and a plot subroutine handles output plotting using the standard software provided by CalComp.

An input subroutine specifies the subject vehicle, driving cycle configuration, and route terrain profile. The inputs are vehicle data, engine performance data, power drive characteristics, acceleration, cruising speed, deceleration, vehicle idle time at bus stops, number of bus stops per mile, grade profile along route, head or tail winds, and adhesion characteristics between tires and road.

Calculations are performed to generate the following components of force acting on the vehicle:

a) aerodynamic drag,

b) gravity,

c) wheel drag, and

d) vehicle thrust.

The method used to calculate these factors depends upon the operational mode (acceleration, cruise, or deceleration) and the gear number in which the vehicle is presently operating. Thrust is constrained by the limits of tire-ground adhesion.

The model is written in the FORTRAN IV language and has been run. A model 663 CalComp plotter and associated software provide the graphic output. Since the model accumulates performance data from all driving cycle segments as they are computed, and prints and plots them at the end of a run; storage requirements are a function of the number of segments handled in a run.

In the program all dynamic variables are local or passed as parameters between the various subroutines. All the constants and tables are placed in labeled common files and accessed from there.

Following is a glossary of terms, constants, variables, tables, and arrays used in the program.

3.1.1 Glossary of Symbols

SYMBOL	NAME	DESCRIPTION
FIG. 3	ACLOAD(10)	ACCESSORY LOAD AS A FUNCTION OF ENGINE SPEED
T_A	ACTORQ	ACCESSORY LOAD
	ATORGS(60)	ENG TORS RECORDED SINCE LAST GENERAL OUTPUT
	AVIB	AIR PRESSURE (PSI)
P	AVIM	AIR DENSITY (LB/FT**3)

SYMBOL	NAME	DESCRIPTION
	AVIR	AIR TEMPERATURE (°F)
ϕ	AVIO	GRADE ANGLE (RAD)
V_W	AVIS	WIND SPEED (MPH)
T_{CI}	BAOC	CONVERTER INPUT TORQUE
N_{CI}	BAON	CONVERTER INPUT SPEED (RPM)
B_S	BS	BRAKE SETTING
FC	BSFC	BRAKE SPECIFIC FUEL CONSUMPTION
	COMM(26)	COMMENT CARDS FOR HEADING TITLES
ΔT	DELTA	INTEGRATION TIME STEP (SEC)
Δt	DELT	LEAD TIME FOR NEXT CYCLE VELOCITY IN AUTO DRIVER
	DT	TIME OF ONE CLOCK PULSE
	EPS	USED TO TEST FOR CONSTANT ENGINE SPEED
N_E	ESDOT	ENGINE ACCELERATION (RPM/SEC)
	ESDOTO	PREVIOUS VALUE OF ENGINE ACCELERATION
	ESPEED(60)	ENG SPDS RECORDED SINCE PREVIOUS GENERAL OUTPUT
	FTIME(60)	TIMES AT WHICH ESPEED AND ATORGS ARE SAVED
FW	FUELWT	WEIGHT OF ONE GALLON OF FUEL
TFC	FUELE	CUMULATIVE FUEL CONSUMED (LBS)
	GR1	RATIO OF FIRST GEAR
	HRPSEC	HOURS PER SECOND
	LBC1GI(10)	INDEX FOR ASSIGNING GEAR EFFICIENCY CALCULATIONS
T_P	1 CLOCK	CUMULATIVE NUMBER OF CLOCK PULSES
	1CLOKO	TIME AT PREVIOUS OUTPUT OF VARIABLES
T_{PO}	ICLOK1	ICLOCK AT COMPLETION OF LAST INTEGRATION
	ICYCLE	NUMBER OF TIMES THE PROGRAM HAS ITERATED
	ICYEND	END OF DRIVING CYCLE INDICATOR
	IGEAR	GEAR SHIFT INDICATOR
	INDIC	OUTPUT INDICATOR

SYMBOL	NAME	DESCRIPTION
	IOUT	NUMBER OF CLOCK PULSES ALLOWED BETWEEN OUTPUTS
	IPAOF(18,20)	FUEL CONSUMP AS FUNCTION OF ENG SPD AND LINE NO
	IPDX(20,20)	JOINT PROBABILITY DENSITY DISTRIBUTION
	ISHIFT	ICLOCK AT START OF LAST SHIFT
	ISPEED(20)	INT STORAGE FOR PRINTOUT OF SPD FOR JNT PROS DEN
	ITICYC	ICLOCK AT START OF DRIVING CYCLE
	IVEPA(685)	AUTO DRIVING CYCLE VELOCITIES AT 1 SEC INTERVALS
	LOADEQ	ROAD LOAD CALCULATION CONTROL
	LOCK	INDICATES IF CONVERTER IS LOCKED UP
	MAP1(55,17)	STEADY STATE ENG TRQ AS FUNCT OF THROTTLE AND ENG SPD
	MAP3(17,17)	FUEL RATE AS A FUNCTION OF ENGINE SPEED AND ENGINE TORQUE
	MAXLIN	MAXIMUM NUMBER OF LINES SPECIFIED PER PAGE
	NDIM(2)	NUMBER OF VARIABLES USED IN JOINT PROB DENSITY
	NFUEL	NUMBER OF ELEMENTS IN FUEL ARRAY
	NGEAR	NUMBER OF TRANSMISSION GEAR RATIOS
	NG1	CURRENT GEAR NUMBER
	NG1OLD	GEAR AT PREVIOUS ITERATION
	NGT(2)	NUMBER OF SAMPLES WHICH EXCEED VMAX(1 AND 2)
	NLINE	NUMBER OF LINES ON CURRENT PAGE
	NLT(2)	NUMBER OF SAMPLES LESS THAN VMIN (1 AND 2)
	NREC	OUTPUT RECORD NUMBER
	NRUN	RUN NUMBER
	NVEPA	NUMBER OF VELOCITIES SPECIFIED IN DRIVING CYCLE
	NVOLT(15)	VOLTAGES FOR DACS AND ADCS
HP	OBHP	OBSERVED BRAKE HORSEPOWER
T_E	PAOC	ENGINE SHAFT TORQUE (ALSO REFERRED TO AS FLYWHEEL TRQ)

SYMBOL	NAME	DESCRIPTION
	PAOFR	FUEL CONSUMPTION RATE (LB/HR)
	PAOFRO	PREVIOUS VALUE OF PAOFR
N_E	PAON	ENGINE SPEED (RMP)
J_E	RIE	ENGINE INERTIA (LBM FT SQD)
	RIEINV	INVERSE OF ENGINE INERTIA
	SCALEF	ENGINE SIZE SCALE FACTOR
T_{SS}	SSTORQ	STEADY STATE ENGINE TORQUE
SR	TA11SR	SPEED RATIO
$1/K_I^2$	TAI3IK	INVERSE SQUARE OF SIZE FACTOR
K_I	TAI3KI	SIZE FACTOR
TR	TAOiTR	CONVERTER TORQUE RATIO
T_{CO}	TAOC	CONVERTER OUTPUT TORQUE
N_{CO}	TAON	CONVERTER OUTPUT SPEED
	TBC1G1(10,4)	POLYNOMIAL COEFFICIENTS FOR CAL- CULATING GEAR EFFIEICNEY
	TBC1GR(10)	GEAR RATIOS
	TBDTH	MINIMUM TIME ALLOWED BETWEEN SHIFTS
	TBDTMS	LENGTH OF TIME FOR SHIFTING
η_{TR}	TB01EF	TRANSMISSION EFFICIENCY
GI	TB01GI	TRANSMISSION GEAR INDEX
GR_{TR}	TB01GR	TRANSMISSION GEAR RATIO
	TCEFF	TORQUE CONVERTER EFFICIENCY
	TIDLE	THROTTLE IDLE SETTING
T	TIME	TIME FROM START OF DRIVING CYCLE (SEC)
	TIMAVG(5)	TIMER AVERAGES
	TIMLEN(5)	TIMER LENGTHS
	TIMMAX(5)	TIMER MAXIMUMS
	TMAS	MAXIMUM ENGINE TORQUE
	TORQ	RATIO OF STEADY STATE TORQUE TO MAXIMUM TORQUE
T_S	TS	THROTTLE SETTING

SYMBOL	NAME	DESCRIPTION
J_{CT}	TVIJCT	MOMENT OF INERTIA OF TORQUE CONVERTER TURBINE
J_{RA}	TVIJRA	MOMENT OF INERTIA OF REAR AXLE GEARS
J_{TR}	TVIJTR	MOMENT OF INERTIA OF TRANSMISSION GEARS
J_{TW}	TVIJTW	MOMENT OF INERTIA OF TIRES AND WHEELS
	TVICRL(16)	ROAD LOAD TORQUE AT DRIVESHAFT
J	TV1MJ	TOTAL MOMENT OF INERTIA OF DRIVETRAIN
N_{DS_U}	T8DN	UNCORRECTED DRIVE SHAFT SPEED
GR_{RA}	T811GR	NOMINAL REAR AXLE RATIO
	T8INV(11)	DRIVESHAFT SPEED AS A FUNCTION OF VEHICLE SPEED
GR_{RA}	T911GR	EFFECTIVE REAR AXLE RATIO
T_{DS}	T9IC	DRIVESHAFT TORQUE
N_{DS}	T9IN	DRIVESHAFT SPEED
T_{RA}	T90C	REAR AXLE TORQUE
	T9I1	REAR AXLE EFFICIENCY
η_{RA}	VAL(2)	VALUES OF VARIABLES FOR CALL TO PRBDEN
	VAR(10)	EXTRA SPACE FOR VARIABLES
V_i	VEPA	NEXT DRIVING CYCLE VELOCITY
	VINT(2)	INTERVAL SIZE FOR JOINT PROBABILITY DENSITY
	VMAX(2) PROBABILITY DEN	MAXIMUM VALUES FOR JOINT PROBABILITY DENSITY
	VMIN(2)	MINIMUM VALUES FOR JOINT PROBABILITY DENSITY
F_D	VVDF	SUM OF DRAG FORCES AND FRICTION (LBF)
	VVDMI	EQUIVALENT MASS OF VEHICLE (SLUGS)
C_D	VVI1CD	DRAG COEFFICIENT
C_F	VVI1CF	TIRE COULOMB FRICTION COEFFICIENT
μ	VVI1RF	ROLLING FRICTION COEFFICIENT

SYMBOL	NAME	DESCRIPTION
K_B	VVI2BR	BRAKE CONSTANT (USUALLY STATIC WEIGHT OF VEHICLE)
A_{MAX}	VVIAMX	MAX. ACCEL. (G'S) BASED ON MAX COEFF OF TIRE FRICTION
A_{MAXS}	VVIAS	MAX ACCEL. (G'S) BASED ON SLIDING COEFF OF TIRE FRICTION
R_T	VVIDRR	TIRE RADIUS
f_M	VVIFUM	MAXIMUM COEFFICIENT OF TIRE FRICTION
f_s	VVIFUS	SLIDING COEFFICIENT OF TIRE FRICTION
A_F	VVILFR	FRONTAL AREA (SQ FR)
M	VVIM	VEHICLE MASS (LBM)
M_{DR}	VVIMDR	MASS ON DRIVE SHEELS
M_I	VVIMI	INERTIAL MASS OF VEHICLE
H	VVISH	HEIGHT OF VEHICLE CENTER OF GRAVITY (IN)
WB	VVISWS	WHEEL BASE (IN)
A	VVOA	VEHICLE ACCELERATION (FT/SEC/SEC)
	VVOAO	PREVIOUS VALUE OF VVOA
D	VVOD	VEHICLE DISTANCE TRAVELED (MILES)
V	VVOS	VEHICLE SPEED (MPH)
	VVOSO	PREVIOUS VALUE OF VVOS
	WHLOLD	PREVIOUS VALUE OF WHEEL SLIP INDICATOR
	WHLSLP	WHEEL SLIP INDICATOR
	X(225)	DUMMY ARRAY FOR TAPE OR DISK OUTPUT

3.1.2 Glossary of Constants

CONSTANT	MEANING
AVIB	AIR PRESSURE (psi)
AVIM	AIR DENSITY (LB/FT773)
AVIR	AIR TEMPERATURE (F)
DT	TIME OF ONE CLOCK PULSE
EPS	USED TO TEST FOR CONSTANT ENGINE SPEED
FUELWT	WEIGHT OF ONE GALLON OF FUEL
FR1	RATIO OF FIRST GEAR
HRPSEC	HOURS PER SECOND
IOUT	NUMBER OF CLOCK PULSES ALLOWED BETWEEN OUTPUTS
IPRNT	PRINT CONTROL
LOADEQ	ROAD LOAD CALCULATION CONTROL
MAXLIN	MAXIMUM NUMBER OF LINES SPECIFIED PER PAGE
NGEAR	NUMBER OF TRANSMISSION GEAR RATIOS
NVEPA	NUMBER OF VELOCITIES SPECIFIED IN DRIVING CYCLE
RIE	ENGINE INERTIA (LBM-FT 2)
RIEINV	INVERSE OF ENGINE INERTIA
SCALEF	ENGINE SIZE SCALE FACTOR
T8I1GR	NOMINAL REAR AXLE RATIO
TBDTH	MINIMUM TIME ALLOWED BETWEEN SHIFTS
TBDTMS	LENGTH OF TIME FOR SHIFTING
TIDLE	THROTTLE IDLE SETTING
TMAX	MAXIMUM ENGINE TORQUE
TVIJCT	MOMENT OF INERTIA OF TORQUE CONVERTER TURBINE
TVIJRA	MOMENT OF INERTIA OF REAR AXLE GEARS
TVIJTR	MOMENT OF INERTIA OF TRANSMISSION GEARS
TVIJTW	MOMENT OF INERTIA OF TIRES AND WHEELS
VACMAX	MAXIMUM MANIFOLD VACUUM (IN OF HG)
VVI1CD	DRAG COEFFICIENT
VVI1CF	TIRE COULOMB FRICTION COEFFICIENT
VVI1RF	ROLLING FRICTION COEFFICIENT
VVI2BR	BRAKE CONSTANT (USUALLY STATIC WEIGHT OF VEHICLE)
VVIAMX	MAX ACCEL (G'S) BASED ON MAX COEFF OF TIRE FRICTION
VVIAS	MAX ACCEL (G'S) BASED ON SLIDING COEFF OF TIRE FRICTION

CONSTANT	MEANING
VVIDRR	TIRE RADIUS
VVIFUM	MAXIMUM COEFFICIENT OF TIRE FRICTION
VVIFUS	SLIDING COEFFICIENT OF TIRE FRICTION
VVILFR	FRONTAL AREA (SQ FT)
VVIM	VEHICLE MASS (LBM)
VVIMDR	MASS ON DRIVE WHEELS
VVISH	HEIGHT OF VEHICLE CENTER OF GRAVITY (IN)
VVISWB	WHEEL BASE (IN)

3.1.3 Glossary of Dynamic Variables

VARIABLE	MEANING
ACTORQ	ACCESSORY LOAD
AVIO	GRADE ANGLE (RAD)
AVIS	WIND SPEED (MPH)
BS	BRAKE SETTING
DELT	LEAD TIME FOR NEXT CYCLE VELOCITY IN AUTO DRIVER
DELTA	INTEGRATION TIME STEP (SEC)
EMISE	EMISSIONS (NOT USED)
EMISF	EMISSION RATE (NOT USED)
ESDOT	ENGINE ACCELERATION (RPM/SEC)
ESDOTO	PREVIOUS VALUE OF ENGINE ACCELERATION
FUELE	CUMULATIVE FUEL CONSUMED (LBS)
ICLOCK	CUMULATIVE NUMBER OF CLOCK PULSES
ICLOKO	TIME AT PREVIOUS OUTPUT OF VARIABLES
ICLOK1	ICLOCK AT COMPLETION OF LAST INTEGRATION
ICYCLE	NUMBER OF TIMES THE PROGRAM HAS ITERATED
ICYEND	END OF DRIVING CYCLE INDICATOR
IGEAR	GEAR SHIFT INDICATOR
IGO	GO SWITCH INDICATOR
INDIC	OUTPUT INDICATOR
ISHIFT	1CLOCK AT START OF LAST SHIFT
ITICYC	ICLOCK AT START OF DRIVING CYCLE
NGI	CURRENT GEAR NUMBER
NLINE	NUMBER OF LINES ON CURRENT PAGE

VARIABLE	MEANING
NFUEL	NUMBER OF ELEMENTS IN FUEL ARRAY
NGIOLD	GEAR AT PREVIOUS ITERATION
NREC	OUTPUT RECORD NUMBER
NRUN	RUN NUMBER
OBHP	OBSERVED BRAKE HORSEPOWER
PAOC	ENGINE SHAFT TORQUE (ALSO REFERRED TO AS FLYWHEEL TRQ)
PAOFT	FUEL CONSUMPTION RATE (LB/HR)
PAOFRO	PREVIOUS VALUE OF PAOFT
PAON	ENGINE SPEED (RMP)
PPOB	ENGINE VACUUM (IN. OF HG.)
SSTORQ	STEADY STATE TORQUE
T8DN	UNCORRECTED DRIVE SHAFT SPEED
T9I1GR	EFFECTIVE REAR AXLE RATIO
T9IC	DRIVESHAFT TORQUE
T9IN	DRIVESHAFT SPEED
T9OC	REAR AXLE TORQUE
T9ON	DRIVESHAFT SPEED
TAI1SR	SPEED RATIO
TAI3IK	INVERSE SQUARE OF SIZE FACTOR
TAI3KI	SIZE FACTOR
TAO1TR	CONVERTER TORQUE RATIO
TAOC	CONVERTER OUTPUT TORQUE
TAON	CONVERTER OUTPUT SPEED
TBO1EF	TRANSMISSION EFFICIENTY
TBO1GI	TRANSMISSION GEAR INDEX
TBO1GR	TRANSMISSION GEAR RATIO
TIME	TIME FROM START OF DRIVING CYCLE (SEC)
TORQ	RATIO OF STEADY STATE TORQUE TO MAXIMUM TORQUE
TS	THROTTLE SETTLE
TVIMJ	TOTAL MOMENT OF INERTIA OF DRIVETRAIN
VEPA	NEXT DRIVING CYCLE VELOCITY
VVDF	SUM OF DRAG FORCES AND FRICTION (LBF)
VVDMI	EQUIVALENT MASS OF VEHICLE (SLUGS)
VVOA	VEHICLE ACCELERATION (FT/SEC/SEC)

VARIABLE	MEANING
VVOAO	PREVIOUS VALUE OF VVOA
VVOD	VEHICLE DISTANCE TRAVELED (MILES)
VVOS	VEHICLE SPEED (MPH)
VVOSO	PREVIOUS VALUE OF VVOS
WHLOLD	PREVIOUS VALUE OF WHEEL SLIP INDICATOR
WHLSLP	WHEEL SLIP INDICATOR

3.1.4 Glossary of Logic Variables

INISAT	0 - INITIALIZATION OF ENGINE SPEED COMPLETE. CAR IN NEUTRAL.
	1 - ENGINE BEING INITIALIZED. CAR IN NEUTRAL.
IREADY	0 - ENGINE NOT IN STEADY STATE.
	1 - GO LIGHT TURNED ON.

3.1.5 Glossary of Tables

TABLE	MEANING
ACLOAD(10)	ACCESSORY LOAD AS A FUNCTION OF ENGINE SPEED
COMM(26)	COMMENT CARDS FOR HEADING TITLES
IBC1GI(10)	INDEX FOR ASSIGNING GEAR EFFICIENCY CALCULATIONS
IVEPA(685)	AUTO DRIVING CYCLE VELOCITIES AT 1 SEC INTERVALS
MAP1(10,17)	STEADY STATE TORQUE AS A FUNCTION OF THROTTLE AND ENGINE SPD
MAP3	FUEL CONSUMPTION AS A FUNCTION OF TORQUE AND ENGINE SPEED
NDIM(2)	NUMBER OF VARIABLES USED IN JOINT PROB DENSITY
T8INV(11)	DRIVE SHAFT SPEED AS A FUNCTION OF VEHICLE SPEED
TAI3KP(20)	SIZE FACTOR AS A FUNCTION OF SPEED RATIO (NOT USED)
TBC1GI910,4)	POLYNOMIAL COEFFICIENTS FOR CALCULATING GEAR EFFICIENCY
TBC1GR(10)	GEAR RATIOS
TV1CRL(16)	ROAD LOAD TORQUE AT DRIVESHAFT
VINT(2)	INTERVAL SIZE FOR JOINT PROBABILITY DENSITY
VMAX(2)	MAXIMUM VALUES FOR JOINT PROBABILITY DENSITY
VMIN(2)	MINIMUM VALUES FOR JOINT PROBABILITY DENSITY

3.1.6 Glossary of Arrays

ARRAY	MEANING
ATORQS(60)	ENG TRQS RECORDED SINCE LAST GENERAL OUTPUT
ESPEED(60)	ENG SPDS RECORDED SINCE PREVIOUS GENERAL OUTPUT
FTIME(60)	TIMES AT WHICH ESPEED AND ATORQS ARE SAVED
IPDX(20,20)	JOINT PROBABILITY DENSITY DISTRIBUTION
ISPEED(20)	INT STORAGE FOR PRINTOUT OF SPD FOR JNT PROB DEN
NGT(2)	NUMBER OF SAMPLES WHICH EXCEEDED VMAX(1 AND 2)
NLT(2)	NUMBER OF SAMPLES LESS THAN VMIN (1 AND 2)
NVOLT(15)	VOLTAGES FOR DACS AND ADCS
TIMAVG(5)	TIMER AVERAGES
TIMLEN(5)	TIMER LENGTHS
TIMMAX(5)	TIMER MAXIMUMS
VAL(2)	VALUES OF VARIABLES FOR CALL TO JPBDEN
VAR(10)	EXTRA SPACE FOR VARIABLES
X(225)	DUMMY ARRAY FOR TAPE OR DISK OUTPUT
AWAY(20,3)	SPEED RATIO, TORQUE RATIO AND INVERSE SIZE FACTOR FOR TORQUE CONVERTER

3.2 BUS SIMULATION PROGRAM LISTING

The bus simulation program, Simula, is listed below.

```
BUS SIMULATION PROGRAM                                                     DA
 *                                  **** SIMULA ****
        SUBROUTINE SIMULA
 C****  BUS MODIFICATIONS DONE BY RICHARD HUDSON
        COMMON /ENGIN/SCALEF,TIDLE,EVS,TS
        DIMENSION NLT(2),NGT(2)
        COMMON /LOCK1/ ACCLOCK,DECLOCK
        COMMON /LOCK2/ ACCRUIS
        DIMENSION MAP1(55,17),MAP3(17,17)
        COMMON /MAPS/ MAP1,MAP3
        COMMON /PRNT/ IOUT,IPRNT,LOADEQ,MAXLIN
        COMMON /STEADY/ EPS
        COMMON /TIMEI/ DT
        DIMENSION IPDY(20,20)
        COMMON IPDX
        COMMON     TEST(3),FTIME(60),ESPEED(60),ATORQS(60)
        COMMON     DRGHP(140),RAYHP(140)
        COMMON     XOBHP(140),ACCHP(140),FLYHP(140),CONHP(140)
        COMMON     TIMMAX(5),TIMLEN(5),TIMAVG(5),VAR(2)
        COMMON     XTAOC(140),XTOIC(140),XT90C(140),GEAR(140)
        COMMON     XTIME(140),XSSTOR(140),XPAOC(140),XACTOR(140)
 C      PLACED IN COMMON FOR STORAGE REASONS
        INTEGER UDNSET
        NRUN=0
 C----  INITIALIZE ALL CONSTANTS AND TABLES
 *
 *
        CALL INICON
 C----  OUTPUT CONSTANTS ON TAPE
 C----ENGINE MAPS
        CALL MAPER
      5 CONTINUE
        NRUN=NRUN+1
        N=1
 C----  CHANGE INITIALIZED CONSTANTS FOR NEW RUN
        CALL AGNCON
 C----  READ IN DRIVING CYCLE
        CALL RDEPA
        CALL OUTCON
 C-----  OUTPUT CONSTANT TO THE LINE PRINTER
        CALL PRTCON
 C----  INITIALIZE VARIABLES
        CALL INIVAR (SFORCE,LOCK,UDNSET,TIME,ICLOCK,ICLOK1
       C ,ISHIFT,NREC,SS,TB01GR,TB01GI,NGI,NGIOLD,ICYEND,VV0A,VANALG,
       C  HPWHLM,HPRAXM,HPTRANM,HPTCCM,HPENGM,HPWHLP,HPRAXP,HPTRANP,
       C  HPTCCP,HPENGP,HPACC,
       C  ACTORQ,PAOC,SFORCEM,PIDLE,
       C TAO1TR,TAI1SR,BAOC,
       C TIMMAX,TIMLEN,TIMAVG,PAON,BAON,SSTORQ,TAON,ESDOTO,VAR)
        INDIC=0
        ICYEND=0
        INISWT=1
        IREADY=0
        IGO=1
```

```
      TEST(IGS)=0
      TEST(3)=0
      NFUEL=0
      ISMAX=20
      ISAVE=ISMAX+1
   10 CONTINUE
C---- BOOK KEEPING ROUTINES FOR POWER
      CALL      POWER(PAOC,PAON,TAON,TAOC,T9IN,T9IC,T90N,T90C,ACTORQ
     C   ,SSTORQ,VVDA,BFORCE,BFORCEM,
     C HPWHLM,HPRAXM,HPTRANM,HPTQCM,HPENGM
     C    ,HPWHLP,HPRAXP,HPTRANP,HPTQCP,HPENGP,HPACC)
C---- UPDATE SYSTEM CLOCK
      ICLOCK=ICLOCK+1
      TIME=ICLOCK*DT
C*****THIS IS THE TEST FOR SEEING IF THE TORQUE CONVERTER IS LOCKED UP
C***** LOCK\ 1 MEANS THE TC IS EITHER LOCKED LOCKING OR UNLOCKING
C***** ACCLOCK  IS THE SPEED AT WHICH YOU LOCK THE TC
C***** IF THE ENGINE IS AT WIDE OPEN THROTTLE,
C***** ACCRUIS IS THE SPEED TO LOCK UP IF NOT AT WIDE OPEN THROTTLE
       IF (LOCK .GT. 0 .OR. VVOS .GT. ACCLOCK .OR.
     C  (TMAX.GT. SSTORQ+1. .AND.VVOS .GT. ACCRUIS       ))
     CCALL  LOCKUP(VVOS,TIME,LOCK,TAI1SR,TA01TR)
C---- CALL TO ACESS AND TRQCONV IN ENGTRQ
C---- ENGINE AND TORQUE CONVERTER
      CALL ENGTRQ(TA01TR,T9I1,T801EF,T801GR,T9I1GR,
     C SSTORQ,ACTORQ,VVDF,VVDJ,VVOS,PAON,TAI1SR,PAOC,ICLOCK,
     C ICLOK1,TAON,BAON,ESO3T,BAOC,TAOC,LOCK  )
      IF(TEST(3))15,20,20
   15 CONTINUE
C---- AUTOMATIC DRIVER
      CALL       EPAVEL (TIME,VEPA,ICYEND,DELT)
      CALL AUTSDR (VVOS,T9I1,T801EF,T801GR,T9I1GR,TA01TR,VVDJ,
     C VVDMI,TAI1SR,ACTORQ,PAON,DELT,VVDF,SSTORQ,BS,BFORCE,TIME,VEPA,
     C TMAX)
      GO TO 25
   20 CONTINUE
C---- THROTTLE SETTING
      CALL RIXON2(PAON,TS,TORQ,MAP1)
      SSTORQ=TORQ*SCALEF
   25 CONTINUE
C---- HORSEPOWER
      OSHP=SSTORQ*PAON/5252
C---- CALCULATE FUEL CONSUMPTION
      CALL RIXON22(PAON,SSTORQ,PAOFR,MAP3)
C---- DURING INITIALIZATION SKIP OTHER CALCULATIONS
      IF(INISWT)30,30,60
   30 CONTINUE
      ISAVE=ISAVE+1
      IF(ISAVE-ISMAX)50,35,35
   35 ISAVE=0
      NFUEL=NFUEL+1
      IF(NFUEL-60)45,45,40
   40 NFUEL=60
```

```
   45 CONTINUE
      FTIME(NFUEL)=ICLOCK*DT
      ATORQS(NFUEL)=SSTORQ
      ESPEED(NFUEL)=PAON
   50 CONTINUE
C---- TIRE GROWTH SUBROUTINE
      CALL TG9I5(VV0S,T9IN,T9I1GR)
C---- GEAR SHIFT SUBROUTINE
      CALL GRSHFT(T881GR,ICLOCK,ISHIFT,T9IN,TMAX,UDNSFT,
     C  SSTORQ,T881GI,TAON)
C---- TRANSMISSION EFFICIENCY
      CALL TREFF(TA9C,T881GR,T881EF,T881GI,T9IN,T9IC)
C---- REAR AXLE EFFICIENCY
      CALL        RAEFF(T9IC,T9IN,T9I1GR,T99C,T9I1)
C---- VEHICLE DYNAMICS
      CALL  VEDYN( T881GI,VV0S,BS,T99C,T881GR,T9I1GR,VV0A
     C ,VVDF,T9I1,VVDFBR,VVDMI,DELTAT,VV0AO,
     C IVIMJ)
C---- JOINT PROBABILITY DISTRIBUTION
      CALL PROBEN (SSTORQ,PAON,NLT,NGT,IPOX)
      ICYCLE=ICYCLE+1
C---- INTEGRATION SUBROUTINE
      CALL INTGRT(ICLOCK,ICLOK1,NTIMEP,VV0S,
     C VV0A,VV0AO,VV0SO,PAOFR,VV0D,FUELE,PAOFRO)
C---- CHECK FOR END OF DRIVING CYCLE
      NTIME=ICLOCK
      NTIMEP=NTIME-ICLOKO
      IF(ICYEND-1)55,90,90
C---- CHECK FOR OUTPUTS
   55 IF(NTIMEP-IOUT)10,85,85
   60 CONTINUE
C---- RESET INTEGRATION TIME COUNTER DURING INITIALIZATION
      ICLOK1=ICLOCK
C---- INITIALIZATION SECTION
      IF(IREADY)65,65,75
   65 CONTINUE
C---- ENGINE IN STEADY STATE
      RATE=ABS(ESDOT)
      IF(RATE-EPS)70,70,10
   70 CONTINUE
      IREADY=1
      TEST(109)=-1.
      GO TO 10
   75 CONTINUE
      IF(TEST(109))80,10,10
   80 CONTINUE
      INISAT=0
      TEST(3)=-1.
      CALL INICER(PAON,SSTORQ,PAOFR,INDIC,ICLOCK,TIME
     C ,ICLOK1,T881EF,T9IN,T8DN,T99N,T9I1GR,VV0S,VV0A,VV0D
     C ,FUELE,EMISF,EMISE,ITICYC,ISHIFT,IGEAR,WHLOLD,
     CVVDMI,DELTAT,T9IC,T9I1,LOCK,
     C NTIME,ICYCLE,NGIOLD,NGI,T881GR,T881GI,PAOFRO,VV0AO
```

```
      C ,VV0S0,ISEG,IPDX,TIMMAX,TIMAVG,TIMLEN,NLT,NGT,VFPA,
      C GG,T90C,VVDF,VVDFER,TVIMJ,TA0C,
      C ICL0KO)
   85 CONTINUE
C---- OUTPUT SECTION
C***** DUE TO SPACE LIMITATIONS ONLY THE FIRST 140 CYCLES  ARE RECORDED
       CALL OUTVAR
       INDIC=1
       CALL OUTPUT (NLINE,PAGFR,0BHP,VV0S,FUELE,
      C  VVGA,TIME,VVMA,PA0N,SST0RQ,TAI1SR,TA01TR,TB01EF,
      C T9I1,TB01GI,TA0N,TA0C,PA0C,VV0D)
       NFUEL=0
       ISAVE=ISMAX+1
       ICL0K0=ICL0CK
       IF (N .GT. 140) GOTO 110
       XTIME(N)=TIME
       XSSTOR(N)=SST0RQ
       XACTOR(N)=ACT0RQ
       XPA0C(N)=PA0C
       XTA0C(N)=TA0C
       XT9IC(N)=T9IC
       XT90C(N)=T90C
       GEAR(N)=TB01GI
       X0BHP(N)=SST0RQ*PA0N/5252
       ACCHP(N)=ACT0RQ*PA0N/5252
       FLYHP(N)=PA0C*PA0N/5252
       C0NHP(N)=(TA0C*PA0N/5252)*TAI1SR
       DRSHP(N)=((T9IC*PA0N/5252)*(1.0/TB01GR))*TAI1SR
       RAXHP(N)=((T90C*PA0N/5252)*(1.0/T9I1GR))*TAI1SR*(1.0/TB01GR)
       N=N+1
  110 CONTINUE
       G0 T0 10
   90 CONTINUE
C---- TERMINATION SECTION
       CALL OUTVAR
       END FILE 16
       CALL OUTPUT (NLINE,PAGFR,0BHP,VV0S,FUELE,
      C  VV0A,TIME,VVMA,PA0N,SST0RQ,TAI1SR,TA01TR,TB01EF,
      C T9I1,TB01GI,TA0N,TA0C,PA0C,VV0D)
       CALL J0PSUM(IPDX,ICYCLE,NLT,NGT,VV0D,FUELE,HPWHLP,
      C HPWHLM,HPRAXP,HPRAXM,HPTRANP,HPTRANM,HPTGCP,
      C HPTGCM,HPENGP,HPENGM,HPACC,TIME,
      C XTIME,XSSTOR,XPA0C,XACTOR,XTA0C,XT9IC,XT90C,GEAR
      C ,X0BHP,ACCHP,FLYHP,C0NHP,DRSHP,RAXHP)
       READ 95,IST0P
   95 FORMAT (I2)
       IF(IST0P)100,100,96
   96 CONTINUE
       G0 T0 5
  100 CONTINUE
       PAUSE
       RETURN
       END
```

3.3 PROGRAM SUBROUTINES

The overall program consists of the mainline program and the subroutines which are listed below and described in the following pages.

The relationship of the subroutines to the mainline program is clearly shown in Figure 7, the mainline program flow chart. Program subroutines are described in the following subsections.

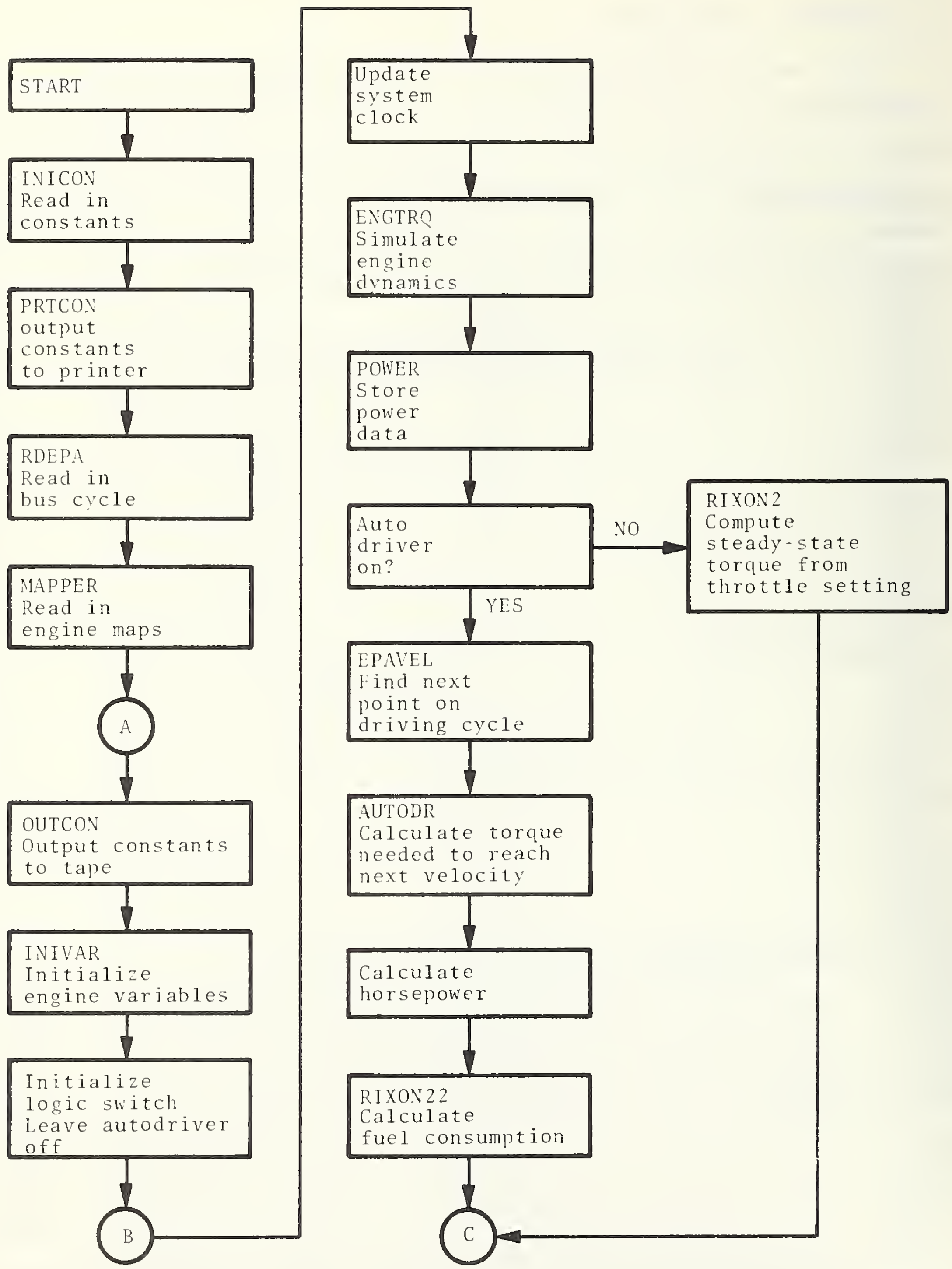


FIGURE 7. FLOW DIAGRAM FOR SIMULA

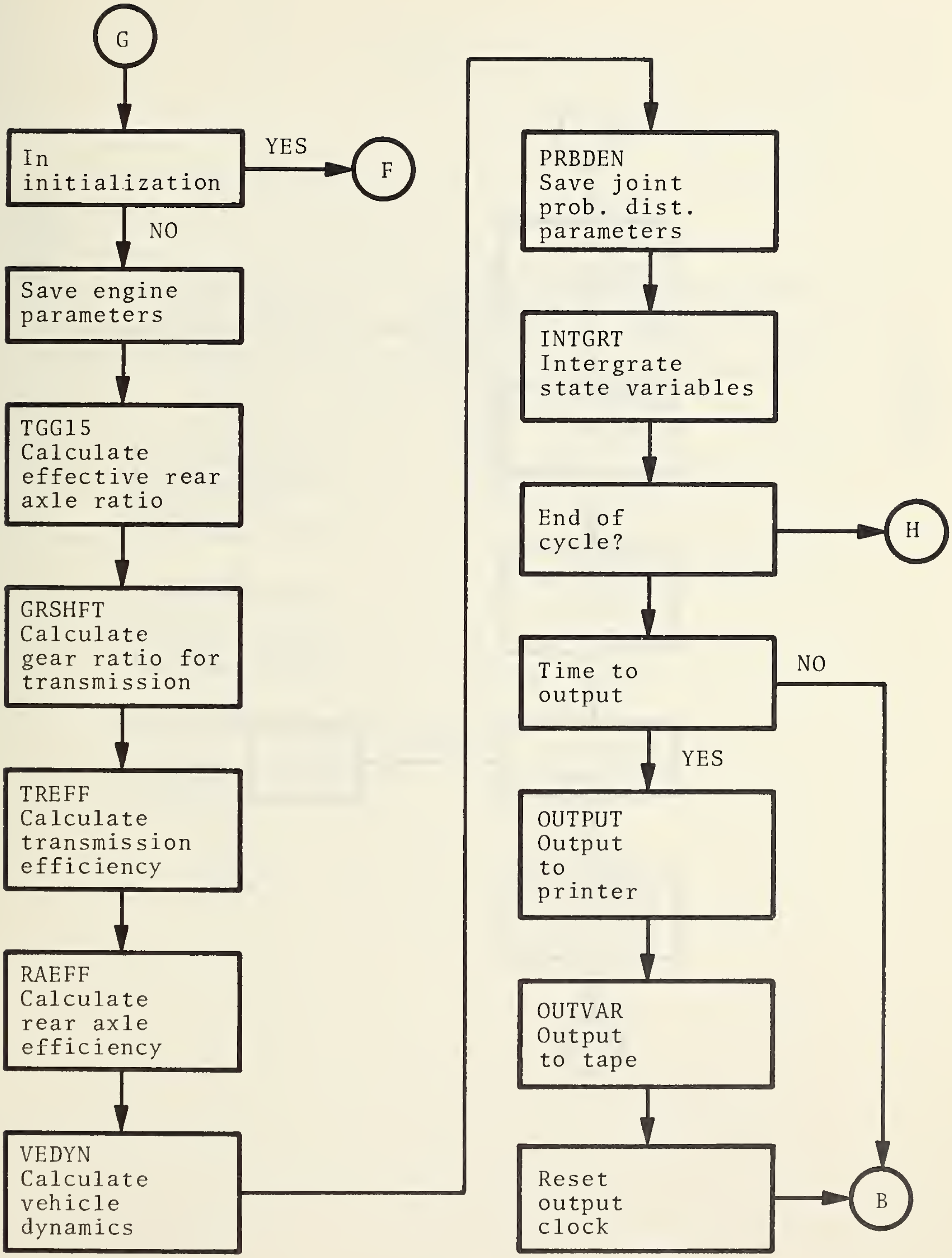


FIGURE 7. FLOW DIAGRAM FOR SIMULA (CONT'D)

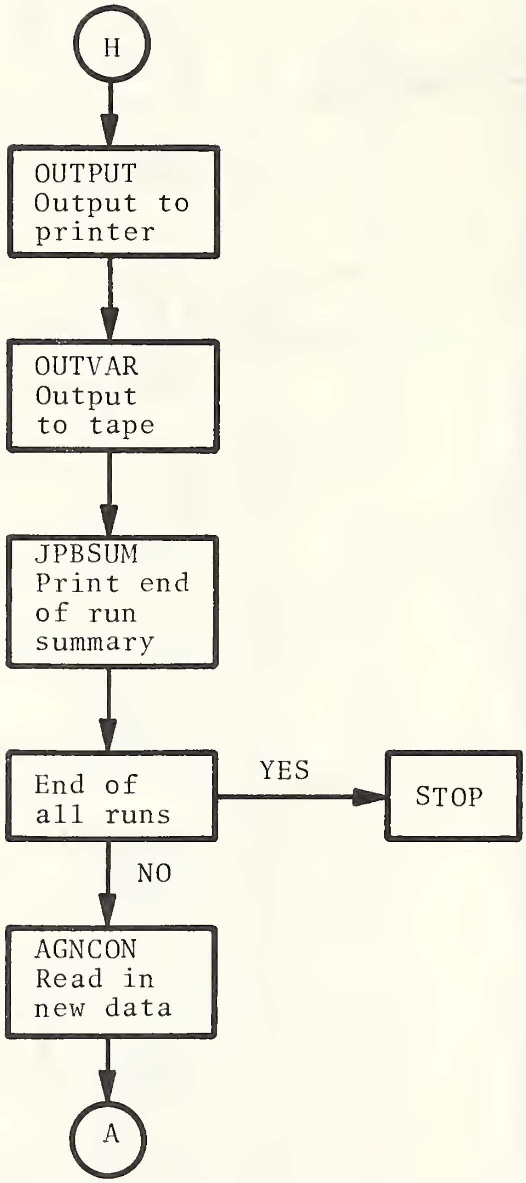


FIGURE 7. FLOW DIAGRAM FOR SIMULA (CONT'D)

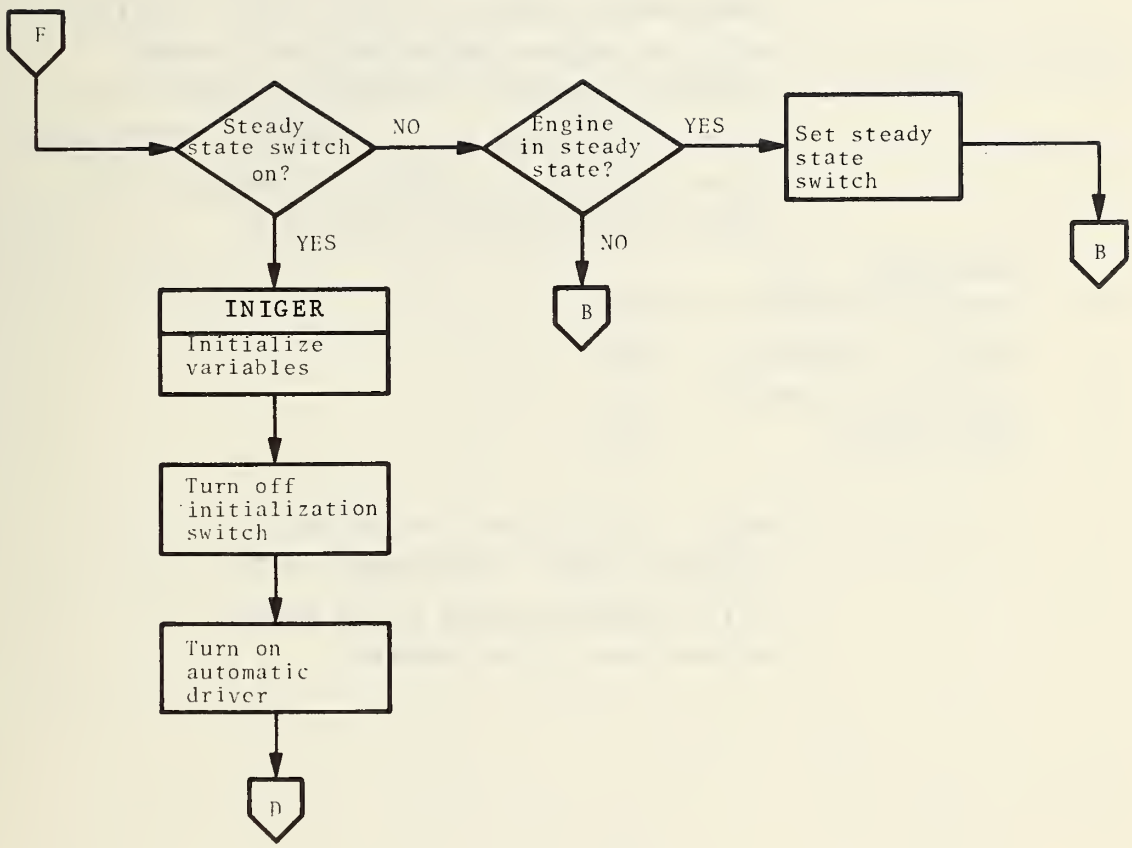


FIGURE 7. FLOW DIAGRAM FOR SIMULA (CONT'D)

3.3.1 Subroutine to Read Data - AGNCON

SUBROUTINE NAME: AGNCON

TYPE OF SUBROUTINE: Input

DESCRIPTION: This subroutine will be used when it is necessary to make a set of runs in which only one or two parameters are varied. AGNCON is written to read in those parameters which are being changed. The cards to be read in by AGNCON are added to the back of the standard data deck.

EQUATION: N/A

INPUT VARIABLES: N/A

OUTPUT VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: N/A

NOTE: No listing for AGNCON IS provided here. Statements will vary depending upon which parameters are to be changed.

```
*                                    **** AGNCON ****
      SUBROUTINE AGNCON
C***** THIS SUBROUTINE IS USED TO CHANGE THE BUS OR CYCLE CHARACTE
C***** WITHOUT HAVING TO REINITIALIZE THE ENTIRE SYSTEM
   10 CONTINUE
      RETURN
      END
```

3.3.2 Accessory Load Subroutine - ACCESS

SUBROUTINE NAME: ACCESS

TYPE OF SUBROUTINE: System computation

DESCRIPTION: This subroutine calculates accessory load in foot-pounds given the engine speed in revolutions per minute (RPM's).

MODELING: The accessory loads are stored at 200 RPM intervals. Figure 8 illustrates a typical accessory load curve from which the points are taken. Linear interpolation is used for non-node points.

EQUATION: $T_A = g_4 \ (N_E)$

INPUT VARIABLES: PAON - Engine speed

OUTPUT VARIABLES: ACTORQ - Accessory torque loss

OTHER VARIABLES: ACLOAD(10) - Accessory load table

PIDLMIN - Minimum engine speed table good for

PIDLMAX - Maximum engine speed table good for

PROGRAM VARIABLES: I - Low index

II - High index

FLOW CHART: N/A

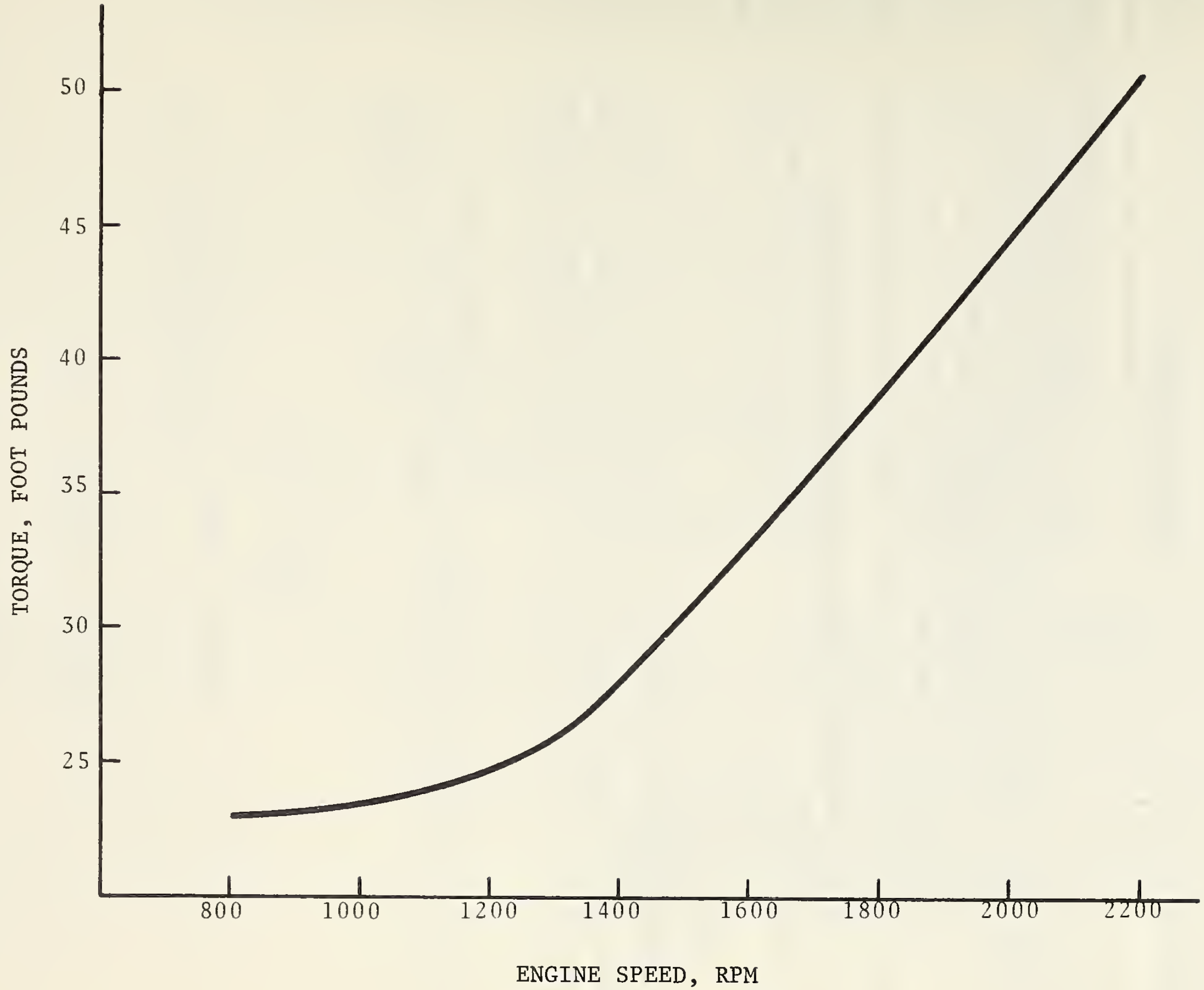


FIGURE 8. ACCESSORY TORQUE AS A FUNCTION OF ENGINE SPEED

```
*                                      **** ACCESS ****
       SUBRØUTINE ACCESS(PAØN,ACTØRQ)
C----- CØMPUTE ACCESSØRY LØAD
C***** THIS SUBRØUTINE DETERMINES THE ACCESSØRY LØAD THAT IS USED BY THE
C***** BUS FØR A GIVEN ENGINE SPEED.  A LINEAR INTERPØLATIØN METHØD IS U
C***** PIDLMIN AND PIDLMAX ARE THE BØUNDS ØF THE ARRAY AKCESS
C***** WHICH HØLDS THE ACCESSØRIES IN 200 RPM INCREMENTS
C-----RICK HUDSØN 9/21/76 FØR THE BUS
       CØMMØN /AKCESS/ ACLØAD(10),PIDLMIN,PIDLMAX
       IF (PAØN .LT. PIDLMIN) GØTØ 10
       IF (PAØN .GT. PIDLMAX) GØTØ 20
       I=PAØN/200-3
       II=I+1
       REM=PAØN-(I+3.)*200.
       ACTØRQ=ACLØAD(I) + REM*(ACLØAD(II)-ACLØAD(I))/200.
       GØTØ 999
    10 CØNTINUE
       ACTØRQ=ACLØAD(1)
       GØTØ 999
    20 CØNTINUE
       ACTØRQ=ACLØAD(10)
   999 CØNTINUE
       RETURN
       END
```

3.3.3 Automatic Driver - AUTODR

PROGRAM NAME: AUTODR

TYPE OF SUBROUTINE: System computation

DESCRIPTION: This subroutine specifies the steady state torque required to follow a given velocity profile.

MODELING:

This subroutine is the controller for a closed loop feedback control system in which the vehicle velocity is the controlled variable (see Figure 9]. The "error" is the difference between the actual vehicle velocity and the velocity specified at the next cycle point. The automatic driver determines the engine torque required to overcome accessory load, friction and acceleration forces to reach the next cycle velocity.

Subroutine EPAVEL supplies the automatic driver (AUTODR) with the velocity required at the next specified point in time and the time difference between that time and the current time. The cycle velocities are specified at one second interfals.

The automatic driver calculates the acceleration required to reach the next cycle point within the time difference,

$$A_R = \frac{V_i - V}{\Delta t}$$

The steady state torque required of the engine to provide this acceleration is

$$T_{SS} = \frac{A_R M_I + R}{K} + T_A$$

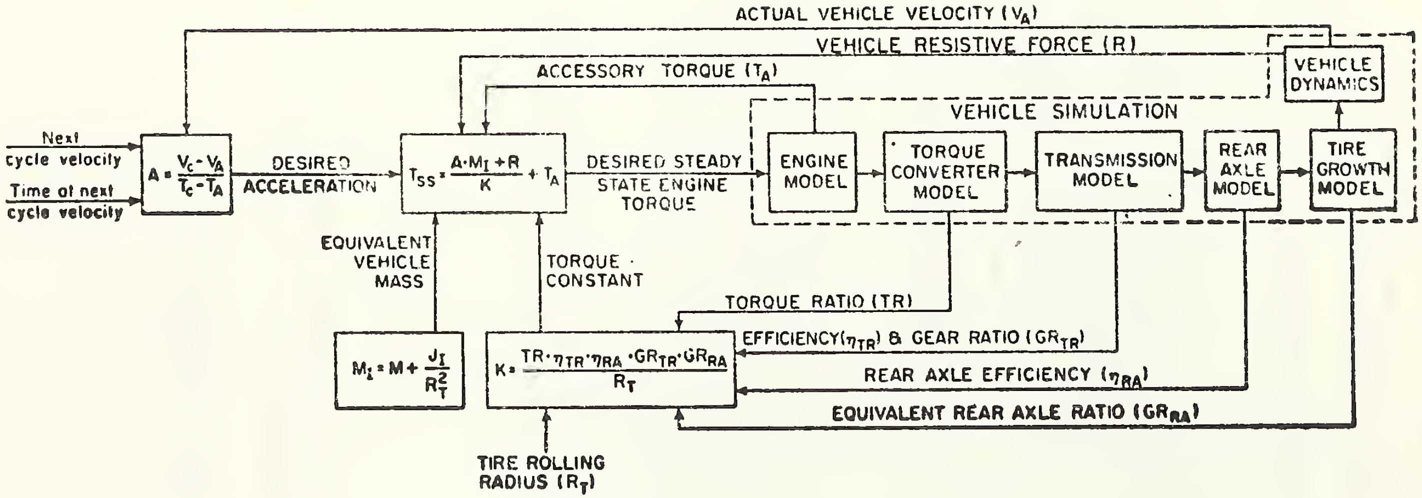


FIGURE 9. AUTOMATIC DRIVER ALGORITHM

K is the torque multiplication factor from the engine to the rear wheels. Its value is determined by using the gear ratios and efficiencies calculated in the previous iteration (see Figure 4). K will become zero at zero driveshaft torque because the driveshaft and rear axle efficiencies are zero. This means very large engine torques would be required as K approaches zero. To prevent this, a minimum transmission and rear axle efficiency of 0.8 is assumed when calculating K. A similar problem exists if Δt approaches zero in the acceleration calculation. To prevent this EPAVEL supplies the next required velocity when Δt becomes less than .1 second .

To prevent the engine from attempting to overcome the vehicle rolling resistance at idle, the resistive force of the vehicle is set to 0 when there is no vehicle speed.

The subroutine also ensures that the limits of the engine are not exceeded. It determines the maximum engine torque and the minimum engine torque possible by checking the wide open and closed throttle torques of the engine at the given speed. It supplies only the maximum engine torque if the maximum torque is exceeded, or calculates the required braking force when the minimum engine torque is not enough to slow the vehicle as rapidly as required.

EQUATIONS:

1) $$A_R = \frac{V_i - V}{\Delta t} \qquad \text{where: } \Delta t \geq 0.1$$

2) $$K = \frac{TR \cdot \eta_{RA} \cdot \eta_{TR} \cdot GR_{RA} \cdot GR_{TR} \cdot GR_{BG}}{R_T}$$

$$\text{where: } \eta_{RA} \geq 0.8$$
$$\eta_{TR} \geq 0.8$$

3) $$M_I = (M_I)_V + J_E \cdot \frac{SR \cdot GR_{RA} \cdot GR_{TR} \cdot GR_{BG}{}^2}{RT}$$

where: $(M_I)_V$ is the inertial mass of the vehicle as calculated in the vehicle dynamics subroutine (VEDYN). It does not include the rotary inertia of the engine.

4) $$T_{SS} = \frac{A_R \cdot M_I + R}{K} + T_A$$

5) $$F_B = \frac{(T_{SS})_{min} - (T_{SS})_{required}}{K}$$

INPUT VARIABLES:

Variable Name	Symbol	Description
VEPA	V_i	Required cycle velocities
VVOS	V	Vehicle velocity
DELT	Δt	Time difference between next cycle point and current time
T9I1	η_{RA}	Rear axle gear efficiency
TB01EF	η_{TR}	Transmission gear efficiency
TB01GR	GR_{TR}	Transmission gear ratio
T9I1GR	GR_{RA}	Equivalent rear axle gear ratio
BGRT10	GR_{BG}	Bevel Gear Ratio
TAON	N_{CO}	Converter output speed
PAON	N_E	Engine speed
LOCK		Indicates if torque converter is locked
BAOC		Converter input speed

OUTPUT VARIABLES:

PAOC	T_E	Engine output torque
TAOC	T_{CO}	Converter output torque

OTHER PROGRAM VARIABLES:

TAI1SR	SR	Speed ratio
TAI3KI	K_I	Input size factor
TAI3IK	$1/K_I^2$	Inverse input size factor squared
TA01TR	TR	Torque ratio

CONSTANTS IN MEMORY:

AWAY(20,30		Column one hold speed ratio column two the torque ratio and column three the inverse size factor squared
BGRT10		Bevel Gear Ratio

Variable Name	Symbol	Description
VVDF	R	Vehicle road load
TA01TR	TR	Converter torque ratio
TAI1SR	SR	Converter speed ratio
VVDMI	$(M_I)_V$	Inertial vehicle mass
ACTORQ	T_A	Accessory torque loss
PAON	N_E	Engine speed
TMAX	$(T_{SS})_{MAX}$	Maximum steady state engine torque
SST	$(T_{SS})_{MIN}$	Minimum steady state engine torque

OUTPUT VARIABLES:

SSTORQ	T_{SS}	Steady state engine torque
BS	B_S	Brake setting
VVDJ	M_I	Inertial vehicle mass including engine rotary inertia
BFORCE	F_B	Braking force

VARIABLES WHICH MUST BE STORED IN MEMORY:

VVI2BR	K_B	Brake constant

RIE	J_E	Rotary engine inertia
VVIDRR	R_T	Tire Radius

NOTE: R_T is considered constant only because the effect of tire growth is considered as an effective change in rear axle ratio (see TGG15).

OTHER PROGRAM VARIABLES:

T9ID	η_{RA}	Dummy rear axle efficiency variable
TB01ED	η_{TR}	Dummy transmission efficiency variable
AEPA	A_R	Acceleration required to reach next cycle velocity
GR	GR	Gear ratio from engine to rear wheels
TQMULT	K	Total driveline torque multiplication factor

SUBROUTINES REQUIRED:

RIXON2 (PAON, TIDLE, SST, MAP1)

```
*                              **** AUTODR ****
          SUBROUTINE AUTODR (VVOS,T9I1,TB01EF,TB01GR,T9I1GR,TA01TR,VVOJ,
        C VVOMI,TAI1SR,ACTORQ,PAON,DELT,VVDF,SSTORQ,BS,BFORCE,TIME,VEPA,
        C TMAX)
C-----DAN KAPELLEN,ALGORITHIM BY N. BEACHLEY, 1-8-74
C***** RICK HUDSON 1/77 FOR THE BUS
C-----SUBROUTINE TO ANTICIPATE ENGINE STEADY STATE TORQUE AND BRAKE
C-----SETTING REQUIRED TO FOLLOW A GIVEN DRIVING CYCLE.
          COMMON /BGEAR/ BGRTIO
          COMMON /ENGIN/SCALEF,TIDLE,EVS,TS
          COMMON /INERTIA/ RIE,RIEINV
          DIMENSION MAP1(55,17),MAP3(17,17)
          COMMON /MAPS/ MAP1,MAP3
          COMMON /MASS/ VVILFR,VVI1CD,VVI1RF,VVIMI,VVI2BR,VVIM,VVINDR,
         C              VVISWB,VVISH,VVIAMX,VVIAS
          COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
C***** VEPA IS CALCULATED IN EPAVEL
*
          AEPA=(VEPA-VVOS)/DELT
          IF(VEPA .LE. 0.1 .AND. VVOS .LE. 0.1) VVDF = 0.0
*
C***** T9ID AND TB01ED ARE SET TO .8 MINIMUMS TO AVOID DIVISION BY ZERO
          T9ID=T9I1
          IF(T9ID .LT. 0.8) T9ID = 0.8
*
          TB01ED=TB01EF
          IF(TB01ED .LT. 0.8) TB01ED = 0.8
*
C-----DETERMINE TORQUE MULTIPLICATION FROM ENGINE TO REAR WHEELS,
C-----GEAR RATIO,REAR AXLE RATIO, BEVEL GEAR RATIO IN DENOMINATER
          GR=VVIDRR/(TB01GR*T9I1GR*BGRTIO)
          TQMULT=(TA01TR*T9ID*TB01ED)/GR
C---- DETERMINE TOTAL EQUIVALENT MASS OF VEHICLE INCLUDING ROTARY INERT
C     OF DRIVETRAIN AND ENGINE).
          VVOJ=VVOMI+RIE*((TAI1SR/GR)**2)/32.1739
C---- ANTICIPATE THE STEADY STATE ENGINE TORQUE REQUIRED TO ACHIEVE THE
C-----NEXT CYCLE VELOCITY.
          SSTORQ=(AEPA*VVOJ*1.4667+VVDF)/TQMULT+ACTORQ
          IF(AEPA .LT. 0.05 .AND. PAON .LT. 950.0)
        1 SSTORQ = SCALEF*(SSTORQ+(950.0-PAON)/RIEINV)
C---- FOR POSITIVE STEADY STATE TORQUE CHECK THAT ENGINE IS NOT REQUIRE
C---- TO EXCEED ITS MAXIMUM TORQUE CAPABILITY.
          CALL FIXON2(PAON,100.,TMAX,MAP1)
          TMAX=TMAX*SCALEF
           IF (SSTORQ .GT. TMAX)SSTORQ=TMAX
      C     BS=0.;
      C     BFORCE=0.;
      C     GOTO 900
C---- DETERMINE MAXIMUM NEGATIVE STEADY STATE TORQUE POSSIBLE FOR GIVEN
C---- ENGINE SPEED.
          CALL FIXON2(PAON,TS,SST,MAP1)
          SST=SST*SCALEF
          IF(SSTORQ .LT. SST) CONTINUE;
```

```
      C     BFORCE=(SST-SSTORQ)*TQMULT;
      C     BS=BFORCE/VVI23R;
      C     SSTORQ=SST;
      C     GOTO 900
C---- TORQUE REQUIRED AT THE ENGINE AND THE DECELERATION TORQUE PRO
C---- BY THE ENGINE TIMES THE TORQUE MULTIPLICATION.
C---- DETERMINE THE REQUIRED BRAKE FORCE AS THE DIFFERENCE BETWEEN
C---- THE BRAKE SETTING IS THE REQUIRED BRAKING FORCE DIVIDED BY TH
C---- BRAKE CONSTANT.
****  IF(SSTORQ .LT. TMAX .AND.SSTORQ .GT. SST) THEN
      BS=0.
      BFORCE=0.
  900 CONTINUE
      RETURN
      END
```

3.3.4 Integration of Engine Speed - ENGTRQ

SUBROUTINE NAME: ENGTRQ

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates engine accelerations based on needed flywheel torque, accessory torque and steady state torque. If the torque converter is locked up the engine speed is calculated directly based on gear ratios and efficiencies from the previous iteration. After the engine speed is calculated the input speed for the torque converter is determined. See Figure 10.

MODELING: A second order integration scheme is used. This subroutine is used in the all-digital program only.

EQUATION: For locked up torque converter

$$TM = FG_{TR} * GR_{RA} * GR_{BG} * TR_{TQ} * \eta_{RA} * TA/RT$$

$$N_{VN} = (T_S - T_A - F_D/TM) * TM/F_B * DT + N_{VO}$$

$$N_E = N_{VN} * GR_{TR} * GR_{RA} * GR_B/(SR_{TQ} * RT)$$

For unlocked torque converter

$$\Delta N_E = \frac{T_{SS} - T_A - T_E}{J_R}$$

$$N_E = N_E + (\Delta N_{E\ OLD} + \Delta N_{E\ NEW}) * (T_P - T_{PO}) * DT/2$$

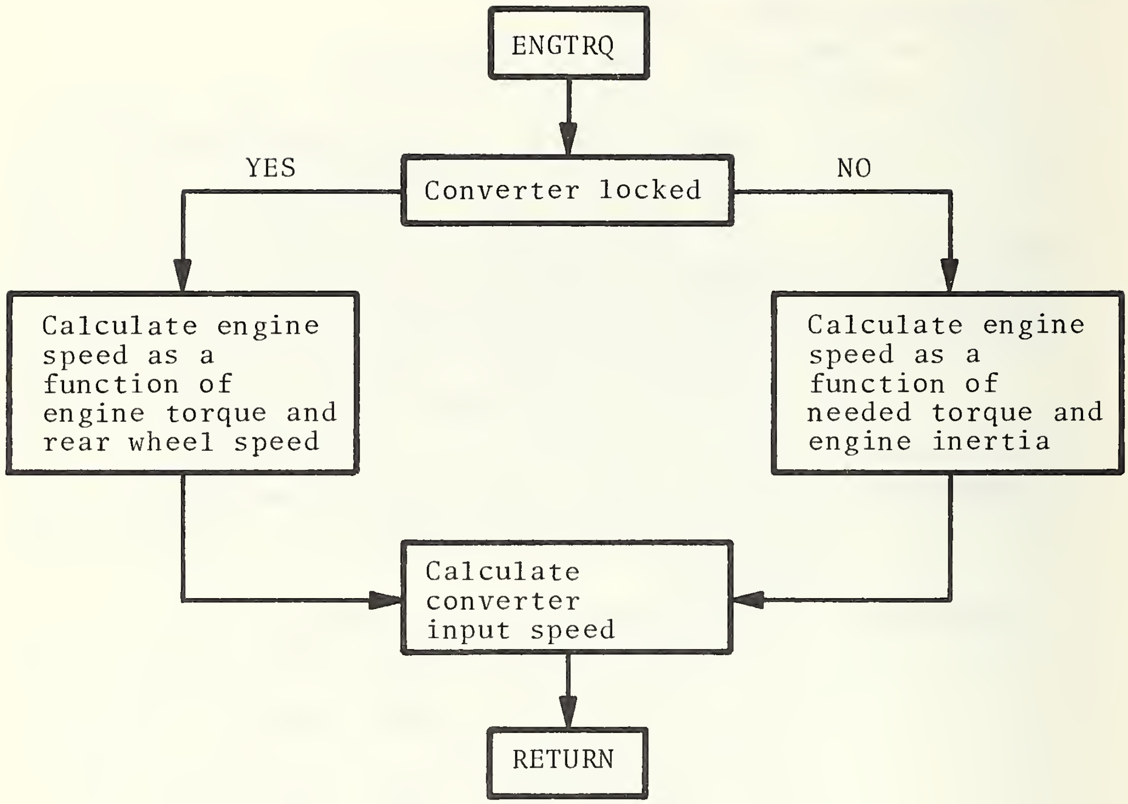


FIGURE 10. ENGTRQ FLOW DIAGRAM

Variables Used	Symbol	Meaning
Input		
ACTORQ	T_A	Accessory Torque
BAON	N_{CI}	Converter input speed
ICLOCK	T_P	Present time pulse
ICLOCK 1	T_{PO}	Past Time pulse
LOCK		Indicates if converter is locked
PAOC	T_E	Engine output torque
PAON	N_E	Engine speed
SSTORQ	T_{SS}	Engine torque
TAI1SR	SR	Speed ratio
TAO1TR	TR	Torque ratio
TAON	T_{CO}	Converter output speed
TBO1EF	η_{TR}	Transmission gear efficiency
TBO1GR	GR_{TR}	Transmission gear ratio
T9I1	η_{RA}	Rear axle efficiency
T9I1GR	GR_{RA}	Rear axle gear ratio
VVDF	F_D	Total drag force
VVDJ		
VVOS	V	Vehicle velocity
Output		
BAOC	T_{CI}	Converter input torque
BAON	N_{CI}	Converter input speed
PAOC	T_E	Engine output torque
PAON	N_E	Engine speed
TAI1SR	SR	Speed ratio
TAO1TR	TR	Torque ratio
TAOC	T_{CO}	Converter output torque

Variable Used	Symbol	Meaning
Local Variables		
ESDOT	ΔN_E	Engine acceleration
ESDOTO	ΔN_{EP}	Previous Engine acceleration
Constants Used		
BGRT10	GR_{BG}	Level gear ratio
DT	ΔT	Length of time pulse
RIEINV		Inverse engine inertia
VV1DRR	W_R	Wheel radius

```
*                                              **** ENGTRQ ****-
          SUBROUTINE ENGTRQ(TA01TR,T9I1,TB81EF,TB81GR,T9I1GR,
         C SSTQRQ,ACTORQ,VVDF,VVDJ,VV0S,PA0N,TAI1SR,PA0C,ICLOCK,
         C ICLOK1,TA0N,BA0N,ESDOT,BA0C,TA0C,LOCK)
C---- R.R.RADTKE 3/5/74
C***** RICK HUDSON 1/77 FOR THE BUS
          COMMON /BGEAR/ BGRTI0
          COMMON /INERTIA/ RIE,RIEINV
          COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
          COMMON/TIMEI/ DT
*
C *****14.00656=5280/60*2*PI
C***** ACTORQ TORQUE USED BY THE ACCESSORIES
C***** BA0C CONVERTER INPUT TORQUE
C***** BA0N TORQUE CONVERTER INPUT SPEED
C***** BGRTI0 BEVEL GEAR RATIO
C***** BEVEL GEAR IS LOCATED BETWEEN THE ENGINE AND THE IMPELLER OF TH
C***** TORQUE CONVERTER
C***** LOCK INDICATES IF THE LOCK ON THE CONVERTER IS ON
C***** PA0C ENGINE TORQUE AT THE FLYWHEEL
C***** PA0N ENGINE SPEED
C***** TAI1SR CONVERTER SPEED RATIO
C***** TA01TR CONVERTER TORQUE RATIO
*
          CALL ACCESS (PA0N,ACTORQ)
          CALL TQCONV(LOCK,PA0C,ACTORQ,TA01TR,
         C TAI1SR,TA0N,BA0N,BA0C,TA0C)
          IF (LOCK .GE. 1)
         C TM=(TA01TR*T9I1*TB81EF*TB81GR*T9I1GR*BGRTI0)/VVIDRR ;
         C  ACEL=(SSTQRQ-ACTORQ-VVDF/TM)*TM/(VVDJ*1.4667)
         C EVV0S=ACEL*DT+VV0S ;
         C PA0N= EVV0S*TB81GR*T9I1GR*BGRTI0*14.00565/(TAI1SR*VVIDRR);
         C GOTO 900
          ESDOT=(SSTQRQ-ACTORQ-PA0C)*RIEINV
          PA0N=PA0N+(ESDOT+ESDOTO)*(ICLOCK-ICLOK1)*DT/2.
          ESDOTO=ESDOT
      900 CONTINUE
          BA0N=PA0N/BGRTI0
      999 CONTINUE
          RETURN
          END
```

3.3.5 Subroutine to Obtain Target Velocity - EPAVEL

SUBROUTINE NAME: EPAVEL

DESCRIPTION: See RDEPA - Section

3.3.6 Gearshift - GRSHFT

SUBROUTINE NAME: GRSHFT

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: The gear shift subroutine determines the transmission gear number and gear ratio as a function of the driveshaft speed.

MODELING: In this simulation the driveshaft speed at which shift occurs is stored in memory.

This is done in the initialization subroutine (INICON). The shifting criteria can be specified for 2 or 3 gears.

The gear shift subroutine retrieves driveshaft speeds at which upshift and downshift will occur.

The block diagram in Figure 11 shows the general procedure for determining the gear ratio.

When a shift takes place the program changes the gear ratio linearly between gears for a period of 1/2 second to simulate slipping of the clutch bands. To prevent the transmission from upshifting and downshifting continuously, some form of hysteresis must also be introduced. This is accomplished by holding the transmission in the new gear for another second before allowing it to shift again.

The program returns the converter turbine speed for use in calculating the speed ratio.

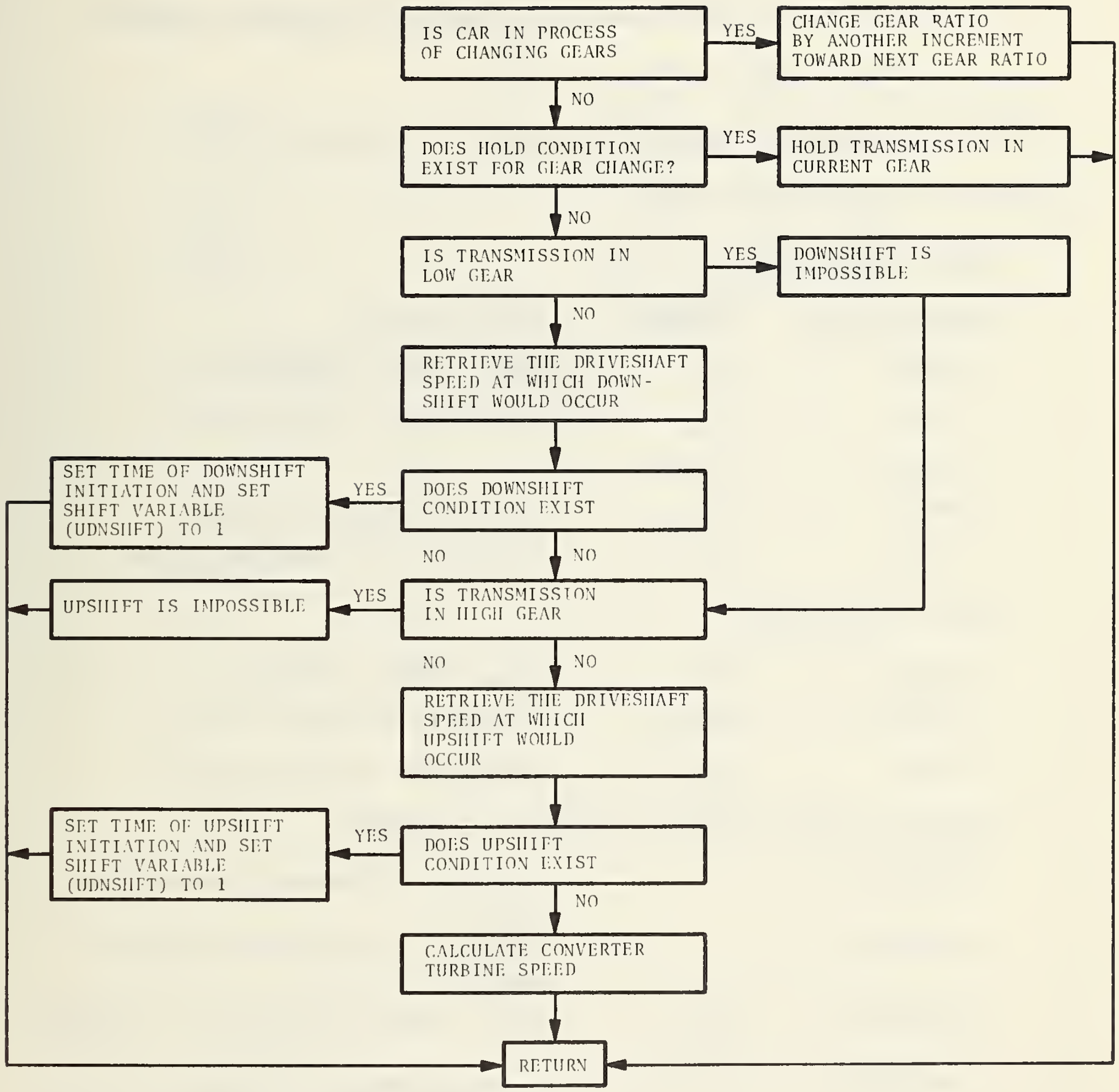


FIGURE 11. GRSHFT FLOW DIAGRAM

EQUATIONS:

1) Equation to determine gear ratio during gear change.

$$GR_{TR} = GR_i + (GR_{i \pm 1}) \cdot \frac{t_N}{t_s}$$

2) Equation to determine converter turbine speed

$$N_{CO} = N_{PS} * GR_{TR}$$

INPUT VARIABLES:

Program Name	Symbol	Description
TB01GI	GI	Gear index (number)
T9IN	N_{DS}	Driveshaft speed
ICLOCK	Time	
TMAX	T_{MAX}	Maximum engine torque
SSTORQ	T_{SS}	Steady State engine torque

OUTPUT VARIABLES

TB01GI	GI	Gear index (number)
TB01GR	GR_{TR}	Transmission gear ratio
TA0N	N_{CO}	Converter turbine speed

VARIABLES WHICH MUST BE STORED IN MEMORY:

GRMIN(I)		Minimum driveshaft speed for Gear I
GRMAX(I)		Maximum driveshaft speed for Gear I
TBC1CI(I)	GR_i	Gear ratios for gears 1 through i
IBC1GI(I)	GI_i	A bookkeeping variable to determine when bus is in low and high gear. 1 = low gear, 3 = high gear, 2 = intermediate gears
TBDTMS	t_s	Time allowed for gear shift
TBDTH	t_h	Time alloted for shift hysteresis

OTHER PROGRAM VARIABLES:

I	i	Integer form of gear index
UDNSFT		Integer indicating if shift is in progress
IGEAR	± 1	Indicates pushift or downshift
TBDTIN	t_N	Time elapsed since gear shift
ISHIFT		Time at which shift is initiated

TRANSMISSION SHIFT SCHEDULE

UPSHIFT	DRIVESHAFT RPM
1-2	920
2-3	1580
DOWNSHIFT	
3-2	1520
2-1	550

```
*                               **** GRSHFT ****
          SUBROUTINE GRSHFT(TB01GR,ICLOCK,ISHIFT,T9IN,TMAX,UDNSFT,
         C  SSTORQ,TB01GI,TAGN)
C***** RICK HUDSON 1/77
C***** THIS SUBROUTINE CALCULATES THE GEAR RATIO AS A FUNCTION OF THE
C***** DRIVESHAFT SPEED
C***************************************************************************
C---- TB01GI- CURRENT GEAR IN WHICH VEHICLE IS OPERATING.
C---- T9IN-DRIVESHAFT SPEED (RPM).
C---- ICLOCK-TIME. (ONE-HUNDRETHS OF A SECOND).
C-----------------OUTPUT VARIABLES------------------------------------------
C---- TB01GI-NEW GEAR INDEX IF VEHICLE CHANGES GEARS.
C---- TB01GR-TRANSMISSION GEAR RATIO.
C---- -------------INPUT VARIABLES-----------------------------------------
C---- ISHIFT- TIME AT WHICH SHIFT IS INITIATED.
C------------------PROGRAM CONSTANTS---------------------------------------
C***** GRMIN MINIMUM DRIVESHAFT SPEED FOR THE INDEXED GEAR
C***** GRMAX MAXIMUM DRIVESHAFT SPEED FOR THE INDEXED GEAR
C***** GRMAXCR MAXIMUM DRIVESHAFT SPEED FOR THE INDEXED GEAR IF THE BUS IS
C***** IN CRUISE MODE
C----- TBC1GI(I)- GEAR RATIOS FOR GEARS 1 THROUGH I.
C---- IBC1GI(I)- BOOKKEEPING VARIABLE TO DETERMINE WHEN CAR IS IN HIGH
C---- AND LOW GEAR.  USEFUL FOR TRANSMISSIONS WITH MORE THAN 3 GEARS.
C---- TBDTMS-TIME ALLOWED FOR GEAR SHIFT.
C-----------------OTHER PROGRAM VARIABLES----------------------------------
C---- TBDTH-DELAY TIME AFTER SHIFT BEFORE ANOTHER SHIFT CAN OCCUR.
C***** UDNSFT UPSHIFT OR DOWNSHIFT INDICATER
C---- TBDTIN-TIME ELAPSED SINCE GEAR SHIFT)
C***************************************************************************
          COMMON /SHIFTER/ GRMAX(3),GRMIN(3),GRMAXCR(3)
          COMMON /SFTIME/ TBDTMS,TBDTH
          COMMON /TGRTIO/ TBC1GR(10),GR1
          INTEGER UDNSFT
          I=TB01GI
          II=TB01GI-UDNSFT
C---- CALCULATE TIME ELAPSED SINCE LAST GEAR SHIFT.
          TBDTIN=ICLOCK-ISHIFT
C---- DETERMINE IF VEHICLE IS IN PROCESS OF CHANGING GEARS.
          IF(TBDTIN-TBDTMS)10,10,11
C-----IF CHANGE IS IN PROGRESS, CALCULATE NEW GEAR RATIO BASED ON TIME.
       10 TB01GR=TBC1GR(I)+(TBC1GR(II)-TBC1GR(I))*TBDTIN/TBDTMS
          GOTO 999
       11 CONTINUE
C***** CHECK TO SEE IF UPSHIFT CONDITIONS EXIST
          IF (T9IN .GT. GRMAX(I) .OR. (T9IN .GT. GRMAXCR(I) .AND. TMAX.GT.
         C    SSTORQ+1.))  GOTO 50
          ITEMP=I-1
C***** CHECK TO SEE IF WE ARE IN LOW ALREADY
           IF (ITEMP .LE. 0) GOTO 90
C***** CHECK TO SEE IF DOWNSHIFT CONDITIONS EXIST
          IF (T9IN .LT. GRMIN(I)) GOTO 60
C***** NO SHIFTING DURING THIS ITERATION
          UDNSFT=0
```

```
            GØTØ 90
      50 CØNTINUE
C        UPSHIFT
            ISHIFT=ICLØCK
            TBØ1GI=I+1
            UDNSFT=1
            GØTØ 95
      60 CØNTINUE
C        DØWNSHIFT
            ISHIFT=ICLØCK
            TBØ1GI=I-1
            UDNSFT=-1
            GØTØ 95
      90 CØNTINUE
            TBØ1GR=TBC1GR(I)
            GØTØ 999
      95 CØNTINUE
            TBØ1GR=TBC1GR(I)
     999 CØNTINUE
            TAØN=TØIN*TBØ1GR
            RETURN
            END
```

3.3.7 Subroutine to Initialize Maps and Tables - INICON

SUBROUTINE NAME: INICON

TYPE OF SUBROUTINE: INITIALIZATION

DESCRIPTION: This subroutine reads in maps and tables needed by the system computation routines. It reads in all constants that are required and calculates other constants as necessary. It also calculates acceleration limits of the vehicle, accounting for weight transfer.

EQUATIONS: Maximum vehicle acceleration accounting for weight transfer without tire slippage:

$$A_{MAX} = f_M \cdot M_{DR} \cdot W_B/(M \cdot (W_B - A_{MIN} \cdot H))$$

Maximum vehicle acceleration with tires slipping:

$$A_{MAXS} = f_s \cdot M_{DR} \cdot W_B/(M \cdot (W_O - A_{MIN} \cdot H))$$

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: N/A

```
*                               **** INICØN ****
C---- SUBRØUTINE TØ INITIALIZE MAPS
C---- K.R.RADTKE 3/4/74
      SUBRØUTINE INICØN
      CØMMØN /AKCESS/ ACLØAD(10),PIDLMIN,PIDLMAX
      CØMMØN /AIR/ AVIB,AVIR,AVIØ,AVIS,AVIM
       CØMMØN /BGEAR/ BGRTIØ
      CØMMØN /CRØSCØR/ VMIN(2),PMAX(2),VINT(2),NDIM(2)
      CØMMØN /CØMMENT/ CØMM(26)
      CØMMØN /CØNTRØL/ GAIN,DELMIN,NVEPA,IVEPA(685)
      CØMMØN /DSSPD/ TØINV(10)
      CØMMØN /ENGIN/SCALEF,TIDLE,EVS,TS
      CØMMØN /GAS/ FUELWT
      CØMMØN /GEAREF/ TBC1GI(10,4),IBC1GI(10)
      CØMMØN /INERTIA/ RIE,RIEINV
      CØMMØN /LØCKER/ TIMLØCK,SRNEW,TRNEW,TRØLD,SRØLD
      CØMMØN /LØCK1/ ACCLØCK,DECLØCK
      CØMMØN /LØCK2/ ACCRUIS
      CØMMØN /MASS/ VVILFR,VVI1CD,VVI1RF,VVIMI,VVI2BR,VVIM,VVIMDR,
     C                 VVISWB,VVISH,VVIAMX,VVIAS
      CØMMØN /PMØMENT/ TVIJCT,TVIJTR,TVIJRA,TVIJTW
      CØMMØN /PRNT/ IØUT,IPRNT,LØADEQ,MAXLIN
      CØMMØN /RØLD/ TVICRL(16)
      CØMMØN/RGRTIØ/ TØI1GR
      CØMMØN /SFTIME/ TBDTMS,TBDTH
      CØMMØN /SHIFTER/ GRMAX(3),GRMIN(3),GRMAXCR(3)
      CØMMØN /STEADY/ EPS
      CØMMØN /TGRTIØ/ TBC1GR(10),GR1
      CØMMØN /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
      CØMMØN/TIME1/ DT
      CØMMØN/TQC/ AAAY(20,3)
*
  100 FØRMAT(11I7/6I7)
  101 FØRMAT(20I4)
  102 FØRMAT(16I5)
  103 FØRMAT(10I5)
  104 FØRMAT(8E10.3)
  105 FØRMAT(8I10)
  106 FØRMAT(16F5.1)
  107 FØRMAT(5E11.5)
  108 FØRMAT(10I1)
  109 FØRMAT(12F6.1)
  110 FØRMAT(13A6/13A6)
  111 FØRMAT(13I6)
  112 FØRMAT(F10.6)
  200 FØRMAT(X,11I7/6I7)
  201 FØRMAT(X,20I4)
  202 FØRMAT(X,16I5)
  203 FØRMAT(X,10I5)
  204 FØRMAT(X,8E10.3)
  205 FØRMAT(X,8I10)
  206 FØRMAT(X,16F5.1)
  207 FØRMAT(X,5E11.5)
```

```
      208 FORMAT(X,10I1)
      209 FORMAT(12F6.1)
      210 FORMAT(X,13A6/13A6)
      211 FORMAT(13I6)
      212 FORMAT(F10.6)
*
      120     FORMAT (8F10.3)
      130 FORMAT (1H1)
          PRINT 130
          READ 110,COMM
          PRINT 110, COMM
          READ 120,VVIMI,VVI2SR,VVIM,VVIMDR
          PRINT 120,VVIMI,VVI2SR,VVIM,VVIMDR
C-----ENGINE INERTIA,MAX TORQUE,MAX VAC, ENGINE SCALF FACTOR,IDLE SETT
          READ 104,RIE,TMAX,SCALEF,TIDLE,PIDLMIN ,PIDLMAX
          PRINT 204,RIE,TMAX,SCALEF,TIDLE,PIDLMIN,PIDLMAX
C---- ACCESSORY LOAD
          READ 104,ACLOAD
          OUTPUT(108) 'ACLOAD'
          PRINT 204,ACLOAD
C---- READ IN DEFINITION OF CROSS CORRELATION
          READ 104,VMIN(1),PMAX(1),VINT(1)
          READ 104,VMIN(2),PMAX(2),VINT(2)
          OUTPUT(108) 'VMIN(1), ETC'
          PRINT 204,VMIN(1),PMAX(1),VINT(1)
          OUTPUT(108) 'VMIN(2), ETC'
          PRINT 204,VMIN(2),PMAX(2),VINT(2)
          NDIM(1)=(PMAX(1)-VMIN(1))/VINT(1)+1
          NDIM(2)=(PMAX(2)-VMIN(2))/VINT(2)+1
C---- GEAR INDEX AS A FUNCTION OF DRIVE SHAFT SPEED AND ENGINE VACUUM
          DO 50 N=1,10
          TBC1GR(N)=0.
       50 CONTINUE
          READ 103,NGEAR
          OUTPUT(108) 'NGEAR'
          PRINT 203,NGEAR
          NGM1=NGEAR*2-3
C---- POLYNOMIAL INDEX FOR CALCULATING GEAR EFFICIENCY
          OUTPUT(108) 'TBC1GI(I,J)'
          DO 30 J=1,4
          READ 107,(TBC1GI(I,J),I=1,10)
          PRINT 207,(TBC1GI(I,J),I=1,10)
       30 CONTINUE
C---- GEAR EFFICIENCY INDEX
          READ 108,IBC1GI
          OUTPUT(108) 'IBC1GI'
           PRINT 208,IBC1GI
C---- GEAR RATIOS
          READ 104,(TBC1GR(J),J=1,NGEAR)
          OUTPUT(108) 'TBC1GR(J)'
          PRINT 204,(TBC1GR(J),J=1,NGEAR)
          READ 112, BGRTIO
          OUTPUT (108) 'BEVEL GEAR RATIO BGRTIO'
```

```
          PRINT 112,BGRTIO
C-----FIRST GEAR RATIO, POLAR MOMENT OF TORQUE CONVT. TURBINE, POLAR
C-----MOMENT OF TRANS. GEARS, LENGTH OF SHIFT, TIME BETWEEN SHIFTS
          READ 104, GR1,TVIJCT,TVIJTR,TBDTMS,TBDTH
          OUTPUT(108) 'GR1, ETC'
          PRINT 204,GR1,TVIJCT,TVIJTR,TBDTMS,TBDTH
C-----REAR AXLE RATIO, POLAR MOMENT OF REAR AXLE GEARS
          READ 104, T8I1GR,TVIJRA
          OUTPUT(108) 'T8I1GR, ETC'
          PRINT 204,T8I1GR,TVIJRA
C-----TIRE ROLLING RADIUS,COEFF. OF MAX TIRE FRICTION, SLIDING COEFF. OF
C-----TIRE FRICTION, TIRE COULOMBIC FRICTION COEFF., POLAR MOMENT OF
C-----TIRES AND WHEELS
          READ 104, VVIDRR,VVIFUM,VVIFUS,VVI1CF,TVIJTW
          OUTPUT(108) 'VVIDRR, ETC'
          PRINT 204,VVIDRR,VVIFUM,VVIFUS,VVI1CF,TVIJTW
C---- DRIVE SHAFT SPEED AS A FUNCTION OF VEHICLE SPEED
          READ 109,T8INV
          OUTPUT(108) 'T8INV'
          PRINT 209,T8INV
C-----INERTIAL MASS OF VEHICLE,FRONTAL AREA,BRAKE CONSTANT,DRAG COEFF.,
C-----VEHICLE MASS,ROLLING FRICTION COEFF.,MASS ON DRIVE WHEELS
          READ 104,VVILFR,VVI1CD,VVI1RF
          OUTPUT (108) 'VVILFR,VVI1CD,VVI1FR'
          PRINT 104, VVILFR,VVI1CD,VVI1RF
C-----WHEEL BASE, HEIGHT OF VEHICLE CENTER OF GRAVITY, FUEL WEIGHT
          READ 104, VVISWB,VVISH,FUELWT
          OUTPUT(108) 'VVISWB, ETC'
          PRINT 204,VVISWB,VVISH,FUELWT
C-----AIR PRESSURE, AIR TEMP, GAIN FOR VEDYN, AUTO DRIVER MIN. LEAD TIME
          READ 104,AVIB,AVIR,GAIN,DELMIN
          OUTPUT(108) 'AVIB, ETC'
          PRINT 204,AVIB,AVIR,GAIN,DELMIN
          READ 105,IOUT,IPRNT,LOADEQ
          OUTPUT(108) 'IOUT, ETC'
          PRINT 205,IOUT,IPRNT,LOADEQ
C---- DRIVESHAFT RESISTIVE TORQUE ROAD LOAD DATA
          READ 106,TVICRL
          OUTPUT(108) 'TVICRL'
          PRINT 206,TVICRL
C---- TIME INCREMENT
          READ 112, DT
          OUTPUT(108) 'DT'
          PRINT 212,DT
          READ 104,AVIO,AVIS
          OUTPUT (108)AVIO,AVIS
    113 FORMAT (4F10.5,F10.7)
          READ 113,(GRMAX(I),I=1,3)
           OUTPUT (108)'GRMAX     '
          PRINT 113,(GRMAX(I),I=1,3)
          OUTPUT (108) 'GRMAXCR CRUISE)'
          READ 113,(GRMAXCR(I),I=1,3)
          PRINT 113,(GRMAXCR(I),I=1,3)
```

```
      OUTPUT (108) 'GRMIN 1-3'
      READ 113, (GRMIN(I),I=1,3)
      PRINT 113,(GRMIN(I),I=1,3)
  999 CONTINUE
      OUTPUT (108) 'ALLISON TEST DATA'
      OUTPUT (108) 'SPEED RATIO*TORQUE RATIO*ONE/K**2     '
      DO 20,I=1,20
  500 FORMAT (2F10.5,F10.8)
      READ 500,( AWAY(I,J),J=1,3)
      PRINT 500,(AWAY(I,J),J=1,3)
   20 CONTINUE
  400 FORMAT (8F10.5)
      READ 400, SRNEW,TRNEW,SROLD,TROLD,TIMLOCK
      PRINT 400, SRNEW,TRNEW,SROLD,TROLD,TIMLOCK
      READ 400, ACCLOCK,DECLOCK
      PRINT 400, ACCLOCK,DECLOCK
      READ 400,ACCRUIS
       OUTPUT (108) ACCRUIS
      VVIAMY=VVIFUM*VVIMDR*VVISWB/(VVIM*(VVISWB-VVIFUM*VVISH))
      VVIAS=VVIFUS*VVIMDR*VVISWB/(VVIM*(VVISWB-VVIFUS*VVISH))
C---- INVERSE ENGINE INERTIA
      RIEINV=60*32.1739/(2.*3.14159*RIE)
C---- HOURS PER SECOND
C---- CALCULATE AIR DENSITY
      AVIM=2.702912*AVIB/(459.67+AVIR)
C---- LINES PER PAGE
      MAXLIN=48
C---- ENGINE STABILITY COMPARATOR
      EPS=10.0
      TMAX=TMAX*SCALEF
      RETURN
      END
```

3.3.8 Initialization after Engine Reaches Steady State - INIGER

SUBROUTINE NAME: INIGER

TYPE OF SUBROUTINE: Initialization

DESCRIPTION: This subroutine initializes all dynamic variables which are not initialized in INIVAR. The subroutine is called after the engine has reached a steady state speed before the driving cycle begins. This subroutine then puts the bus into first gear.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: N/A

```
*                                    **** INIGER ****
      SUBROUTINE INIGER(PAON,SSTORQ,PAOFR,INDIC,ICLOCK,TIME
     C ,ICLOK1,TO01EF,T9IN,T8DN,T93N,T9I1GR,VVOS,VVOA,VVOD
     C ,FUELE,EMISF,EMISE,ITICYC,ISHIFT,IGEAR,WHLOLD,
     CVVDMI,DFLTAT,T9IC,T9I1,LOCK,
     CNLINE,ICYCLE,NGIOLD,NGI,TO01GR,TO01GI,PAOFRO,VVOAO
     C ,VVOSO,ISEQ,IPDX,TIMMAX,TIMAVG,TIMLEN,NLT,NGT,VFPA,
     C OS,T90C,VVDF,VVDFBR,TVIMJ,TAOC,
     C ICLOKO)
C***** THIS SUBROUTINE INITIALIZES VARIABLE TO START THE CYCLE
      DIMENSION NLT(2),NGT(2)
      DIMENSION IPDX(20,20)
      DIMENSION TIMMAX(5),TIMLEN(5),TIMAVG(5)
      COMMON /TGRTIO/ TOC1GR(10),GR1
      COMMON/RGRTIO/ T8I1GR
      COMMON /MAPS/ MAP1,MAP3
      DIMENSION MAP1(55,17),MAP3(17,17)
      COMMON /SETIME/ TBDTMS,TBDTH
      COMMON /PRNT/ IOUT,IPRNT,LOADEQ,MAXLIN
      LOCK=0
      INDIC=0
      ICLOCK=0
      TIME=0
      ICLOKO=-(IOUT+1)
      ICLOK1=0
      TO01EF=.93
      T9IN=0
      T8DN=0
      T90N=0
      T9I1GR=T8I1GR
      VVOS=0
      VVOA=0
      VVOD=0
      FUELE=0
      EMISF=0
      EMISE=0
      ITICYC=0
      ISHIFT=-TBDTH-1
      IGEAR=0
      WHLOLD=0
      NLINE=MAXLIN+5
      ICYCLE=0
      NGIOLD=1
      NGI=1
      TO01GR=GR1
      TO01GI=1
      PAOFRO=0
      VVOAO=0
      VVOSO=0
      ISEQ=0
      DO 10 I=1,20
      DO 5 J=1,20
      IPDX(I,J)=0
```

```
    5 CONTINUE
   10 CONTINUE
      DO 15 I=1,5
      TIMMAX(I)=0
      TIMAVG(I)=0
      TIMLEN(I)=0
   15 CONTINUE
      NLT(1)=0
      NLT(2)=0
      NGT(1)=0
      NGT(2)=0
      CALL RIXON22(PAON,SSTORQ,PAOFR,MAP3)
      CALL TREFF(TAOC,TB01GR,TB01EF,TB01GI,T9IN,T9IC)
      CALL RAEFF(T9IC,T9IN,T9I1GR,T90C,T9I1)
      CALL  VEDYN( TB01GI,VV0S,BS,T90C,TB01GR,T9I1GR,VV0A
     C ,VVDF,T9I1,VVDFBR,VVDMI,DELTAT,VV0AO,
     C TVINJ)
      PAOFRO=PAOFR
      VV0A=0.
      VV0AO=VV0A
      VEPA=0
      RETURN
      END
```

3.3.9 Initialize Engine Variables - INIVAR

SUBROUTINE NAME: INIVAR

TYPE OF SUBROUTINE: Initialization

DESCRIPTION: This subroutine initializes those variables necessary for the engine calculations. When the engine reaches a steady state speed with the vehicle at rest, INIGER initializes all other variables.

MODELING: N/A

EQUATIONS: Initial Engine Acceleration:

$$\Delta N_E = (T_{SS} - T_A - T_E)/J_E$$

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

```
*                                              **** INIVAR ****
      SUBROUTINE INIVAR (BFORCE,LOCK,UDNSFT,TIME,ICLOCK,ICLOK1
     C ,ISHIFT,NREC,BS,TB01GR,TB01GI,NGI,NGIOLD,ICYEND,VV0A,VANALG,
     C HPWHLM,HPRAXM,HPTRANM,HPTQCM,HPENGM,HPWHLP,HPRAXP,HPTRANP,
     C  HPTQCP,HPENGP,HPACC,
     C ACTORQ,PAOC,BFORCEM,PIDLE,
     C TA01TR,TAI1SR,BAOC,
     C TIMMAX,TIMLEN,TIMAVG,PAON,BAON,SSTORQ,TAON,ESDOTO,VAR)
C***** INTIALIZES VARIABLES AT START OF RUN
      DIMENSION TIMMAX(5),TIMLEN(5),TIMAVG(5),VAR(2)
      COMMON /ENGIN/SCALEF,TIDLE,EVS,TS
      COMMON /INERTIA/ RIE,RIEINV
      COMMON /MAPS/ MAP1,MAP3
      DIMENSION MAP1(55,17),MAP3(17,17)
       COMMON /BGEAR/ BGRTIO
      HPWHLM=HPRAXM=HPTRANM=HPTQCM=HPENGM=HPWHLP=HPRAXP=HPTRANP=
     C  HPTQCP=HPENGP=HPACC=0.0
      BFORCE=BFORCEM=0.
      LOCK=0
      UDNSFT=0
      TIME=0
      ICLOCK=0
      ICLOK1=0
      ISHIFT=0
      TS = 100*TIDLE
      NREC=0
      BS=0
      TB01GR=0
      TB01GI=0
      NGI=0
      NGIOLD=0
      ICYEND=0
      VV0A=0.
      VANALG=0
      DO 5 I=1,5
      TIMMAX(I)=0
      TIMAVG(I)=0
    5 CONTINUE
      PAON=900.
      BAON=PAON/BGRTIO
      CALL RIXON2(PAON,TS,SSTORQ,MAP1)
      SSTORQ=SSTORQ*SCALEF
      TAON=0
      CALL TQCONV( LOCK,PAOC,SSTORQ,ACTORQ,TA01TR,
     C TAI1SR,TAON,BAON,BAOC,TAOC)
      CALL ACCESS (PAON,ACTORQ)
      ESDOTO=(SSTORQ-ACTORQ-PAOC)*RIEINV
      VAR(2)=50.
      RETURN
      END
```

3.3.10 Integrate System Variables - INTGRT

SUBROUTINE NAME: INTGRT

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine integrates vehicle acceleration, vehicle speed and fuel rate to get vehicle velocity, distance traveled and fuel expended respectively.

MODELING: A second order integration sheme is used.

EQUATION: (Typical) $V = V_0 + (A_0 + A) \cdot (\Delta T)/2$

INPUT VARIABLES:

ICLOCK	-	Value of System clock
ICLOK1	-	Last value of system clock
VVOS	-	Last vehicle speed
VVOD	-	Last distance traveled
FUELE	-	Fuel expended
VVOA	-	New vehicle acceleration
PAOFR	-	New fuel rate
VVOA0	-	Old vehicle acceleration
PAOFR0	-	Old fuel rate

OUTPUT VARIABLES:

VVOS	-	New velocity
VVOD	-	New distance
FUELE	-	New fuel consumed
VVOA0	-	Old acceleration for next iteration
VVOS0	-	Old speed for next iteration
PAOFR0	-	Old fuel rate for next iteration
ICLOK1	-	Current value of system clock

BUS SIMULATIØN PRØGRAM

```
*                                          **** INTGRT ****
      SUBRØUTINE INTGRT(ICLØCK,ICLØK1,NTIMEP,VVØS,
     C VVØA,VVØAO,VVØSO,PAØFR,VVØD,FUELE,PAØFRO)
C***** THIS SUBRØUTINE INTEGRATES THE PRØGRAM VARIABLES
      CØMMØN/TIMEI/ DT
      NTIMEP=ICLØCK
      DELTA=(NTIMEP-ICLØK1)*DT*.5
C***** SPEED
      VVØS=VVØS+(VVØAO+VVØA)*DELTA
*
C*****THIS IS TØ ASSURE US THAT THE BUS WILL STØP AT VERY LØW SPE
      IF (VVØA .LE. 0 .AND. VVØS .LT. .1)VVØS=VVØA=0.0
*
C***** DISTANCE
      VVØD=VVØD+(VVØSO+VVØS)*DELTA/3600.
C***** FUEL
      FUELE=FUELE+(PAØFRO+PAØFR)*DELTA/3600.
      VVØAO=VVØA
      VVØSO=VVØS
      PAØFRO=PAØFR
      ICLØK1=NTIMEP
      RETURN
      END
```

3.3.11 Terminate Subroutine - JPBSUM

SUBROUTINE NAME: JPBSUM

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine prints out a summary of the run, including the joint probability distribution, the gas mileage, total distance traveled, and power used.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

```
*                              **** JOBSUM ****
      SUBROUTINE JOBSUM(IPDX,ICYCLE,NLT,NGT,VV0D,FUELE,HPWHLP,
     C HPWHLM,HPRAXP,HPRAXM,HPTRANP,HPTRANM,HPTGCP,
     C HPTGCM,HPENGP,HPENGM,HPACC,TIME,
     C XTIME,XSSTOR,XPAOC,XACTOR,XTAOC,XT91C,XT90C,GEAR
     C ,X0BHP,ACCHP,FLYHP,CONHP,DRSHP,RAXHP)
C***** THIS SUBROUTINE OUTPUTS TO THE LINE PRINTER THE PROBABILITY
C***** DENSITY INFORMATION, THE MILEAGE INFORMATION AND THE TORQUE TA
C***** OF THE FIRST 140 SECONDS
      DIMENSION SUMJ(20),X(225),NGT(2),NLT(2)
      DIMENSION IPDX(20,20)
      DIMENSION XTIME(140),XSSTOR(140),XPAOC(140),XACTOR(140)
      DIMENSION XTAOC(140),XT91C(140),XT90C(140),GEAR(140)
      DIMENSION X0BHP(140),ACCHP(140),FLYHP(140),CONHP(140)
      DIMENSION DRSHP(140),RAXHP(140)
      COMMON /SPD/ ISPEED(20)
      COMMON /CRESCOR/ VMIN(2),VMAX(2),VINT(2),NDIM(2)
      COMMON /GAS/ FUELWT
      COMMON /STOPPER/ NSTOP
C---- TERMINATION SUBROUTINE
C***** RICK HUDSON 1/77
C---- R.R.RADTKE 3/5/74
  200 FORMAT(1H1,          40X,36HJOINT PROBABILITY DENSITY (PER CENT
  199 FORMAT (/,(20X,13A6))
  201 FORMAT(//,39X,43HENGINE STEADY STATE TORQUE VS. ENGINE SPEED)
  202 FORMAT(  /,52X,15HSPEED INTERVALS )
  203 FORMAT(1H )
  204 FORMAT(8X,20I6)
  205 FORMAT(1X,6HTORQUE,/,1X,9HINTERVALS)
  206 FORMAT(1X,I3,1H-,I3,20F6.2)
  207 FORMAT(/,5X,I5,38H SAMPLES FELL BELOW THE MINIMUM TORQUE,
     1 /,5X,I5,36H SAMPLES EXCEEDED THE MAXIMUM TORQUE,
     2 /,5X,I5,37H SAMPLES FELL BELOW THE MINIMUM SPEED,
     3 /,5X,I5,35H SAMPLES EXCEEDED THE MAXIMUM SPEED)
  208 FORMAT(1H1,5X,I7,37H ITERATIONS TOOK PLACE OVER THE CYCLE)
  209 FORMAT(8H TOTALS,20F6.2)
  212 FORMAT(12X,46HONE SAMPLE TAKEN DURING EACH PROGRAM ITERATION)
      PRINT 200
      PRINT 201
      PRINT 202
      PRINT 205
      ISPEED(1)=VMIN(2)
      INT=VINT(2)
      NLIM=NDIM(2)
      DO 5 I=2,NLIM
      ISPEED(I)=ISPEED(I-1)+INT
    5 CONTINUE
      N2=NDIM(2)-1
      PRINT 204,(ISPEED(I),I=1,N2)
      PRINT 204,(ISPEED(I),I=2,NLIM)
      PRINT 203
      ITORQ1=VMIN(1)
      INT=VINT(1)
```

```
         N1=NDIM(1)-1
         DO 10 I=1,NLIM
      10 SUMJ(I)=0
         DO 20 I=1,N1
         ITORQ2=ITORQ1+INT
         DO 15 J=1,N2
         X(J)=FLOAT(IPOX(I,J))*100./FLOAT(ICYCLE)
         SUMJ(J)=SUMJ(J)+X(J)
      15 CONTINUE
         PRINT 206,ITORQ1,ITORQ2,(X(J),J=1,N2)
         ITORQ1=ITORQ2
      20 CONTINUE
         PRINT 205
         PRINT 203
         PRINT 209,(SUMJ(J),J=1,N2)
         PRINT 203
         PRINT 208,ICYCLE
         PRINT 212
         PRINT 207,(NLT(I),NOT(I),I=1,2)
     210 FORMAT(///,10X,17HMILES PER GALLON=,F7.3)
         FUMPG=VVOD*FUELWT/FUELE
         PRINT 210,FUMPG
     505 FORMAT(10X,17HGALLONS PER MILE= ,F7.3)
         FUGPM=1/FUMPG
         PRINT 505, FUGPM
     507 FORMAT (40HPOWER REQUIRED BY THE REAR AXLE              ,F8.2,10X,F8.2)
     506 FORMAT (//,40HPOWER REQUIRED BY THE WHEEL
        C ,F8.2,10X,F8.2    )
     508 FORMAT (40HPOWER REQUIRED BY THE DRIVE SHAFT            ,F8.2,10X,F8.2)
     509 FORMAT (40HPOWER REQUIRED BY THE TORQUE CONVERTER     , F8.2,10X,
        C  F8.2)
     510 FORMAT (40HPOWER REQUIRED BY THE ENGINE FLYWHEEL        ,F8.2,10X,F8.2)
     511 FORMAT (40HPOWER REQUIRED BY THE ACCESSORIES            ,F8.2,10X,F8.2)
     512 FORMAT(40X , 27HDRIVE**************MOTORING    )
     513 FORMAT (10X,///, 25HNUMBER OF STOPS PER MILE=
        C ,I2)
     514 FORMAT (///,40X,20HHORSEPOWER-SECONDS                )
     515 FORMAT (40HPOWER LOST TO BRAKES
        C ,18X,F8.2)
         PRINT 513,NSTOP
         PRINT 211,VVOD
         PRINT 514
         PRINT 512
         PRINT 506, HPWHLP,HPWHLM
         PRINT 507 ,HPRAXP,HPRAXM
         PRINT 508 ,HPTRANP,HPTRANM
         PRINT 509, HPTQCP,HPTQCM
         PRINT 510,HPENGP,HPENGM
         PRINT 511,HPACC
     211 FORMAT(10X,9HDISTANCE=,F7.4)
         PRINT 213
     213 FORMAT(1H1,20X,28HTORQUE VALUES IN DRIVE TRAIN)
         PRINT 214
```

```
  214 FORMAT(//,22X,6HENGINE,16X,12HTRANSMISSION,5X,9HREAR AXLE)
      PRINT 230
  230 FORMAT(/,33X,7HDYNAMIC,3X,7HDYNAMIC,2X,7HDYNAMIC,3X,7HDYNAMIC)
      PRINT 215
  215 FORMAT(5X,4HTIME,3X,8HINSTANT.,4X,4HACC.,4X,8HFLYWHEEL,2X,
     19HCONVERTER,2X,6HDRIVE-,3X,9HREAR AXLE,6X,4HGEAR)
      PRINT 216
  216 FORMAT(13X,6HENGINE,4X,6HTORQUE,4X,6HTORQUE,4X,6HOUTPUT,
     14X,5HSHAFT,5X,6HOUTPUT)
      PRINT 217
  217 FORMAT(13X,6HTORQUE,24X,6HTORQUE,4X,6HTORQUE,4X,6HTORQUE)
      ITEMP=TIME
      IF (TIME .GT. 140) ITEMP=140
      DO 500 , I=1,ITEMP
      PRINT 218,XTIME(I),XSSTOR(I),XACTOR(I),XPAOC(I),XTAOC(I),
     1XTOIC(I),XTOOC(I),GEAR(I)
  500 CONTINUE
  218 FORMAT(7F10.2,F9.0)
      PRINT 219
  219 FORMAT(1H1,18X,32HHORSEPOWER VALUES IN DRIVE TRAIN)
      PRINT 214
      PRINT 230
      PRINT 215
      PRINT 220
  220 FORMAT(13X,6HENGINE,6X,2HHP,8X,2HHP,6X,6HOUTPUT,4X,
     15HSHAFT,5X,6HOUTPUT)
      PRINT 221
      DO 501 I=1,ITEMP
  221 FORMAT(15X,2HHP,6X,4HLOSS,18X,2HHP,8X,2HHP,8X,2HHP)
      PRINT 218,XTIME(I),XSSHP(I),ACCHP(I),FLYHP(I),CONHP(I),DRSHP(I
     1RAXHP(I),GEAR(I)
  501 CONTINUE
      RETURN
      END
```

3.3.12 Converter Lockup - LOCKUP and LOCKCAL

SUBROUTINE NAMES: LOCKUP and LOCKCAL

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: These subroutines simulate the effect of the torque converter lockup process by calculating the torque ratio and speed ratio of the torque converter.

MODELING: This routine is activated if the vehicle velocity has exceeded a maximum acceleration velocity or a maximum cruising velocity. It is activated during each iteration thereafter until the vehicle velocity drops below a minimum for the lockup. When the subroutine is first activated it calculates the converter's speed ratio and torque ratio and changes them linearly between the old ratios and the lockup ratios over 1-1/2 second period. When it unlocks it follows the same process.

INPUT VARIABLES:

VVOS	Vehicle Velocity
TIME	

INPUT AND OUTPUT VARIABLES:

LOCK	Indicates whether torque converter is locking, locked,or unlocking
TIME	Time of run
TAI1SR	Torque converter speed ratio
TA0LTR	Torque converter Torque ratio

CONSTANTS IN MEMORY:

ACCLOCK	Speed at which lockup occurs if accelerating
DELOCK	Speed at which you unlock
ACCRUS	Speed at which lockup occurs if cruising

CONSTANTS IN MEMORY (CONTINUED)

TIMLOCK	Length of time taken to lockup

PROGRAM VARIABLES:

SRNEW	Speed ratio when locked up
TRNEW	Torque ratio when locked up
SROLD	Speed ratio after unlocking
TROLD	Torque ratio after unlocking
DELSR	Δ speed ratio
DELTR	Δ torque ratio
DONLOCK	Time lockup is complete

TC490 LOCKUP SCHEDULE

WOT LOCKUP	28 MPH
CR LOCK	21 MPH
UNLOCK	9 MPH

```
*                                   **** LOCKUP ****
      SUBROUTINE LOCKUP(VVGS,TIME,LOCK,TAI1SR,TA01TR)
C***** THIS SUBROUTINE SIMULATES THE CONVERTER LOCKING US
C*****LOCK IS USED AS A FLAG TO SEE IF WE ARE LOCKING(2) UNLOCKING (3)
C***** ARE ALREADY LOCKED  (1)
*
      COMMON /LOCK1/ ACCLOCK,DECLOCK
      COMMON /LOCKER/ TIMLOCK,SRNEW,TRNEW,TROLD,SROLD
*
      GO TO (2,100,200,300) LOCK+1
    2 CONTINUE
C***** LOCKUP
      LOCK = 2
      CALL LOCKCAL(LOCK,TAI1SR,TA01TR,TIME,DONLOCK,DELSR,DELTR)
      TA01TR=TA01TR+DELTR
      TAI1SR=TAI1SR+DELSR
      GOTO 999
*
  100 CONTINUE
C***** LOCKED UP
      IF (VVGS .LT. DECLOCK) GOTO 110
      TAI1SR= SRNEW
      TA01TR=TRNEW
      GOTO 999
  110 CONTINUE
C***** UNLOCK
      LOCK=3
      CALL LOCKCAL(LOCK,TAI1SR,TA01TR,TIME,DONLOCK,DELSR,DELTR)
      TAI1SR=TAI1SR+DELSR
      TA01TR=TA01TR+DELTR
      GOTO 999
*
  200 CONTINUE
C***** LOCKING UP
       IF (DONLOCK .LT. TIME) GOTO 210
      TA01TR=TA01TR+DELTR
      TAI1SR=TAI1SR+DELSR
      GOTO 999
  210 CONTINUE
C***** LOCKIED UP
      LOCK=1
      TAI1SR= SRNEW
      TA01TR=TRNEW
      GOTO 999
*
  300 CONTINUE
C***** UNLOCKING
      IF ( DONLOCK .LT. TIME) GOTO 310
      TA01TR=TA01TR+DELTR
      TAI1SR=TAI1SR+DELSR
      GOTO 999
  310 CONTINUE
C***** UNLOCKED
```

```
BUS SIMULATION PROGRAM
      LOCK=0
  999 CONTINUE
      RETURN
       END
```

```
*                                        **** LOCKCAL ****
      SUBROUTINE LOCKCAL(LOCK,SR,TR,TIME,DONLOCK,DELSR,DELTR)
C***** THIS SUBROUTINE CALCULATES THE CHANGES IN THE CONVERTER CONDIT
C***** LOCKUP
      COMMON /LOCKER/ TIMLOCK,SRNEW,TRNEW,TROLD,SROLD
      COMMON/TIMEI/ DT
*  28 DEC 1976
*
      DTT = DT*TIMLOCK
      GO TO (200,300) LOCK-1
*
  200 CONTINUE
C***** LOCKING UP
      DELSR=(SRNEW-SR)*DTT
      DELTR=(TRNEW-TR)*DTT
      GOTO 999
*
  300 CONTINUE
C***** UNLOCKING
      DELTR=(TROLD-TR)*DTT
      DELSR=(SROLD-SR)*DTT
*
  999 CONTINUE
      DONLOCK=TIME+TIMLOCK
      RETURN
      END
```

3.3.13 Subroutine to Input Engine Map - MAPER

SUBROUTINE NAME: MAPER

TYPE OF SUBROUTINE: Input

DESCRIPTION: This subroutine reads in the engine maps used to calculate fuel consumption and minimum engine torque.

MODELING: The program reads in the engine speed on the first card. The second card reads in nine torques. The third card reads in the corresponding fuel rate and the fourth card reads in corresponding throttle setting. The fifth card is blank. This is repeated for eight different engine speeds. Next the first line of the arrays to be used by RIXON2. MAPER then creates MAP1 which is engine torque as a function of throttle setting and engine speed. MAP3 which is fuel consumption as a function of engine speed and engine torque. See RIXON2 for a complete description of the make up and use of the arrays.

CONSTANTS STORED	MEANING
MAP1	Engine torque as a function of engine speed and throttle setting
MAP3	Fuel consumption as a function of engine speed and torque.

```
*                                        **** MAPER ****
      SUBROUTINE MAPER
C***** THIS SUBROUTINE READS IN THE ENGINE MAPS
      COMMON /MAPS/ MAP1,MAP3
      DIMENSION MAP1(55,17),MAP3(17,17)
      DIMENSION F(50,9)
  900 FORMAT(5X,9F7.2)
*
C----READ NEW MAPS
  910 FORMAT (9I7)
      DO 10 I=1,40,1
      READ 900,(F(I,J),J=1,9)
      PRINT 900,(F(I,J),J=1,9)
   10 CONTINUE
      DO 11 I=1,17
      DO 14 J=1,17
      MAP1(I,J)=0
   14 CONTINUE
   11 CONTINUE
       READ 910 ,(MAP1(1,K),K=1,8) , MAP1(2,1)
      OUTPUT (108) 'FIRST LINE IN ARRAY'
      PRINT 910 ,(MAP1(1,K),K=1,8) , MAP1(2,1)
      DO 20 I=3,53,1
      MAP1(I,1)=(I-3)*2
   20 CONTINUE
      DO 30 I=2,11,1
      MAP1(2,I)=I*200+400
   30 CONTINUE
      DO 40 I=2,11,1
      NN=2+(I-2)*5
      J=2
      IT=(F(NN,J-1)*F(NN+2,J)-F(NN,J)*F(NN+2,J-1))/
     1(F(NN+2,J)-F(NN+2,J-1))
      MAP1(3,I)=IT*100
   40 CONTINUE
      K=3
      DO 100 N=2,100,2
      K=K+1
      L=1
      DO 90 I=4,39,5
      L=L+1
      DO 50 J=2,9,1
      TS=F(I,J)/0.8093
   61 IF(TS-N)610,60,70
  610 IF (N .EQ. 100 .AND. J .EQ. 9) GOTO 70
      GOTO 50
   60 TOR=F(I-2,J)*100
      MAP1(K,L)=TOR
      GO TO 90
   70 TOR=100*(F(I-2,J-1)+(F(I-2,J)-F(I-2,J-1))*((N*80.930/100-
     1F(I,J-1))/(F(I,J)-F(I,J-1))))
      MAP1(K,L)=TOR
      GO TO 90
```

```
      50 CONTINUE
      90 CONTINUE
     100 CONTINUE
          READ 910 ,(MAP3(1,K),K=1,8) , MAP3(2,1)
         PRINT 910 ,(MAP3(1,K),K=1,8),MAP3(2,1)
         I=3
         DO 210 IT=-50,950,100
         MAP3(I,1)=IT
         I=I+1
     210 CONTINUE
         DO 310 I=2,11,1
         MAP3(2,I)=I*200+400
     310 CONTINUE
         K=1
         DO 54 N=0,9,1
         K=K+1
         M=1
         J=2
         DO 52 I=-50,950,100
         J=J+1
         IF(I-F(2+N*5,M)) 39,49,59
      39 MAP3(J,K)=F(3+N*5,1)*100
         GO TO 52
      49 MAP3(J,K)=F(3+N*5,M)*100
         GO TO 52
      59 IF(I-F(2+N*5,M+1)) 65,65,66
      66 M=M+1
         IF(M-9) 59,55,55
      55 MAP3(J,K)=F(3+N*5,9)*100
         M=M-1
         GO TO 52
      65 MAP3(J,K)=(F(3+N*5,M)-((F(3+N*5,M)-F(3+N*5,M+1))*(I-F(2+N*5,M))
        1/(F(2+N*5,M+1)-F(2+N*5,M))))*100
      52 CONTINUE
      54 CONTINUE
         PRINT 502
     502 FORMAT(/,18HMAP1-ENGINE TORQUE,/)
         DO 130 I=1,53,1
         ISIZEY=9
         PRINT 500,(MAP1(I,J),J=1,ISIZEY)
     130 CONTINUE
C        PRINT 503
     503 FORMAT(/,20HMAP2-MANIFOLD VACUUM,/)
C        DO 131 I=1,13,1
C        PRINT 500,(MAP2(I,J),J=1,11)
C    131 CONTINUE
         PRINT 504
     504 FORMAT(/,14HMAP3-FUEL RATE,/)
         DO 132 I=1,13,1
         PRINT 500,(MAP3(I,J),J=1,ISIZEY)
     132 CONTINUE
     500 FORMAT(11I7)
         RETURN
         END
```

3.3.14 Subroutine to Output Constants - OUTCON

SUBROUTINE NAME: OUTCON

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine outputs constants describing the current computer run as the first record on the record of performance data file.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

```
*                                **** OUTCON ****
        SUBROUTINE OUTCON
C***** USED TO OUTPUT TO THE TAPE DRIVE CONSTANTS THAT ARE RELAVENT
        CONTINUE
        RETURN
        END
```

3.3.15 <u>Subroutine to Output During Execution - OUTPUT</u>

SUBROUTINE NAME: OUTPUT

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine prints out information during the execution of the all-digital program. It skips to the top of the page and prints new titles after fifty lines have been printed on one page.

EQUATIONS:

1) Brake specific fuel consumption

   FC = FR/HP

2) Fuel consumption in miles/hour

   FMPG – V * FW/TFC

3) Torque converter efficiency

   $N_{CO} * T_{CO}/(N_E * T_E)$

INPUT VARIABLES: S/L

OUTPUT VARIABLES: None

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

```
*                                 **** OUTPUT ****
      SUBROUTINE OUTPUT (NLINE,PA0FR,0BHP,VV0S,FUELE,
     C  VV0A,TIME,VVMA,PA0N,SSTURQ,TAI1SR,TA01TR,T001EF,
     C T911,T001GI,TA0N,TA0C,PA0C,VV0D)
C***** OUTPUTS INFORMATION TO THE LINE PRINTER DURING EXECUTION
      COMMON /COMMENT/ COMM(26)
      COMMON /GAS/ FUELWT
      COMMON /PRNT/ IOUT,IPRNT,LOADEQ,MAXLIN
C---- SUBROUTINE TO OUTPUT DURING EXECUTION
C---- R.R.RADTKE 3/5/74
   90 FORMAT(1H1,20X,13A6,/,21X,13A6)
  102 FORMAT(/, 9X,21H------VEHICLE--------,2X,20H-------ENGINE-------,
     12X,21H------FUEL RATE------,2X,6HACCUMU,2X,19H--TORQUE CONVERTOR-
     2,2X,12H-DRIVETRAIN-)
  103 FORMAT (3X,4HTIME,2X,21HDIST.  SPEED   ACCEL.,2X,19HSPEED  TORQUE
     1POWER,3X,22H(LB/   *INSTANTANEOUS*,1X,6HLATIVE,2X,19HSPEED TORQUE
     2EFFIC ,2X,12H TR    RA  GE)
  104 FORMAT (2X,5H(SEC),2X,22H(MI)    (MPH) (MPH/SEC),1X,19H(RPM) (FT-LB
     1)  (HP),3X,21HHP-HR) (LB/HR)  (MPG),3X,5H(MPG),2X,18HRATIO RATIO
     2IENCY,3X,12HEFF. EFF. AR)
  105 FORMAT (1X,F7.2,F6.3,F7.2,F9.3,F8.0,F7.1,F6.1,F8.3,F8.2,F8.2,F8.2
     1,F7.3,F7.3,F6.3,F7.3,1X,F4.3,F3.0)
  106 FORMAT (1X,F7.2,F6.3,F7.2,F9.3,F8.0,F7.1,F6.1,5X,3H*  ,F8.2,F8.2
     1,F8.2,F7.3,F7.3,F6.3,F7.3,1X,F4.3,F3.0)
C***** BRAKE SPECIFIC FUEL CONSUMPTION
      BSFC=PA0FR/0BHP
C**** FUEL IN MILES PER GALLON
      FMPG=VV0S*FUELWT/PA0FR
 ***** TORQUE CONVERTER EFFICIENCY
      TCEFF=TA0N*TA0C/(PA0N*PA0C)
      FMPGC=0
      IF(FUELE)4,4,3
C***** CONTINUOUS FUEL IN MILES PER GALLON
    3 FMPGC=VV0D*FUELWT/FUELE
    4 CONTINUE
      VVMA=VV0A
      NLINE=NLINE+1
C***** CHECK TO SEE IF AT END OF PAGE
      IF(NLINE-MAXLIN)20,20,5
    5 CONTINUE
C***** IF SO OUTPUT PAGE EJECT AND PRINT HEADING
      PRINT 90,(COMM(I),I=1,26)
      PRINT 102
      PRINT 103
      PRINT 104
      IF(NLINE-MAXLIN-4)10,10,15
   10 MAXLIN=47
   15 NLINE=1
   20 CONTINUE
      IF(BSFC)80,80,70
   70 CONTINUE
      IF(BSFC-2.)73,73,80
   80 CONTINUE
```

```
      PRINT 106,TIME,VVØD,VVØS,VVMA,PAØN,SSTØRQ,ØBHP,        PAØFR,FMPG,
     1FMPGC,TAI1SR,TAØ1TR,TCEFF,TBØ1EF,T9I1,TBØ1GI
      GØ TØ 99
   73 CØNTINUF
      PRINT 105,TIME,VVØD,VVØS,VVMA,PAØN,SSTØRQ,ØBHP,BSFC,PAØFR,FMPG,
     1FMPGC,TAI1SR,TAØ1TR,TCEFF,TBØ1EF,T9I1,TBØ1GI
   99 CØNTINUE
      RETURN
      END
```

3.3.16 Tape or Disk Output Subroutine - OUTVAR

SUBROUTINE NAME: OUTVAR

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine outputs the current value of the state vector on the system output file.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES. N/A

FLOW CHART: S/L

BUS SIMULATION PROGRAM

```
*                                        **** OUTVAR ****
      SUBROUTINE OUTVAR
C***** THIS SUBROUTINE OUTPUTS TO THE TAPE DRIVE VARIABLES CHOSE
      CONTINUE
      RETURN
      END
```

3.3.17 Subroutine to Store Power Used - POWER

PROGRAM NAME: POWER

TYPE OF SUBROUTINE: Bookkeeping

DESCRIPTION: This subroutine calculates the power being used by the bus at various points.

MODELING: S/L

VARIABLES: S/L

EQUATIONS: S/L

```
      SUBROUTINE POWER(PAOC,PAON,TAON,TAOC,T9IN,T9IC,T9ON,T9OC,ACTORQ
    C    ,SSTORQ,VVOA,BFORCE,BFORCEM,
    C HPWHLM,HPRAXM,HPTRANM,HPTQCM,HPENGM
    C      ,HPWHLP,HPRAXP,HPTRANP,HPTQCP,HPENGP,HPACC)
      COMMON/TIMEI/ DT
      REAL K
      K=5252.
      ACC=ACTORQ*PAON*DT/K
      ENG=SSTORQ*PAON*DT/K
      TQC=PAON*PAOC*DT/K
       TRAN=TAOC*TAON*DT/K
      RAX=T9IN*T9IC*DT/K
      WHL=RAX*.92
      IF (SSTORQ .GE. 0.) GOTO 20
   10 CONTINUE
      HPWHLM=HPWHLM+WHL
      HPRAXM=HPRAXM+RAX
      HPTRANM=HPTRANM+TRAN
      HPTQCM=HPTQCM+TQC
      HPENGM=HPENGM+ENG
      BRAKE=BFORCE*PAON/5252.   *DT
       BFORCEM=BFORCEM+BRAKE
      GOTO 30
   20 CONTINUE
      HPWHLP=HPWHLP+WHL
      HPRAXP=HPRAXP+RAX
      HPTRANP=HPTRANP+TRAN
      HPTQCP=HPTQCP+TQC
      HPENGP=HPENGP+ENG
   30 CONTINUE
      HPACC=HPACC+ACC
      RETURN
      END
```

3.3.18 Probability Density Function - PRBDEN

SUBROUTINE NAME: PRBDEN

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the joint probability density distribution of engine speed versus steady state torque over a given driving cycle.

MODELING: This subroutine is written in generalized format so that joint probability density of any two variables can be recorded. However, it is presently used to determine the joint probability density of engine speed and torque.

The probability distribution is determined by counting the number of computational iterations the two specified variables fall within given intervals. The joint probability density is determined by JPBSUM at the end of the simulation when the number of samples within each interval is divided by the total number of samples recorded during the run. (One sample is taken during each computational iteration.)

EQUATIONS: N/A

INPUT VARIABLES:

- VAL(2) - Current engine speed
- VAL (1) - Current steady state torque
- NLT(1) - Number of samples below minimum engine speed
- NLT(2) - Number of samples below minimum torque
- NGT(1) - Number of samples above maximum engine speed
- NGT(2) - Number of samples above maximum torque
- IPDX(20,20) - New probability distribution
- VMIN(1) - Minimum torque
- VMIN(2) - Minimum engine speed

INPUT VARIABLES (CONTINUED)

VMAX(1) - Maximum torque
VMAX(2) - Maximum engine speed
VINT(1) - Size of torque interval
VINT(2) - Size of engine speed interval
INT1 - Torque index
INT2 - Engine speed index
S/L

```
 *                               **** PRODEN ****
C---- SUBROUTINE TO CALCULATE THE JOINT PROBABILITY DENSITY OF TWO VARIAB
C---- DAN KAPELLEN 2/74
      SUBROUTINE PRODEN (VAL1,VAL2,NLT,NGT,IPDX)
      COMMON /CRBSCWR/ VMIN(2),VMAX(2),VINT(2),NDIM(2)
      DIMENSION IPDX(20,20)
      DIMENSION NLT(2),NGT(2)
C**********************************************************************
C---- THIS SUBROUTINE CALCULATES THE JOINT PROBABILITY DENSITY OF TWO
C---- SPECIFIED FUNCTIONS DURING THE DRIVING CYCLE.  THE PROGRAM
C---- VARIABLES ARE AS FOLLOWS,
C------------------INPUT VARIABLES-------------------------------------
C---- VAL1   ----CURRENT VALUE OF FIRST SPECIFIED VARIABLE.
C-----VAL2   ----CURRENT VALUE OF SECOND SPECIFIED VARIABLE.
C------------------OUPUT VARIABLES-------------------------------------
C---- NLT(I)---NUMBER OF SAMPLES BELOW SPECIFIED MINIMUM FOR EACH VARIABL
C---- NGT(I)---NUMBER OF SAMPLES ABOVE SPECIFIED MAXIMUM FOR EACH VARIABL
C---- IPDX(I,J)-INTEGER TABLE OF PROBABILITY DENSITY DISTRIBUTION.
C------------------OTHER PROGRAM VARIABLES-----------------------------
C---- VMIN(I)--SPECIFIED MINIMUM FOR EACH VARIABLE.
C---- VMAX(I)--SPECIFIED MAXIMUM FOR EACH VARIABLE.
C---- VINT(I)--SPECIFIED INTERVAL LENGTH FOR EACH VARIABLE.
C---- INT1----TABLE INDEX FOR FIRST VARIABLE.
C---- INT2----TABLE INDEX FOR SECOND VARIABLE.
C---- THE JOINT PROBABILITY DENSITY IS DETERMINED AS A PERCENTAGE AT THE
C---- END OF THE CYCLE IN JPBSUM.
C**********************************************************************
C---- DETERMINE IF VALUE OF VARIABLES FALL BELOW THEIR SPECIFIED MINIMUM.
      IF(VAL1  -VMIN(1))131,132,132
  132 IF(VAL1  -VMAX(1))135,135,134
  131 NLT(1)=NLT(1)+1
      GO TO 135
  134 NGT(1)=NGT(1)+1
      GO TO 135
C---- DETERMINE IF THE VALUE OF THE VARIABLES FALL ABOVE THEIR SPECIFIED
  135 IF(VAL2  -VMIN(2))136,137,137
  137 IF(VAL2  -VMAX(2))140,140,138
  136 NLT(2)=NLT(2)+1
      RETURN
  138 NGT(2)=NGT(2)+1
      RETURN
C---- DETERMINE THE TABLE INDICES FOR EACH OF THE VARIABLES AS DETERMINED
C---- BY THE INTERVAL IN WHICH THE VALUES FALL.
  140 INT1=(VAL1  -VMIN(1))/VINT(1)+1.
      INT2=(VAL2  -VMIN(2))/VINT(2)+1.
C---- UPDATE THE PROPER ARRAY ELMENT IN THE TABLE.
      IPDX(INT1,INT2)=IPDX(INT1,INT2)+1
      RETURN
      END
```

3.3.19 Subroutine to Print Constants - PRTCON

SUBROUTINE NAME: PRTCON

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine skips to the top of the page and prints out the constants defining the car being simulated.

EQUATION: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

```
*                                          **** PRTCON ****
C-----DAN KAPELLEN 4/30/74
**************************************************************************************
      SUBROUTINE PRTCON
      COMMON /AIR/ AVIE,AVIR,AVIO,AVIS,AVIM
      COMMON /AKCESS/ ACLOAD(10),PIDLMIN,PIDLMAX
       COMMON /BGEAR/ BGRTIO
      COMMON /COMMENT/ COMM(26)
      COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
      COMMON /DSSPD/ T8INV(32)
      COMMON /ENGIN/SCALEF,TIDLE,EVS,TS
      COMMON /EPASH/ VCRUS,ACEL,DECEL, TDWELL
      COMMON /GAS/ FUELWT
      COMMON /GEAREF/ TBC1GI(10,4),IBC1GI(10)
      COMMON /INERTIA/ RIE,RIEINV
      COMMON /LOCK1/ ACCLOCK,DECLOCK
      COMMON /MASS/ VVILFR,VVI1CD,VVI1RF,VVIMI,VVI2BR,VVIM,VVIMDR,
     C              VVISWB,VVISH,VVIAMX,VVIAS
      COMMON /PMOMENT/ TVIJCT,TVIJTR,TVIJRA ,TVIJTW
      COMMON /PRNT/ IOUT,IPRNT,LOADEQ,MAXLIN
      COMMON /RDLD/ TVICRL(16)
      COMMON/RGRTIO/ T8I1GR
      COMMON /SFTIME/ TBDTMS,TBDTH
      COMMON /STOPPER/NSTOP
      COMMON /SHIFTER/ GRMAX(3),GRMIN(3),GRMAXCR(3)
      COMMON /TGRTIO/ TBC1GR(10),GR1
      COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
      COMMON/TIMEI/ DT
      COMMON /TORCCON/ TAI3KP
      COMMON/TQC/ ARAY(20,3)
    1 FORMAT (1H1     ,41X,38HVEHICLE PARAMETERS USED FOR SIMULATION )
    3 FORMAT(21X,13A6,/,21X,13A6)
    4 FORMAT(    120H ************************************************************
     1***************************************************************************
     2**)
    5 FORMAT (42X,1H*,27X,1H*,48X,1H*)
    6 FORMAT (1X,40H---------VEHICLE CHARACTERISTICS---------,1X,1H*,2X,
     123H---TORQUE CONVERTOR----,2X,1H*,2X,44H----------------TRANSMISS
     229N----------------,2X,1H*)
    7 FORMAT (1X,15HREAR AXLE RATIO,16X,F7.2,3X,1H*,2X,23HSPEED   TORQUE
     1    1/K**2,2X,1H*,2X,44HGEAR RATIOS                     SCHEDULE
     2 ,2X,1H*)
    8 FORMAT (1X, 9HMASS (LB),20X,F8.1,4X,1H*,2X,24HRATIO    RATIO   (10
     1*-4),2H *, 15X,29H                                ,4X,1H*)
    9 FORMAT (1X,25HMASS ON DRIVE WHEELS (LB),4X,F8.1,4X,1H*,27X,1H*,15X
     C , 33H                                 ,1H* )
   10 FORMAT (1X,20HFRONTAL AREA (SQ FT),11X,F6.1,4X,1H*,25X,9H  *    1ST
     1,F6.3,36X,          1H*)
   11 FORMAT (1X,31HCOEFFICIENT OF ROLLING FRICTION,F9.4,33X,3H2ND,F6.3
     1      ,5X,15HLOCKUP AT           ,2X,F5.1,2X,3HMPH)
   12 FORMAT (1X,16HDRAG COEFFICIENT,15X,F8.3,34X,3H3RD,F6.3
     C   , 5X,15HUNLOCK AT         ,2X,F5.1,2X,3HMPH)
   13 FORMAT (1H+,41X,1H*,F7.3,F9.3,F9.4,3H  *,48X,1H*)
```

```
      14 FØRMAT (1X,23HTIRE STATIC RADIUS (FT),8X,F8.3,34X,3H4TH,F6.3
     C ,5X,15HUPSHIFT 1-2       ,2X,F5.0,2X,3HRPM)
      15 FØRMAT (1X,26HENGINE INERTIA (LBM-FT**2),5X,F7.2,35X,3H5TH,F6.3
     C ,5X,15HUPSHIFT 2-3       ,2X,F5.0,2X,3HRPM)
      16 FØRMAT (1X,25HTC. CØNV. TURBINE INERTIA,6X,F7.2,35X,3H6TH,F6.3
     C ,5X,15HDØWNSHIFT 3-2    ,2X,F5.0,2X,3HRPM)
      17 FØRMAT (1X,31HTRANSMISSIØN INERTIA (3RD GEAR),F7.2,35X,5HBEVEL
     C,F4.2  ,5X,15HDØWNSHIFT 2-1    ,2X,F5.0,2X,3HRPM)
      18 FØRMAT (1X,17HREAR AXLE INERTIA,14X,F7.2)
      19 FØRMAT (1X,23HINERTIA ØF DRIVE WHEELS,8X,F7.2)
      20 FØRMAT (1X,26HSTATIC TIRE FRICTIØN CØEF.,5X,F7.2)
      21 FØRMAT (1X,28HSLIPPING TIRE FRICTIØN CØEF.,3X,F7.2)
      22 FØRMAT (1X,15HWHEEL BASE (IN),16X,F7.2)
      23 FØRMAT (1X,29HCENTER ØF GRAVITY HEIGHT (IN),2X,F7.2)
      24 FØRMAT (1X,21HIDLE THRØTTLE SETTING,10X,F7.2)
      26 FØRMAT (1X,28HDELAY TIME AFTER SHIFT (SEC),3X,F7.2)
      25 FØRMAT (1X,29HTRANSMISSIØN SHIFT TIME (SEC),2X,F7.2)
      27 FØRMAT (1X,23HAMBIENT TEMPERATURE (F),8X,F6.1)
      28 FØRMAT (1X,25HBARØMETRIC PRESSURE (PSI),6X,F9.4)
      29 FØRMAT (1X,22HAIR DENSITY (LB/CU FT),9X,F9.4)
      30 FØRMAT (1X,19HENGINE SCALE FACTØR,12X,F8.3)
      31 FØRMAT (1H ,21HFUEL DENSITY (LB/GAL),10X,F7.2,80X,1H*)
      32 FØRMAT (42X,1H*,F7.3,F9.3,F9.4,3H  *)
      33 FØRMAT (1H ,42H******************************************,28X,49H*
     1************************************************)
      34 FØRMAT (1H ,41X,1H*,27X,1H*,3X,20HDRIVESHAFT RØAD LØAD,3H  *
     C ,22X,1H*)
      35 FØRMAT (1H ,9X,19H--TIRE EXPANSIØN---,13X,1H*,27X,1H*,3X,20H----TØ
     CRQUE TABLE----  ,2X,1H*,22X,1H*)
      36 FØRMAT (1H ,9X,19HVEHICLE  DRIVESHAFT,13X,1H*,27X,1H*,3X,
     C 25HVEHICLE   RØAD LØAD    *  ,20X,1H*)
      37 FØRMAT (1H ,9X,19H SPEED    SPEED(RPM),13X,1H*,27X,1H*,5X,
     C  5HSPEED,5X,6HTØRQUE,4X,1H*,22X,1H*)
      38 FØRMAT (1H ,9X,F6.1,5X,F6.1,15X,1H*,27X,1H*,4X,F6.1,5X,F5.1,5X,
     C 1H*,22X,1H*)
      39 FØRMAT (1H ,73X,18HTHIS TABLE IS USED,3X,1H*,22X,1H*)
      40 FØRMAT (1H ,41X,1H*,27X,1H*,1X,24HRD LØAD EQUATIØN IS USED,1H*
     C  ,22X,1H*)
      41 FØRMAT (1H ,42H *****************************************,28X,26H*
     1*************************  )
      43 FØRMAT (1H+,95X,1H*)
      50 FØRMAT (1H+,44X,12HDRIVE CYCLE     )
      51 FØRMAT (1H+,44X,12HSTØPS/MILE  ,2X,I4)
      52 FØRMAT(1H+,44X,12HMAX. ACCEL.  ,2X,F4.1,1X,6HMPHPS  )
      53 FØRMAT (1H+,44X,12HDECELERATIØN  ,2X,F4.1,1X,6HMPHRPS  )
      54 FØRMAT (1H+,44X,12HCRUISE SPEED,2X,F4.1,1X,6HMPH      )
         PRINT 1
         PRINT 3, (CØMM(I),I=1,26)
         PRINT 4
         PRINT 6
         PRINT 5
         PRINT 7,T8I1GR
         PRINT 8,VVIM
```

```
      PRINT 9,VVIMDR
      MV=1
      MP=MV-1
      PRINT 10,VVILFR,TBC1GR(1)
      I=1
      TR=AWAY(I,2)
      SR=AWAY(I,1)
      SF=AWAY(I,3)*10000.
      PRINT 11,VVI1RF,TBC1GR(2),ACCLOCK
      MV=2
      MP=MV-1
      PRINT 13,SR,TR,SF
      PRINT 12,VVI1CD,TBC1GR(3),DECLOCK
      ASSIGN 81 TO ISTATE
   70 CONTINUE
      GO TO 72
   71 CONTINUE
   72 CONTINUE
      MV=MV+1
      MP=MV-1
      I=I+1
      SR=AWAY(I,1)
      TR=AWAY(I,2)
      SF=AWAY(I,3)*10000.
      PRINT 13,SR,TR,SF
      GO TO ISTATE
   81 CONTINUE
      PRINT 14,VVIDRR,TBC1GR(4),GRMAX(1)
      ASSIGN 82 TO ISTATE
      GO TO 70
   82 CONTINUE
      PRINT 15,RIE,TBC1GR(5),GRMAX(2)
      ASSIGN 83 TO ISTATE
      GO TO 70
   83 CONTINUE
      PRINT 16,TVIJCT,TBC1GR(6),GRMIN(3)
      ASSIGN 84 TO ISTATE
      GO TO 70
   84 CONTINUE
      PRINT 17,TVIJTR,BGRTIO,GRMIN(2)
      ASSIGN 85 TO ISTATE
      GO TO 70
   85 CONTINUE
      PRINT 18,TVIJRA
      ASSIGN 86 TO ISTATE
      GO TO 70
   86 CONTINUE
      PRINT 19,TVIJTW
      ASSIGN 87 TO ISTATE
      GO TO 71
   87 CONTINUE
      PRINT 20, VVIFUM
      ASSIGN 88 TO ISTATE
```

```
      GO TO 71
   88 CONTINUE
      PRINT 21,VVIFUS
      ASSIGN 89 TO ISTATE
      GO TO 71
   89 CONTINUE
      PRINT 22,VVISWB
      ASSIGN 90 TO ISTATE
      GO TO 71
   90 CONTINUE
      PRINT 23,VVISH
      ASSIGN 91 TO ISTATE
      GO TO 71
   91 CONTINUE
      PRINT 24,TIDLE
      ASSIGN 92 TO ISTATE
      GO TO 71
   92 CONTINUE
      TST=DT*TBDTMS
      PRINT 25,TST
      ASSIGN 93 TO ISTATE
      GO TO 71
   93 CONTINUE
      TAS=DT*TBDTH
      PRINT 26,TAS
      ASSIGN 94 TO ISTATE
      GO TO 71
   94 CONTINUE
      PRINT 27,AVIR
      ASSIGN 95 TO ISTATE
      GO TO 71
   95 CONTINUE
      PRINT 28,AVIB
      ASSIGN 96 TO ISTATE
      GO TO 71
   96 CONTINUE
      PRINT 29, AVIM
      ASSIGN 97 TO ISTATE
      GO TO 71
   97 CONTINUE
      PRINT 30,SCALEF
      ASSIGN 98 TO ISTATE
      GO TO 71
   98 CONTINUE
      PRINT 31,FUELWT
      ASSIGN 99 TO ISTATE
      GO TO 71
   99 CONTINUE
      ASSIGN 100 TO ISTATE
      GO TO 74
   73 CONTINUE
      GO TO 75
   74 CONTINUE
```

```
   75 CONTINUE
      I=I+1
      SR=AWAY(I,1)
      TR=AWAY(I,2)
      SF=AWAY(I,3)
C     PRINT 32,SR,TR,SF
      GO TO ISTATE
  100 CONTINUE
      PRINT 4
      ASSIGN 101 TO ISTATE
      GO TO 74
  101 CONTINUE
      PRINT 43
      ASSIGN 1001 TO ISTATE
      GO TO 74
 1001 CONTINUE
      PRINT 34
      ASSIGN 102 TO ISTATE
      GO TO 74
  102 CONTINUE
      PRINT 35
      ASSIGN 103 TO ISTATE
      GO TO 74
  103 CONTINUE
      PRINT 43
      ASSIGN 1002 TO ISTATE
      GO TO 74
 1002 CONTINUE
      PRINT 36
      PRINT 50
      ASSIGN 104 TO ISTATE
      GO TO 74
  104 CONTINUE
      PRINT 37
      PRINT 51,NSTOP
      ASSIGN 105 TO ISTATE
      GO TO 74
  105 CONTINUE
      PRINT 43
      DO 60 K=1,11
      V=10*(K-1)
      I=I+1
      SR=AWAY(I,1)
      TR=AWAY(I,2)
      SF=AWAY(I,3)
C     PRINT 32,SR,TR,SF
      PRINT 38,V,TOINV(K),V,TVICRL(K)
      IF (K .EQ.1) CONTINUE;
     CPRINT 52,ACEL
      IF (K .EQ. 2) PRINT 53,DECEL
      IF (K .EQ. 3) PRINT 54,VCRUS
   60 CONTINUE
      ASSIGN 107 TO ISTATE
```

```
      GO TO 74
  107 CONTINUE
      PRINT 43
      ASSIGN 108 TO ISTATE
      GO TO 74
  108 CONTINUE
      IF(LOADEQ) 61,61,62
   61 CONTINUE
      PRINT 39
      GO TO 63
   62 CONTINUE
      PRINT 40
   63 CONTINUE
      ASSIGN 109 TO ISTATE
      GO TO 74
  109 CONTINUE
      PRINT 4
   64 CONTINUE
C-----GO TO TOP OF NEXT PAGE
  909 FORMAT (1H1)
      RETURN
      END
```

3.3.20 Storage and System Computation - RDEPA, EPACALC, EPAVEL

PROGRAM NAMES: RDEPA, EPACALC

TYPE OF SUBROUTINE: Storage and System Computation

DESCRIPTION: RDEPA reads a bus cycle which includes rate of acceleration, velocity of cruise, rate of deceleration, number of stops in cycle, distance of cycle and dwell time of stop. EPACALC calculates the driving cycle velocities at one second intervals. RDEPA then stores them. EPAVEL retrieves the appropriate velocity as a function of time and supplies it to the automatic driver. See Figure 12.

MODELING: Bus cycle velocities are generalized to have four phases, acceleration, cruise, deceleration,and dwell. PEACALC determines the velocity as a function of time and the phase of the cycle.

These cycle velocities are stored in a one dimensional array.

Since they are specified at one second intervals of time, their array location also specifies the cycle time. RDEPA stores two cycle points per word to save core space. This is the reason the velocity array is only dimensioned at 685 words instead of 1370 as would be required for the EPACVS cycle if one point per word was stored.

EPAVEL determines the next cycle point based on time and unpacks the required velocity from the two points per work storage. EPAVEL also prevents Δt from becoming less than a specified value. The next cycle velocity and Δt are returned for use in the automatic drive. See Figure 13.

Any cycle with less than 1370 points at one second intervals can be used.

SUBROUTINE RDEPA

CONSTANTS READ IN:

Name	Symbol	Description
ACEL		Rate of acceleration (mph/sec)
VCRUS		Cruise velocity
DECEL		Rate of deceleration (mph/sec)
NSTOP		Number of stops per route
RTLNGT		Route length
TDWELL		Dwell time at stop

VARIABLES USED:

TA	TA	Time acceleration stops
TC	TC	Time cruising stops
TD	TD	Time deceleration stops
DTD		Time spend deceleration
TE	TE	Time of one cycle
DLNGTH		Distance traveled during one cycle
ITEML, KPLACE, NUEL, KREM		Variables used to pack array

EQUATIONS:

$$TA = VCRUS/ACEL$$

$$DTD = VCRUS/DECEL$$

$$TC = (3600. * DLNGTH - .5\ (DTD^2 DECEL + TA^2 * ACEL))/VCRUS + TA$$

$$TD = TC + DTD$$

$$TE = TD + TDWELL$$

CONSTANTS STORED:

IVEPA (I)	Array holding target velocity
NVEPA	Length of run (sec)

SUBROUTINE EPACALC

INPUT VARIABLES:

TA	Time acceleration stops
TC	Time cruising stops
TD	Time decelerating stops
TUTIME	Present time interval

OUTPUT VARIABLES:

RVEL	Target velocity at time Tutime

SUBROUTINE EPAVEL

INPUT VARIABLES:

Program Name	Symbol	Description
TIME	t	Time from start of driving

OUTPUT VARIABLES:

VEPA	V_p	Next required cycle velocity
DELT	Δ_t	Time difference between next cycle point and current time.
ICYEND		Used as a flag to indicate the end of the cycle.

OTHER PROGRAM VARIABLES:

ITEM2 KPLACE KREM, ITEM1, IVEL	Variables used to unpack two cycle velocities per word of core.

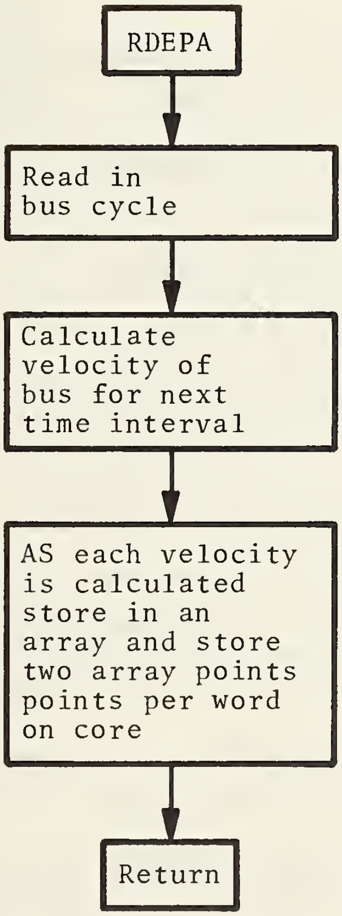


FIGURE 12. RDEPA FLOW DIAGRAM

```
*                                      **** RDEPA ****
      SUBROUTINE RDEPA
*
*   17 NOV 1976
*     READS IN EPA DATA
*
      COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
*     ACEL-ACCELERATION(MPH/SEC)
C     VCRUS-CRUISING VELOCITY
C     DECEL-DECELERATION FT/SEC**2
C     NSTOP-NUMBER OF STOPS
C     RTLNGT-ROUTE LENGTH(MILES)
C     CALCULATES
C     TA TIME ACCELERATION STOPS
C     TC TIME CRUISING STOPS
C     TD TIME DECELERATING STOPS
*     TDWELL-TIME AT THE BUS STOP
*     TE-TIME FOR ONE CYCLE  =TIDLE+TD
*     DLNGTH-LENGTH OF EACH CYCLE(MILES)
*
      COMMON /EPASH/ VCRUS,ACEL,DECEL, TDWELL
      COMMON /STOPPER/NSTOP
*
  100 FORMAT(3F8.3,I8,2F8.3)
  990 FORMAT(17HEPA DATA FOLLOWS )
 1000 FORMAT(X,5HACEL=,F5.2,2X,7H DECEL=,F5.2,2X,6HVCRUS=,F5.2,2X
     1 6HNSTOP=,I2,2X,7HRTLNGT=,F5.2,2X,7HTDWELL=,F5.2)
 1005 FORMAT(3HTA=,F7.3,2X,3HTC=,F7.3,2X,3HTD=,F7.3,2X,3HTE=,F7.3
     1 4HDTD=,F6.3)
 1010 FORMAT(X,13(I7,2X),I7)
 1015 FORMAT(6HNVEPA=,I5)
 1020 FORMAT(12HEND EPA DATA)
*
C***** READ IN CYCLE INFORMATION
      READ 100,ACEL,VCRUS, DECEL,NSTOP,RTLNGT,TDWELL
      PRINT 990
      PRINT 1000,ACEL,DECEL,VCRUS,NSTOP,RTLNGT, TDWELL
      DLNGTH = RTLNGT/FLOAT(NSTOP)
      TA=VCRUS/ACEL
      DTD=VCRUS/DECEL
      TC = 0.5*(DTD*DTD*DECEL + TA*TA*ACEL)
      TC = (3600.0*DLNGTH -TC)/VCRUS + TA
      TD=TC+DTD
      TE = TD + TDWELL
      PRINT 1005,TA,TC,TD,TE,DTD
      RVEL = 0.0
      PTIME = 0.0
      DO 5 I = 1,685
          IVEPA(I) = 0
    5 CONTINUE
*
      DO 32 I = 1,NSTOP
      TR = FLOAT(I)*TE
```

```
      TU = TR - TE
   10 CONTINUE
      PTIME = PTIME + 1.0
      TUTIME = PTIME - TU
      CALL EPACALC(RVEL,TUTIME,TA,TC,TD)
      NVEL=RVEL*10.
      IPTIME = PTIME
      KPLACE = IPTIME/2
      KREM = IPTIME - 2*KPLACE
      IF(KREM) 40,40,20
   40 CONTINUE
      IVEPA(KPLACE)=NVEL*4096+ITEMP1
      GOTO 30
   20 CONTINUE
      ITEMP1=NVEL
   30 CONTINUE
      IF(PTIME + 1.0 .GE. TR) GO TO 32
      GO TO 10
   32 CONTINUE
*
      IF(KREM) 34,34,33
   33 CONTINUE
      IVEPA(KPLACE) = ITEMP1
   34 CONTINUE
      N = PTIME + 1.0
      NN = 0.5*N
      PRINT 1015,NN
      K = 0
      DO 60 J = 1,NN,14
         K = K + 14
         IF(K - NN) 55,55,50
   50    K = NN
   55    PRINT 1010,(IVEPA(I),I=J,K)
   60    CONTINUE
      PRINT 1020
      NVEPA=NSTOP*TE
      RETURN
      END
```

```
*                                     **** EPACALC ****
        SUBROUTINE EPACALC(RVEL,TUTIME,TA,TC,TD)
*
*  17 NOV 1976
C**** RETURNS THE VELOCITY THE VEHICLE MUST REACH IN T+1 SEC.
C**** INPUT FROM RDEPA IN COMMON IS VCRUS-CRUISING SPEED
C**** ACEL-ACCELERATION
C**** DECEL-DECELERATION
C**** TA-TIME THE ACCELERATION CYCLE ENDS
C**** TC-TIME THE CRUISING CYCLE ENDS
C**** TD TIME THE DECELERATION CYCLE ENDS
*       TIDLE-TIME AT BUS STOP
*       TE-TIME FOR ONE CYCLE  =TD + TIDLE
*       TUTIME = PTIME - TU FROM RDEPA
C
        COMMON /EPASH/ VCRUS,ACEL,DECEL, TDWELL
*
        IF(TUTIME-TA) 10,20,20
     20 IF(TUTIME-TC) 30,40,40
     40 IF(TUTIME-TD) 50,60,60
C**** ACCELERATING
     10 RVEL=RVEL+ACEL
        GOTO 90
C**** LETS CRUISE
     30 RVEL=VCRUS
        GOTO 90
C**** DECELERATE
     50 CONTINUE
        RVEL=RVEL-DECEL
        IF(RVEL) 60,90,90
C**** STOP THE BUS
     60 CONTINUE
        RVEL=0
     90 CONTINUE
        NVEL=RVEL*10.0
        RETURN
        END
```

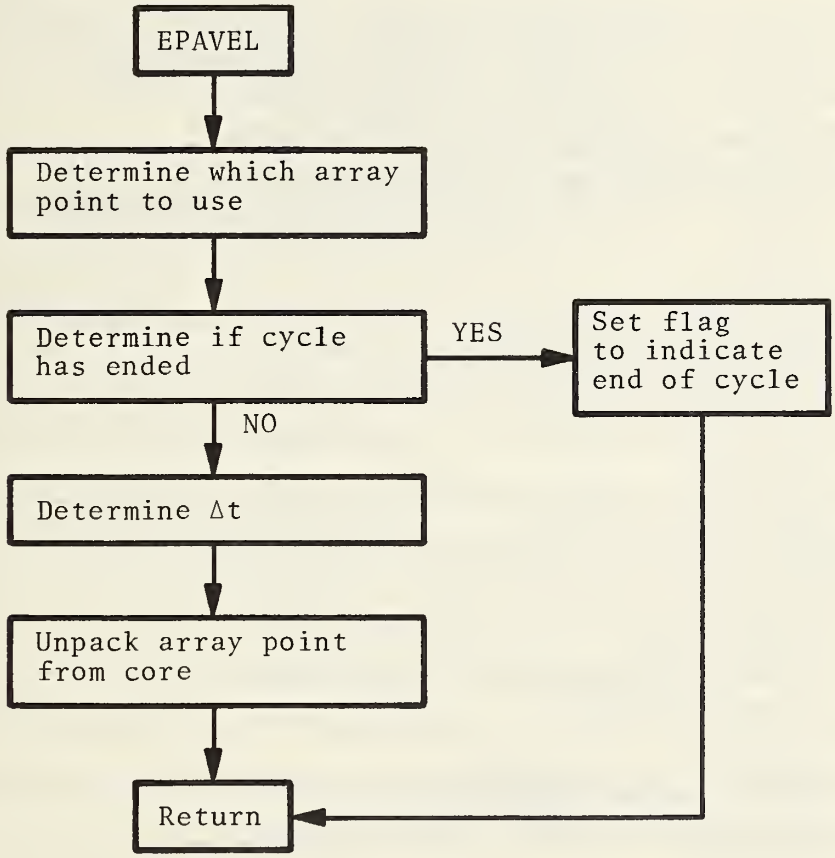


FIGURE 13. EPAVEL FLOW DIAGRAM

```
*                                        **** EPAVEL ****
      SUBROUTINE  EPAVEL (TIME,VEPA,ICYEND,DELT)
C***** RETURNS VEPA AND DELT AND ICYEND
C***** VEPA THE NEXT CYCLE TARGET VELOCITY
C***** DELT THE AMOUNT OF TIME TO REACH THE CYCLE VELOCITY
C***** ICYEND FLAG TO INDICATE THE END OF THE RUN
      COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
      I=TIME
      II=I+1
   16 CONTINUE
      DELT=FLOAT(II)-TIME
      IF(DELT-DELMIN)15,10,10
   15 II=II+1
      IF(II-NVEPA)7,7,6
    6 CONTINUE
      II=NVEPA
      ICYEND=1
      GO TO 10
    7 CONTINUE
      GO TO 16
   10 CONTINUE
      KPLACE=II/2
      KREM=II-2*KPLACE
      IF(KREM)35,35,30
   30 CONTINUE
      ITEMP1=IVEPA(KPLACE+1)
      ITEMP2=(ITEMP1/4096)*4096
      IVEL=ITEMP1-ITEMP2
      GO TO 40
   35 CONTINUE
      ITEMP1=IVEPA(KPLACE)
      IVEL=ITEMP1/4096
   40 CONTINUE
      VEPA=IVEL/10.
      RETURN
      END
```

3.3.21 Rear Axle Efficiency - RAEFF

PROGRAM NAME: RAEFF

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the rear axle efficiency as a function of driveshaft torque and speed. It returns the rear axle output torque for use in the vehicle dynamics subroutine (VEDYN).

MODELING: This model is basically similar to the transmission efficiency model (see TREFF) except for the manner in which the data were curve fit.

A plot of the efficiency curves as a function of torque at constant speed is given by Figure14. Since all values for efficiency are between 0.9 and 1.00, each data point is modeled as 0.0 plus a change $\Delta\eta$.

$$n = 0.90 + \Delta\eta$$

The $\Delta\eta$ is calculated using a second degree polynomial as a function of driveshaft speed.

$$\eta = 0.90 + C_1 + C_2 N_{DS} + C_3 N_{DS}$$

The three coefficients, C_1, C_2, C_3, are modeled over the torque range using polynomial fits up to degree 6. The resulting curve fit is a three-dimensional surface as shown in Fig.15.

When the driveshaft torque falls below the lower boundary to which the curve fit can be reasonably extended based on available data, the efficiency is exponentially interpolated between the efficiency at the boundary for the given speed and zero (Eqs. 2 and 3). If the driveshaft torque is beyond the range to which the curve fit can be reasonably extended, the efficiency is assumed to be the same as that at the boundary. Since the latter case happens very seldom, the sole purpose of the provision is to prevent incongruities in the program if it does occur.

A table of rear axle efficiencies generated by the program is presented in Fig.16.

It may be noted from the flow and block diagrams in Figs. 17 and 18 that the driveshaft torque can be changed a number of times in this subroutine. These are for purposes of calculating the efficiency only, and the original value of driveshaft torque is restored at the end of the program through use of a dummy variable.

EQUATIONS:

1) $\eta_{RA} = f(N_{DS}, T_{DS})$

For driveshaft torques below range of $f(N_{DS}, T_{DS})$,

2) $K = \dfrac{\ln(1.-\eta_{RA_L})}{T_{DS_L}}$

3) $\eta RA = 1. - \exp(K \cdot T_{DS})$

4) $T_{RA} = T_{DS} \cdot \eta_{RA} \cdot CR_{RA}$

INPUT VARIABLES:

Program Name	Symbol	Description
T9IN	N_{DS}	Driveshaft speed
T9IC	T_{DS}	Driveshaft torque
T9I1GR	GR_{RA}	Rear axle ratio equivalent

OUTPUT VARIABLES:

T9I1	η_{RA}	Rear axle efficiency
T9OC	T_{RA}	Rear axle output torque

VARIABLES WHICH MUST BE STORED IN MEMORY

None

OTHER PROGRAM VARIABLES:

T9DC	T_{DS_D}	Dummy driveshaft torque variable
T9DN	N_{DS_D}	Dummy driveshaft speed variable
T9DCL	T_{DS_L}	Torque at lower boundary of data
T9DCU	T_{DS_U}	Torque at upper boundary of data
INTERP	FLAG	Flag set to determine if interpolation is necessary

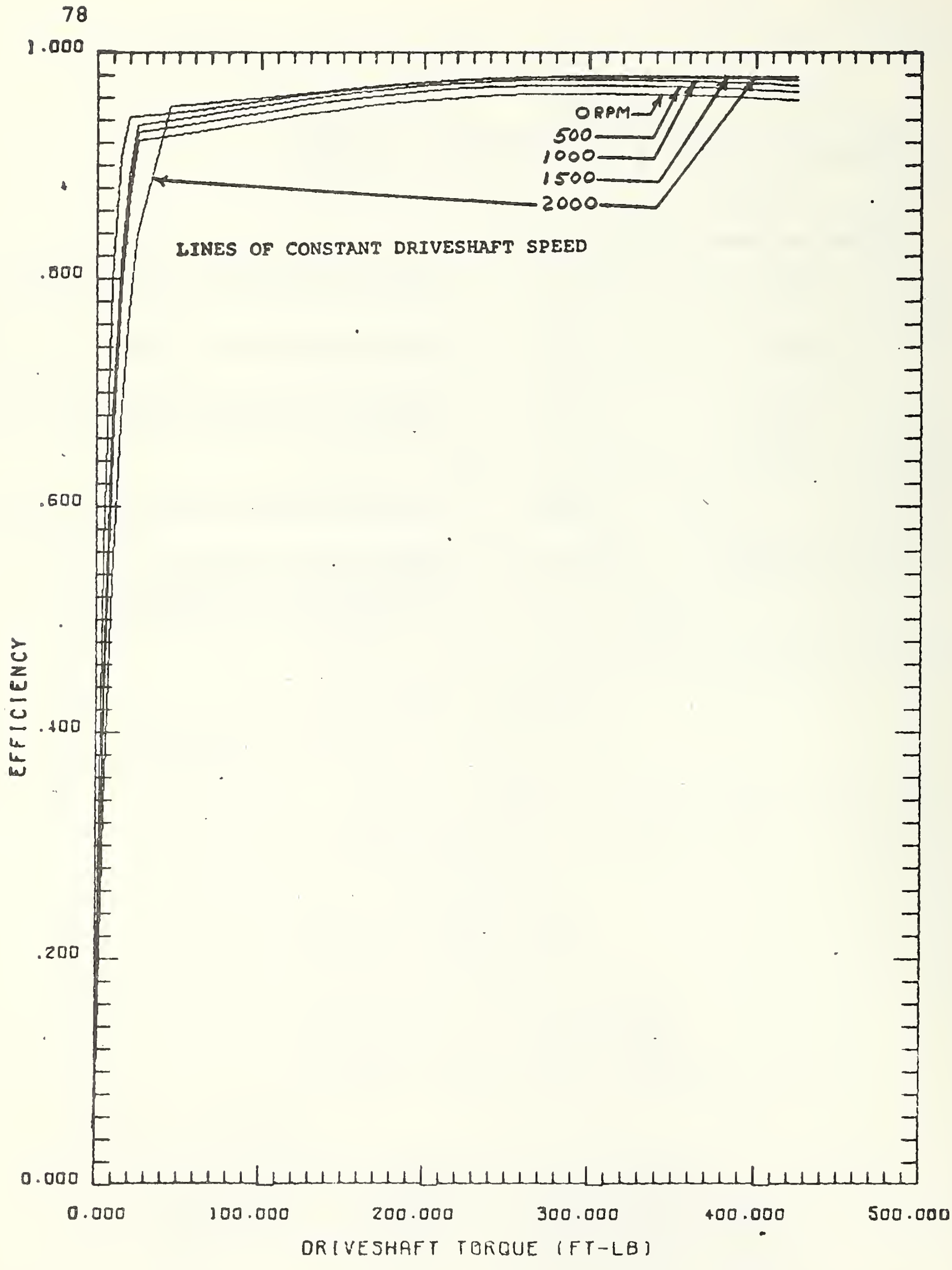


FIGURE 14. REAR AXLE EFFICIENCY

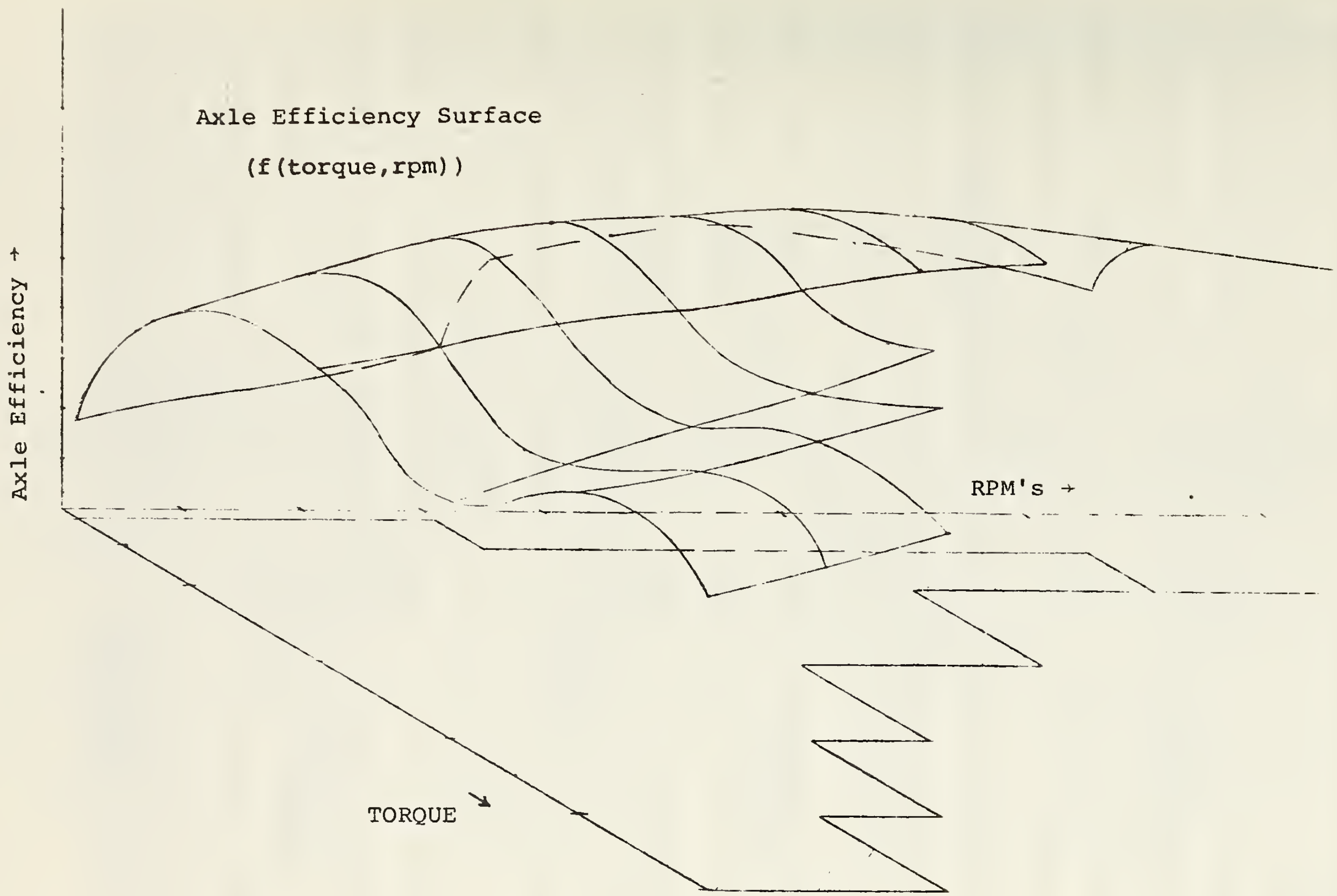


FIGURE 15. REAR AXLE EFFICIENCY VS TORQUE AND RPM

Driveshaft speed, rpm

Driveshaft torque, ft-lb	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800
0.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
20.	.7379	.7400	.7421	.7443	.7465	.7488	.7510	.9410	.8277	.5861	.4544	.3713	.3190	.2720	.2399	.2199	.1937	.1769	.1610	.1443
40.	.9253	.9280	.9308	.9335	.9362	.9388	.9415	.9441	.9467	.9492	.9088	.7424	.6280	.5441	.4798	.4288	.3873	.3529	.3237	.2986
60.	.9296	.9326	.9354	.9381	.9407	.9431	.9455	.9478	.9499	.9519	.9539	.9557	.9420	.8101	.7197	.6932	.5810	.5293	.4055	.4479
80.	.9343	.9373	.9402	.9429	.9454	.9477	.9498	.9518	.9535	.9551	.9565	.9577	.9588	.9596	.9595	.8374	.7797	.7057	.6973	.5972
100.	.9389	.9421	.9450	.9477	.9501	.9523	.9542	.9559	.9574	.9585	.9595	.9602	.9606	.9609	.9608	.9605	.9600	.8821	.8092	.7465
120.	.9435	.9467	.9497	.9523	.9547	.9567	.9585	.9600	.9611	.9620	.9626	.9628	.9628	.9625	.9619	.9610	.9598	.9583	.9565	.8957
140.	.9477	.9510	.9540	.9566	.9589	.9609	.9625	.9638	.9647	.9653	.9656	.9655	.9651	.9644	.9633	.9619	.9601	.9580	.9558	.9529
160.	.9515	.9548	.9578	.9604	.9627	.9646	.9661	.9672	.9680	.9684	.9689	.9681	.9679	.9663	.9649	.9631	.9609	.9584	.9555	.9522
180.	.9548	.9582	.9611	.9637	.9659	.9678	.9692	.9702	.9709	.9711	.9710	.9704	.9695	.9682	.9665	.9644	.9619	.9591	.9558	.9522
200.	.9575	.9609	.9639	.9665	.9686	.9704	.9718	.9727	.9733	.9734	.9732	.9725	.9715	.9700	.9681	.9658	.9632	.9601	.9566	.9527
220.	.9597	.9631	.9660	.9686	.9708	.9725	.9738	.9747	.9752	.9753	.9750	.9743	.9731	.9716	.9696	.9672	.9645	.9613	.9576	.9536
240.	.9613	.9646	.9676	.9701	.9723	.9740	.9753	.9762	.9767	.9768	.9765	.9757	.9746	.9730	.9710	.9686	.9658	.9626	.9590	.9549
260.	.9623	.9656	.9686	.9711	.9732	.9750	.9763	.9772	.9777	.9778	.9775	.9768	.9757	.9742	.9722	.9699	.9671	.9640	.9604	.9565
280.	.9627	.9661	.9690	.9715	.9737	.9754	.9768	.9777	.9783	.9784	.9782	.9776	.9765	.9751	.9733	.9711	.9685	.9655	.9621	.9583
300.	.9627	.9660	.9689	.9715	.9736	.9754	.9768	.9778	.9784	.9787	.9785	.9780	.9771	.9759	.9742	.9722	.9698	.9670	.9638	.9603
320.	.9623	.9655	.9684	.9709	.9731	.9749	.9764	.9775	.9782	.9786	.9786	.9782	.9775	.9765	.9750	.9733	.9711	.9686	.9657	.9625
340.	.9619	.9647	.9675	.9701	.9723	.9741	.9757	.9768	.9777	.9782	.9789	.9782	.9778	.9769	.9758	.9743	.9724	.9703	.9678	.9649
360.	.9603	.9635	.9663	.9689	.9711	.9731	.9747	.9760	.9770	.9777	.9780	.9781	.9779	.9773	.9765	.9753	.9738	.9720	.9699	.9678
380.	.9590	.9621	.9649	.9675	.9698	.9718	.9735	.9749	.9761	.9770	.9776	.9779	.9779	.9777	.9771	.9763	.9752	.9736	.9721	.9703
400.	.9574	.9605	.9634	.9659	.9683	.9704	.9722	.9738	.9751	.9762	.9770	.9776	.9779	.9780	.9779	.9774	.9757	.9736	.9721	.9721
420.	.9558	.9589	.9617	.9643	.9667	.9689	.9700	.9726	.9741	.9754	.9765	.9774	.9780	.9784	.9782	.9778	.9757	.9736	.9721	.9721
440.	.9542	.9572	.9600	.9627	.9651	.9674	.9695	.9719	.9731	.9747	.9760	.9772	.9782	.9790	.9795	.9778	.9757	.9736	.9721	.9721
460.	.9526	.9556	.9584	.9611	.9636	.9660	.9683	.9703	.9723	.9740	.9757	.9772	.9785	.9797	.9795	.9778	.9757	.9736	.9721	.9721
480.	.9512	.9541	.9570	.9597	.9623	.9648	.9671	.9694	.9716	.9736	.9755	.9773	.9790	.9805	.9795	.9778	.9757	.9736	.9721	.9721
500.	.9499	.9528	.9556	.9584	.9611	.9637	.9662	.9687	.9710	.9733	.9755	.9776	.9797	.9805	.9795	.9778	.9757	.9736	.9721	.9721
520.	.9488	.9517	.9546	.9574	.9602	.9629	.9656	.9682	.9708	.9733	.9758	.9783	.9806	.9805	.9795	.9778	.9757	.9736	.9721	.9721
540.	.9480	.9509	.9538	.9566	.9595	.9623	.9652	.9680	.9708	.9736	.9764	.9791	.9814	.9805	.9795	.9778	.9757	.9736	.9721	.9721
560.	.9474	.9503	.9532	.9562	.9591	.9621	.9651	.9681	.9711	.9742	.9772	.9803	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
580.	.9472	.9501	.9530	.9560	.9591	.9622	.9653	.9685	.9718	.9750	.9784	.9819	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
600.	.9472	.9501	.9531	.9562	.9594	.9626	.9659	.9693	.9727	.9762	.9799	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
620.	.9476	.9505	.9536	.9567	.9600	.9633	.9668	.9703	.9740	.9777	.9816	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
640.	.9483	.9513	.9543	.9575	.9609	.9644	.9680	.9717	.9755	.9795	.9836	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
660.	.9493	.9523	.9554	.9587	.9621	.9657	.9694	.9733	.9774	.9816	.9859	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
680.	.9505	.9535	.9567	.9601	.9636	.9673	.9712	.9752	.9794	.9838	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
700.	.9520	.9550	.9583	.9617	.9653	.9691	.9731	.9773	.9817	.9863	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
720.	.9537	.9567	.9600	.9635	.9672	.9711	.9752	.9796	.9841	.9888	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
740.	.9554	.9585	.9619	.9654	.9692	.9732	.9775	.9819	.9866	.9913	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
760.	.9573	.9604	.9638	.9675	.9713	.9754	.9797	.9843	.9891	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
780.	.9591	.9623	.9658	.9695	.9734	.9776	.9820	.9866	.9915	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
800.	.9609	.9642	.9677	.9714	.9754	.9796	.9841	.9888	.9938	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
820.	.9626	.9659	.9694	.9732	.9773	.9815	.9861	.9908	.9959	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
840.	.9641	.9674	.9710	.9748	.9789	.9832	.9878	.9926	.9979	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
860.	.9653	.9687	.9723	.9761	.9802	.9846	.9892	.9940	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
880.	.9662	.9696	.9732	.9771	.9812	.9856	.9902	.9950	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
900.	.9667	.9701	.9738	.9777	.9818	.9861	.9907	.9955	.9987	.9938	.7879	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
920.	.9668	.9703	.9739	.9778	.9819	.9862	.9908	.9956	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
940.	.9665	.9699	.9736	.9779	.9815	.9858	.9902	.9949	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
960.	.9657	.9691	.9727	.9765	.9806	.9848	.9891	.9937	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
980.	.9644	.9678	.9714	.9751	.9791	.9832	.9875	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1000.	.9626	.9660	.9695	.9732	.9770	.9810	.9852	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1020.	.9604	.9637	.9672	.9708	.9745	.9783	.9823	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1040.	.9579	.9611	.9645	.9679	.9715	.9752	.9790	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1060.	.9551	.9582	.9615	.9648	.9682	.9717	.9753	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1080.	.9522	.9552	.9583	.9614	.9646	.9679	.9712	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1100.	.9494	.9522	.9551	.9580	.9610	.9640	.9671	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1120.	.9469	.9495	.9521	.9548	.9575	.9602	.9630	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1140.	.9448	.9472	.9496	.9520	.9544	.9569	.9593	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1160.	.9437	.9458	.9479	.9500	.9520	.9541	.9562	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721
1180.	.9430	.9455	.9473	.9490	.9507	.9529	.9564	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9278	.9757	.9736	.9721	.9721
1200.	.9455	.9469	.9483	.9496	.9509	.9522	.9554	.9935	.9987	.9938	.9874	.9833	.9819	.9805	.9795	.9778	.9757	.9736	.9721	.9721

FIGURE 16. REAR AXLE EFFICIENCIES GENERATED BY RAEFF (THE CURVED LINES INDICATE THE LIMITS OF EXPERIMENTAL DATA.)

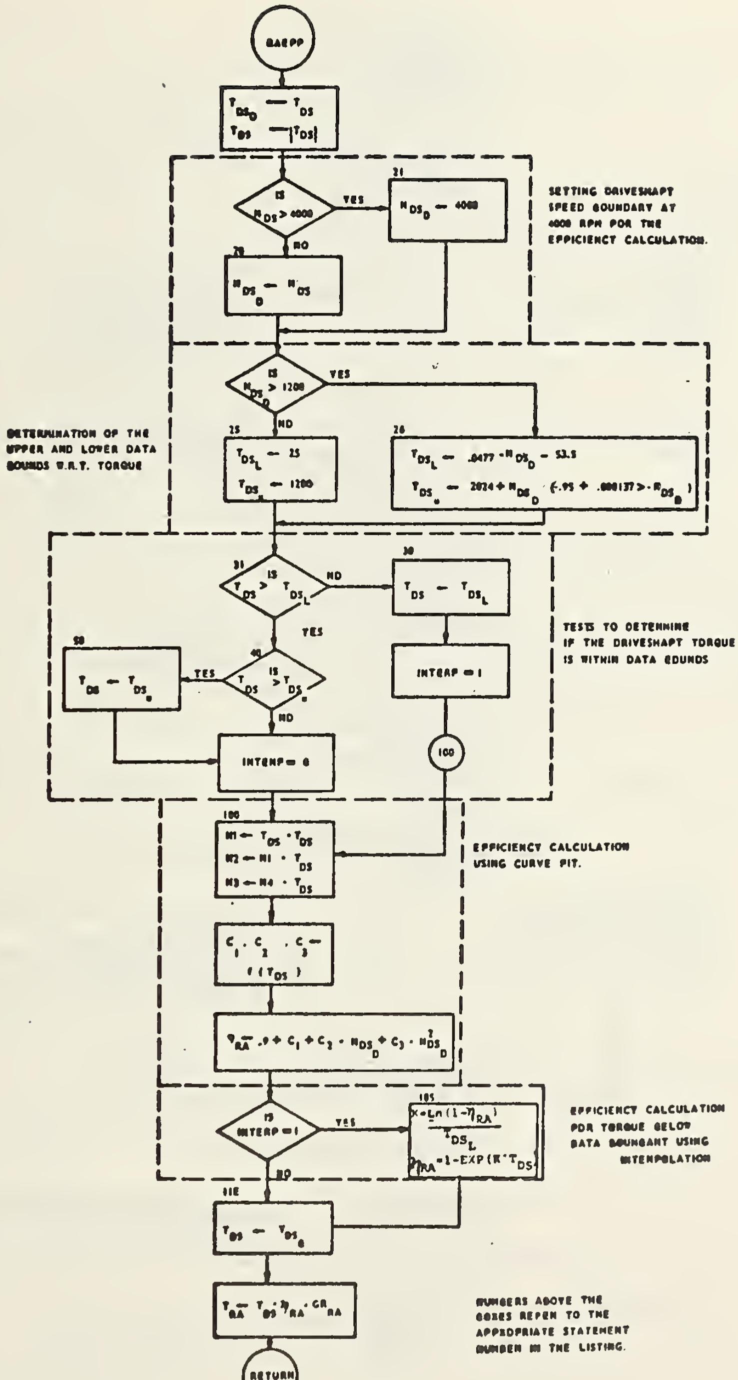


FIGURE 17. REAR AXLE EFFICIENCY FLOW DIAGRAM

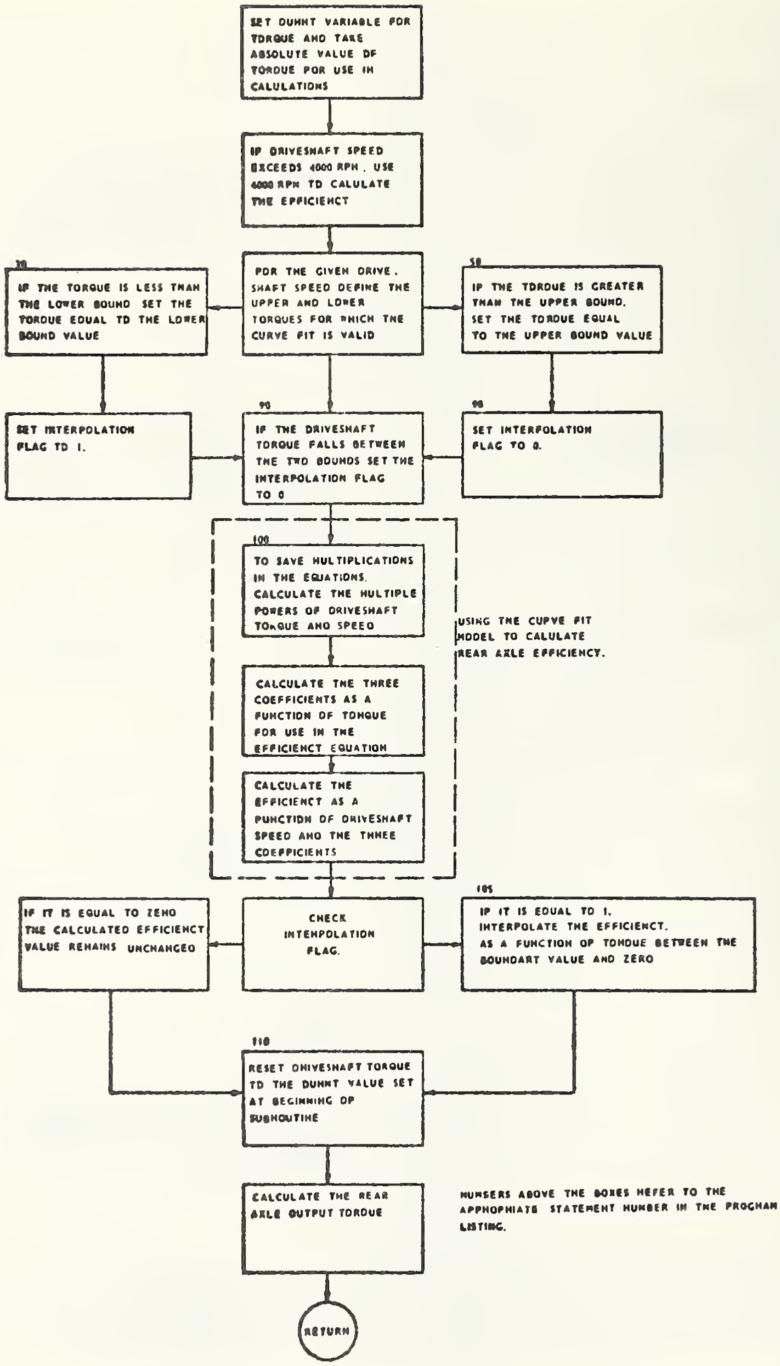


FIGURE 18. REAR AXLE EFFICIENCY BLOCK DIAGRAM

```
*                                       **** RAEFF ****
          SUBROUTINE RAEFF(T9IC,T9IN,T9I1GR,T98C,T9I1)
C---- SUBROUTINE TO DETERMINE REAR AXLE EFFICIENCY.
C---- DAN KAPELLEN 10/73, REVISED 2/74
C**********************************************************************
C--- THIS SUBROUTINE CALCULATES THE REAR AXLE EFFICIENCY AS A FUNCTIO
C---- DRIVESHAFT TORQUE AND SPEED.  IT RETURNS THE REAR AXLE OUTPUT T
C---- USE IN THE VEHICLE DYNAMICS SUBROUTINE (VEDYN).  THE VARIABLES I
C---- PROGRAM ARE AS FOLLOWS,
C---- INPUT VARIABLES--------------------------------
C---- T9IC-DRIVESHAFT TORQUE
C---- T9IN-DRIVESHAFT SPEED.
C---- T9I1GR-EQUIVALENT REAR AXLE RATIO
C---- OUTPUT VARIABLES-------------------------------
C---- T9I1-REAR AXLE EFFICIENCY.
C---- T98C-REAR AXLE OUTPUT TORQUE
C---- OTHER PROGRAM VARIABLES-----------------------
C---- T9DC-DUMMY DRIVESHAFT TORQUE ,USED TO PRESERVE VALUE OF T9IC.
C---- T9DN-DUMMY DRIVESHAFT SPEED,USED TO PRESERVE VALUE OF T9IN.
C-----T9DCL-LOWEST TORQUE AT WHICH CURVE FIT IS CONSIDERED VALID.
C---- T9DCU-HIGHEST TORQUE AT WHICH CURVE FIT IS CONSIDERED VALID.
C---- INTERP-FLAG SET TO INDICATE INTERPOLATION IS NECESSARY BETWEEN C
C**********************************************************************
C---- SET DUMMY DRIVESHAFT TORQUE.
          T9DC=T9IC
C-----USE THE ABSOLUTE VALUE OF DRIVESHAFT TORQUE TO CALCULATE THE EFF
          T9IC=ABS(T9IC)
C---- IF DRIVESHAFT SPEED EXCEEDS 4000 RPM, USE 4000 RPM TO CALCULATE
          IF(T9IN-4000.)20,20,21
       21 T9DN=4000.
          GO TO 22
       20 CONTINUE
C---- SET DUMMY DRIVESHAFT SPEED.
          T9DN=T9IN
       22 CONTINUE
C---- DEFINE THE UPPER AND LOWER TORQUES FOR WHICH THE CURVE FIT IS VA
          IF(T9DN-1200.)25,25,26
       25 T9DCL=25.
          T9DCU=1200.
          GO TO 31
       26 T9DCL=.0477*T9DN-53.5
          T9DCU=2024.+T9DN*(-.95 +.000137*T9DN)
       31 CONTINUE
C---- IF THE TORQUE IS LESS THAN THE LOWER BOUND, SET THE TORQUE EQUAL
C---- LOWER BOUND VALUE OF TORQUE.
          IF(T9IC-T9DCL)30,40,40
       30 T9IC=T9DCL
C---- THEN SET THE INTERPOLATION FLAG TO 1.
          INTERP=1
          GO TO 100
       40 CONTINUE
C---- IF THE TORQUE IS GREATER THAN THE UPPER BOUND, SET IT EQUAL TO T
          IF(T9IC-T9DCU)90,90,50
```

```
      50 T9IC=T9DCU
C---- IF THE D.S. TORQUE FALLLS BETWEEN THE TWO BOUNDS SET THE INT. F
      90 INTERP=0
     100 CONTINUE
C----TO SAVE MULTIPLICATIONS,CALCULATE THE MULTIPLE POWERS OF D.S. TO
         H1=T9IC*T9IC
         H2=T9IC*H1
         H3=T9IC*H2
         H4=T9IC*H3
         H5=T9IC*H4
         H6=T9DN*T9DN
C---- CALCULATE THE THREE COEFFICIENTS AS A FUNCTION OF TORUQE.
         C1=1.867E-2+(1.1314E-4)*T9IC+(1.6491E-6)*H1+(-9.0929E-9)*H2
       1    +(1.688E-11)*H3+(-1.3281E-14)*H4+(3.7756E-18)*H5
         C2=1.1143E-5+(7.8431E-8)*T9IC+(-2.9137E-10)*H1+(3.7934E-13)*H2
       2    +(-1.6109E-16)*H3
         C3=2.3793E-9+(-7.6401E-11)*T9IC+(2.418E-13)*H1+(-2.4452E-16)*H2
       3    +(7.8702E-20)*H3
C---- CALCULATE THE EFFICIENCY AS A FUNCTIN OF D.S. SPEED AND THE 3 C
         T9I1=C1+C2*T9DN+C3*H6+.90
C---- CHECK THE INTERPOLATION FLAG.
         IF (INTERP)110,110,105
C---- IF .GT. THAN 0 INTERPOLATE THE EFFICIENCY AS A FUNCTION OF D.S.
C---- BETWEEN ZERO EFF. AND THE EFF. CALCULATED AT THE CURVE FIT BOUN
     105 CONTINUE
         IF(1.00-T9I1) 106,107,107
     106 CONTINUE
         T9I1=1.00
     107 CONTINUE
C---- THIS INTERPOLATION USES AN EXPONENTIAL, FIRST CALCULATE THE CON
C---- USED IN THE EXPONENTIAL BASED ON THE TORQUE AND EFF AT THE CURV
         SK=ALOG(1.-T9I1)/T9DCL
C---- THEN CALCULATE THE INTERPOLATED EFFICIENCY.
C---- THEN CALCULATE THE INTERPOLATED EFFICIENCY.
         T9I1=1.-EXP(SK*ABS(T9DC))
C---- RESET THE DRIVESHAFT TORQUE TO ITS ORIGINAL VALUE.
     110 T9IC=T9DC
C---- CALCULATE THE REAR AXLE OUTPUT TORQUE.
         T9OC=T9IC*T9I1*T9I1GR
         RETURN
         END
```

3.3.22 Subroutine to Interpolate with Equally Spaced Grid Points - RIXON 2, RIXON 22

SUBROUTINE NAME: RIXON2 and RIXON22

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: The subroutine RIXON2 is used to evaluate a function of two variables from a table of function values at equally spaced grid points. The steady state torque as a function of engine speed and throttle setting is one such function. Fuel consumption as a function of steady state torque and engine speed is another function of this type.

MODELING: The function values are stored at the intersections of a lattice network whose x and y increments are different constants. The four function values at the corners of the rectangle which surround the input point are found. Interpolation is used in the x direction to obtain two function values which bracket the function value at the input point in the y direction. Then linear interpolation is used again to approximate the function value at the input point. If the input point exceeds the limit of the lattice network, extrapolation from the closest rectangle is used.

EQUATIONS: S/L

INPUT VARIABLES: X - the X coordinate at which the function is to be evaluated
Y - the Y coordinate at which the function is to be evaluated

OUTPUT VARIABLES: Z - the approximated value of the function at the point (X,Y)

OTHER VARIABLES: IA(50,17) - the table of function values at the intersections of the lattice network

NOTE: The first row of IA contains information describing how the data are stored in the rest of IA. The second row of IA and the first column of IA, save for the element in the first row, do not contain function values at the grid points.

IA(1,1) is the minimum X value

IA(1,2) is the maximum X value

IA(1,3) is one less than the number of X values

IA(1,4) is the minimum Y value

IA(1,5) is the maximum Y value

IA(1,6) is the one less than the number of Y values

IA(1,7) is the Z value multiplier

IA(1,8) is the Z value divisor

PROGRAM VARIABLES: DELX - X constant increment

DELY - Y constant increment

CONSX - X interpolation factor

CONSY - Y interpolation factor

I1 - The index for least Y lattice points

I2 - The index for greatest Y lattice points

Z11 - Function value at least S, least Y lattice points

Z12 - Function value at least Y, greatest X lattice points

Z21 - Function value at greatest Y, least X lattice points

Z22 - Function value at greatest Y, greatest X lattice points

```
 *                                        **** RIXON2 ****
             SUBROUTINE RIXON2(X,Y,Z,IA)
 C----       SUBROUTINE TO INTERPOLATE EQUALLY SPACED POINTS
 C----       R.R.RADTKE 2/19/74
             DIMENSION IA(55,17)
             RMINX=IA(1,1)
             RMAXX=IA(1,2)
             RNINCX=IA(1,3)
             RMINY=IA(1,4)
             RMAXY=IA(1,5)
             RNINCY=IA(1,6)
             RMULZ=IA(1,7)
             RDIVZ=IA(1,8)
             MXINC=IA(1,3)-1
             MYINC=IA(1,6)-1
 C
 C
 C----       COMPUTE X INDICES
             DELX=(RMAXX-RMINX)/RNINCX
             J1=(X-RMINX)/DELX+1.
             IF(J1-1)5,10,10
           5 J1=1
          10 CONTINUE
             IF(J1-MXINC)20,20,15
          15 J1=MXINC
          20 CONTINUE
             CONSX=(X-(J1-1)*DELX-RMINX)/DELX
 C----       X DATA STARTS IN COLUMN 2
             J1=J1+1
             J2=J1+1
 C
 C
 C----       COMPUTE Y INDICES
             DELY=(RMAXY-RMINY)/RNINCY
             I1=(Y-RMINY)/DELY+1.
             IF(I1-1)25,30,30
          25 I1=1
          30 CONTINUE
             IF(I1-MYINC)40,40,35
          35 I1=MYINC
          40 CONTINUE
             CONSY=(Y-(I1-1)*DELY-RMINY)/DELY
 C----       Y DATA STARTS IN ROW 3
             I1=I1+2
             I2=I1+1
 C
 C
 C----       Z INTERPOLATION
             Z11=IA(I1,J1)
             Z12=IA(I1,J2)
             Z21=IA(I2,J1)
             Z22=IA(I2,J2)
             Z1=Z11+CONSX*(Z12-Z11)
```

```
      Z2=Z21+CONSX*(Z22-Z21)
      Z=Z1+CONSY*(Z2-Z1)
      Z=Z*RMULZ/RDIVZ
      RETURN
      END
```

3.3.23 Subroutine to Account for Effect of Tire Expansion - TGG15

PROGRAM NAME: TGG15

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This program determines a "corrected" driveshaft speed and an "equivalent" rear axle ratio based on vehicle speed.

MODELING: As vehicle speed increases, centrifugal force causes the tire diameter to increase. Therefore, for a given vehicle speed, the driveshaft speed is less and the driveshaft torque is greater than it would be if the tire maintained the same radius.

A table of driveshaft speeds obtained experimentally at 10-mph increments is read into memory in the initialization subroutine (INICON). The tire expansion subroutine, based on vehicle speed, linearly interpolates between the stored points to obtain the corrected or actual driveshaft speed. Although the tire expansion is not linear (it is a function of ω^2) linear interpolation is sufficient since the change in tire radius is not large (see Fig. 19).

An equivalent rear axle ratio is calculated rather than a new tire rolling radius because this makes the effect of tire expansion easier to recognize when analyzing results.

Since data are generally not available (or necessary) over 100 mph, this model is only accurate to 100 mph. To keep the program running in the event 100 mph is exceeded, the equivalent rear axle ratio is assumed to be the same as the iteration before 100 mph was exceeded. The driveshaft speed is then calculated on this basis. This is the function of statement number 15 in the program: listing and flow diagram (Fig. 20).

EQUATIONS:

$$N_{DS_U} = \frac{\frac{5280}{60} V \; GR_{RA}}{2R_T}$$

$$N_{DS} = f(V)$$

$$GR_{RA} = GR_{RA} \frac{N_{DS}}{N_{DS_U}}$$

INPUT VARIABLES:

Program Name	Symbol	Description
VVOS	V	Vehicle speed

OUTPUT VARIABLES:

T9IN	N_{DS}	Actual driveshaft speed
T9I1GR	GR_{RA}	Equivalent rear axle ratio
T8I1GR	GR_{RA}	Nominal rear axle ratio

VARIABLES TO BE STORED IN MEMORY:

T8INV(J)	N_{DS_J}	Table of driveshaft speeds
VVIDRR	R_T	Tire radius

OTHER PROGRAM VARIABLES:

Program Name	Symbol	Description
T8DN	N_{DS}	Uncorrected driveshaft speed
T8DNHI	N_H	Upper interpolation point
T8DNLO	N_L	Lower interpolation point
DIFF	Diff	Difference between current vehicle speed and vehicle speed at lower interpolation point.

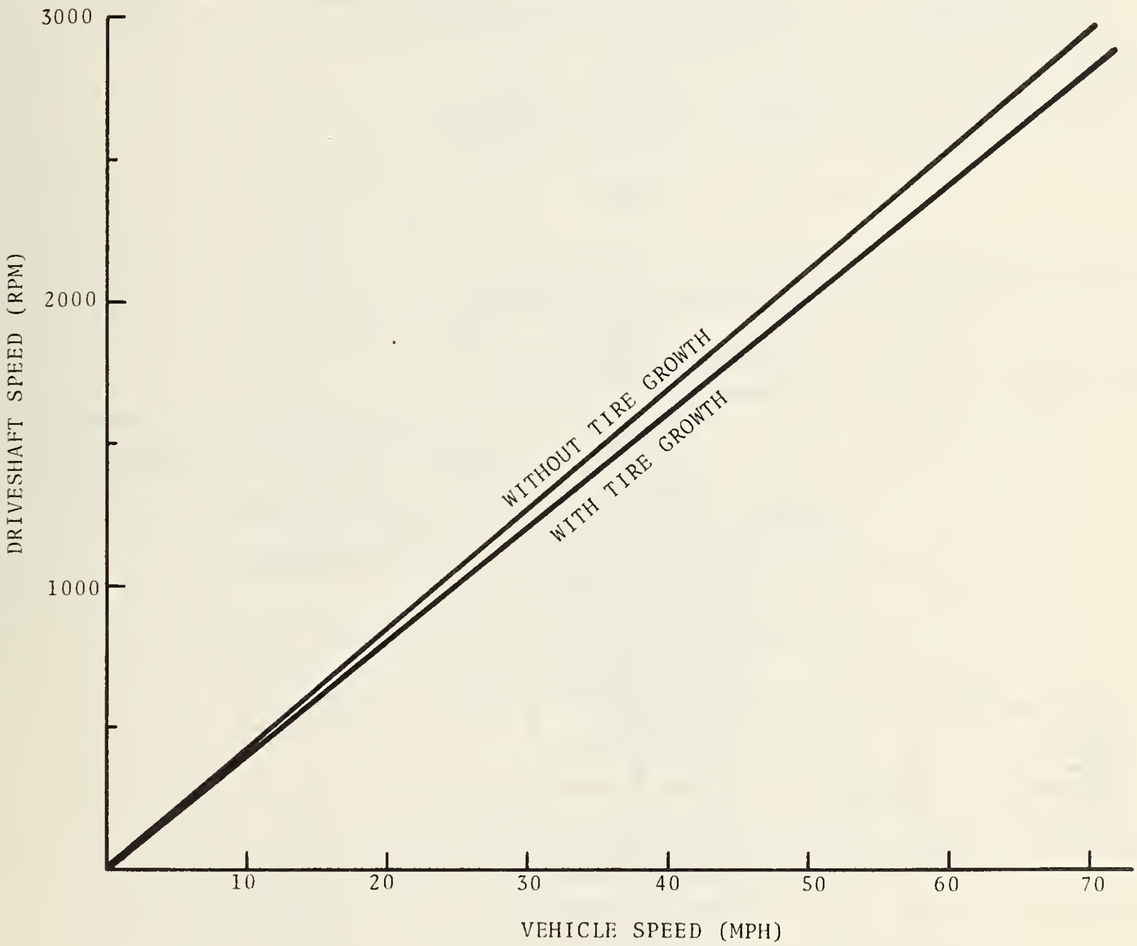
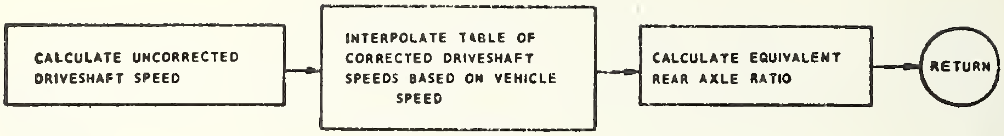


FIGURE 19. VEHICLE VS DRIVESHAFT SPEED



Tire Growth Flow Diagram

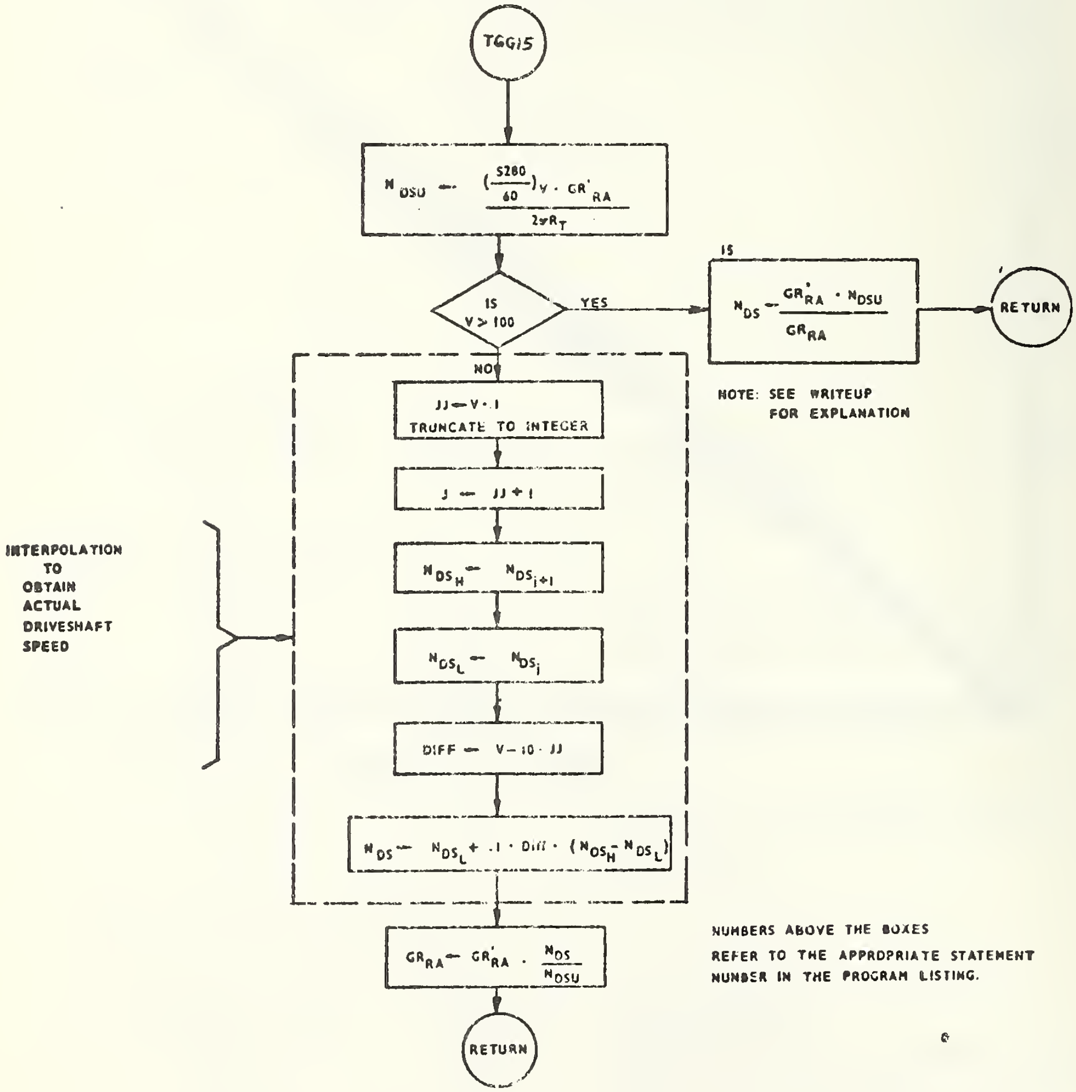


FIGURE 20. BLOCK AND FLOW DIAGRAM FOR TIRE GROWTH

```
*                                **** TGG15 ****
C---- SUBROUTINE TO DETERMINE EFFECTIVE REAR AXLE RATIO AND D.S. SPEED
      SUBROUTINE TGGI5(VVOS,T9IN,T9I1GR)
      COMMON /DSSPD/ T8INV(12)
      COMMON/RGRTIO/ T8I1GR
      COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
C***********************************************************************
C---- THIS SUBROUTINE DETERMINES A 'CORRECTED' DRIVESHAFT SPEED AND AN
C---- 'EQUIVALENT' REAR AXLE RATIO BASED ON A TABLE OF DRIVESHAFT SPEED
C---- AS A FUNCTION OF VEHICLE SPEED OBTAINED FROM EXPERIMENTAL DATA.
C---- THE PROGRAM VARIABLES ARE AS FOLLOWS,
C-------------------INPUT VARIABLES--------------------------------------
C -----BGRTIO   BEVEL GEAR RATIO
C---- VVOS----VEHICLE SPEED.
C-------------------OUT PUT VARIABLES------------------------------------
C-----T9IN----'CORRECTED' DRIVESHAFT SPEED TAKING INTO ACCOUNT TIRE GROW
C---- T9I1GR---EQUIVALENT REAR AXLE RATIO.
C-------------------PROGRAM CONSTANTS------------------------------------
C---- T8INV(J)-TABLE OF DRIVESHAFT SPEEDS AS A FUNCTION OF VEHICLE SPEED
C---- VVIDRR---TIRE RADIUS.
C---- T8I1GR--NOMINAL REAR AXLE RATIO.
C-------------------OTHER PROGRAM VARIABLES------------------------------
C---- T8DN----UNCORRECTED DRIVESHAFT SPEED.
C---- T8DNHI--UPPER INTERPOLATION DRIVESHAFT SPEED.
C-----T8DNLO--LOWER INTERPOLATION DRIVESHAFT SPEED.
C---- DIFF-----DIFFERENCE BETWEEN CURRENT VEHICLE SPEED AND VEHICLE
C---- SPEED AT LOWER INTERPOLATION POINT.
C***********************************************************************
C---- CALCULATE THE UNCORRECTED DRIVESHAFT SPEED.
      T8DN=14.00545*VVOS*T8I1GR        /VVIDRR
C---- TEST IF THE VEHICLE SPEED EXCEEDS THE RANGE OF THE TABLE.
      IF(VVOS-100.)5,5,15
    5 CONTINUE
C---- DETERMINE INDICES FOR UPPER AND LOWER INTERPOLATION SPEEDS.
      JJ=VVOS*.1
C---- DETERMINE THE DRIVESHAFT SPEEDS AT THE UPPER AND LOWER INTERPOLATI
      J=JJ+1
      T8DNHI=T8INV(J+1)
      T8DNLO=T8INV (J)
      DIFF=VVOS-10.*JJ
C---- INTERPOLATE TABLE FOR CORRECTED DRIVESHAFT SPEED.
      T9IN=T8DNLO+.1*DIFF*(T8DNHI-T8DNLO)
      IF (T9IN-.1) 11,11,10
C---- CALCULATE THE 'EQUIVALENT REAR AXLE RATIO BASED ON THE RATIO
C---- OF THE CORRECTED TO UNCORRECTED DRIVESHAFT SPEED.
   10 T9I1GR=T8I1GR*T9IN/T8DN
      GOTO 998
   11 T9I1GR=T8I1GR
      GOTO 998
   15 CONTINUE
      T9IN=T9I1GR*T8DN/T8I1GR
  998 CONTINUE
      RETURN
      END
```

3.3.24 Torque Converter - TQCONV, VELTERP

PROGRAM NAMES: TQCONV and VELTERP

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the square of the inverse input size factor and the torque ratio as functions of speed ratio. The converter input torque and converter output torque are then calculated for use in subsequent subroutines. See Figure 21.

If the converter is locked the speed ratio and torque ratio are retrieved from memory in lockup.

MODELING: The speed ratio is determined by dividing the converter output speed by the converter input speed. The converter output speed is determined from the current vehicle speed and gear ratio, which are calculated by other routines. This speed ratio is used to calculate the inverse input size factor and the torque ratio.

To use this subroutine it is necessary to input a table of the torque ratio and the square of the inverse input size factor as a function of speed ratio based on experimental data.

This array called AWAY holds the speed ratio, torque ratio and inverse size factor. VELTERP chains through the speed ratios and finds where the calculated speed ratio falls. A linear interpolation is then used to determine the torque ratio and the inverse size factor.

The torque converter input torque is calculated. This is divided by the Bevel Gear ratio to determine the engine torque. The torque converter output torque is then determined.

If the torque converter is locked, the torque ratio and speed ratio is retrieved from memory and the engine output torque, torque converter, input torque and output torque are calculated.

Figure 22 shows a typical curve of torque ratio as a function of speed ratio and Fig. 23 is a curve of the square of the inverse size factor as a function of speed ratio.

EQUATIONS USED:

1) For speed ratio

$$SR = N_{CO}/N_{CI}$$

2) For input torque

$$T_{CI} = N_{CI}^{2} * 1/K_I^2$$

3) For output torque

$$T_{CO} = T_{CI} * TR$$

4) For flywheel torque if unlocked

$$T_E = T_{CI}/GR_{BG}$$

5) For flywheel torque if locked

$$T_E = T_{SS} - T_A$$

VARIABLE NAME	SYMBOL	MEANING
ACTORQ	T_A	Accessory Torque
BAON	N_{CI}	Converter input speed
LOCK		Indicates if converter's locked
SSTORQ	T_{SS}	Engine torque
TAON	N_{CO}	Converter output speed

OUTPUT VARIABLES		
BAOC	T_{CI}	Converter input torque
PAOC	T_E	Flywheel torque
TAOC	T_{CO}	Converter output torque

TA01TR	TR	Converter torque ratio
TAI1ST	SR	Converter speed ratio

CONSTANTS ACCESSED

Variable Name	Symbol	Meaning
BGRT10	GR_{BG}	Bevel gear ratio
AWAY		Table holds torque ratio and inverse size factor as a function of speed ratio

LOCAL VARIABLES

TAI3IK	$1/K_I^2$	Inverse size factor

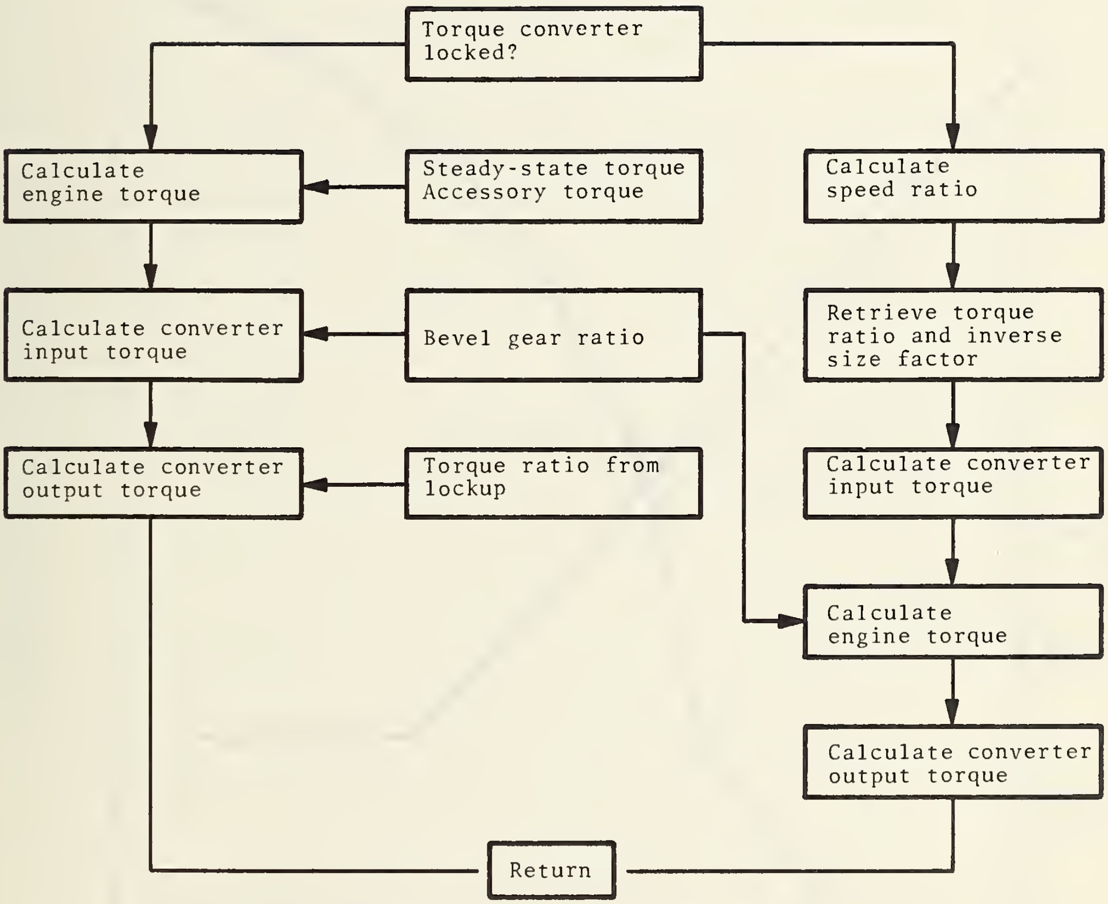


FIGURE 21. TQCONV FLOW DIAGRAM

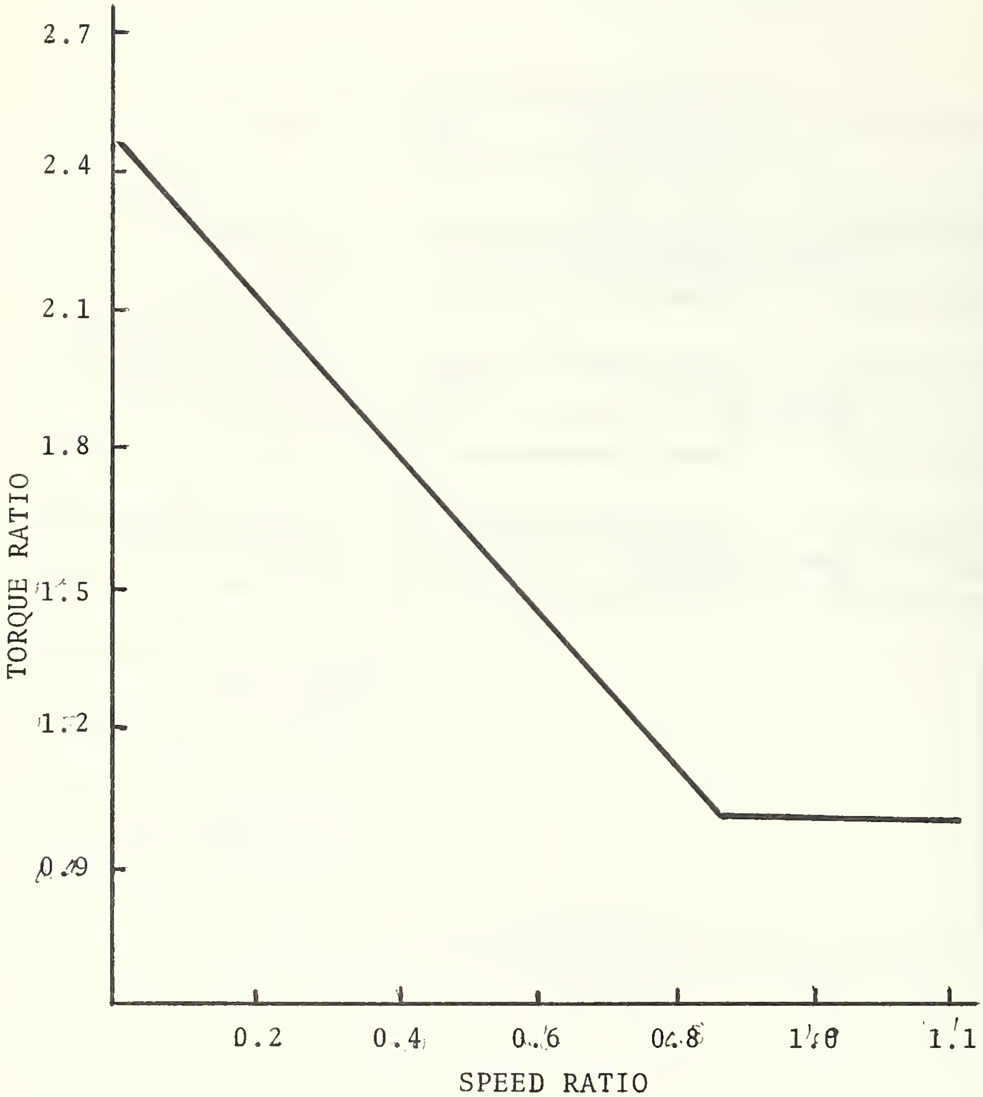


FIGURE 22. SPEED RATIO VS TORQUE RATIO

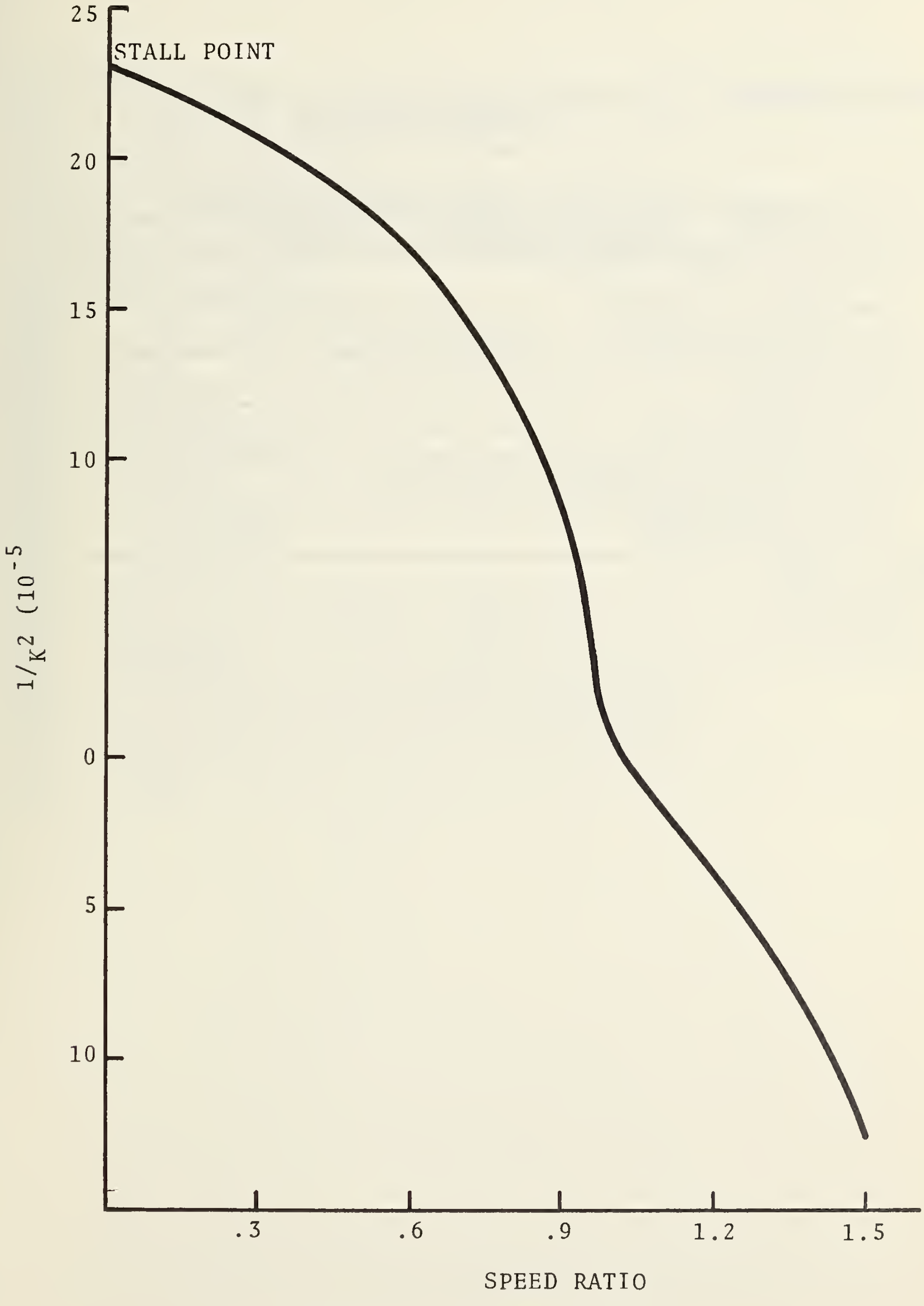


FIGURE 23. SPEED VS $1/K^2$

```
 *                                  **** TQCONV ****



        SUBROUTINE TQCONV( LOCK,PABC,SSTORQ,ACTORQ,TA01TR,
      C TAI1SR,TABN,BABN,BABC,TABC)
        COMMON /BGEAR/ BGRTIO
        IF (LOCK .GE. 1)
      C PABC=SSTORQ-ACTORQ;
      CBABC=PABC*BGRTIO;
      CTABC=BABC*TA01TR  ;
      C GOTO 900
    10 CONTINUE
        TAI1SR=TABN/BABN
        CALL VELTERP(TAI1SR,TA01TR,TAI3IK)
        BABC=BABN*BABN*TAI3IK
        PABC=BABC/BGRTIO
        TABC=BABC*TA01TR
   900 CONTINUE
   999 CONTINUE
        RETURN
        END
```

```
*                              **** VELTERP ****
      SUBROUTINE VELTERP(SR,TR,RBK)
      DIMENSION AWAY(20,3)
      COMMON /TCC/AWAY
C***** FIRST COLLUMN HOLDS THE SPEED RATIO
C***** IT IS CHAINED THROUGH TO FIND INTERPOLATION POINTS
C***** THE SECOND COLUMN HOLDS THE TORQUE RATIOS
C***** THE THIRD COLUMN HOLDS THE INVERSE SIZE FACTOR
C***** SR SPEED RATIO
C***** TR TORQUE RATIO
C***** RBK INVERSE SIZE FACTOR
      IF(SR   .GT. AWAY(20,1)) GOTO 5
      IF (SR   .LT. AWAY(1,1)) GOTO 10
      I=0
      GOTO 20
    5 CONTINUE
      TR=AWAY(20,2)
      RBK=AWAY(20,3)
      GOTO 30
   10 CONTINUE
      TR=AWAY(1,2)
      RBK=AWAY(1,3)
      GOTO 30
   20 CONTINUE
      I=I+1
      IF (AWAY(I+1,1).GT. SR   ) GOTO 40
      GOTO 20
   40 CONTINUE
      DELTX=(SR   -AWAY(I,1))/(AWAY(I+1,1)-AWAY(I,1))
      TR=AWAY(I,2)+DELTX*(AWAY(I+1,2)-AWAY(I,2))
      RBK=AWAY(I,3)+DELTX*(AWAY(I+1,3)-AWAY(I,3))
   30 CONTINUE
      RETURN
      END
```

3.3.25 Transmission Gear Efficiency - TREFF

PROGRAM NAME: TREFF

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the transmission efficiency for the gear in which the bus is running as a function of driveshaft torque and speed.

MODELING: The transmission gear efficiency data are modeled by a two-dimensional polynomial least squares curve fit of the form:

$$\eta = \eta_o + \frac{\partial \eta}{\partial} \Delta T + \frac{\partial \eta}{\partial N} \Delta N + \frac{\partial^2 \eta}{\partial N^2} \Delta N^2 + \frac{\partial^2 \eta}{\partial T^2} \Delta T^2$$

$$+ \frac{\partial^2 \eta}{\partial T \partial N} \Delta T \Delta N + \frac{\partial^3 \eta}{\partial N^3} \Delta N^3 + \frac{\partial^3 \eta}{\partial T^3} \Delta T^3$$

$$+ \frac{\partial^3 \eta}{\partial N \partial T^2} \Delta N \Delta T^2 + \frac{\partial^3 \eta}{\partial N^2 \partial T} \Delta N^2 \Delta T$$

where

η = Gear efficiency

η_o = Gear efficiency at a selected operating point

ΔN = Driveshaft speed variation about the selected operating point

ΔT = Driveshaft torque variation about the selected operating

The $\frac{\partial \eta}{\partial T}$ term is a measure of the change in efficiency with respect to torque at constant speed; $\frac{\partial \eta}{\partial N}$ is a measure of the change in efficiency with respect to speed at constant torque, etc. The $\frac{\partial^2 \eta}{\partial T \partial N}$ represents a measure of the change in efficiency with respect to the combined torque-speed surface. The number of terms in the equation could be extended for a closer fit. This fit uses nine terms.

The partial differential terms become the coefficients in the curve fit used to model gear efficiency as a function of driveshaft speed and torque. These coefficients are selected by a least squares algorithm.

However, this curve is only used to fit the available data. Provisions must be made for cases when the range of the available data is exceeded. The data do not extend to zero torque or zero speed. Therefore reasonable extrapolations need to be made. The extrapolation to zero speed had already been made for the data used in this program for 1st and 2nd gear and these points were incorporated in the curve fit. Once the curve fits were made, efficiencies were calculated well beyond the upper and lower torque bounds of the data to determine how far the fits could reasonably be extended with respect to driveshaft torque. The curves in Figs. 24, 25 and 26 show the efficiencies as a function of driveshaft torque at constant speeds for 1st, 2nd and 3rd gear, respectively. These curves were used as an aid in determining how far the model could reasonably be extended. Further, plotting the curves by the computer gave a check of data and interpolation scheme of the program.

One of the problems in obtaining transmission gear efficiency in the simulation occurs because the data give efficiency as a function of driveshaft torque and speed. The speed is known but the torque is supplied from the engine side of the transmission and the driveshaft torque is unknown until the efficiency of the transmission is known. To circumvent this problem the driveshaft torque is estimated using the current torque into the transmission and the efficiency calculated in the previous iteration. In both the real time and digital simulations, the entire program iterates often enough that the change in efficiency is not large enough to warrant an iterative procedure to obtain efficiency.

The coefficients for the curve fit equation are read in for each gear and are stored in a matrix. In cases where more than three gears are used in the simulation, first and last gear use the first and third gear efficiencies respectively and all the intermediate gears use the second gear efficiency model, since no efficiency data for more than three gears are presently available.

The data obtained for the transmission used in the simulation did not include efficiencies for low torques. Since efficiency is zero when the torque is zero some means of reflecting the efficiencies between this point and the lower boundary of the data needed to be employed. This is done by using an exponential interpolation (see Eqs. 3 and 4). However, in the transmission, as has been previously indicated, it is necessary to use the efficiency of the previous iteration to estimate the current driveshaft torque. If the efficiency is allowed to be zero, each succeeding iteration will result in zero driveshaft torque and the car won't move. For this reason the efficiency is interpolated between the curve fit boundary and a small arbitrary efficiency (0.05).

In cases where the torque exceeds the maximum torque allowed for the model the efficiency is just set to the value at the boundary. Since this happens very seldom the resulting error is not significant and the sole purpose is to prevent incongruities in the program when this does occur.

Shift criteria prevent 1st and 2nd gear from exceeding the speed boundaries and 3rd gear has its boundary set at 4000 RPM (about 115 mph for a 2.75 rear axle).

The curve fit equation (Statement 70 in the program) is organized so as to minimize the number of operations. The last statement of the program calculates driveshaft speed based on the new efficiency.

A flow diagram and a block diagram of the subroutine are given in Figs. 27 and 28.

EQUATIONS:

1) $T_{DS} = T_{CO} \cdot GR_{TR} \cdot \eta_{TR}$

2) $\eta_{TR} = \eta_o + C_1\Delta T + C_2\Delta N + C_3\Delta T^2 + C_4\Delta N^2 + C_5\Delta T\Delta N + C_6\Delta T^3 + C_7\Delta N^3 + C_8\Delta T\Delta N^2 + C_9\Delta T^2\Delta N$

The efficiency interpolation equation for use below the valid region of curve fit is:

$\eta_{TR} = 1. - .95 \exp(K \cdot T_{DS})$

where

$$K = \frac{\ln(\ (1. - \eta_{TR_L})/.95)}{T_{DS_L}}$$

INPUT VARIABLES:

Variable Name	Symbol	Description
T9IC	T_{DS}	Driveshaft torque
T9IN	N_{DS}	Driveshaft speed
TA0C	T_{CO}	Converter output torque
TB01GR	GR_{TR}	Transmission gear ratio
TB01EF	η_{TR}	Transmission gear efficiency (from previous iteration)
TB01GI	BI	Gear index

OUTPUT VARIABLES:

Variable Name	Symbol	Description
T9IC	T_{DS}	New driveshaft torque
TB01EF	η_{TR}	New transmission gear efficiency

VARIABLES WHICH MUST BE STORED IN MEMORY:

TBC1GI(J)	GI_j; j = 1, 10	Indicates which gear to use for efficiency calculation. Has value 1, 2 or 3; 1 indicates low gear, 3 indicates high gear, 2 indicates intermediate gears.
TBC1GI(I,ID)	$C_{i,id}$; i = 1,10 id = 1,4	Coefficients of curve fit equation.

OTHER PROGRAM VARIABLES:

I	i	Indicates use of first, second or third gear efficiency model.
ID	id	Indicates which of the four sets of coefficients to use in the curve fit (second gear uses two different sets).
T9DCMN	T_{DS_L}	Lowest torque for which curve fit is valid.
T9DCM	T_{DS_U}	Highest torque for which curve fit is valid.
DBD3T	ΔT_{DS}	Difference between the current driveshaft torque and the driveshaft torque at the curve fit operating point.
DBD3N	ΔN_{DS}	Difference between the current driveshaft speed and the driveshaft speed at the curve fit operating point.
INTERP	FLAG	A flag which is set to 1 if interpolation is required.

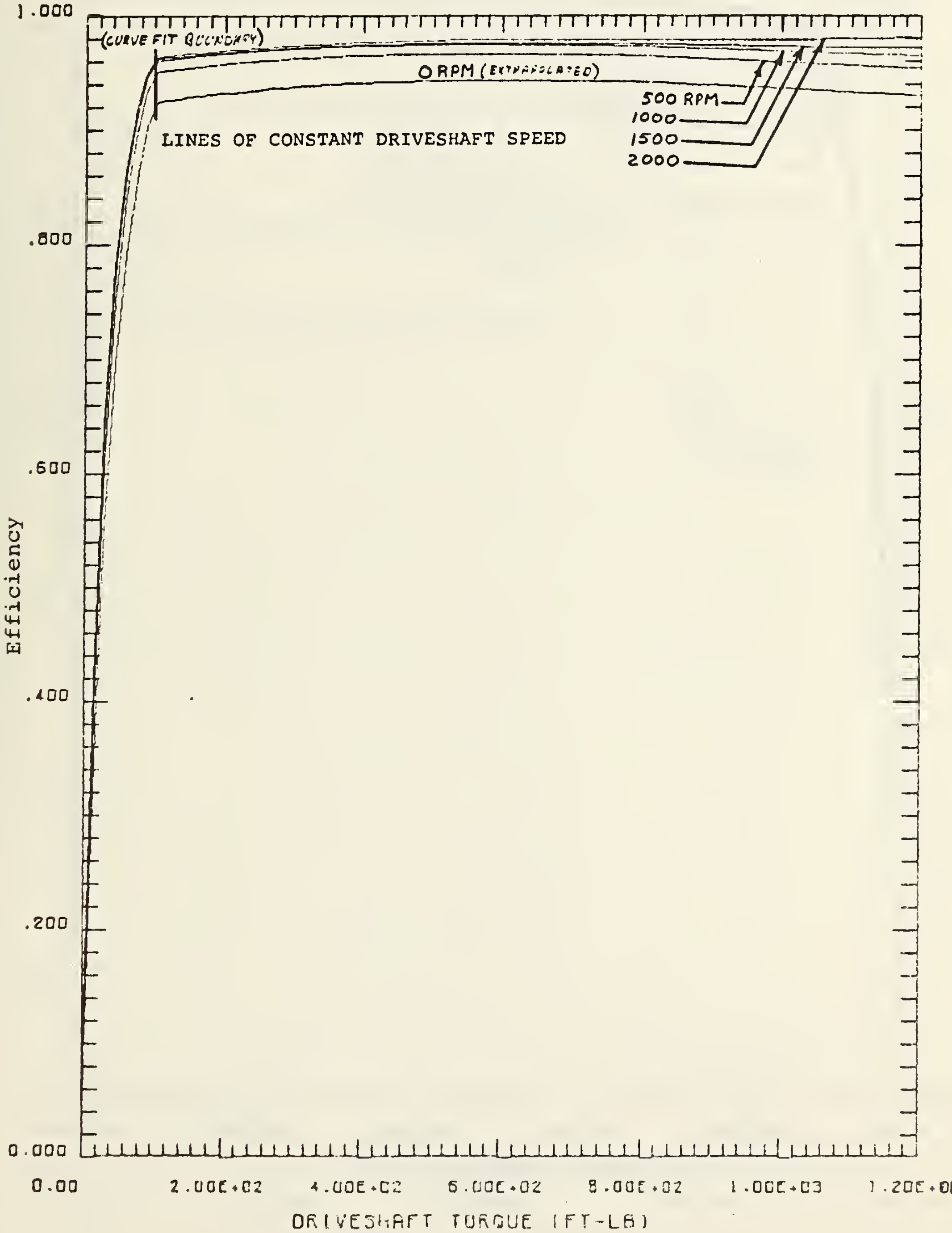


FIGURE 24. TRANSMISSION EFFICIENCY - FIRST GEAR

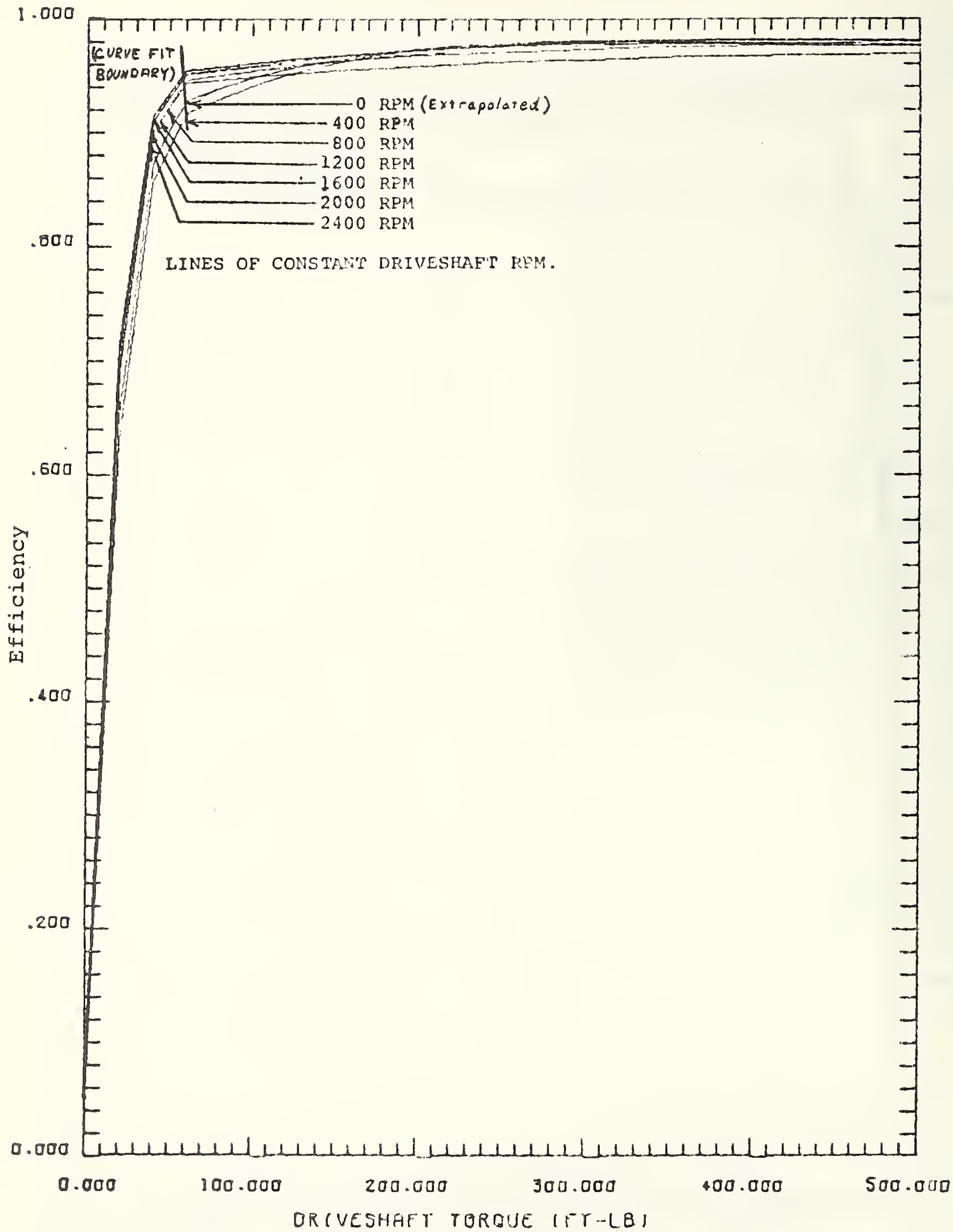


FIGURE 25. TRANSMISSION EFFICIENCY - SECOND GEAR

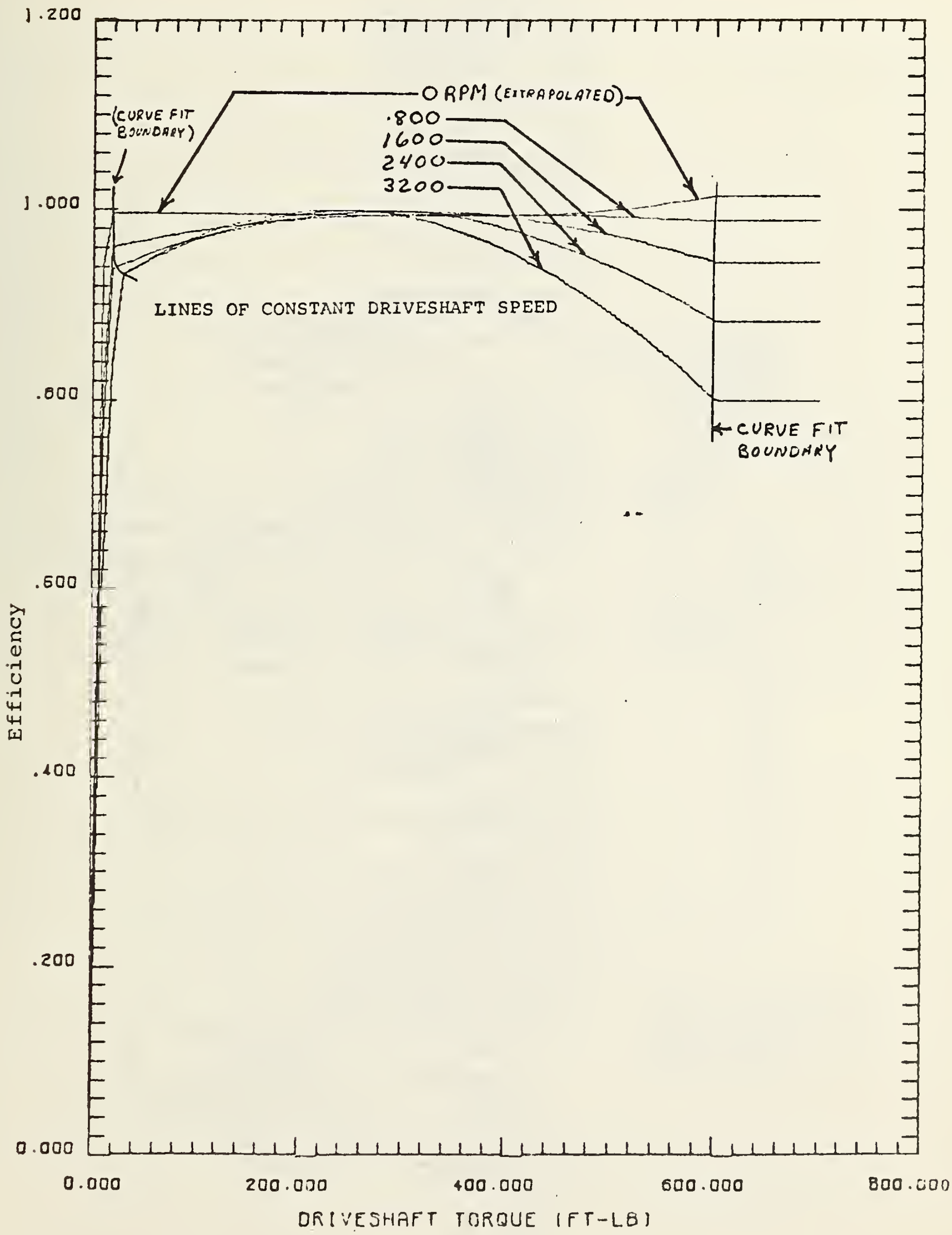


FIGURE 26. TRANSMISSION EFFICIENCY - THIRD GEAR

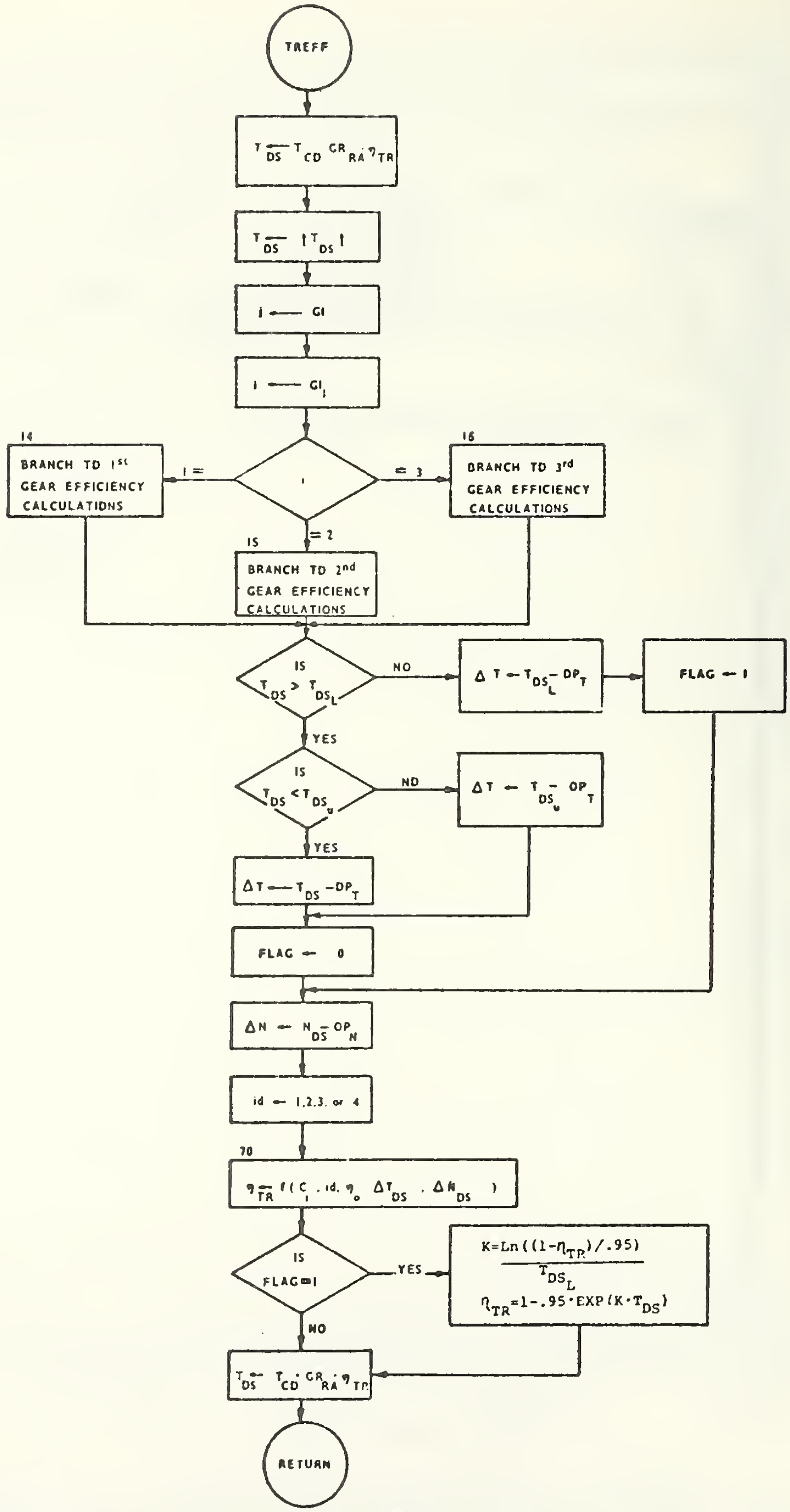


FIGURE 27. TRANSMISSION GEAR EFFICIENCY DIAGRAM

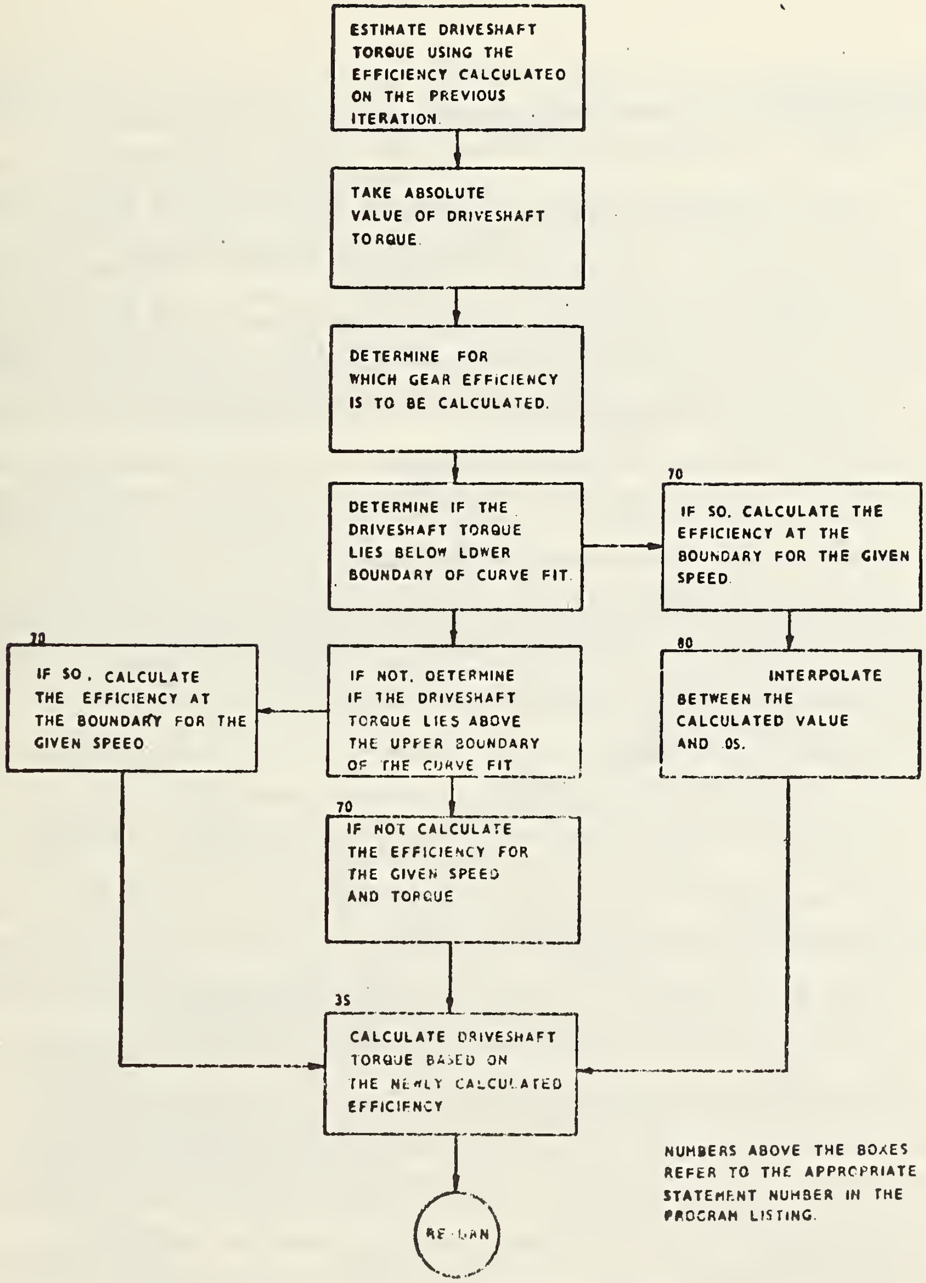


FIGURE 28. TRANSMISSION GEAR EFFICIENCY BLOCK DIAGRAM

```
      *                          **** TREFF ****
      C---- SUBROUTINE TO DETERMINE TRANSMISSION GEAR EFFICIENCY
      C****
      C--- AS A FUNCTION OF DRIVESHAFT TORQUE AND SPEED FOR THE GEAR IN WHICH
      C---- DAN KAPELLEN 10/73, REVISED 2/12/74
            SUBROUTINE TREFF(TA8C,TB81GR,TB81EF,TB81GI,T9IN,T9IC)
            COMMON /GEAREF/ TBC1GI(10,4),IBC1GI(10)
      C---- THIS SUBROUTINE CALCULATES THE EFFICIENCY FOR A C-6 AUTOMATIC
      C-----TRANSMISSION AS A FUNCTION OF DRIVESHAFT TORQUE AND SPEED BASED ON
      C----  DATA SUPPLIED FOR EACH OF THE THREE GEARS.  THE DATA IS MODELED
      C---- WITH A THREE DIMENSIONAL CURVE FIT BASED ON A TAYLOR SERIES EXPANS
      C---- THE VARIABLES USED IN THIS SUBROUTINE ARE AS FOLLOWS,
      C---- T9IN=DRIVESHAFT SPEED (RPM)
      C---- T9IC=DRIVESHAFT TORQUE (FT-LB)
      C---- TB91EF=TRANSMISSION GEAR EFFICIENCY
      C---- T9DCMN=MINIMUM DRIVESHAFT TORQUE FOR WHICH EFFICIENCY DATA WAS AVA
      C---- T9DCM=MAXIMUM DRIVESHAFT TORQUE FOR WHICH EFFICIENCY DATA WAS AVAI
      C---- INTERP=A FLAG USED TO DETERMINE IF THE EFFICIENCY IS TO BE INTERPO
      C---- TBD3T1,2,3=DRIVESHAFT TORQUE OPERATORS USED IN THE CURVE FITS
      C---- TBD3N1,2,3=DRIVESHAFT SPEED OPERATORS USED IN THE CURVE FITS
      C*********************************************************************
      C---- THIS SUBROUTINE CALCULATES THE TRANSMISSION GEAR EFFICIENCY AS A F
      C---- CAR IS RUNNING.  THE PROGRAM VARIABLES ARE AS FOLLOWS,
      C---- INPUT VARIABLES-----------------------------
      C-----BGRTIO--- THE BEVEL GEAR RATIO
      C---- T9IC-DRIVESHAFT TORQUE
      C---- T9IN-DRIVESHAFT SPEED
      C---- TA8C-CONVERTOR OUTPUT TORQUE
      C---- TB91GR-TRANSMISSION GEAR RATIO
      C---- TB91EF-TRANSMISSION GEAR EFFICIENCY FROM PREVIOUS ITERATION.
      C-----TB81GI-GEAR IN WHCIH CAR IS BEING DRIVEN
      C---- OUTPUT VARIABLES----------------------------
      C---- T9IC-DRIVESHAFT TORQUE AS CALCULATED BASED ON THE NEW EFFICIENCY
      C---- TB81EF-NEW TRANSMISSION GEAR EFFICIENCY
      C---- OTHER PROGRAM VARIABLES--------------------
      C---- TBC1GI(J)-INDICATES WHICH GEAR TO USE FOR THE EFFICIENCY CALCULATI
      C---- TBC1GI(I,ID)-COEFFICIENTS OF THE CURVE FIT EQUATIONS
      C---- ID-INDICATES WHICH SET OF CURVE FIT COEFFICIENTS TO USE
      C---- T9DCMN--LOWEST D.S. TORQUE FOR WHICH CURVE FIT IS CONSIDERED VALID
      C---- T9DCM-HIGHEST D.S. TORQUE FOR WHICH CURVE FIT IS CONSIDERED VALID.
      C---- DBD3T-DEVIATION FROM CURVE FIT D.S. TORQUE OPERATING POINT.
      C---- DBD3N--DEVIATION FROM CURVE FIT D.S. SPEED OPERATING POINT.
      C---- INTERP-A FLAG WHICH IS SET TO 1 IF INTERPOLATION IS REQUIRED.
      C*********************************************************************
      C---- ESTIMATE CURRENT DRIVESHAFT TORQUE BASED ON EFF. FROM PREVIOUS ITE
            T9IC=TA8C*TB81GR*TB81EF
      C---- USE ABSOLUTE VALUE OF DRIVESHAFT TORQUE FOR EFFICIENCY CALCULATION
            T9IC=ABS(T9IC)
      C---- DETERMINE WHICH GEAR EFFICIENCY IS TO BE CALCULATED.
            J=TB81GI
            I=IBC1GI(J)
            IF(I-2)14,15,16
      C*********************************************************************
```

```
      C*****************************FIRST GEAR EFFICIENCY*************************
      C*MMM*********************************************************************
      C---- DETERMINE IF THE DRIVESHAFT TORQUE FALLS BELOW LOWER BOUNDARY OF CU
   14 T9DCMN=100.
      IF(T9IC-T9DCMN)22,31,23
      C---- IF SO CALCULATE THE EFFICIENCY AT THE BOUNDARY.
   22 DBD3T =T9DCMN -500.
      C-----SET THE INTERPOLATION FLAG TO 1.
      INTERP=1
      GO TO 10
      C---- DETERMINE IF THE D.S. TORQUE LIES BEYOND THE UPPER BOUNDARY OF CURV
   23 T9DCM=1600.
      IF(T9IC-T9DCM)31,31,24
      C---- IF SO CALCULATE THE EFFICIENCY AT THE UPPER BOUNDARY.
   24 DBD3T =T9DCM-500.
      GO TO 25
   31 DBD3T =T9IC-500.
   25 INTERP=0
   10 DBD3N =T9IN-600.
      ID=1
      GO TO 70
      C**************************************************************************
      C***************************SECOND GEAR EFFICIENCY*************************
      C---------------------------SECOND GEAR USES TWO SETS OF CURVE FIT EQUATI
      C**************************************************************************
   15 CONTINUE
      IF(T9IN-2400.)44,40,40
      C---- DETERMINE IF THE DRIVESHAFT TORQUE FALLS BELOW LOWER BOUNDARY OF CU
   40 T9DCMN=50.
      IF(T9IC-T9DCMN)41,34,42
   41 DBD3T =T9DCMN-175.
      ID=3
      C-----SET THE INTERPOLATION FLAG TO 1.
      INTERP=1
      GO TO 11
      C---- DETERMINE IF THE D.S. TORQUE LIES BEYOND THE UPPER BOUNDARY OF CURV
   42 T9DCM=500.
      IF(T9IC-T9DCM)34,34,43
      C---- IF SO CALCULATE THE EFFICIENCY AT THE UPPER BOUNDARY.
   43 DBD3T =T9DCM-175.
      ID=3
      GO TO 50
      C---- REPEAT PROCESS FOR DRIVESHAFT SPEEDS LESS THAN 2400 RPM.
   44 T9DCMN=50.
      IF(T9IC-T9DCMN)46,36,47
   46 DBD3T =T9DCMN-400.
      ID=2
      INTERP=1
      GO TO 11
   47 T9DCM=900.
   48 IF(T9IC-T9DCM)36,36,49
   49 DBD3T =T9DCM-400.
      ID=2
```

```
      GO TO 50
   36 DBD3T = T9IC-400.
      ID=2
      GO TO 11
   34 DBD3T = T9IC-175.
      ID=3
   50 INTERP=0
   11 DBD3N = T9IN-2400.
      GO TO 70
C*****************************************************************************
C****************************THIRD GEAR EFFICIENCY****************************
C*****************************************************************************
   16 CONTINUE
      IF(T9IN-2000.)66,60,60
C---- DETERMINE IF THE DRIVESHAFT TORQUE FALLS BELOW LOWER BOUNDARY OF
   60 T9DCMN=30.
   61 IF(T9IC-T9DCMN)62,33,63
   62 DBD3T =T9DCMN-275.
C-----SET THE INTERPOLATION FLAG TO 1.
      INTERP=1
      GO TO 12
C---- DETERMINE IF THE D.S. TORQUE LIES BEYOND THE UPPER BOUNDARY OF C
   63 T9DCM=600.
      IF(T9IC-T9DCM)33,33,65
C---- IF SO CALCULATE THE EFFICIENCY AT THE UPPER BOUNDARY.
   65 DBD3T =T9DCM-275.
      GO TO 67
C---- REPEAT PROCESS FOR DRIVESHAFT SPEEDS LESS THAN 2000 RPM.
   66 T9DCMN=20.
      IF(T9IC-T9DCMN)62,33,63
   33 DBD3T = T9IC-275.
   67 INTERP=0
   12 DBD3N = T9IN-2000.
      ID=4
   70 CONTINUE
C---- CALCULATE THE EFFICIENCY FOR THE DESIRED D.S. SPEED AND TORQUE.
      TB91EF=TBC1GI(1,ID)+DBD3T*(TBC1GI(2,ID)+DBD3N*(TBC1GI(6,ID)
     1+DBD3N*TBC1GI(9,ID))+DBD3T*(TBC1GI(4,ID)+DBD3N*TBC1GI(10,ID)
     2+DBD3T*TBC1GI(7,ID)))+DBD3N*(TBC1GI(3,ID)+DBD3N*(TBC1GI(5,ID)
     3+DBD3N*TBC1GI(8,ID)))
C---- CHECK INTERPOLATION FLAG.
      IF(INTERP)35,35,80
   80 CONTINUE
C---- IF .GT. ZEROINTERPOLATE BETWEEN THE CALCULATED BOUNDARY EFFICIEN
      IF(1.00-TB91EF)81,82,82
   81 CONTINUE
      TB91EF=1.00
   82 CONTINUE
C---- THIS INTERPOLATION USES AN EXPONENTIAL, FIRST CALCULATE THE CONS
C---- USED IN THE EXPONENTIAL BASED ON THE TORQUE AND EFF AT THE CURVE
      SK=ALOG((1.-TB91EF)/.95)/T9DCMN
C---- THEN CALCULATE THE INTERPOLATED EFFICIENCY.
      TB91EF=1.-.95*EXP(SK*T9IC)
```

```
C---- CALCULATE THE NEW D.S. TORQUE BASED ON THE NEWLY CALCULATED EFF
   35 CONTINUE

      IF (TB01EF .GT. 1.0) TB01EF= .998
      T9IC=TABC*TB01GR*TB01EF
      RETURN
      END
```

3.3.26 Vehicle Dynamics Subroutine - VEDYN

PROGRAM NAME: VEDYN

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine determines the vehicle acceleration based on the difference between the force driving the vehicle and the resistive forces. It also tests for conditions of tire spinning or skidding.

MODELING: The road load power requirement is the most important part of this subroutine. It is defined as the force that must be provided by the engine to propel a vehicle at a constant speed. This force acts on the wheels at the tireroad interface of the drive sheels. As can be seen in the block diagram of Fig. 29, there are two options for determining road load as a function of vehicle speed: 1) by use of the road load equation, and 2) by linearly interpolating between steady state driveshaft torques in speed increments of 10 mph. The first option allows the user to specify and vary frontal area, drag coefficient, tire rolling friction, grade angle,and mass independently. The second option allows the user to store the total road load torque required at the driveshaft at speed increments of 10 mph. The latter is useful when road load torque data are obtained experimentally at the driveshaft for a specific vehicle and a curve fit is not desired.

The braking force is determined from a brake constant and a brake setting. The brake constant is set equal to the vehicle mass in the initialization program (INICON). The brake setting varies between 0 and 1. This means that if the tires did not slip the resultant deceleration at full brake would be slightly more than 1 g, since road load adds to the brake force.

The net tractive force available to accelerate the vehicle is determined by computing the difference between the force applied to the tire-road interface by the engine and the resistive vehicle forces (Eq. 3).

Dividing the net tractive force by the inertial mass of the vehicle determines the resultant acceleration (Eq. 6).

However, the vehicle acceleration is limited by the coefficient of friction between the tires and road surface. The magnitude of the acceleration or deceleration is tested against the maximum and minimum possible as determined by the coefficient of static friction. If the maximum or minimum value is exceeded, the acceleration is set to the acceleration attained with the tires spinning or the deceleration with the tires skidding. (See note at end of "variables which must be stored in memory".)

Negative velocities are prevented by comparing the vehicle speed to $A\Delta t$ where Δt is the time step and A is the acceleration. Whenever the velocity would become negative within the next time step if calculated in the normal manner the acceleration is set equal to the current velocity (see statements 56 and 59 in the listing.) This works well in the all-digital version, but in the real time simulations where the time steps vary between iterations, a larger time step is assumed than would ever be expected to occur. A flow diagram of the subroutine is given in Fig. 30.

It is also worthy to note that this program is presented in its most flexible form. The user can tailor it to decrease computation time and core space. If a user is sure no conditions for wheelslip will be encountered, this part of the program could be eliminated as well as grade angle and wind velocity if not needed, so that one of the options could be omitted. The rotational inertia of the drive train can also be approximated by a constant.

EQUATIONS:

1) $$F_D = \frac{C_D A_F (V + V_W)^2}{2gc} \frac{5280^2}{3600} + \mu M(1 + C_G V) + M \cdot \sin\phi$$

F_D = Total drag

2) $$R = F_D + B_S K_B$$

R = Total vehicle resistive force including brakes

3) $$F_A + T_{RA}/R_T - R$$

F_A = Net acceleration force available

4) $$J = ((J_{CT} + J_{TR}) \cdot GR^2_{TR} + J_{RA}) \cdot GR^2_{RA} + J_{TW}$$

J - Effective inertia at the rear wheels

5) $$M_I = M + J/R_T^2$$

M_I = Equivalent mass of the vehicles

6) $A = \frac{F_A \cdot g_c}{M_I}$

A = Acceleration of vehicle

7) $A = A_{MINS} \cdot g$ if $A/g \leq -A_{MIN}$

8) $A = A_{MAXS} \cdot g$ if $A/g \geq A_{MAX}$

A_{MINS} = maximum deceleration (see note on next page)

A_{MAXS} = maximum acceleration

INPUT VARIABLES:

Variable Name	Symbol	Description
VVOS	V	Vehicle speed (mph)
T9OC	T_{RA}	Rear axle output torque (ft-lb)
VVIBBR or BS	B_S	Brake setting
TBO1GR	GR_{TR}	Transmission gear ratio
T9I1GR	GR_{RA}	Equivalent rear axle ratio
TBO1GI	GI	Gear index
AVIO	ϕ	Wind speed (mph)

OUTPUT VARIABLES:

VVOA	A	Vehicle acceleration
VVDF	F_D	Road load force

VARIABLES WHICH MUST BE STORED IN MEMORY:

VVIM	M	Vehicle mass (lb)
VVILFT	A_F	Frontal area (ft^2)
VVI1CD	C_D	Drag coefficient
VVI1RF	μ	Coefficient of rolling friction
TVIJRA	J_{RA}	Rear axle gear inertia ($lbm\text{-}ft^2$)
TVIJCT	J_{CT}	Torque converter turbine inertia ($lbm\text{-}ft^2$)
TVIJTR	J_{TR}	Transmission gear inertia (3rd gear)
TVICRL	T_i	Table of road load torques

LOADEQ	FLAG	Used to determine the method of calculating road load
VVIFUM	f_M	Coefficient of static tire friction (g's)
VVIFUS	f_s	Coefficient of slipping tire friction (g's)
VVIMAX	A_{MAX}	Maximum vehicle acceleration (g's)
VVIAS	A_{MAXS}	Maximum vehicle acceleration with wheel spin (g's)
VVI2BR	K_B	Brake constant

NOTE: This program assumes all four wheels to brake. Therefore the coefficient of static and slipping tire friction are also the maximum (A_{MIN}) and skidding (A_{MINS}) decelerations respectively. The maximum (A_{MAX}) and slipping (A_{MAXS}) acceleration are calculated in the initialization program (INICON) taking into account weight transfer and assuming the power wheels to be at the rear of the vehicle.

OTHER PROGRAM VARIABLES:

Variable Name	Symbol	Description
SINAVO	$SIN(\phi)$	Sine approximation for grade angle
TVIMJ	J	Rotary inertia of drive train as seen at the rear wheels
VVDFBR	R	Total vehicle resistive force including brakes (lb)
VVDFN	F_A	Net force available at the pavement to accelerate the vehicle (lb)
VVDMI	M_I	Inertial mass of vehicle (g's)
WHLSLP		Used in real time simulation to control the noise generator for indicating tire slipping conditions to the driver.

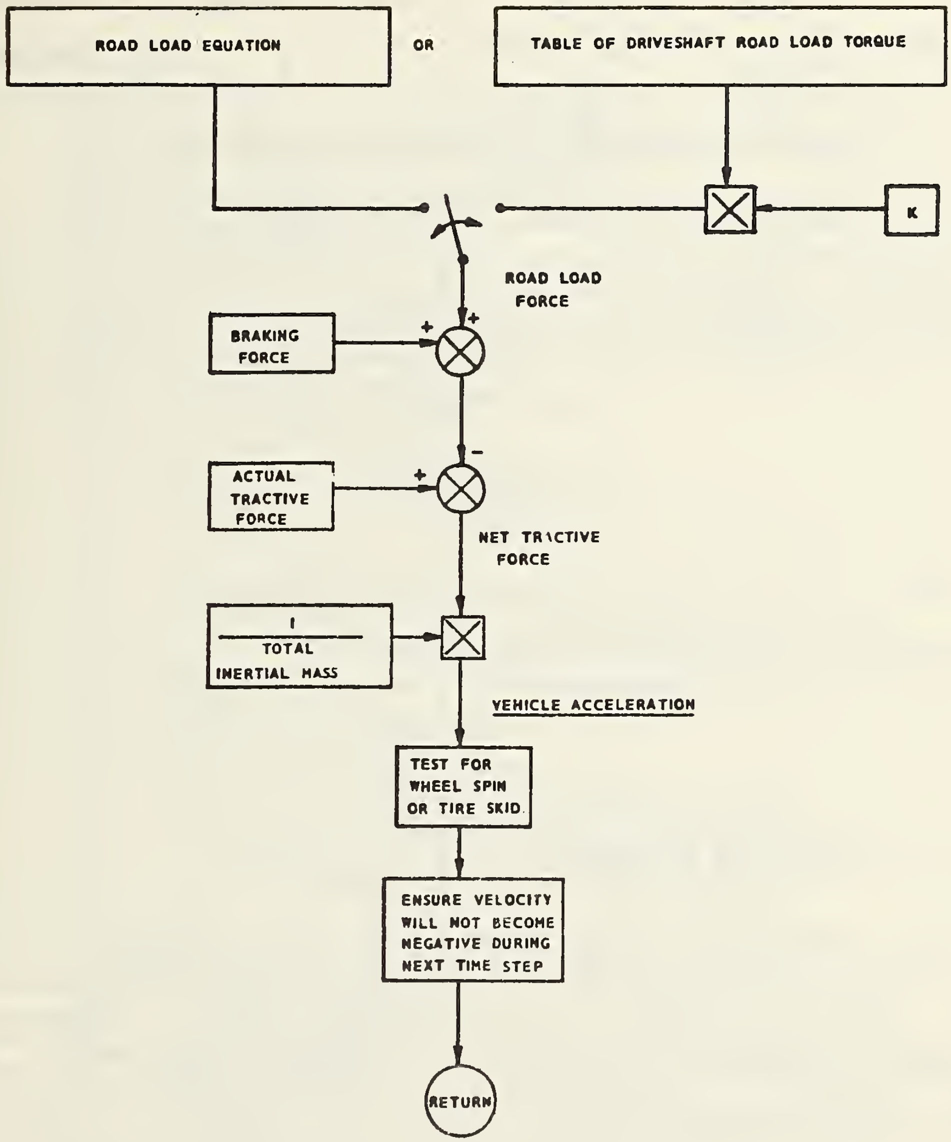


FIGURE 29. VEHICLE DYNAMICS BLOCK DIAGRAM

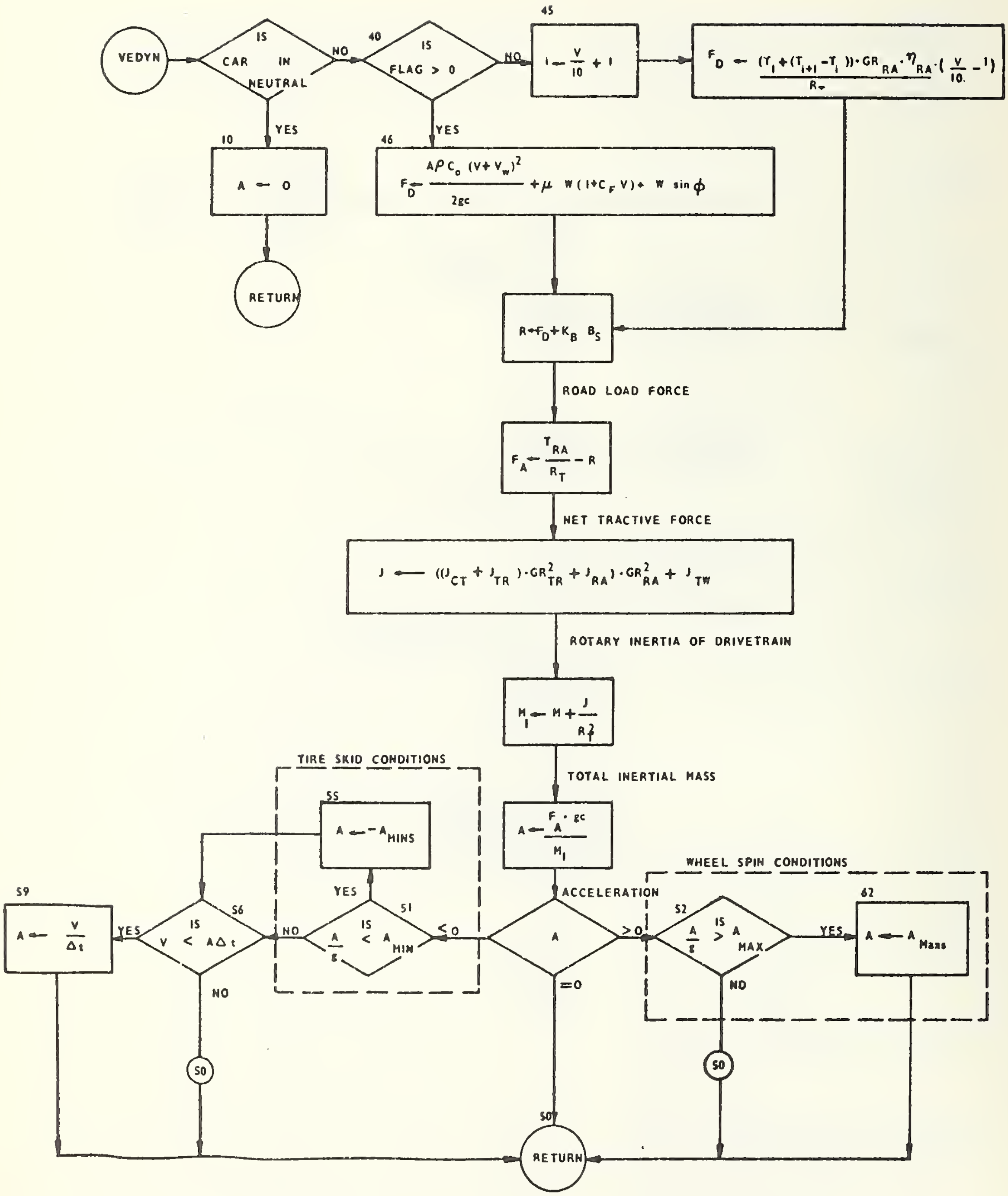


FIGURE 30. VEHICLE DYNAMICS FLOW DIAGRAM

```
      *                                    **** VEDYN ****
            SUBROUTINE VEDYN( TB01GI,VVOS,BS,T99C,TB01GR,T911GR,VVOA
           C ,VVDF,T9I1,VVDFBR,VVDMI,DELTAT,VVOAO,
           C TVIMJ)
      C---- SUBROUTINE TO SIMULATE VEHICLE ACCELERATION AND BRAKING DYNAMICS
      C---- DAN KAPELLEN 10/73
      C************************************************************************
      C---- THIS SUBROUTINE DETERMINES THE VEHICLE ACCELERATION BASED ON THE
      C---- DIFFERENCE BETWEEN THE FORCE DRIVING THE VEHCLE AND THE RESISTIVE
      C---- FORCES.  IT ALSO TESTS FOR CONDITIONS OF TIRE SPINNING OR SKIDDING.
      C---- INPUT VARIABLES-------------------------------------------------
      C---- VVOS- VEHICLE SPEED (MPH).
      C---- T99C-REAR AXLE OUTPUT TORQUE (FT-LB).
      C----  BS-BRAKE SETTING (0 TO 1)
      C---- TB01GR-TRANSMISSION GEAR RATIO.
      C---- T911GR-EQUIVALENT REAR AXLE RATIO.
      C---- TB01GI-GEAR IN WHICH CAR IS OPERATING.
      C---- AVIS-WIND SPEED (MPH)
      C---- GRADE ANGLE (RAD)
      C---- OUTPUT VARIABLES------------------------------------------------
      C---- VVOA-VEHICLE ACCELERATION (MPH/SEC)
      C---- VVDF-VEHICLE ROAD LOAD FORCE AT TIRE ROAD INTERFACE (LB).
      C---- WHLSLP- USED IN R. T. SIMULATION TO CONTROL TIRE SLIP NOISE GENERAT
      C---- PROGRAM CONSTANTS-----------------------------------------------
      C---- VVIM-VEHICLE MASS (LB).
      C---- VVILFR-FRONTAL AREA (SQ. FT.).
      C---- VVI1CD-DRAG COEFFICIENT.
      C---- VVI1RF-COEFFICIENT OF ROLLING FRICTION.
      C---- VVIFUM-COEFFICIENT OF STATIC TIRE FRICTION (G'S).
      C---- VVIFUS-COEFFICIENT OF SLIPPING TIRE FRICTION (G'S).
      C---- VVIMAX-MAX VEHICLE ACCEL (G'S).  CALCULATED IN 'INICON'.
      C---- VVIAS-MAX VEHICLE ACCEL WITH WHEEL SPIN(G'S). CALC. IN 'INICON'.
      C---- VVI2BR-BRAKE CONSTANT. (LB).
      C---- TVI,TVIJCT
      C---- TVIJCT,TVIJTR,TVIJRA,TVIJTW- POLAR MOMENT OF INERTIA OF TORQUE
      C---- CONVERTER TURBINE, TRANSMISSION, REAR AXLE, AND REAR WHEELS
      C---- RESPECTIVELY(LBM-FT**2).
      C---- LOADEQ-A USED IN A LOGICAL  MANNER TO TO DETERMINE WHETHER
      C---- LOADEQ- USED TO DETERMINE IF ROAD LOAD EQUATION IS OF TABLE IS USED.
      C---- OTHER PROGRAM VARIABLES-----------------------------------------
      C---- SINAVG-SINE APPROXIMATION FOR GRADE ANGLE.
      C---- TVIMJ-TOTAL ROTARY INERTIA OF DRIVETRAIN REFLECTED TO REAR WHEELS.
      C---- VVDFBR- TOTAL RESISTIVE FORCE ACTING ON VEHICLE INCLUDING BRAKES.
      C---- VVDFN-NET FORCE AVAILABLE TO ACCELERATE VEHICLE.
      C---- VVDMI-TOTAL INERTIAL MASS OF VEHICLE (G'S).
      C**********************************************************************
            COMMON /AIR/ AVIB,AVIR,AVIO,AVIS,AVIM
            COMMON /PMOMENT/ TVIJCT,TVIJTR,TVIJRA ,TVIJTW
            COMMON /PRNT/ IOUT,IPRNT,LOADEQ,MAXLIN
            COMMON /MASS/ VVILFR,VVI1CD,VVI1RF,VVIMI,VVI2BR,VVIM,VVIMDR,
           C               VVISWB,VVISH,VVIAMX,VVIAS
            COMMON /RDLD/ TVICRL(16)
            COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
```

```
*
C---- APPROXIMATE GRADE ANGLE TO AVOID USE OF SINE FUNCTION.
      SINAVO=AVIO*(1.-AVIO*AVIO/6.)
      WHLSLP=0.
C---- IF CAR IS NOT IN GEAR SET ACCELERATION TO ZERO AND RETURN.
      IF (T801GI-.5) 10,10,40
   10 VVOA=0.
      RETURN
   40 CONTINUE
C---- IF LOADEQ IS 1, USE ROAD LOAD EQUATION.  IF ZERO USE D.S. TORQUE TABL
      IF(LOADEQ)45,45,46
   45 I=VVOS/10.+1.
      VVDF=(TVICRL(I)+(TVICRL(I+1)-TVICRL(I))*(VVOS/10.-I))*T9I1GR*T9I1/
     1VVIDRR
      GO TO 47
   46 CONTINUE
      CVVI1RF=.005+VVI1RF*VVOS**2. *.0000001
      VVDF=.0334294*VVI1CD*VVILFR*AVIM*((VVOS+AVIS)**2)+
     CVVIM*(.005+3.59*(VVOS*22./15.)**2. *10.**(-7))
     C  +SINAVO*VVIM
   47 CONTINUE
C---- ADD RESISTIVE FORCE TO BRAKING FORCE TO OBTAIN TOTAL RESISTIVE FORCE
      VVDFBR=VVDF+VVI2BR*BS
C---- OBTAIN NET FORCE AVAILABLE TO ACCELERATE THE VEHICLE.
      VVDFN=T99C/VVIDRR-VVDFBR
C---- CALCULATE TO TOTAL ROTARY INERTIA OF THE DRIVETRAIN AS SEEN AT THE
      TVIMJ=(TVIJCT+TVIJTR)*((T801GR*T9I1GR)**2)+TVIJRA*(T9I1GR**2)
     2+TVIJTW
C---- REAR WHEELS.
C---- DETERMINE THE INERTIAL MASS OF THE VEHICLE.
      VVDMI=(VVIM +(TVIMJ/(VVIDRR**2)))/32.1739
C-----DETERMINE VEHICLE ACCELERATION.
      VVOA=VVDFN /VVDMI
C*****************************************************************************
C---- DETERMINE IF THERE ARE ANY CONSTRAINTS ON THE CALCULATED ACCELERATIO
C*****************************************************************************
      IF(VVOA) 51,50,52
C---- IF ACCEL IS NEGATIVE CHECK IF TIRES ARE SKIDDING.
   51 IF (VVOA/32.1739+VVIFUM) 55,56,56
   55 CONTINUE
      WHLSLP=-1.
C---- IF TIRES ARE SKIDDING SET DECEL TO THAT OCCURING UNDER SLIDING CONDI
      VVOA=-VVIFUS*32.1739
   56 CONTINUE
C---- ENSURE VELOCITY WILL NOT BECOME NEGATIVE DURING NEXT TIME STEP.
      DELTAT=.01
      IF(VVOS+VVOA*DELTAT*.681818)59,59,50
   59 VVOA=-VVOS*1.46667/DELTAT
      RETURN
C---- FOR POSITIVE ACCEL DETERMINE IF WHEELS ARE SPINNING.
   52 IF (VVOA-VVIAMX*32.1739) 50,50,62
   62 CONTINUE
      WHLSLP=-1.
```

```
C---- IF WHEELS ARE SPINNING SET ACCEL TO MAX POSSIBLE UNDER SLIP.
      VVOA=VVIAS*32.1739
   50 CONTINUE
      ABVVOA=ABS    (VVOA)
      IF(ABVVOA .LE. .01) VVOA=.0
C---- CHANGE VEHICLE ACCLERATION FROM FT/SEC/SEC TO MPH/SEC.
      VVOA=VVOA*.681818
      IF (VVOA .LE. 0 .AND. VVOS .LT. .1) VVOS=VVOA=VVOAO=0
      RETURN
      END
```

3.3.27 Subroutine to Interpolate Torque Ratio and Inverse Size Factor - VELTERP

SUBROUTINE NAME: VELTERP

DESCRIPTION: SEE TQCONV

3.4 INPUT FORMATS

Data is entered into the system by the subroutines INICON, MAPER and RDEPA. AGNCON can be used to revise data and vary parameters when doing a series of runs. The following is a description of the input form.

VARIABLE	INPUT FORMAT	MEANING
COMM	13A6/13A6	Comment for heading
VVIMI	8E10.3	Inertial mass of bus
VVI2BR		Brake constant
VVIM		Vehicle mass
VVIMDR		Mass on drive wheels
RIE	8E10.3	Engine inertia
TMAX		Maximum engine torque
SCALEF	8E10.3	Engine size scale factor
TIDLE		Throttle idle setting
PIDLMIN		Minimum engine speed
PIDLMAX		Maximum engine speed
ACLOAD	8E10.3	Accessory load torque
VMIN(1)	8E10.3	Maximum value for joint prob.
PMAX(1)		Minimum value for joint prob. den.
VINT(1)		Interval size for joint prob. den.
VMIN(2)	8E10.3	(same as above except for second variable)
PMAX(2)		
CINT(2)		
NGEAR	I5	Number of transmission gears
TBC1GI	E11.5	Polynomial coefficients for calculating gear efficiencies
ITC1GI	I1	Index for assigning gear efficiency calculations
TBC1GR	8E10.3	Gear ratios for transmission
BGRTIO	F10.6	Bevel gear ratio
GR1	8E10.3	Gear ratio for first gear
TVIJCT		Polar moment of converter
TVIJTR		Polar moment of transmission
TBDTMS		Length of shift
TBDTH		Time between shifts

VARIABLE	INPUT FORMAT	MEANING
T8I1GR	8E10.3	Rear axle ratio
TVIJRA		Polar moment of rear axle
VVIDRR	8E10.3	Tire rolling radius
VVIFUM		Coefficient of maximum tire friction
VVIFUS		Sliding coefficient of tire friction
VVI1CF		Tire coulomb friction coefficient
TVIJTW		Polar moment of tires and wheels
T8INV	F6.1	Corrected driveshaft speed
VVILFR	8E10.3	Frontal area
VVI1CD		Drag coefficient
VVI1RF		Rolling friction coefficient
VVISWB	8E10.3	Wheel base
VVISH		Height of vehicle center of gravity
FUELWT		Fuel weight
AVIB	8E10.3	Air pressure
AVIR		Air temperature
GAIN		Gain for vedyn
DELMIN		Autodr minimum lead time
IOUT	K10	DT's between printouts
IPRNT		Print control
LOADEQ		Road load calculator switch
TVICRL	F5.1	Roadload
DT	F10.6	Time increment
AVIO	8E10.3	Grade angle
AVIS		Wind speed
GRMAX(I)	4F10.5	Maximum driveshaft speed for Gear I
GRMAXCR(I)	8F10.5	Maximum driveshaft speed while cruising
GRMIN(I)	F10.5	Minimum driveshaft speed for Gear I
AWAY	2F10.5,F10.8	Converter Gear Ratio and size factor
SRNEW	8F10.5	Speed ratio during lockup
TRNEW		Torque ratio during lockup
SROLD		Speed ratio when unlocking
TROLD		Speed ratio when unlocking
TIMLOCK		Length of lockup

VARIABLE	INPUT FORMAT	MEANING
ACCLOCK	8F10.5	Lockup velocity at wide open throttle
DECLOCK		Unlock velocity
ACCRUIS	8F10.5	Lockup velocity for cruising mode
MAPER		
F(50,9)	5x,9F7.2	Array to hold torque and fuel maps
MAP1(1,I)	9I7	First line of MAP1
MAP3(1,I)	9I7	First line of MAP3
RDEPA		
ACEL	3F8.3,I8,F8.3	Acceleration rate
VCRUIS		Cruise speed
DECFL		Deceleration rate
NSTOP		Number of stops
RTLNGT		Route length
TDWELL		Time spent at dwell
SIMULA		
ISTOP	I2	End of computer run flag

3.5 SAMPLE DATA DECK

This section reproduces a sample data deck.

```
*DATA
          2.5 MPHPS                    **BUS SIMULATION**                     25 MPH
          TORQUE CONVERTER TC490        24350 LB.        TRANSMISSION V730
 24350.     24350.     24350.     12175.
 37.54      1040.0     25.8       1.0         0.030       900.0       2200.
 23.        24.4       26.3       29.        34.4        42.         51.8        64.3
 64.3       64.3       64.3
 250.       750.       50.
 500.       2400.      100.
    3
 .97100E+00 .31633E-05 .19142E-04-.61697E-07-.35170E-07
 .24961E-08 .43930E-10 .22369E-10 .11561E-10 .19293E-10
 .97600E+00-.11786E-04-.78043E-05-.28614E-06 .78379E-09
 .46761E-08 .16687E-09 .22690E-11 .37415E-11-.83041E-10
 .96970E+00 .18473E-03-.11159E-05-.12043E-05-.50000E-08
 .10000E-06 .23667E-08 .89999E-12 .13525E-09-.65877E-09
 .99859E+00 .14185E-04 .27977E-05-.81397E-06-.15365E-08
 .42516E-07 .38182E-09-.62692E-12-.31066E-10-.46935E-09
123
2.0667     1.40       1.000
 .875
2.0667     2.50       3.50       10.0       15.0
 5.143     4.5
1.708      .8         .65        .01        40.52
   .    420.  840. 1260. 1680. 2100. 2520. 2980. 3400. 3820. 4240.
 75.       .7         .008
295.6      48.        7.21
14.3747    60.        0.03       .1
          20         -1          1

.05

 920.      1580.      9999.
  680.     1580.      9999.
  9999.    550.       1520.
     .00000    2.45995.000231207
     .10000    2.33082.000228655
     .20000    2.16999.000221179
     .30000    1.98506.000206864
     .40000    1.80236.000194834
     .45000    1.70567.000189145
     .50000    1.61217.000183530
     .55000    1.52337.000178040
     .60000    1.44011.000171737
     .70000    1.27716.000157817
     .75000    1.19261.000148809
     .80000    1.10623.000138923
     .83000    1.05307.000129790
     .86200     .99755.000116967
     .91230     .99811.000081106
     .92460     .99829.000071215
     .92480     .99829.000071035
1.0        .998       0.0
 1.25      .998       -.000045
1.50       .998       -.000130
```

1.0		.96	.6	1.3		.5			
28.0		8.6							
22.5									
	800.								
800	-144.4	0.0	144.4	263.9	369.6	475.8	529.4	682.8	728.
800	11.	11.	11.	17.17	24.2	28.27	30.64	40.56	52.8
800	0.0	.5	1.5	2.5	3.5	4.5	5.5	31.2	81.
800									
	1000.								
1000	-107.	0.0	107.	215.	309.8	404.4	498.9	593.5	732.
1000	16.	16.	16.	21.8	27.5	33.6	40.14	47.58	58.8
1000	0.0	1.0	2.0	3.0	5.0	6.0	33.0	38.	81.
1000									
	1200.								
1200	-130.	0.0	130.	260.9	354.5	449.06	542.7	637.3	731.1
1200	19.	19.	19.	25.64	32.64	39.5	47.	55.4	66.33
1200	0.0	5.7	11.4	17.87	24.35	30.8	37.29	43.77	81.
1200									
	1400.								
1400	-130.	0.0	130.	258.	352.6	446.4	544.0	637.7	731.5
1400	22.	22.	22.	30.291	37.98	44.05	54.81	63.7	74.88
1400	0.0	6.6	13.2	20.74	28.28	35.8	43.35	50.91	81.
1400									
	1600.								
1600	-170.	0.0	170.7	261.9	351.2	443.8	535.0	626.2	717.2
1600	26.	26.	26.	39.4	45.48	52.02	61.29	71.34	83.25
1600	0.0	7.8	15.6	23.9	32.25	40.59	48.9	57.24	81.
1600									
	1800.								
1800	-198.	0.0	198.4	281.	364.7	447.9	531.0	612.7	697.3
1800	34.	34.	34.	42.42	50.63	59.4	68.8	78.75	90.58
1800	0.0	10.2	20.4	29.0	37.5	46.1	54.6	59.5	81.
1800									
	2000.								
2000	-217.	0.0	217.9	293.6	369.5	445.1	520.7	596.1	672.2
2000	42.	42.	42.	49.9	58.0	66.6	75.0	85.8	97.5
2000	0.0	12.45	24.9	33.54	42.2	50.85	59.5	68.16	81.
2000									
	2200.								
2200	-230.	0.0	236.	304.6	373.1	442.6	512.3	582.5	651.7
2200	50.	50.	50.	57.4	65.4	73.8	83.	92.55	104.4
2200	0.0	15.5	30.9	39.24	47.6	55.95	64.29	72.66	81.
2200									
	800	2200	7	0	100	50	1	100	0
	800	2200	7	-50	950	10	1	100	0
2.5	25.	2.5			5 1.0	16.			
1									

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4. Letter Communication from GMC, Detroit Allison Division, 1975.
5. "California Steam Bus Project Technical Evaluation," R. A. Renner IRT - REPT - 301 - R, Jan. 1973.
6. Letter Communication AiResearch Mfg. Company, 1975.

APPENDIX A
Plot Program

TYPE OF SUBROUTINE: Output

DESCRIPTION: This program takes the output from OUTVAR and plots it on a Calcomp plotter.

MODELING: This program inputs from a tape with a maximum of twenty-five channels each of which holds values of a variable outputed by OUTVAR. Channel 1 holds the x axis values which is usually time. Six plots can be done using the same x axis. The program will then ask if more plots are wanted so up to 24 plots can be made from the same tape. Following is a complete listing of the plot program and a sample plot.

The Calcomp subroutines used are described in (3).

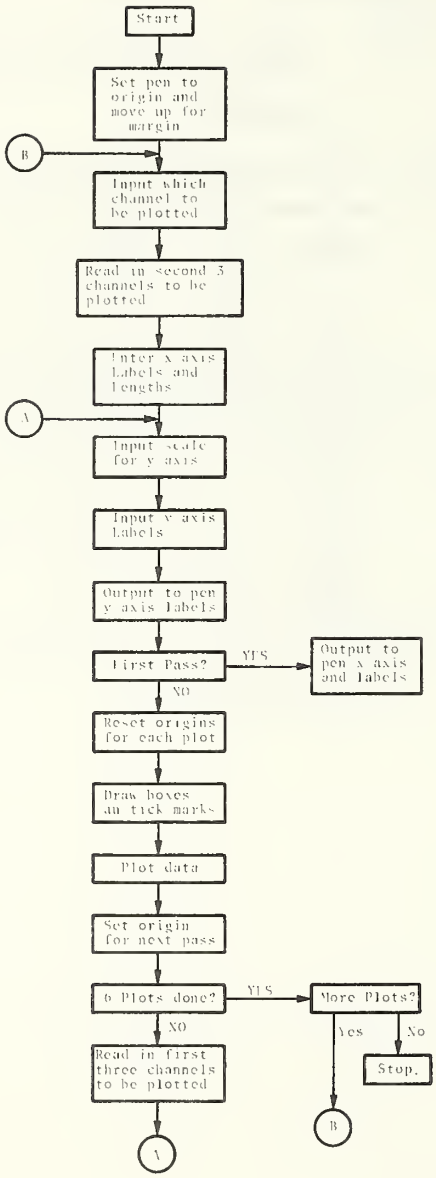

FIGURE A-1 FLOW DIAGRAM FOR PLOT PROGRAM

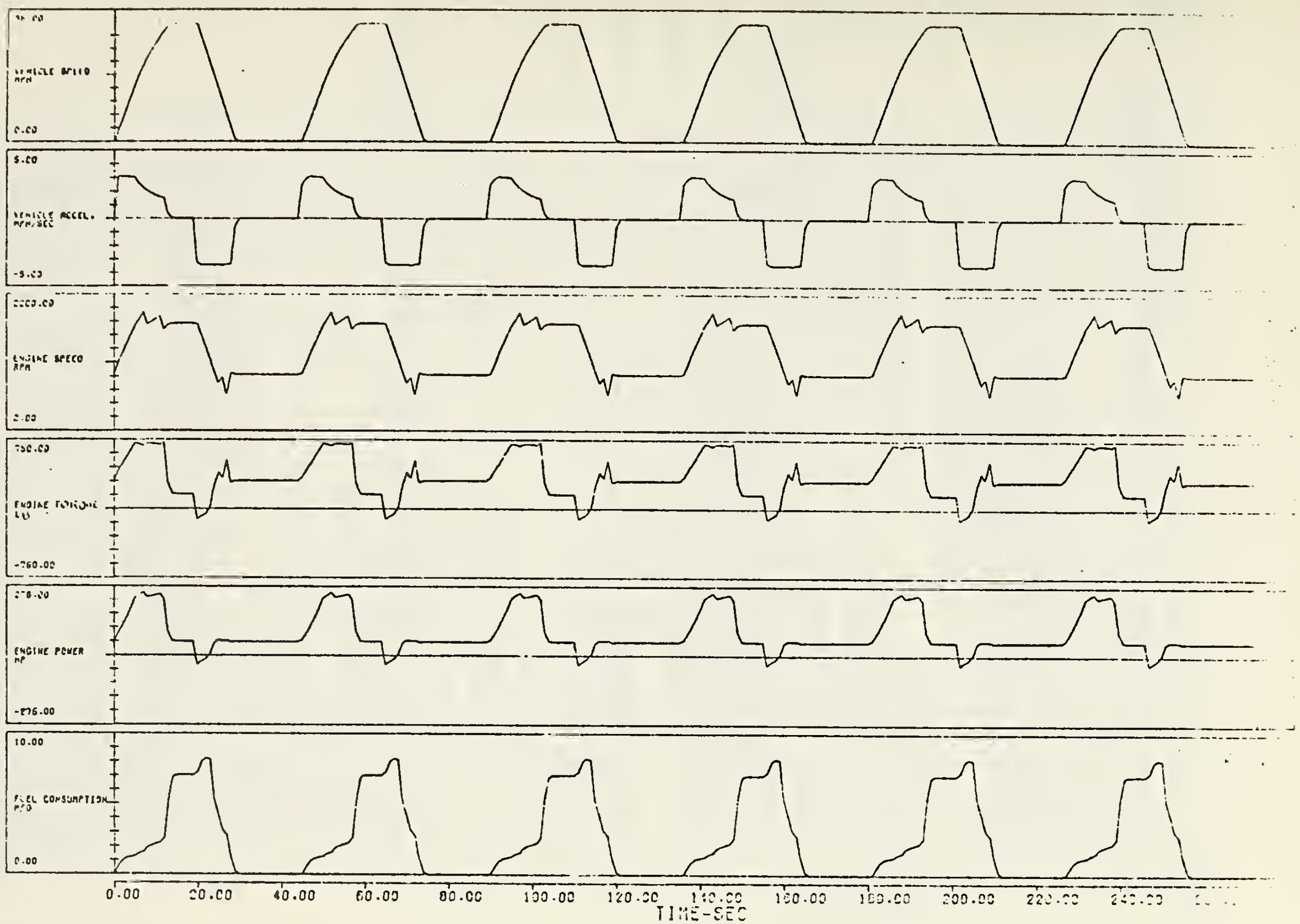

FIGURE A-2. GRAPHIC DISPLAY OF TYPICAL OUTPUT DATA

@FORTRAN LS,BO

```
*
      DIMENSION B(25),ARRAY1(1500),ARRAY2(1500),ARRAY3(1500),X(1500)
      REAL MAX(3),MIN(3)
      REAL MMAX
      DIMENSION INPUT(10),RINPUT(5)
      EQUIVALENCE (INPUT(1),RINPUT(1))
      DIMENSION NC(3,2),NCH(6)
      EQUIVALENCE (NCH(1),NC(1,1))
      DIMENSION C1(6),C2(6),C3(6),C4(6)
*
 1001 FORMAT(10I)
 1002 FORMAT(10(I,/))
 1003 FORMAT(10A8)
 1030 FORMAT(' CHANNEL',I4,2X,'MAXIMUM IS',F10.3,2X,'MINIMUM IS',F10.3)
 1031 FORMAT(F10.3)
 1032 FORMAT(' MAX =',F10.3)
 1040 FORMAT(' ENTER Y AXIS LABELS FOR EACH CHANNEL WHEN ASKED.',/,
     *' TWO (2) LINES ARE REQUIRED EACH UP TO 16 CHARACTERS',/,
     *' PROGRAM WILL ECHO YOUR ENTRY. IF YOU DONT LIKE IT,'/,
     *' PRESS SS2 AND CLEAR PAUSE TO REENTER BOTH LINES')
 1041 FORMAT(' ENTER 2 LINES FOR CHANNEL',I4)
 1042 FORMAT(' NUMBER OF POINTS IS ',I5)
*
      CALL PLOTS(0,0,16)
C ** MOVE ORIGIN UP 0.6 INCHES TO START
      CALL PLOT(0.0,0.6,-3)
    1 CONTINUE
      NPASS = 1
*
C ** CHANNEL SELECTION
C **
   50 DO 51 K=1,10
   51 INPUT(K) = 0
      OUTPUT(102) ' ENTER CHANNELS TO BE PLOTTED -- EX.  9,2,4,7,3,5'
      READ(101,1001) INPUT
C ** DETERMINE NUMBER OF CHANNELS
      NCHANS = 0
      DO 55 K=1,10
      IF(INPUT(K).EQ.0) GO TO 60
      NCHANS = NCHANS + 1
   55 CONTINUE
   60 IF(NCHANS.GT.6) OUTPUT(102)' TO MANY CHANNELS -- FIRST 6 USED'
      OUTPUT(102)' YOU HAVE SELECTED THE FOLLOWING CHANNELS'
      OUTPUT(102) ' TO CHANGE -- PRESS SS2'
      WRITE(102,1002)(INPUT(K),K=1,6)
      PAUSE 02
      IF(SENSE SWITCH 2) 50,70
   70 DO 72 J=1,2
      DO 71 I=1,3
      NC(I,J) = INPUT(I+3*(J-1))
   71 CONTINUE
   72 CONTINUE
```

```
C ** ENTER AXIS LABELS
      WRITE(101,1040)
   80 DO 84 K=1,6
      DO 81 J=1,10
   81 INPUT(J) = 4H
   82 WRITE(101,1041) NCH(K)
      READ(101,1003) (RINPUT(J),J=1,2)
      READ(101,1003) (RINPUT(J),J=3,4)
      OUTPUT(102) ' YOUR ENTRY WAS'
      WRITE(102,1003) (RINPUT(J),J=1,2)
      WRITE(102,1003) (RINPUT(J),J=3,4)
      PAUSE 02
      IF(SENSE SWITCH 2) 82,83
   83 C1(K) = RINPUT(1)
      C2(K) = RINPUT(2)
      C3(K) = RINPUT(3)
      C4(K) = RINPUT(4)
   84 CONTINUE
C **
C ** PLOT SECTION -- PLOTS CHANNELS IN REVERSE ORDER
C **
      DO 700 NPASS =1,2
C ** SET UP NEW ORIGIN IF SECOND PASS
      IF(NPASS.EQ.2) CALL PLOT(-1.0,1.8,-3)
      MPASS = 2
      IF(NPASS.EQ.2) MPASS = 1
  100 NT = 0
C ** CLEAR ARRAYS
      DO 105 K=1,1500
      ARRAY1(K) = 0.0
      ARRAY2(K) = 0.0
      ARRAY3(K) = 0.0
      X(K) = 0.0
  105 CONTINUE
C ** READ TAPE AND LOAD ARRAYS
      REWIND 100
      CALL EOFSET(150S)
  110 READ(100) B
      NT = NT+1
      X(NT) = B(1)
      ARRAY1(NT) = B(NC(1,MPASS))
      ARRAY2(NT) = B(NC(2,MPASS))
      ARRAY3(NT) = B(NC(3,MPASS))
      IF(NT.LT.1498) GO TO 110
      OUTPUT(102)' MORE THAN 1498 POINTS IN FILE'
      GO TO 160
C ** EOF SECTION
  150 OUTPUT(102)' EOF ENCOUNTERED'
  160 WRITE(102,1042) NT
      IF(NPASS.EQ.2) GO TO 200
C ** ENTER X AXIS LENGTH
      OUTPUT(102) ' ENTER X AXIS LENGTH IN INCHES -- F10.3'
      READ(101,1031) XALEN
      OUTPUT(102) ' ENTER X AXIS LABEL -- 1A8'
```

```
      READ(101,1003) DX
C ** DETERMINE MAX AND MIN
  200 DO 210 K=1,3
      MAX(K) = -999999.0
      MIN(K) = 999999.0
  210 CONTINUE
      DO 220 K=1,NT
      IF(ARRAY1(K).GT.MAX(1)) MAX(1)=ARRAY1(K)
      IF(ARRAY1(K).LT.MIN(1)) MIN(1)=ARRAY1(K)
      IF(ARRAY2(K).GT.MAX(2)) MAX(2)=ARRAY2(K)
      IF(ARRAY2(K).LT.MIN(2)) MIN(2)=ARRAY2(K)
      IF(ARRAY3(K).GT.MAX(3)) MAX(3)=ARRAY3(K)
      IF(ARRAY3(K).LT.MIN(3)) MIN(3)=ARRAY3(K)
  220 CONTINUE
      OUTPUT(102)' ENTER DESIRED MAXIMUMS FOR Y AXIS'
      OUTPUT(102)'   USE POS. NUMBER FOR PLOT FROM 0 TO MAX'
      OUTPUT(102)'   USE NEG. NUMBER FOR PLOT FROM -MAX TO +MAX'
      OUTPUT(102)' IF YOU MAKE A MISTAKE, PRESS SS2 AND CLEAR PAUSE'
      DO 230 K=1,3
      MMAX = MAX(K)
  225 WRITE(102,1030) NC(K,MPASS),MMAX  ,MIN(K)
      OUTPUT(102) ' ENTER DESIRED MAXIMUM -- F10.3'
      READ (102,1031) MAX(K)
      WRITE(102,1032) MAX(K)
      PAUSE 02
      IF(SENSE SWITCH 2)  225,230
  230 CONTINUE
C ** SET FIRST VALUE AND SCALE FACTOR
      IF(MAX(1).GT.0.0) ARRAY1(NT)=0.0
      IF(MAX(1).GT.0.0) ARRAY1(NT+1)=MAX(1)/1.6
      IF(MAX(1).LE.0.0) ARRAY1(NT)=MAX(1)/0.8
      IF(MAX(1).LE.0.0) ARRAY1(NT+1)=-MAX(1)/0.8
      IF(MAX(2).GT.0.0) ARRAY2(NT)=0.0
      IF(MAX(2).GT.0.0) ARRAY2(NT+1)=MAX(2)/1.6
      IF(MAX(2).LE.0.0) ARRAY2(NT)=MAX(2)/0.8
      IF(MAX(2).LE.0.0) ARRAY2(NT+1)=-MAX(2)/0.8
      IF(MAX(3).GT.0.0) ARRAY3(NT)=0.0
      IF(MAX(3).GT.0.0) ARRAY3(NT+1)=MAX(3)/1.6
      IF(MAX(3).LE.0.0) ARRAY3(NT)=MAX(3)/0.8
      IF(MAX(3).LE.0.0) ARRAY3(NT+1)=-MAX(3)/0.8
      X(NT)=0.0
      TT = X(NT-1)/AXLEN
      IT = X(NT-1)/AXLEN
      IF(TT.GT.IT) TT=IT+1.0
      X(NT+1)=TT
      ZERO=0.0
      NPLTS = 3
      DO 602 N = 1,NPLTS
C **
C    Y1 IS YAXIS FOR LOWER SCALE NUMBER
C    Y2 IS YAXIS FOR 2ND LINE OF YAXIS LABEL
C    Y3 IS YAXIS FOR 1ST LINE OF YAXIS LABEL
C    Y4 IS YAXIS FOR TOP SCALE NUMBER
C **
```

```
      Y1=0.2+(N-1)*1.7
      Y2=Y1+0.6
      Y3=Y1+0.7
      Y4=Y1+1.35
      M=4-N
      L = M
      IF(NPASS.EQ.1) L=7-N
C ** WRITE YAXIS LABELS
      IF(MAX(M).GT.0.0) CALL NUMBER(-.2,Y1,0.07,ZERO,0.0,2)
      IF(MAX(M).LE.0.0) CALL NUMBER(-.2,Y1,0.07,MAX(M),0.0,2)
      CALL SYMBOL(-.2,Y2,.07,C3(L),0.0,8)
      CALL SYMBOL(999.,999.,.07,C4(L),0.0,8)
      CALL SYMBOL(-.2,Y3,.07,C1(L),0.0,8)
      CALL SYMBOL(999.,999.,.07,C2(L),0.0,8)
      IF(MAX(M).GT.0.0) CALL NUMBER(-.2,Y4,.07,MAX(M),0.0,2)
      IF(MAX(M).LE.0.0) CALL NUMBER(-.2,Y4,.07,-MAX(M),0.0,2)
  602 CONTINUE
  610 CALL PLOT(1.0,0.0,-3)
      IF(NPASS.EQ.2) GO TO 620
C ** DRAW X AXIS IF FIRST PASS
      CALL AXIS(0.0,0.0,DX,-8,AXLEN,0.0,0.0,TT)
  620 DO 600 N=1,3
C ** SET NEW ORIGIN AT LOWER LEFT OF PLOT FOR EACH CHANNEL
      IF(N.EQ.1) CALL PLOT(0.0,0.1,-3)
      IF(N.NE.1) CALL PLOT(0.0,1.7,-3)
C ** DRAW BOX AROUND TITLE
      CALL PLOT(-1.3,0.0,2)
      CALL PLOT(-1.3,1.6,2)
      CALL PLOT(0.0,1.6,2)
      CALL PLOT(0.0,0.0,2)
C ** DRAW Y AXIS TICK MARKS
      DO 601 NN=1,9,1
      PN=NN*0.160
      IF(NN.NE.5) CALL PLOT(-0.05,PN,3)
      IF(NN.EQ.5) CALL PLOT(-0.10,PN,3)
      CALL PLOT(0.05,PN,2)
  601 CONTINUE
C ** DRAW BOX AROUND PLOT
      CALL PLOT(0.0,0.0,3)
      CALL PLOT(AXLEN,0.0,2)
      CALL PLOT(AXLEN,1.60,2)
      CALL PLOT(AXLEN,0.8,3)
      M = 4-N
C ** DRAW CENTERLINE IF NECESSARY
      IF(MAX(M).LE.0.0) CALL PLOT(0.0,0.8,2)
      CALL PLOT(0.0,1.6,3)
      CALL PLOT(AXLEN,1.6,2)
  600 CONTINUE
      NT=NT-1
      IF(MAX(3).GT.0.0) CALL PLOT(0.0,-3.4,-3)
      IF(MAX(3).LE.0.0) CALL PLOT(0.0,-3.6,-3)
      CALL LINE(X,ARRAY3,NT,1,0,0)
      IF(MAX(3).GT.0.0) CALL PLOT(0.0,-0.2,-3)
      IF(MAX(2).GT.0.0) CALL PLOT(0.0,1.9,-3)
```

```
      IF(MAX(2).LE.0.0) CALL PLOT(0.0,1.7,-3)
      CALL LINE(X,ARRAY2,NT,1,0,0)
      IF(MAX(2).GT.0.0) CALL PLOT(0.0,-0.2,-3)
      IF(MAX(1).GT.0.0) CALL PLOT(0.0,1.9,-3)
      IF(MAX(1).LE.0.0) CALL PLOT(0.0,1.7,-3)
      CALL LINE(X,ARRAY1,NT,1,0,0)
      IF(MAX(1).GT.0.0) CALL PLOT(0.0,-0.2,-3)
  700 CONTINUE
C ** SET UP ORIGIN FOR NEW PLOT
      XNEW = AXLEN + 10.0
      CALL PLOT(XNEW,-8.4,-3)
C ** MORE PLOTS
      REWIND 100
      OUTPUT(102)' TYPE 1 IF YOU WANT MORE PLOTS'
      READ(101,1001) INPUT(1)
      IF(INPUT(1).EQ.1) GO TO 1
C ** OTHERWISE TERMINATE
      CALL PLOT(0.0,0.0,999)
      CALL EXIT
      END
```

APPENDIX B

Bus Simulation Program Listing

```
BUS SIMULATION PROGRAM                                              DATE 29 MAR 1977    PAGE    0002

      2.5 MPHPS                  **BUS SIMULATION**                 25 MPH
      TORQUE CONVERTER TC490       24350 LB.        TRANSMISSION V730
24350.000 24350.000 24350.000 12175.000
  .375E 02  .104E 04  .258E 02  .100E 01  .300E-01  .900E 03  .220E 04
ACLOAD
  .231E 02  .244E 02  .263E 02  .290E 02  .344E 02  .420E 02  .518E 02  .643E 02
  .543E 02  .643E 02
VMIN(1), ETC
 -.250E 03  .750E 03  .520E 02
VMIN(2), ETC
  .500E 03  .240E 04  .100E 03
NGEAR
     3
TECOEI(I,J)
 [illegible]
-.24951E-05 -.39320E-10 .22369E-10 .11561E-10 .19293E-10
 [illegible] .78379E-09
-.46761E-03 .16687E-09 .22439E-11 .37415E-11-.93041E-10
 [illegible]
 .10000E-06 .23667E-03 -.97395E-12 .13925E-09-.65577E-09
 [illegible]
-.49516E-07 .33172E-09-.62502E-12-.31066E-10-.46935E-09
[illegible]
123000000
[illegible](J)
  .257E 01  .140E 01  .100E 01
[illegible] GEAR RATIO STATI[illegible]
  .675000
GRI, ETC
  .307E 01  .250E 01  .350E 01  .100E 02  .150E 02
[illegible], ETC
  .514E 01  .450E 01
[illegible], ETC
  .171E 01  .800E 00  .650E 00  .100E-01  .405E 02
TGINV
  .0 .0210 .0420 .01260 .01680 .02100 .02520 .02980 .03400 .03820 .04240 .0    .0
VVI[illegible]
 .750E 02  .700E 00  .800E-02
[illegible], ETC
  .236E 03  .430E 02  .721E 01
[illegible], ETC
  .145E 02  .600F 02  .300E-01  .100F 00
[illegible], ETC
         20          -1          1
[illegible]
   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
DT
  .050000
[illegible] = .[illegible]
AVIS = .[illegible]
[illegible]
[illegible]1585.000009999.00000
[illegible] CRUISE)
```

```
BUS SIMULATION PROGRAM
480.00001580.00000939.00000
[illegible]
9399.00000 550.000001520.00000
ALLISON TEST DATA
SPEED RATIO*TORQUE RATIO*ONE/K**2
     .00000   2.45955 .00023121
     .10000   2.33962 .00022865
     .20000   2.18520 .00022118
     .30000   1.95804 .00020656
     .40000   1.82738 .00019453
     .45000   1.70567 .00018915
     .50000   1.61217 .00018353
     .55000   1.52337 .00017204
     .60000   1.44011 .00017174
     .70000   1.27716 .00015782
     .75000   1.19061 .00014561
     .80000   1.10683 .00013802
     .85000   1.05307 .00012775
     .86900    .99755 .00011497
     .91230    .99711 .00008120
     .92460    .99629 .00007122
     .92490    .99627 .00007103
    1.00000    .99500 .00000100
    1.25000    .99500-.00014500
    1.50000    .99500-.00013000
    1.70000    .96000    .50000   1.30000    .50000
   25.00000   8.60000
ACCRDIS = 22.50000000
    800.00     .00     .00     .00     .00     .00     .00     .00     .00
   -144.40     .00  144.40  263.00  363.60  475.60  529.40  657.60  778.00
     11.00   11.00   11.00   17.17   24.20   24.27   30.64   40.56   52.80
       .00     .50    1.50    2.50    3.50    4.50    5.50   31.20   81.00
       .00     .00     .00     .00     .00     .00     .00     .00     .00
   1000.00     .00     .00     .00     .00     .00     .00     .00     .00
   -107.00     .00  107.00  215.00  309.80  404.40  498.90  593.50  732.00
     15.00   16.00   15.00   21.50   27.50   33.60   40.14   47.58   56.80
       .00    1.00    2.00    3.00    5.00    6.00   33.00   38.00   81.00
       .00     .00     .00     .00     .00     .00     .00     .00     .00
   1200.00     .00     .00     .00     .00     .00     .00     .00     .00
   -130.00     .00  130.00  260.90  354.50  449.06  542.70  637.30  731.10
     19.00   19.00   19.00   25.64   32.64   39.50   47.00   56.40   66.33
       .00    5.70   11.40   17.57   24.35   30.60   37.29   43.77   81.00
       .00     .00     .00     .00     .00     .00     .00     .00     .00
   1400.00     .00     .00     .00     .00     .00     .00     .00     .00
   -130.00     .00  130.00  258.00  352.60  446.40  544.00  637.70  731.50
     22.00   22.00   22.00   30.79   37.38   44.00   54.61   63.70   74.88
       .00    6.60   13.20   20.74   28.28   35.80   43.35   50.91   81.00
       .00     .00     .00     .00     .00     .00     .00     .00     .00
   1600.00     .00     .00     .00     .00     .00     .00     .00     .00
   -175.00     .00  175.75  261.95  351.20  443.80  535.00  626.20  717.20
     26.00   26.00   26.00   39.40   45.48   52.02   61.29   71.34   83.25
       .00    7.25   15.60   23.50   32.25   40.00   48.50   57.24   81.00
       .00     .00     .00     .00     .00     .00     .00     .00     .00
```

BUS SIMULATION PROGRAM DATE 29 MAR 1977 PAGE 0004

1800.00	.00	.00	.00	.00	.00	.00	.00	.00
-193.00	.00	195.40	281.00	364.70	447.90	531.00	612.70	697.30
34.00	34.00	34.00	42.42	50.63	59.40	68.80	78.75	90.58
.00	10.20	20.40	29.00	37.50	46.10	54.60	59.20	81.00
.00	.00	.00	.00	.00	.00	.00	.00	.00
2000.00	.00	.00	.00	.00	.00	.00	.00	.00
-217.00	.00	217.90	293.60	369.50	445.10	520.70	594.10	672.20
42.00	42.00	42.00	49.00	56.00	66.60	75.90	85.60	97.50
.00	12.45	24.50	33.54	42.20	50.85	59.50	65.16	81.00
.00	.00	.00	.00	.00	.00	.00	.00	.00
2200.00	.00	.00	.00	.00	.00	.00	.00	.00
-220.00	.00	236.00	304.60	373.10	442.60	512.30	582.50	651.70
50.00	50.00	50.00	57.40	65.40	73.80	83.00	92.65	104.40
.00	15.50	30.90	39.24	47.60	55.95	64.29	72.66	81.00
.00	.00	.00	.00	.00	.00	.00	.00	.00

FIRST LINE IN ARRAY

800	2200	7	0	150	50	1	100	0
800	2200	7	-50	950	10	1	100	0

MAP1-ENGINE TORQUE

800	2200	7	0	150	50	1	100	0
0	800	1000	1200	1400	1600	1800	2000	2200
0	-14400	-10700	-13000	-13000	-17000	-19200	-21700	-23000
2	13557	6619	-3306	-9811	-13472	-16658	-18878	-20598
4	34152	22624	-3415	-6673	-9944	-13516	-16057	-18196
6	49487	32286	-1925	-3435	-6416	-10374	-13236	-15734
8	[illegible]	[illegible]	1765	-247	-2850	-7232	[illegible]	-13392
10	54457	41172	5457	2340	641	-4030	-7594	-10991
12	[illegible]	[illegible]	[illegible]	6176	[illegible]	[illegible]	-4772	-8559
14	56419	42305	12440	9317	7725	2198	-1951	-6187
16	57336	40272	16133	[illegible]	11657	5346	873	-3745
18	55392	43428	13405	15321	14810	6495	3705	-1383
20	[illegible]	[illegible]	[illegible]	[illegible]	17713	11643	6535	1051
22	60234	44571	25957	20216	19492	14791	9371	3531
24	[illegible]	[illegible]	[illegible]	[illegible]	21270	17940	12204	6512
26	62216	45704	30471	26178	23049	20456	15037	8492
28	[illegible]	[illegible]	[illegible]	28209	[illegible]	22011	17870	10973
30	64145	46527	35347	30240	26595	23565	20703	13453
32	[illegible]	[illegible]	37714	32270	[illegible]	[illegible]	22664	15933
34	66081	47370	40291	34301	30757	26674	24062	18414
36	67247	48037	42464	35326	31785	28272	[illegible]	20894
38	68013	48103	44837	38345	33519	29526	26918	23375
40	68335	49870	47174	40364	35255	31420	28336	24610
42	68533	51744	49309	42343	37052	33014	29754	26142
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31173	27473
46	69427	57442	[illegible]	44485	40646	36201	32592	28804
48	65774	[illegible]	[illegible]	[illegible]	[illegible]	37772	34010	30146
50	65120	60143	59395	50670	44241	39378	35429	31463
52	65257	60265	61263	52752	46019	40904	36847	32749
54	69414	61186	63631	54536	47795	42470	38262	34116
56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39677	35442
58	69708	62229	64523	58848	51348	45610	41092	36768

60	69555	62750	64936	60854	53124	47193	42506	38107
62	70002	63271	65344	62641	54055	45775	43921	39455
64	70149	63773	65751	64045	56665	50357	45336	40801
66	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51940	46700	42149
68	70443	64536	64567	65055	60205	53520	48165	43496
70	70530	65357	65475	65559	61575	56519	49560	44845
72	70736	65573	67383	56064	63014	59216	50594	46198
74	70323	654[illegible]	67735	64506	63655	61462	52407	47591
76	71030	66021	65198	67073	64254	62059	53217	45903
78	71177	[illegible]	[illegible]	67577	[illegible]	62656	53726	[illegible]
80	71324	67344	69014	68052	65494	63353	56435	51610
82	71471	[illegible]	[illegible]	[illegible]	[illegible]	67370	[illegible]	52978
84	71618	69006	69029	69001	66733	64407	59454	54325
86	71765	[illegible]	70237	69506	67353	65244	60453	55653
88	71912	70049	70645	70100	67973	65881	61422	57040
90	72059	[illegible]	71033	70605	68593	66517	62361	58378
92	72206	71032	71461	71109	69213	67154	63341	59739
94	72352	[illegible]	[illegible]	71614	69833	67791	64300	61082
96	72497	72134	72276	72119	70453	68428	65259	62425
98	72645	[illegible]	72634	72673	71073	69065	66219	63768
100	72793	73177	73092	73128	71693	69702	67178	65111

MAP3-FUEL RATE

800	2200	7	-50	950	10	1	100	0
0	300	1000	1200	1400	1600	1600	2000	2200
-50	1100	1600	1900	2200	2600	3400	4700	5000
50	1100	1600	1900	2200	2600	3400	4200	5000
150	1128	1670	2001	2329	2600	3400	4800	5000
250	1593	2300	2508	2977	3765	3925	4534	5151
350	2283	3009	3230	3776	4539	4918	5591	6270
450	2723	3675	3927	4444	5205	5963	6720	7477
550	3197	4415	4764	5537	6294	7111	7974	8628
650	[illegible]	[illegible]	[illegible]	[illegible]	7445	8396	9405	10471
750	5280	5850	6633	7487	8325	9058	9750	10439
850	5280	5850	6633	7487	8325	9058	9750	10439
950	5280	5850	6633	7487	8325	9058	9750	10439

EPA DATA FOLLOWS

ACCEL= 2.50 DECEL= 2.50 VCRUS=25.00 NSTOP= 5 RTLNGT= 1.00 TDWELL=16.00

[illegible] TC= 27.500 TD= 30.000 TE= 54.500 DTD=10.000

NVEPA= 137

[illegible]	409575	614525	819375	1024225	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250
819425	614575	409725	204675	25	0	0	0	0	0	0	0	0	204525
409575	614525	819375	1024275	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	921850
717000	512150	307300	102450	0	0	0	0	0	0	0	0	102400	307250
[illegible]	[illegible]	[illegible]	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	819475
614575	409725	204675	25	0	0	0	0	0	0	0	0	204825	409675
614525	819375	1024225	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	921850	717000
512150	307300	102450	0	0	0	0	0	0	0	0	102400	307250	512100
716950	921850	1024255	1024250	1024250	1024250	1024250	1024250	1024250	1024250	1024250	921850	717000	512150
307300	102450	0	0	0	0	0	0	0	0	0			

END EPA DATA

BUS SIMULATION PROGRAM — DATE 29 MAR 1977 — PAGE 0006

VEHICLE PARAMETERS USED FOR SIMULATION

2.5 MPHPS — **BUS SIMULATION** — 25 MPH

TORQUE CONVERTER TC490 — 24350 LB. — TRANSMISSION V730

VEHICLE CHARACTERISTICS

REAR AXLE RATIO	5.14
MASS (LB)	24350.0
MASS ON DRIVE WHEELS (LB)	12175.0
FRONTAL AREA (SQ FT)	73.0
COEFFICIENT OF ROLLING FRICTION	.0080
DRAG COEFFICIENT	.700
TIRE STATIC RADIUS (FT)	1.703
ENGINE INERTIA (LB*FT**2)	37.54
TQ. CONV. TURBINE INERTIA	2.50
TRANSMISSION INERTIA (3RD GEAR)	3.50
REAR AXLE INERTIA	4.50
INERTIA OF DRIVE WHEELS	40.52
STATIC TIRE FRICTION COEF.	.80
SLIPPING TIRE FRICTION COEF.	.65
WHEEL BASE (IN)	285.00
CENTER OF GRAVITY HEIGHT (IN)	45.0
IDLE THROTTLE SETTING	.03
TRANSMISSION SHIFT TIME (SEC)	.50
DELAY TIME AFTER SHIFT (SEC)	.75
AMBIENT TEMPERATURE (F)	60.0
BAROMETRIC PRESSURE (PSI)	14.1747
AIR DENSITY (LB/CU FT)	.0737
ENGINE SCALE FACTOR	1.000
FUEL DENSITY (LB/GAL)	7.21

TORQUE CONVERTER

SPEED RATIO	TORQUE RATIO	1/K**2 (10**-4)
.000	2.440	2.3121
.100	2.340	2.2865
.200	2.170	2.2118
.300	1.925	2.0066
.400	1.802	1.9483
.450	1.706	1.8914
.500	1.612	1.8553
.550	1.523	1.7604
.600	1.440	1.7174
.700	1.277	1.5762
.750	1.193	1.4421
.800	1.105	1.3202
.830	1.053	1.2979
.862	.996	1.1697
.912	.998	.8120
.925	.996	.7121
.925	.998	.7103
1.000	.998	.0000
1.250	.996	-.4500
1.500	.998	-1.3000

TRANSMISSION

GEAR RATIOS		SCHEDULE		
1ST	2.067			
2ND	1.400	LOCKUP AT	28.0	MPH
3RD	1.000	UNLOCK AT	8.6	MPH
4TH	.000	UPSHIFT 1-2	920.	RPM
5TH	.000	UPSHIFT 2-3	1560.	RPM
6TH	.000	DOWNSHIFT 3-2	1520.	RPM
BEVEL	.67	DOWNSHIFT 2-1	550.	RPM

TIRE EXPANSION

VEHICLE SPEED	DRIVESHAFT SPEED(RPM)
.0	.0
10.0	420.0
20.0	840.0
30.0	1260.0
40.0	1680.0
50.0	2100.0
60.0	2520.0
70.0	2930.0
80.0	3360.0
90.0	3820.0
100.0	4240.0

DRIVE CYCLE

STOPS/MILE	5
MAX. ACCEL.	2.5 MPHPS
DECELERATION	2.5 MPHRPS
CRUISE SPEED	25.0 MPH

DRIVESHAFT ROAD LOAD TORQUE TABLE

VEHICLE SPEED	ROAD LOAD TORQUE
.0	.0
10.0	.0
20.0	.0
30.0	.0
40.0	.0
50.0	.0
60.0	.0
70.0	.0
80.0	.0
90.0	.0
100.0	.0

NO LOAD EQUATION IS USED.

BUS SIMULATION PROGRAM DATE 29 MAR 1977 PAGE 0007

2.5 MPHPS **BUS SIMULATION** 25 MPH

TORQUE CONVERTER TC490 24350 LB. TRANSMISSION V730

TIME (SEC)	VEHICLE DIST. (MI)	VEHICLE SPEED (MPH)	VEHICLE ACCEL. (MPH/SEC)	ENGINE SPEED (RPM)	ENGINE TORQUE (FT-LB)	ENGINE POWER (HP)	FUEL RATE (LB/HP-HR)	FUEL RATE INSTANTANEOUS (LB/HR)	FUEL RATE INSTANTANEOUS (MPG)	ACCUMULATIVE (MPG)	TORQUE CONVERTER SPEED RATIO	TORQUE CONVERTER TORQUE RATIO	TORQUE CONVERTER EFFICIENCY	DRIVETRAIN TR EFF.	DRIVETRAIN RA EFF.	DRIVETRAIN GEAR
.00	.000	.00	.000	804.	248.0	38.0	.435	16.50	.00	.00	.000	2.460	.000	.937	.967	1.
1.00	.000	2.57	2.573	974.	308.8	57.3	.454	26.59	.70	.35	.174	2.214	.419	.935	.946	1.
2.00	.001	5.05	2.478	1055.	345.8	69.5	.438	30.43	1.20	.70	.350	1.893	.674	.947	.958	1.
3.00	.003	7.59	2.533	1154.	392.6	86.5	.395	34.19	1.50	.96	.473	1.663	.786	.951	.953	1.
4.00	.006	10.10	2.624	1284.	439.7	107.5	.390	41.88	1.78	1.18	.565	1.465	.864	.956	.960	1.
5.00	.009	12.61	2.508	1396.	486.4	129.3	.374	48.29	1.88	1.35	.675	1.318	.895	.960	.963	1.
6.00	.013	15.11	2.565	1514.	536.0	154.6	.377	58.22	1.87	1.48	.748	1.196	.899	.963	.966	1.
7.00	.017	17.62	2.530	1631.	605.8	182.3	.376	68.54	1.75	1.57	.821	1.058	.859	.965	.960	2.
8.00	.022	20.12	2.556	1607.	666.5	203.9	.374	76.21	1.90	1.63	.637	1.379	.883	.965	.972	2.
9.00	.029	22.62	2.506	1676.	703.3	226.4	.365	82.61	1.97	1.68	.687	1.295	.896	.963	.977	2.
10.00	.035	24.76	.201	1717.	117.5	38.4	.799	30.67	5.87	1.76	.746	1.203	.898	.969	.963	2.
11.00	.042	25.00	.000	1286.	94.0	23.0	.903	20.79	8.67	2.01	1.000	.960	.960	.958	.947	2.
12.00	.049	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	2.26	1.000	.960	.960	.958	.947	2.
13.00	.056	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	2.49	1.000	.960	.960	.958	.947	2.
14.00	.063	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	2.70	1.000	.960	.960	.958	.947	2.
15.00	.070	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	2.90	1.000	.960	.960	.958	.947	2.
16.00	.077	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.08	1.000	.960	.960	.958	.947	2.
17.00	.084	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.26	1.000	.960	.960	.958	.947	2.
18.00	.091	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.42	1.000	.960	.960	.958	.947	2.
19.00	.097	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.58	1.000	.960	.960	.958	.947	2.
20.00	.104	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.72	1.000	.960	.960	.958	.947	2.
21.00	.111	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.86	1.000	.960	.960	.958	.947	2.
22.00	.118	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.99	1.000	.960	.960	.958	.947	2.
23.00	.125	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.11	1.000	.960	.960	.958	.947	2.
24.00	.132	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.23	1.000	.960	.960	.958	.947	2.
25.00	.139	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.34	1.000	.960	.960	.958	.947	2.
26.00	.146	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.44	1.000	.960	.960	.958	.947	2.
27.00	.153	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.55	1.000	.960	.960	.958	.947	2.
28.00	.160	24.44	-2.565	1253.	-77.7	-19.6	•	20.24	6.35	4.64	1.000	.960	.961	.965	.957	2.
29.00	.167	21.96	-2.490	1138.	-26.2	-5.6	•	15.34	6.79	4.73	1.000	.960	.961	.956	.944	2.
30.00	.172	19.86	-2.558	1029.	114.7	22.5	.793	17.80	8.05	4.80	1.000	.960	.960	.998	.950	2.
31.00	.178	17.36	-2.533	901.	197.8	33.9	.513	17.39	7.20	4.85	1.000	.960	.959	1.000	.968	2.
32.00	.182	14.87	-2.494	773.	264.1	38.9	.421	16.37	6.55	4.89	1.000	.960	.958	1.000	.972	2.
33.00	.185	12.40	-2.473	652.	273.1	33.8	.477	17.06	5.74	4.91	1.000	.960	.924	.965	.973	1.
34.00	.187	9.27	-2.428	712.	263.8	35.2	.417	14.33	4.36	4.91	1.000	.960	.956	.965	.963	1.
35.00	.191	7.20	-2.432	632.	237.5	30.6	.394	16.01	3.33	4.89	.910	1.036	.945	.963	.952	1.
36.00	.193	4.79	-2.425	650.	224.3	30.3	.447	14.95	2.08	4.85	.458	1.691	.757	.958	.950	1.
37.00	.194	2.41	-2.381	623.	236.1	27.3	.567	15.70	1.04	4.80	.294	2.088	.587	.949	.961	1.
38.00	.194	.00	.000	807.	245.8	37.9	.436	16.53	.00	4.73	.015	2.441	.000	.937	.967	1.
39.00	.194	.00	.000	805.	247.1	37.9	.436	16.52	.00	4.66	.000	2.460	.000	.937	.967	1.
40.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.59	.000	2.460	.000	.937	.967	1.
41.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.52	.000	2.460	.000	.937	.967	1.
42.00	.194	.00	.000	805.	247.1	37.9	.436	16.52	.00	4.46	.000	2.460	.000	.937	.967	1.
43.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.39	.000	2.460	.000	.937	.967	1.
44.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.33	.000	2.460	.000	.937	.967	1.
45.00	.194	.00	.000	805.	247.1	37.9	.436	16.52	.00	4.27	.000	2.460	.000	.937	.967	1.
46.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.21	.000	2.460	.000	.937	.967	1.
47.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.15	.000	2.460	.000	.937	.967	1.

BUS SIMULATION PROGRAM | 2.5 MPHPS | **BUS SIMULATION** | DATE 29 MAR 1977 | PAGE 0008 | 25 MPH

TORQUE CONVERTER TC490 | 24350 LB. | TRANSMISSION V730

-------VEHICLE-------				-------ENGINE-------			------FUEL RATE------			ACCUMU	--TORQUE CONVERTER-			-DRIVETRAIN-		
TIME	DIST.	SPEED	ACCEL.	SPEED	TORQUE	POWER	(LB/	*INSTANTANEOUS*		LATIVE	SPEED	TORQUE	EFFIC	TR	RA	GE
(SEC)	(MI)	(MPH)	(MPH/SEC)	(RPM)	(FT-LB)	(HP)	HP-HR)	(LB/HR)	(MPG)	(MPG)	RATIO	RATIO	IENCY	EFF.	EFF.	AR
48.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.10	.000	2.460	.000	.937	.967	1.
49.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.04	.000	2.460	.000	.937	.967	1.
50.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.99	.000	2.460	.000	.937	.967	1.
51.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.94	.000	2.460	.000	.937	.967	1.
52.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.89	.000	2.460	.000	.937	.967	1.
53.00	.194	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.84	.000	2.460	.000	.937	.967	1.
54.00	.194	.17	2.303	807.	259.2	39.8	.435	17.31	.07	3.79	.000	2.460	.013	.937	.967	1.
55.00	.195	2.57	2.507	937.	303.4	54.1	.460	24.91	.75	3.74	.190	2.188	.435	.940	.956	1.
56.00	.196	5.06	2.712	1073.	347.2	70.9	.433	30.71	1.19	3.69	.343	1.906	.667	.945	.951	1.
57.00	.199	7.59	2.654	1177.	392.4	87.9	.399	35.10	1.56	3.63	.476	1.657	.798	.952	.956	1.
58.00	.200	10.10	2.636	1266.	439.7	107.6	.380	40.93	1.78	3.58	.584	1.466	.864	.956	.959	1.
59.00	.203	12.61	2.605	1335.	486.4	125.2	.374	45.78	1.86	3.53	.675	1.318	.895	.960	.963	1.
60.00	.207	15.11	2.535	1515.	535.0	154.6	.377	55.22	1.87	3.47	.748	1.196	.899	.963	.966	1.
61.00	.212	17.62	2.195	1541.	605.6	172.3	.376	65.54	1.85	3.41	.821	1.068	.889	.968	.950	2.
62.00	.217	20.12	2.556	1607.	666.5	203.9	.374	74.21	1.90	3.34	.637	1.379	.843	.965	.972	2.
63.00	.223	22.61	2.506	1675.	705.3	225.4	.366	82.61	1.97	3.28	.687	1.298	.896	.963	.977	2.
64.00	.229	24.96	.201	1717.	117.5	38.4	.799	30.67	5.87	3.23	.746	1.203	.898	.969	.963	2.
65.00	.236	25.00	.005	1286.	94.5	23.0	.903	20.79	8.67	3.28	1.000	.960	.960	.958	.947	2.
66.00	.243	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.34	1.000	.960	.960	.958	.947	2.
67.00	.250	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.40	1.000	.960	.960	.958	.947	2.
68.00	.257	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.46	1.000	.960	.960	.958	.947	2.
69.00	.264	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.51	1.000	.960	.960	.958	.947	2.
70.00	.271	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.57	1.000	.960	.960	.958	.947	2.
71.00	.278	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.62	1.000	.960	.960	.958	.947	2.
72.00	.285	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.67	1.000	.960	.960	.958	.947	2.
73.00	.292	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.72	1.000	.960	.960	.958	.947	2.
74.00	.299	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.77	1.000	.960	.960	.958	.947	2.
75.00	.306	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.82	1.000	.960	.960	.958	.947	2.
76.00	.313	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.67	1.000	.960	.960	.958	.947	2.
77.00	.320	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.92	1.000	.960	.960	.955	.947	2.
78.00	.327	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.96	1.000	.960	.960	.958	.947	2.
79.00	.333	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.01	1.000	.960	.960	.958	.947	2.
80.00	.340	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.05	1.000	.960	.960	.958	.947	2.
81.00	.347	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.10	1.000	.960	.960	.958	.947	2.
82.00	.354	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.14	1.000	.960	.960	.958	.947	2.
83.00	.361	24.54	-2.505	1253.	-77.7	-19.0	*	20.24	8.85	4.18	1.000	.960	.961	.965	.957	2.
84.00	.368	22.36	-2.553	1156.	-26.2	-5.8	*	18.34	8.79	4.22	1.000	.960	.961	.956	.944	2.
85.00	.374	19.86	-2.553	1030.	114.7	22.5	.793	17.80	8.05	4.26	1.000	.960	.960	.998	.950	2.
86.00	.379	17.36	-2.533	921.	157.8	33.9	.513	17.39	7.20	4.28	1.000	.960	.959	1.000	.968	2.
87.00	.384	14.87	-2.494	773.	264.1	32.9	.491	16.57	6.55	4.30	1.000	.960	.958	1.000	.972	2.
88.00	.387	12.40	-2.489	642.	216.1	35.8	.477	17.06	5.24	4.31	1.000	.960	.934	.965	.970	1.
89.00	.391	9.87	-2.525	742.	263.6	39.2	.417	16.33	4.36	4.32	1.000	.960	.946	.966	.963	1.
90.00	.393	7.39	-2.432	692.	337.5	40.6	.394	16.01	3.43	4.31	.910	1.036	.935	.963	.952	1.
91.00	.394	4.89	-2.425	850.	224.2	36.3	.467	16.95	2.08	4.30	.458	1.691	.757	.958	.950	1.
92.00	.395	2.41	-2.361	823.	238.1	37.3	.447	16.70	1.04	4.28	.244	2.088	.487	.949	.961	1.
93.00	.396	.00	.000	807.	246.8	37.9	.436	16.53	.00	4.26	.015	2.441	.000	.937	.967	1.
94.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.23	.000	2.460	.000	.937	.967	1.

BUS SIMULATION PROGRAM   DATE 29 MAR 1977   PAGE 0009

2.5 MPHPS   **BUS SIMULATION**   25 MPH

TORQUE CONVERTER TC490   24350 LB.   TRANSMISSION V730

TIME (SEC)	VEHICLE DIST. (MI)	VEHICLE SPEED (MPH)	VEHICLE ACCEL. (MPH/SEC)	ENGINE SPEED (RPM)	ENGINE TORQUE (FT-LB)	ENGINE POWER (HP)	FUEL RATE (LB/HP-HR)	FUEL RATE INSTANTANEOUS (LB/HR)	FUEL RATE INSTANTANEOUS (MPG)	ACCUMULATIVE (MPG)	TORQUE CONVERTER SPEED RATIO	TORQUE CONVERTER TORQUE RATIO	TORQUE CONVERTER EFFICIENCY	DRIVETRAIN TR EFF.	DRIVETRAIN RA EFF.	DRIVETRAIN GEAR
95.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.20	.000	2.460	.000	.937	.967	1.
96.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.17	.000	2.460	.000	.937	.967	1.
97.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.14	.000	2.460	.000	.937	.967	1.
98.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.12	.000	2.460	.000	.937	.967	1.
99.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.09	.000	2.460	.000	.937	.967	1.
100.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.06	.000	2.460	.000	.937	.967	1.
101.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.04	.000	2.460	.000	.937	.967	1.
102.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.01	.000	2.460	.000	.937	.967	1.
103.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.98	.000	2.460	.000	.937	.967	1.
104.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.96	.000	2.460	.000	.937	.967	1.
105.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.93	.000	2.460	.000	.937	.967	1.
106.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.91	.000	2.460	.000	.937	.967	1.
107.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.88	.000	2.460	.000	.937	.967	1.
108.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.86	.000	2.460	.000	.937	.967	1.
109.00	.396	.17	2.303	807.	259.2	39.3	.435	17.31	.07	3.85	.000	2.460	.013	.937	.967	1.
110.00	.396	2.87	2.507	937.	303.4	54.1	[illegible]	24.91	.75	3.81	.190	2.128	.434	.942	.956	1.
111.00	.397	5.08	2.712	1073.	347.2	70.9	.433	30.71	1.19	3.78	.343	1.906	.667	.945	.951	1.
112.00	.399	7.59	2.654	1177.	392.4	87.9	.399	35.10	1.55	3.75	.476	1.657	.798	.952	.956	1.
113.00	.401	10.10	2.636	1286.	439.7	107.6	.380	40.93	1.78	3.72	.584	1.466	.864	.956	.959	1.
114.00	.404	12.71	2.605	1395.	486.4	129.2	.374	47.26	1.86	3.65	.675	1.318	.855	.960	.963	1.
115.00	.408	15.11	2.586	1515.	536.0	154.6	.377	58.22	1.87	3.66	.748	1.196	.899	.963	.966	1.
116.00	.412	17.62	2.570	1561.	600.3	182.3	.376	67.14	1.85	3.62	.621	1.258	.759	.965	.965	2.
117.00	.416	20.12	2.556	1607.	666.5	203.9	.374	76.21	1.90	3.58	.637	1.379	.683	.965	.972	2.
118.00	.424	22.61	2.525	1676.	703.3	224.4	.366	82.81	1.97	3.54	.687	1.278	.896	.963	.977	2.
119.00	.431	24.96	.201	1717.	117.5	38.4	.793	30.67	5.87	3.50	.746	1.203	.898	.969	.963	2.
120.00	.438	25.00	.000	1285.	94.0	23.0	.903	20.79	8.67	3.53	1.000	.960	.960	.958	.947	2.
121.00	.445	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.57	1.000	.960	.960	.958	.947	2.
122.00	.452	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.60	1.000	.960	.960	.958	.947	2.
123.00	.458	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.63	1.000	.960	.960	.958	.947	2.
124.00	.465	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.66	1.000	.960	.960	.958	.947	2.
125.00	.472	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.69	1.000	.960	.960	.958	.947	2.
126.00	.479	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.72	1.000	.960	.960	.958	.947	2.
127.00	.486	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.76	1.000	.960	.960	.958	.947	2.
128.00	.493	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.79	1.000	.960	.960	.958	.947	2.
129.00	.500	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.82	1.000	.960	.960	.958	.947	2.
130.00	.507	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.84	1.000	.960	.960	.958	.947	2.
131.00	.514	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.87	1.000	.960	.960	.958	.947	2.
132.00	.521	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.90	1.000	.960	.960	.958	.947	2.
133.00	.528	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.93	1.000	.960	.960	.958	.947	2.
134.00	.535	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.96	1.000	.960	.960	.958	.947	2.
135.00	.542	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.99	1.000	.960	.960	.958	.947	2.
136.00	.549	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.01	1.000	.960	.960	.958	.947	2.
137.00	.556	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.04	1.000	.960	.960	.958	.947	2.
138.00	.563	24.64	-2.508	1243.	-77.7	-19.0	*	20.24	8.85	4.07	1.000	.960	.961	.965	.957	2.
139.00	.569	22.36	-2.556	1156.	-26.2	-5.8	*	18.34	8.79	4.09	1.000	.960	.961	.956	.944	2.
140.00	.575	17.75	-2.552	1023.	114.7	22.5	.793	17.80	8.05	4.12	1.000	.960	.960	.998	.953	2.
141.00	.580	17.36	-2.533	901.	197.8	33.9	.513	17.39	7.20	4.13	1.000	.960	.959	1.000	.968	2.

BUS SIMULATION PROGRAM 2.5 MPHPS **BUS SIMULATION** DATE 29 MAR 1977 PAGE 0010
25 MPH
TORQUE CONVERTER TC490 24350 LB. TRANSMISSION V730

	------VEHICLE-------			-------ENGINE-------			------FUEL RATE------			ACCUMU	--TORQUE CONVERTOR-			-DRIVETRAIN-		
TIME	DIST.	SPEED	ACCEL.	SPEED	TORQUE	POWER	(LB/	-INSTANTANEOUS-		LATIVE	SPEED	TORQUE	EFFIC	TR	RA	GE
(SEC)	(MI)	(MPH)	(MPH/SEC)	(RPM)	(FT-LB)	(HP)	HP-HR)	(LB/HR)	(MPG)	(MPG)	RATIO	RATIO	IENCY	EFF.	EFF.	AR
142.00	.585	14.67	-2.434	773.	254.1	38.9	.421	16.37	6.55	4.15	1.000	.960	.958	1.000	.972	2.
143.00	.588	12.40	-2.669	682.	218.1	35.8	.477	17.06	5.24	4.15	1.000	.960	.924	.965	.970	1.
144.00	.592	9.87	-2.528	768.	263.8	39.2	.417	16.33	4.36	4.16	1.000	.960	.956	.966	.963	1.
145.00	.594	7.39	-2.432	632.	337.5	40.6	.394	16.01	3.33	4.16	.910	1.036	.935	.963	.952	1.
146.00	.596	4.89	-2.425	850.	224.2	36.3	.467	16.95	2.08	4.15	.458	1.691	.757	.958	.950	1.
147.00	.597	2.41	-2.361	823.	238.1	37.3	.447	16.70	1.04	4.14	.244	2.088	.467	.949	.961	1.
148.00	.597	.00	.000	807.	246.8	37.9	.436	16.53	.00	4.12	.015	2.441	.000	.937	.967	1.
149.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.10	.000	2.460	.000	.937	.967	1.
150.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.08	.000	2.460	.000	.937	.967	1.
151.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.07	.000	2.460	.000	.937	.967	1.
152.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.05	.000	2.460	.000	.937	.967	1.
153.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.03	.000	2.460	.000	.937	.967	1.
154.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.01	.000	2.460	.000	.937	.967	1.
155.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.00	.000	2.460	.000	.937	.967	1.
156.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.98	.000	2.460	.000	.937	.967	1.
157.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.96	.000	2.460	.000	.937	.967	1.
158.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.95	.000	2.460	.000	.937	.967	1.
159.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.93	.000	2.460	.000	.937	.967	1.
160.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.91	.000	2.460	.000	.937	.967	1.
161.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.90	.000	2.460	.000	.937	.967	1.
162.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.88	.000	2.460	.000	.937	.967	1.
163.00	.597	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.87	.000	2.460	.000	.937	.967	1.
164.00	.597	.17	2.303	807.	259.2	39.8	.435	17.31	.07	3.85	.000	2.460	.013	.937	.967	1.
165.00	.597	2.57	2.607	937.	303.4	54.1	.463	24.91	.75	3.83	.190	2.165	.434	.940	.956	1.
166.00	.598	5.08	2.712	1073.	347.2	70.9	.433	30.71	1.19	3.81	.343	1.906	.667	.945	.951	1.
167.00	.600	7.57	2.734	1177.	392.4	87.5	.393	35.10	1.56	3.79	.476	1.657	.798	.952	.956	1.
168.00	.603	10.10	2.636	1286.	439.7	107.6	.390	40.93	1.73	3.77	.584	1.466	.864	.956	.959	1.
169.00	.606	12.[illegible]	2.[illegible]	[illegible]	475.4	129.2	.374	48.28	1.[illegible]	3.75	.675	1.318	.895	.96[illegible]	.953	1.
170.00	.610	15.11	2.586	1515.	536.0	154.6	.377	58.22	1.87	3.73	.745	1.196	.899	.963	.966	1.
171.00	.614	17.62	2.190	1551.	605.8	182.3	.376	68.54	1.85	3.70	.321	1.068	.899	.968	.970	2.
172.00	.619	20.12	2.556	1607.	666.5	203.9	.374	76.21	1.90	3.67	.637	1.379	.883	.965	.972	2.
173.00	.625	22.61	2.506	1676.	709.3	226.4	.366	82.81	1.97	3.64	.687	1.298	.856	.963	.977	2.
174.00	.632	24.96	.201	1717.	117.5	38.4	.709	33.67	5.87	3.61	.746	1.203	.895	.969	.963	2.
175.00	.639	25.00	.000	1286.	95.0	23.0	.903	20.79	8.67	3.63	1.000	.960	.960	.955	.947	2.
176.00	.646	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.66	1.000	.960	.960	.958	.947	2.
177.00	.653	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.68	1.000	.960	.960	.958	.947	2.
178.00	.660	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.70	1.000	.960	.960	.958	.947	2.
179.00	.667	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.72	1.000	.960	.960	.958	.947	2.
180.00	.674	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.75	1.000	.960	.960	.958	.947	2.
181.00	.681	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.77	1.000	.960	.960	.958	.947	2.
182.00	.688	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.79	1.000	.960	.960	.958	.947	2.
183.00	.694	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.81	1.000	.960	.960	.958	.947	2.
184.00	.701	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.83	1.000	.960	.960	.958	.947	2.
185.00	.708	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.85	1.000	.960	.960	.958	.947	2.
186.00	.715	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.87	1.000	.960	.960	.958	.947	2.
187.00	.722	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.90	1.000	.960	.960	.958	.947	2.
188.00	.729	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.92	1.000	.960	.960	.958	.947	2.

BUS SIMULATION PROGRAM   DATE 29 MAR 1977   PAGE 0009

2.5 MPHPS   **BUS SIMULATION**   25 MPH

TORQUE CONVERTER TC490   24350 LB.   TRANSMISSION V730

VEHICLE				ENGINE			FUEL RATE				TORQUE CONVERTER			DRIVETRAIN		
TIME (SEC)	DIST. (MI)	SPEED (MPH)	ACCEL. (MPH/SEC)	SPEED (RPM)	TORQUE (FT-LB)	POWER (HP)	(LB/HP-HR)	INSTANTANEOUS (LB/HR)	(MPG)	ACCUMULATIVE (MPG)	SPEED RATIO	TORQUE RATIO	EFFICIENCY	TR EFF.	RA EFF.	GEAR
95.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.20	.000	2.460	.000	.937	.967	1.
96.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.17	.000	2.460	.000	.937	.567	1.
97.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.14	.000	2.460	.000	.937	.967	1.
98.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.12	.000	2.460	.000	.937	.967	1.
99.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.09	.000	2.460	.000	.937	.967	1.
100.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.06	.000	2.460	.000	.937	.967	1.
101.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.04	.000	2.460	.000	.937	.567	1.
102.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	4.01	.000	2.460	.000	.937	.967	1.
103.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.98	.000	2.460	.000	.937	.967	1.
104.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.96	.000	2.460	.000	.937	.967	1.
105.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.93	.000	2.460	.000	.937	.967	1.
106.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.91	.000	2.460	.000	.937	.967	1.
107.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.88	.000	2.460	.000	.937	.967	1.
108.00	.396	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.86	.000	2.460	.000	.937	.967	1.
109.00	.396	.17	2.303	807.	259.2	39.8	.435	17.31	.07	3.84	.000	2.460	.013	.937	.967	1.
110.00	.396	[illegible]	2.507	937.	303.4	54.1	.460	24.91	.75	3.81	.190	2.128	.434	.940	.956	1.
111.00	.397	5.08	2.712	1073.	347.2	70.9	.433	30.71	1.19	3.78	.343	1.906	.667	.945	.951	1.
112.00	.399	7.59	2.654	1177.	392.4	87.9	.399	35.10	1.56	3.75	.476	1.657	.798	.952	.956	1.
113.00	.401	10.10	2.636	1286.	439.7	107.6	.380	40.93	1.78	3.72	.554	1.466	.864	.956	.959	1.
114.00	.404	12.61	2.605	1395.	486.4	129.2	.374	48.28	1.86	3.69	.675	1.318	.855	.960	.963	1.
115.00	.408	15.11	2.586	1515.	536.0	154.6	.377	58.22	1.87	3.66	.748	1.196	.899	.963	.966	1.
116.00	.412	17.62	2.570	1561.	605.3	182.3	.376	67.54	1.85	3.62	.821	1.068	.259	.965	.960	2.
117.00	.416	20.12	2.556	1607.	666.5	203.9	.374	76.21	1.90	3.58	.637	1.379	.683	.965	.972	2.
118.00	.426	22.61	2.505	1676.	700.3	226.4	.346	82.81	1.97	3.54	.687	1.278	.896	.963	.977	2.
119.00	.431	24.96	.231	1717.	117.5	38.4	.799	30.67	5.87	3.50	.746	1.203	.898	.969	.963	2.
120.00	.438	25.00	.000	1285.	94.3	23.0	.903	20.79	8.67	3.53	1.000	.960	.960	.958	.947	2.
121.00	.445	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.57	1.000	.960	.960	.958	.947	2.
122.00	.451	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.60	1.000	.960	.960	.958	.947	2.
123.00	.458	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.63	1.000	.960	.960	.958	.947	2.
124.00	.465	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.66	1.000	.960	.960	.958	.947	2.
125.00	.472	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.69	1.000	.960	.960	.958	.947	2.
126.00	.479	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.72	1.000	.960	.960	.958	.947	2.
127.00	.486	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.76	1.000	.960	.960	.958	.947	2.
128.00	.493	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.79	1.000	.960	.960	.958	.947	2.
129.00	.500	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.82	1.000	.960	.960	.958	.947	2.
130.00	.507	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.84	1.000	.960	.960	.958	.947	2.
131.00	.514	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.87	1.000	.960	.960	.958	.947	2.
132.00	.521	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.90	1.000	.960	.960	.958	.947	2.
133.00	.528	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.93	1.000	.960	.960	.958	.947	2.
134.00	.535	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.96	1.000	.960	.960	.958	.947	2.
135.00	.542	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.99	1.000	.960	.960	.958	.947	2.
136.00	.549	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.01	1.000	.960	.960	.958	.947	2.
137.00	.556	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	4.04	1.000	.960	.960	.958	.947	2.
138.00	.563	24.64	-2.508	1243.	-77.7	-19.0	*	20.24	8.85	4.07	1.000	.960	.961	.965	.957	2.
139.00	.569	22.36	-2.556	1156.	-26.2	-5.8	*	18.34	8.79	4.09	1.000	.960	.961	.956	.944	2.
140.00	.575	[illegible]	-2.552	1023.	114.7	22.5	.793	17.80	8.05	4.12	1.000	.960	.960	.998	.953	2.
141.00	.580	17.36	-2.533	901.	197.8	33.9	.513	17.39	7.20	4.13	1.000	.960	.959	1.000	.968	2.

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25 MPH

TORQUE CONVERTER TC490 24350 LB. TRANSMISSION V730

	-------VEHICLE-------			-------ENGINE-------			-------FUEL RATE-------			ACCUMU	--TORQUE CONVERTER-			-DRIVETRAIN-		
TIME	DIST.	SPEED	ACCEL.	SPEED	TORQUE	POWER	(LB/	*INSTANTANEOUS*		LATIVE	SPEED	TORQUE	EFFIC	TR	RA	GE
(SEC)	(MI)	(MPH)	(MPH/SEC)	(RPM)	(FT-LB)	(HP)	HP-HR)	(LB/HR)	(MPG)	(MPG)	RATIO	RATIO	IENCY	EFF.	EFF.	AR
236.00	.882	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.79	1.000	.960	.960	.958	.947	2.
237.00	.889	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.81	1.000	.960	.960	.958	.947	2.
238.00	.896	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.83	1.000	.960	.960	.958	.947	2.
239.00	.903	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.84	1.000	.960	.960	.958	.947	2.
240.00	.910	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.86	1.000	.960	.960	.958	.947	2.
241.00	.917	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.88	1.000	.960	.960	.958	.947	2.
242.00	.924	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.89	1.000	.960	.960	.958	.947	2.
243.00	.931	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.91	1.000	.960	.960	.958	.947	2.
244.00	.937	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.92	1.000	.960	.960	.958	.947	2.
245.00	.944	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.94	1.000	.960	.960	.958	.947	2.
246.00	.951	25.00	.000	1286.	94.4	23.1	.899	20.80	8.67	3.96	1.000	.960	.960	.958	.947	2.
247.00	.957	24.64	-2.565	1253.	-77.7	-19.0	.	20.24	8.45	3.97	1.000	.960	.961	.965	.957	2.
248.00	.963	22.36	-2.553	1156.	-26.2	-5.6	.	18.34	8.79	3.99	1.000	.960	.961	.956	.944	2.
249.00	.971	19.85	-2.555	1029.	114.7	22.5	.703	17.60	8.05	4.00	1.000	.960	.940	.958	.950	2.
250.00	.976	17.35	-2.533	901.	197.6	33.9	.513	17.39	7.20	4.01	1.000	.960	.959	1.000	.968	2.
251.00	.980	14.87	-2.525	773.	244.1	35.9	.421	16.37	6.55	4.02	1.000	.960	.958	1.000	.972	2.
252.00	.984	12.40	-2.480	862.	213.1	35.6	.477	17.06	5.24	4.02	1.000	.960	.924	.965	.970	1.
253.00	.987	9.87	-2.525	762.	256.6	37.2	.417	16.33	4.36	4.02	1.000	.960	.956	.966	.963	1.
254.00	.990	7.39	-2.432	632.	337.5	40.6	.394	16.01	3.33	4.02	.910	1.036	.935	.963	.952	1.
255.00	.991	4.83	-2.435	850.	224.2	36.3	.467	16.95	2.06	4.02	.458	1.691	.757	.958	.950	1.
256.00	.992	2.42	-2.373	823.	238.1	37.3	.447	16.70	1.05	4.01	.245	2.087	.469	.949	.961	1.
257.00	.993	.00	.000	807.	255.5	37.9	.436	17.53	.00	4.00	.016	2.441	.000	.937	.967	1.
258.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.99	.000	2.460	.000	.937	.947	1.
259.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.98	.000	2.460	.000	.937	.967	1.
260.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.97	.000	2.460	.000	.937	.967	1.
261.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.96	.000	2.460	.000	.937	.967	1.
262.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.95	.000	2.460	.000	.937	.967	1.
263.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.94	.000	2.460	.000	.937	.967	1.
264.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.93	.000	2.460	.000	.937	.967	1.
265.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.92	.000	2.460	.000	.937	.967	1.
266.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.91	.000	2.460	.000	.937	.967	1.
267.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.90	.000	2.460	.000	.937	.967	1.
268.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.89	.000	2.460	.000	.937	.967	1.
269.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.88	.000	2.460	.000	.937	.967	1.
270.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.87	.000	2.460	.000	.937	.967	1.
271.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.87	.000	2.460	.000	.937	.967	1.
272.00	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.86	.000	2.460	.000	.937	.967	1.
272.55	.993	.00	.000	806.	247.1	37.9	.436	16.52	.00	3.85	.000	2.460	.000	.937	.967	1.

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JOINT PROBABILITY DENSITY (PER CENT)

ENGINE STEADY STATE TORQUE VS. ENGINE SPEED

SPEED INTERVALS

TORQUE INTERVALS	500 600	600 700	700 800	800 900	900 1000	1000 1100	1100 1200	1200 1300	1300 1400	1400 1500	1500 1600	1600 1700	1700 1800	1800 1900	1900 2000	2000 2100	2100 2200	2200 2300	2300 2400
-250--200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
-200--150	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
-150--100	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
-100--50	.00	.00	.00	.00	.00	.00	.37	1.23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
-50- 0	.00	.00	.00	.00	.00	.00	.64	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0- 50	.00	.00	.00	.00	.00	.18	.46	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
50-100	.00	.00	.00	.00	.00	.64	.00	32.24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
100-150	.00	.00	.00	.00	.09	.64	.00	.73	.00	.00	.15	.64	.27	.00	.00	.00	.00	.00	.00
150-200	.00	.00	.00	.00	1.56	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
200-250	.00	.00	.00	36.66	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
250-300	.00	.00	2.66	1.56	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
300-350	.00	2.29	.09	.01	1.56	.23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
350-400	.03	.00	.00	.00	.13	1.43	.38	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
400-450	.00	.00	.00	.00	.00	.07	1.17	.92	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
450-500	.00	.00	.00	.00	.00	.00	.02	.71	1.30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
500-550	.00	.00	.00	.00	.00	.00	.00	.00	.18	1.10	.55	.00	.00	.00	.00	.00	.00	.00	.00
550-600	.00	.00	.00	.00	.00	.00	.00	.00	.00	.18	1.19	.00	.00	.00	.00	.00	.00	.00	.00
600-650	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.01	.18	.00	.00	.00	.00	.00	.00	.00
650-700	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.73	1.28	.00	.00	.00	.00	.00	.00	.00
700-750	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.74	.64	.00	.00	.00	.00	.00	.00
TORQUE INTERVALS																			
TOTALS:	.03	2.29	2.75	38.23	3.35	3.17	3.04	35.89	1.48	1.28	3.66	3.85	.92	.00	.00	.00	.00	.00	.00

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559 ITERATIONS TOOK PLACE OVER THE CYCLE

ONE SAMPLE TAKEN DURING EACH PROGRAM ITERATION

0 SAMPLES FELL BELOW THE MINIMUM TORQUE

0 SAMPLES EXCEEDED THE MAXIMUM TORQUE

0 SAMPLES FELL BELOW THE MINIMUM SPEED

0 SAMPLES EXCEEDED THE MAXIMUM SPEED

MILES PER GALLON= 3.847

GALLONS PER MILE= .260

NUMBER OF STOPS PER MILE= 5

DISTANCE= .9927

	HORSEPOWER-SECONDS DRIVE	MOTORING
POWER REQUIRED BY THE WHEEL	6396.16	-102.14
POWER REQUIRED BY THE REAR AXLE	7495.83	-111.02
POWER REQUIRED BY THE DRIVE SHAFT	7765.10	-115.35
POWER REQUIRED BY THE TORQUE CONVERTER	11631.45	-120.04
POWER REQUIRED BY THE ENGINE FLYWHEEL	13438.13	-86.07
POWER REQUIRED BY THE ACCESSORIES	1510.67	

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TORQUE VALUES IN DRIVE TRAIN

	ENGINE			TRANSMISSION		REAR AXLE	
TIME	INSTANT. ENGINE TORQUE	ACC. TORQUE	DYNAMIC FLYWHEEL TORQUE	DYNAMIC CONVERTER OUTPUT TORQUE	DYNAMIC DRIVE-SHAFT TORQUE	DYNAMIC REAR AXLE OUTPUT TORQUE	GEAR
1.00	[illegible]	24.34	327.22	[illegible]	1227.55	5949.34	1.
2.00	345.83	24.84	327.96	543.30	1063.14	5216.09	1.
3.00	[illegible]	26.03	365.70	561.23	1103.12	5366.64	1.
4.00	439.68	27.35	422.85	541.92	1071.07	5266.54	1.
5.00	[illegible]	28.67	465.32	536.67	1064.65	5250.06	1.
6.00	536.00	31.94	506.94	530.53	1055.66	5223.04	1.
7.00	605.21	33.21	477.76	446.67	833.45	[illegible]	2.
8.00	666.49	34.52	638.85	770.90	1042.02	5187.19	2.
9.00	709.34	37.23	663.00	758.74	1022.97	5118.20	2.
10.00	117.42	35.86	106.11	111.72	151.50	747.60	2.
11.00	94.04	27.45	67.17	56.42	75.67	367.12	2.
12.00	94.43	27.46	66.79	56.10	75.23	364.98	2.
13.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
14.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
15.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
16.00	94.41	27.46	66.96	56.24	75.43	365.94	2.
17.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
18.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
19.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
20.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
21.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
22.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
23.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
24.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
25.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
26.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
27.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
28.00	-77.74	27.46	-105.34	-59.43	-119.46	-585.72	2.
29.00	-20.17	25.04	-59.35	-49.60	-66.42	-321.12	2.
30.00	114.65	24.73	82.99	69.71	97.41	473.96	2.
31.00	177.77	23.75	170.75	143.43	200.50	975.66	2.
32.00	264.14	23.00	237.65	199.79	279.71	1392.34	2.
33.00	215.12	23.71	173.55	148.14	253.24	1261.15	1.
34.00	269.75	23.00	241.83	203.14	405.63	2001.06	1.
35.00	337.87	23.00	315.22	253.71	554.72	2753.34	1.
36.00	224.23	23.00	273.60	301.24	596.27	2902.13	1.
37.00	235.09	23.00	215.21	392.70	751.57	3646.82	1.
38.00	246.76	23.00	224.32	479.21	927.69	4612.50	1.
39.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
40.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
41.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
42.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
43.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
44.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
45.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.

46.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
47.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
48.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
49.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
50.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
51.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
52.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
53.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
54.00	253.23	23.00	224.14	482.45	934.00	4624.49	1.
55.00	313.41	23.90	286.23	547.01	1055.66	5210.19	1.
56.00	347.17	25.02	341.43	569.47	1112.57	5416.73	1.
57.00	372.40	26.01	380.32	551.45	1094.51	5311.66	1.
58.00	439.66	27.39	424.67	544.93	1076.84	5289.77	1.
59.00	475.41	28.66	464.50	535.66	1063.12	5243.74	1.
60.00	535.98	31.94	507.07	530.71	1056.02	5224.51	1.
61.00	610.85	33.21	477.72	445.61	693.39	4485.77	2.
62.00	566.49	34.52	638.56	770.91	1042.03	5187.23	2.
63.00	709.34	37.23	605.00	758.74	1032.97	5116.21	2.
64.00	117.48	33.56	106.11	111.72	151.50	747.60	2.
65.00	94.04	27.46	67.17	56.42	75.67	367.12	2.
66.00	94.43	27.45	66.79	56.10	75.23	364.96	2.
67.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
68.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
69.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
70.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
71.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
72.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
73.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
74.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
75.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
76.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
77.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
78.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
79.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
80.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
81.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
82.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
83.00	-77.74	27.45	-105.34	-83.49	-119.46	-555.72	2.
84.00	-26.17	25.94	-53.05	-49.60	-66.42	-321.12	2.
85.00	114.05	24.73	82.99	69.71	97.41	473.98	2.
86.00	197.77	23.75	173.75	143.43	200.60	995.66	2.
87.00	254.14	23.00	237.65	159.79	275.71	1392.34	2.
88.00	218.12	23.71	173.98	146.14	253.84	1261.15	1.
89.00	290.75	23.00	241.83	203.14	405.63	2001.05	1.
90.00	337.52	23.00	312.82	233.71	564.72	2753.34	1.
91.00	264.23	23.00	263.60	301.24	596.27	2992.13	1.
92.00	238.09	23.00	218.21	395.70	761.57	3346.62	1.
93.00	246.76	23.00	224.32	473.21	927.63	4612.50	1.
94.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
95.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
96.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
97.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
98.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.

99.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
100.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
101.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
102.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
103.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
104.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
105.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
106.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
107.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
108.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
109.00	259.23	23.00	224.14	482.45	934.00	4624.49	1.
110.00	303.41	23.36	265.03	547.51	1053.88	5210.29	1.
111.00	347.17	25.02	341.43	569.47	1112.57	5416.73	1.
112.00	392.40	26.01	360.32	501.45	1064.51	5311.56	1.
113.00	439.66	27.35	424.67	544.93	1076.84	5265.77	1.
114.00	485.41	23.56	464.50	531.60	1063.12	5243.74	1.
115.00	535.36	31.94	507.07	530.71	1056.02	5224.51	1.
116.00	605.23	33.21	477.72	446.63	893.39	4465.77	2.
117.00	666.49	34.52	638.46	770.91	1042.03	5187.23	2.
118.00	705.34	37.23	693.00	752.74	1022.97	5113.21	2.
119.00	117.48	33.86	106.11	111.72	151.50	747.60	2.
120.00	94.04	27.45	67.17	56.42	75.67	357.12	2.
121.00	94.43	27.46	66.73	56.10	75.23	364.95	2.
122.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
123.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
124.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
125.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
126.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
127.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
128.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
129.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
130.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
131.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
132.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
133.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
134.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
135.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
136.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
137.00	94.43	27.46	66.96	56.24	75.43	365.94	2.
138.00	-77.74	27.46	-105.34	-88.49	-119.46	-565.72	2.
139.00	-26.17	25.94	-59.05	-49.60	-66.42	-321.12	2.
140.00	114.65	24.73	82.99	65.71	97.41	473.36	2.

HORSEPOWER VALUES IN DRIVE TRAIN

	ENGINE			TRANSMISSION		REAR AXLE	
TIME	INSTANT. ENGINE HP	ACC. HP LOSS	DYNAMIC FLYWHEEL HP	DYNAMIC CONVERTER OUTPUT HP	DYNAMIC DRIVE-SHAFT HP	DYNAMIC REAR AXLE OUTPUT HP	GEAR
1.00	57.26	4.51	63.79	20.51	19.16	16.15	1.
2.00	69.48	4.99	65.89	38.23	36.20	34.68	1.
3.00	[illegible]	5.55	86.92	59.81	56.88	54.23	1.
4.00	107.47	6.68	103.36	77.52	74.14	71.17	1.
5.00	[illegible]	7.57	123.66	96.25	93.39	88.95	1.
6.00	154.55	9.21	146.17	114.42	110.37	106.42	1.
7.00	[illegible]	10.37	[illegible]	[illegible]	106.25	104.76	2.
8.00	203.30	10.56	193.45	150.34	145.15	141.07	2.
9.00	236.40	[illegible]	213.21	165.40	160.25	156.54	2.
10.00	35.40	12.70	34.68	27.26	26.40	25.44	2.
11.00	23.07	6.73	16.45	13.22	13.24	12.54	2.
12.00	23.12	6.73	16.36	13.74	13.16	12.47	2.
13.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
14.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
15.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
16.00	23.12	6.73	16.40	13.77	13.19	12.50	2.
17.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
18.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
19.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
20.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
21.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
22.00	23.13	6.73	16.40	13.77	13.19	2.50	2.
23.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
24.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
25.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
26.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
27.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
28.00	-18.38	6.71	-25.72	-21.61	-20.84	-19.95	2.
29.00	-5.76	5.71	-13.30	-10.92	-10.44	-9.66	2.
30.00	22.45	4.84	16.75	13.65	13.63	12.95	2.
31.00	32.52	4.07	25.29	[illegible]	[illegible]	[illegible]	2.
32.00	38.39	3.39	35.01	29.41	29.41	28.59	2.
33.00	35.79	3.39	[illegible]	23.95	23.14	22.44	1.
34.00	39.16	3.34	35.10	29.49	28.49	27.44	1.
35.00	40.62	2.77	37.65	31.07	29.52	28.48	1.
36.00	36.29	3.72	32.95	22.32	21.38	20.31	1.
37.00	37.32	3.01	34.21	15.27	14.48	13.91	1.
38.00	37.90	3.53	34.45	1.14	1.06	1.03	1.
39.00	37.92	3.53	34.39	.00	.00	.00	1.
40.00	37.92	3.53	34.39	.00	.00	.00	1.
41.00	37.92	3.53	34.39	.00	.00	.00	1.
42.00	37.92	3.53	34.39	.00	.00	.00	1.
43.00	37.92	3.53	34.39	.00	.00	.00	1.
44.00	37.92	3.53	34.39	.00	.00	.00	1.
45.00	37.92	3.53	34.39	.00	.00	.00	1.

46.00	37.92	3.53	34.39	.00	.00	.00	1.
47.00	37.92	3.53	34.39	.00	.00	.00	1.
48.00	37.92	3.53	34.39	.00	.00	.00	1.
49.00	37.92	3.53	34.39	.00	.00	.00	1.
50.00	37.92	3.53	34.39	.00	.00	.00	1.
51.00	37.92	3.53	34.39	.00	.00	.00	1.
52.00	37.92	3.53	34.39	.00	.00	.00	1.
53.00	37.92	3.53	34.39	.00	.00	.00	1.
54.00	37.84	3.53	34.45	.00	.00	.00	1.
55.00	55.15	4.27	51.05	13.53	17.42	16.66	1.
56.00	70.94	5.11	69.76	39.93	37.75	35.68	1.
57.00	87.94	5.63	85.24	58.63	55.95	53.53	1.
58.00	107.63	6.70	103.37	77.93	74.51	71.47	1.
59.00	129.21	7.67	123.47	96.11	92.27	88.85	1.
60.00	154.56	9.21	146.22	114.46	110.20	106.45	1.
61.00	182.34	10.06	163.78	110.40	106.25	104.75	2.
62.00	203.90	10.56	193.45	150.34	145.15	141.07	2.
63.00	226.40	11.88	213.21	165.40	160.25	156.54	2.
64.00	38.40	12.70	34.68	27.26	26.40	25.44	2.
65.00	23.03	6.73	16.45	13.82	13.24	12.54	2.
66.00	23.13	6.73	16.36	13.74	13.16	12.47	2.
67.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
68.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
69.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
70.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
71.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
72.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
73.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
74.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
75.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
76.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
77.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
78.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
79.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
80.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
81.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
82.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
83.00	[illegible]	6.71	-25.72	-21.61	-20.34	-19.55	2.
84.00	-5.74	5.71	-13.00	-10.92	-10.44	-9.86	2.
85.00	22.44	4.84	16.25	13.65	13.63	12.95	2.
86.00	33.32	4.07	29.29	24.60	24.60	23.82	2.
87.00	33.37	3.37	35.01	29.41	29.41	28.59	2.
88.00	35.73	3.89	23.84	23.96	23.14	22.44	1.
89.00	39.16	3.34	35.10	29.49	28.49	27.44	1.
90.00	40.62	2.77	37.65	31.07	29.92	28.45	1.
91.00	36.07	3.72	32.35	22.37	21.35	20.31	1.
92.00	37.32	3.61	34.21	15.27	14.48	13.91	1.
93.00	37.90	3.53	34.45	1.14	1.06	1.03	1.
94.00	37.92	3.53	34.39	.00	.00	.00	1.
95.00	37.92	3.53	34.39	.00	.00	.00	1.
96.00	37.92	3.53	34.39	.00	.00	.00	1.
97.00	37.92	3.53	34.39	.00	.00	.00	1.
98.00	37.92	3.53	34.39	.00	.00	.00	1.

99.00	37.92	3.53	34.39	.00	.00	.00	1.
100.00	37.92	3.53	34.39	.00	.00	.00	1.
101.00	37.92	3.53	34.39	.00	.00	.00	1.
102.00	37.92	3.53	34.39	.00	.00	.00	1.
103.00	37.92	3.53	34.39	.00	.00	.00	1.
104.00	37.92	3.53	34.39	.00	.00	.00	1.
105.00	37.92	3.53	34.39	.00	.00	.00	1.
106.00	37.92	3.53	34.39	.00	.00	.00	1.
107.00	37.92	3.53	34.39	.00	.00	.00	1.
108.00	37.92	3.53	34.39	.00	.00	.00	1.
109.00	39.84	3.53	34.45	.00	.00	.00	1.
110.00	54.15	4.27	51.05	18.53	17.42	16.65	1.
111.00	70.34	5.11	69.76	39.93	37.75	35.85	1.
112.00	87.34	5.33	[illegible]	58.65	55.96	53.53	1.
113.00	[illegible]	6.70	103.97	77.53	74.51	71.47	1.
114.00	[illegible]	7.67	123.47	[illegible]	92.27	[illegible]	1.
115.00	[illegible]	9.21	146.22	114.46	110.20	106.45	1.
116.00	[illegible]	[illegible]	143.78	[illegible]	106.55	104.75	2.
117.00	[illegible]	10.56	195.45	150.34	145.15	141.07	2.
118.00	220.40	11.54	213.71	[illegible]	160.25	156.54	2.
119.00	35.40	12.70	34.68	27.26	26.40	25.44	2.
120.00	[illegible]	6.73	[illegible]	13.82	13.24	12.54	2.
121.00	23.13	6.73	16.36	13.74	13.16	12.47	2.
122.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
123.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
124.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
125.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
126.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
127.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
128.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
129.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
130.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
131.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
132.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
133.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
134.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
135.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
136.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
137.00	23.13	6.73	16.40	13.77	13.19	12.50	2.
138.00	[illegible]	5.71	[illegible]	-21.51	[illegible]	[illegible]	2.
139.00	-5.76	5.71	-13.00	-10.92	-10.44	-9.86	2.
140.00	22.45	4.54	16.25	13.65	13.63	12.95	2.

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